AN INTRODUCTION

TO THE

PATHOLOGY

OF

CANCER AND TUMOUR FORMATION

On the Basis of Evolution.

BY

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PART I.—GROWTH.

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To whom all Orders should be Addressed.

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No. 1.—GROWTH.

"The most important truths in Natural Science are discovered, neither by the mere analysis of philosophical ideas, nor by simple experience, but by *reflective experience*, which distinguishes the essential from the accidental in the phenomena observed, and thus finds principles from which many experiences can be derived. This is more than mere experience: it is, so to speak, philosophical experience." JOHANNES MULLER.

INASMUCH as pathology is but a branch of biology, it necessarily follows that when new facts and principles are discovered in the latter, they re-act powerfully on the former.

The history of medicine amply illustrates this statement. Thus, for instance, we are indebted to the genius of the vegetable morphologist, Schleiden, for the famous Cell Theory, which must be ranked among the most important steps by which the science of biology has ever been advanced. Every great pathological epoch has in fact been fore-shadowed by some such precursory innovations.

It is astonishing what relatively long periods often elapse before the significance of such discoveries is duly appreciated. The *vis inertiæ* opposed to all progress is immense. We see this in the case of the modern doctrine of evolution. Already more than a quarter of a century has elapsed since the publication of Darwin's great work on the "Origin of Species," which has revolutionised the rest of biology; but with regard to pathology, it has as yet produced no commensurate results.

Modern pathology has fallen into a narrow groove, born and bred of a pedantic and artificial system of education. My endeavour in this essay will be to contribute something towards the building up and developing of pathology, in accordance with these neglected principles—in short, to give a scientific basis to our pathology of cancer and tumour formation.

History shows that in the application of general principles there are always some anomalies at first, which are afterwards cleared up. And so no doubt it will be in this case.

No scientific man, worthy the name, can contemplate with indifference the great mystery, ever pressing for interpretation, suggested by the existence of the world with all it contains, and all which surrounds it.

"Man," says Goethe, "is not born to solve the riddle of existence, but he must nevertheless attempt it, in order that he may learn how to keep within the limits of the knowable."

We need frequently to be reminded that our knowledge, at the best, can give us but a very imperfect image of things. In whatsoever direction we advance, we shall in the end find this: that beyond a certain point, Nature is dumb to all enquiries.

> "Veil after veil will lift, but there must be
> Veil upon veil behind."

The reality existing behind all appearances is, and ever must be, unknown.

Hence every age has its own interpretation, its own revelation; but above them all is the Eternal Truth.

In such an exceedingly complex science as biology, accurate and diligent empirical observation, though the best of things as far as it goes, will not take us very far, unless at the same time we seek out laws to bind together the immense accumulation of facts.

The need for generalisation never was more urgent than at present, when innumerable, guideless investigators, tempted by the facilities offered by improved microscopes, &c., threaten to stifle the truly scientific spirit under masses of un-unified facts.

When we come to examine the linkéd chain of living things in the light of the doctrine of evolution, we are insensibly led to the important conclusion that life must necessarily have preceded organisation; whence it follows that function—which in its widest sense denotes the totality of all vital actions—in all cases goes before structure, and is from beginning to end its determining cause.

We see, moreover, that the one really essential, universal, physiological property common to all living things is

GROWTH. Crystals also grow, and in ultimate analysis it appears that there is essential community of nature between these two kinds of growth.

The tendency of modern science is to break down the partition between the organic and the inorganic; and to show that both are governed by the operation of forces which are the same in kind, though differently compounded.

Considered therefore in its widest sense, growth must be regarded as a necessary concomitant of evolution; and if evolution is universal, so is growth.

In each case growth is due to the universal tendency of like units to unite and of unlike units to separate. On this subject Mr. Herbert Spencer has expressed himself very clearly. He says:—" The deposit of a crystal from a solution, is a differentiation of the previously mixed atoms, and an integration of one class of atoms into a solid body, and the other class into a liquid solvent. Is not the growth of an organism a substantially similar process? Around a plant there exist certain elements that are like the elements which form its substance, and its increase of size is effected by continually integrating these surrounding like elements with itself. Nor does the animal fundamentally differ in this respect from the plant or crystal. Its food is a portion of the environing matter, that contains some compound atoms like some of the compound atoms constituting its tissues; and either through simple imbibition or through digestion, the animal eventually integrates with itself, units like those of which it is built up, and leaves behind the unlike units."

Growth therefore is an integration with the organism of such environing materials as are of like nature with it.

When the quantity of matter thus integrated exceeds that lost by disintegration, there is increase of size. It is to be regretted that modern physiologists have failed to give this subject that attention which its intrinsic importance demands.

We know, however, that all living things grow by taking into their substance new particles, which they dissolve and convert into fresh protoplasm. This they effect by intercalation of the new particles between the existing molecules, by a process of *intus-susception*. On the other hand, crystals grow by the addition of new particles to their exterior, by *accretion*.

These different modes of growth are consequent on the different states of density or molecular aggregation *inherent* to organic and inorganic matter respectively.

The semi-fluid or viscid state of aggregation is inherent to the former; the solid state to the latter. But in both cases the result is dependent upon the working of the same chemical and physical forces, of which the sun is the ultimate source. The molecular forces determine the form which solar energy will assume.

In proceeding with our investigation into the phenomena of growth in living things, vegetable life cannot be considered apart from animal life, since the same fundamental properties are common to both. Every one acquainted with Schwann's able thesis on the identity of the structure of plants and animals, will, I think, agree with me in maintaining that an acquaintance with the chief facts of vegetable as well as of animal morphology, is essential for a scientific pathologist.

How otherwise can he take that comprehensive survey of the whole domain of vital phenomena which is so necessary? Moreover, in plants, the study of pathological processes is often much simpler than in animals, owing to the absence in them of many factors, such as the nerves and blood-vessels, which, in animals, often complicate and obscure the essential nature of such processes.

The material basis of life in both cases is the same—to wit, the albuminous formative substance called protoplasm. The manifestation in this substance of those peculiar phenomena of motion, which we call *life*, is chiefly the result of two causes. In the first place of its characteristic semi-fluid state of aggregation, owing to the peculiar way in which a certain quantity of water is combined with its solid matter, whereby its units are so far freed from mutual restraints, that incident forces can readily effect changes in their relative positions. In the second place, to its extreme instability, owing to the easy decomposibility of its exceedingly composite albuminious combinations of carbon. It is chiefly by virtue of the latter quality that organic matter is so exceedingly sensitive to the influence of surrounding agencies.

In consequence of this extreme instability of its compounds, minute disturbances can initiate in it great reactions—setting up extensive structural modifications and liberating large quantities of motion.

In short the molecules of this substance are of such kinds and so conditioned as easily to admit of re-arrangement.

Thus the constitution of protoplasm specially adapts it to receive and produce the internal changes, required to balance the external changes, the continuous adjustment of which, according to Mr. Spencer, constitutes life.

The tendency of every such change is towards a state of polar equilibrium, and these changes can never cease until that complete equilibrum is reached, which we call *death*.

Before proceeding to treat of the various ways in which protoplasm is modified, we must first of all consider the manner in which its integral parts are united together ; for whatever has come into being can only be known from the process by which it came into being.

I conceive that the simplest primitive living things must have been exceedingly minute, unstable, structureless molecules of protoplasm, nearly akin to those molecules of nitrogenous colloidal matter, into which all organic matter is resolvable, and like them possessed of varied atomic constitution.

It appears certain that the simplest living things now *extant*, such as the *Monera*, must have originated from these primitive elementary units, by a process of growth and modification in the gradual course of organic evolution.

These creatures are really nothing but small globular bits of fluctuating protoplasm. Though under the most powerful microscopes they appear to have a perfectly homogeneous structure; yet we know by their re-actions that they must really be possessed of a highly complex molecular structure, far beyond the range of vision. It even seems probable that they contain many different kinds of molecules already formed and individualised. In this case their various degrees of segregation may be regarded as the outcome of differentiations already established though invisible. This doctrine of molecules being the ultimate constituents of living things is one of the oldest and most universal ideas extant.* In his provisional hypothesis of Pangenesis, Darwin suggests that each form unit is constantly giving off such molecules, as minute gemmules, during the whole cycle of its existence; and Mr. Spencer's physiological units are the outcome of a similar idea.

Careful study of the phenomena of imbibition of water by protoplasm first led Nägeli to the hypothesis that the water penetrates between its molecules, each being surrounded by layers of varying thickness. He maintains that striation of the cell wall, &c., depends entirely on the quantity of water surrounding its particles. By examination with polarised light, he concludes that these ultimate particles are crystalline; but with this conclusion Strasburger dissents. According to the latter observer, the molecules of protoplasm consist of multivalent atoms of solid substance, united by chemical affinity; and the water present is retained in the intermolecular meshes by capillarity.

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* The five following propositions enunciated by Democritus fairly represent the *present* state of this theory. Strange that the progress of the ages should be so!

1. From nothing comes nothing. Nothing that exists can be destroyed. All changes are due to the combination and separation of molecules.

2. Nothing happens by chance; every occurrence has its cause, from which it follows of necessity.

3. The only existing things are the atoms and empty space; all else is mere opinion.

4. The atoms are infinite in number and infinitely various in form; they strike together, and the lateral motions and whirlings which thus arise are the beginnings of worlds.

5. The varieties of all things depend upon the varieties of their atoms, in number, size, and aggregation.

The *Monera* may be regarded as typical of organic units of form of the lowest grade—plastids, cells, or aggregates of the first order. If we employ the word *cell* in this modified sense, then the old aphorism *Omnis cellula e cellulâ* will acquire new and greatly extended significance. Some such change as this seems desirable; certainly the use of the term in its old sense can no longer be maintained, for there are organisms of which cellular structure, in the current sense, cannot be asserted, and there are certain portions of organisms, for the most part cellular, which are not produced by metamorphosis of cells in the old sense.

We may, I think, safely assume that such forms as the *Monera* have acquired their actual size and relative complexity of molecular structure, as well as their other essential qualities, in accordance with the laws of *Adaptation* and *Heredity*. Of these it is necessary to say just a few words.

The laws of *Adaptation* depend upon the endless variability of protoplasm, owing to the unequal incidence of ever changing external conditions, and their mode of action is the preservation of beneficial variations, by survival of the fittest through natural selection.

The laws of *Heredity* depend upon the persistence of impressions (unconscious memory) in protoplasm. Hence every living thing produces new ones, *each after its kind.* It is by virtue of this property that—in the words of Sir James Paget—"a mark once made on a particle of blood or tissue, is not for years effaced from its successors."

These two sets of phenomena are so completely interwoven, that it is generally impossible to say how much of a given morphological change is attributable to the one, and how much to the other. Taken as a whole they stand in a certain opposition. Heredity is the cause of the stability of organisms, and Adaptation of their modification.

Adaptation is merely the material expression of change of function. But modification of function, and its expression by obvious morphological changes is a gradual process; hence adaptation is only noticeable in a long series of generations, whilst heredity can be recognised in every generation. The inherent tendencies of organisms are then proclivities *inherited* by them from ancestral organisms, which the past succession of living things has bequeathed. Thus *each cell's life the outcome of its former living is.*

All animal and vegetable organisms *commence* their existence in this simplest form, which is permanently retained by the lowest; but the permanent forms of the higher organisms result from the aggregation of these units variously modified. In the words of Oken "every living thing has arisen out of slime, and is nothing but slime in different forms;" thus my conception of the elementary morphological unit or *cell*, reverts to the old-fashioned, so called structureless blastema—the cytoblastema of Schleiden and Schwann. Out of this substance the different organic structures may be moulded, either directly or, as usually happens, with various degrees of indirectness. The hypothesis of evolution compels us to this conclusion, which the facts oblige us to make. On this subject Mr. Spencer remarks, "As structureless portions of protoplasm must have preceded cells in the process of general evolution, so, in the special evolution of each higher organism, there will be an habitual production of cells out of structureless blastema." This conception as to the origin of organic structure is very different from that which prevailed before the time of the cell theory, although along with the difference there is also fundamental similarity. Modern histologists appear to me to attach exaggerated importance to the nucleus and nuclear phenomena.

The typical cell form is more or less spherical—growth being equal in all directions. Modified cell shapes are produced by inequalities of growth. Rapidly growing cells are in a state of tension from the imbibition of water which causes them to swell up. Being also extensible and flexible, growth ensues in the direction of least resistance, which is determined by the mutual pressure of adjacent parts. Every cell after its formation begins at first to grow slowly, then reaches its greatest rapidity of growth, and ultimately growth declines, until at last it ceases.

In the case of crystal formation we see that the whole aggregate exerts a force which constrains the newly integrated units to take up a certain definite form. The re-arrangements of organic units are determined in a precisely similar way. This hypothetical property, as to the real nature of which we are ignorant in both cases, is called *polarity*. Thus regarded, polarity may be defined as the resultant of the physico-chemical forces which determine molecular arrangement. In the words of the far-seeing Schwann, " Living things are nothing but the forms under which substances *capable of imbibition* crystallise." Hence the polarity of protoplasm is an important element in the evolution of organic forms.

In extending this analogy to the multicellular aggregates which comprise the great bulk of plants and animals, the *difference* between living things and ordinary crystallisation, is brought out, owing to the obvious co-existence in their evolution of so many complex, varied and mixed conditions. Here we have a number of cells combined together within certain limits, which do not enter into the combination as dead particles, but each undergoes the particular series of changes, peculiar to its own developmental cycle—produces new ones which repeat the same series of changes, each after its kind—then dies, and is cast out or absorbed. Thus the arrangement and form of the whole organism is constantly changing in all its parts; there is nothing definitely fixed about it, every particle is in a constant state of fluctuation.

In the ordinary course of nature all living matter proceeds from pre-existing living matter, a portion of the latter being detached and acquiring a more or less independent existence.

This is reproduction or growth of the organism beyond its individual limit of size. It is essentially *cell-multiplication* or *discontinuous* growth, so called in contradistinction to that mere increase of individual size which is *continuous* growth. When a cell divides, the resulting cells are at first smaller than the original cell. Under continuous growth are included all the phenomena concerned in determining the composition and size of the organism, whereby the balance between the processes of waste and repair is maintained. Its chief abnormalities may be comprised under the heads of Hypertrophy, Atrophy and Degenerative Metamorphoses.

In every act of reproduction a certain quantity of protoplasm is transferred from the producing to the produced organism, and along with it the molecular motion peculiar to the parental individual. The phenomena of heredity are essentially dependent upon this material continuity and partial identity of the producing and produced organisms. If instead of a succession of individuals thus produced, we substitute, in imagination, a single continuously existing individual, we shall at once see the relation in which an organism stands to the rest of its species, and how the succession of all living things is, as Goëthe says, a linkéd chain.

In the lowest forms of life the various functions are at first exercised equally, or nearly so, by all parts of the protoplasmic body. Yet even these undergo, concurrently with growth, a series of changes from the beginning to the end of their existence; by which their originally homogeneous substance is variously metamorphosed, in accordance with the degree of specialisation attained in the physiological division of labour. Thus a nucleus is differentiated from the homogeneous cell substance, and frequently a cell wall, &c. In the multi-cellular aggregates, the originally like units (blastomeres) undergo analagous changes, which result in the differentiation of the various tissues and organs. All such changes are included under the term development, which is often held to be fundamentally distinct from growth. However this may be, it is certainly convenient to bear the distinction in mind. In all cases development is a change from the incoherent to the coherent, from the indefinite to the definite, from the homogeneous to the heterogeneous—in short, from the general to the special. Every living thing then, arising out of apparently uniform matter, advances to multiformity through insensible changes. In the words of Harvey "there is successive differentiation of a relatively homogeneous rudiment into parts and structures which are characteristic of the adult." The production of all organic forms is in fact by the slow accumulation of modifications upon modifications, and by the slow divergencies resulting from the continual addition of differences to differences. In this respect the development of the aggregate as a whole, repeats the development of its component units.

Thus each simplest living thing has a certain natural period of existence in the ordinary conditions of active life, at the end of this period, if not previously destroyed by some outward force, it degenerates and dies, and its substance is resolved into more highly oxidated compound of its elements. Such is the cyclical series of changes through which every living thing must go. Each cell of a multicellular organism, when once formed, leads normally a double life; it continues to grow of its own inherent power, to the attainment of its own special development; and at the same time it is directed by the influence of the entire organism, in accordance with the requirements of the specific hereditary tendency of the whole.

All sorts and conditions of growth in the end, will be found to depend upon the molecular processes of *Nutrition* —understanding by this term the whole of the material changes wrought in the organism through the influence of the surrounding outer world. These many complicated conditions are never absolutely identical for any two individuals, hence endless variability is a universal property of all organisms. Change of nutrition is unquestionably the true cause of all morphological variations. Herein lies the possibility of evolution, which must in all cases be understood, to be the direct or indirect outcome of the unequal incidence of these ever changing conditions.

Growth being an integration with the organism of such environing matters as are of like nature with it, is necessarily dependent upon the available supply of such materials; of these the most essential is water, for it is certain that living things cannot grow without it, however abundant the other requisites may be. Light, heat, and nutriment are also important factors. It depends upon the nutriment supplied to the female larva of a bee whether it shall become a neuter or a sexually perfect female; and the sexual perfection of many internal parasites is similarly dependent upon the food supply. In reproduction or cell-multiplication to which all organic units are inherently prone, the occurrence and nature of the process, whether by agamogenesis, gamogenesis, or alternation of generations, is determined by the conditions of nutrition. Impregnation must be regarded merely as one of the many conditions which affect the process. The influence of the male element on the germ-cell may, as Caspar Fried Wolff, suggests, be compared to that of a kind of nutriment.

Blood and lymph vessels and nerves have not the slightest *direct* influence on the processes of growth. They are only of importance in so far as they regulate the supply of nutriment, &c. In plants, the early embryo, and the lowest animals, all the phenomena of growth go on without them.

The growth of every living thing is thus determined in accordance with one common formative principle, which manifests itself under many different aspects, but as to the real nature of which we are ignorant.

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

Organic growth has its limits—why is this? Mr. Spencer has answered the question as follows: growth varies according to the surplus of nutrition over expenditure, and is unlimited or has a definite limit, according as the surplus does or does not progressively decrease.

Why should growth tend in the direction of cell multiplication, rather than to the production of large unicellular aggregates? We must seek the answer to this question in the conditions of molecular cohesion in protoplasm. In all cases the process is evidently one of disintegration, and as such, opposed to that integration which constitutes the individual. Diminished nutrition after the organism has attained a certain size, leading to lessened growth, is, according to C. F. Wolff, the chief cause. For cell multiplication does not take place whilst the parental individuals are growing rapidly ; that is, whilst the process of growth greatly exceeds the opposing forces, but it begins when nutrition is nearly equalled by expenditure.

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No. 2.—REPRODUCTION.

"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 laws—of generation, that the first glance was gained of the largest truth of physiology; the truth of the development of ova through partition and multiplication of the embryo cells."

PAGET.

I SUPPOSE it must be in consequence of some deeply ingrained vague instinct of the truth, that the human mind in all ages, climes and zones, manifests such irresistible tendency to penetrate the mystery of the beginning of things, and above all the origin of living things, including our own origin.

The quotation at the head of the chapter, admirably expresses this feeling; its winged words fly as it were by inspiration of genius, to the heart of the matter. Thus it is, and not by method alone, that now and again, as the days of the years roll by, men arise to lighten the darkness which surrounds all knowledge.

It is only in comparatively recent times that the view has been generally adopted, that diseased states are merely modifications of healthy states—perturbations of the normal life, caused by changed and abnormal conditions of existence. This is what is meant, when we say that every pathological process has its physiological prototype. Yet even now the full significance of this great principle of modern pathology, is far from being generally recognised. It is impossible to say in any given case where health ends and disease begins. Thus, no one can determine where what we call normal morphological variations end, and cancer and tumour formations begin. All that we can say is, that when structural or functional changes are hurtful, they belong to the province of pathology. The study of healthy processes must therefore necessarily precede that of the phenonema of disease. " There can be no question " as Mr. Huxley remarks, " as to the nature or value of the connection between medicine and the biological sciences. There can be no doubt that the future of pathology and of therapeutics, and therefore of practical medicine, depends upon the extent to which those who occupy themselves with these subjects are trained in the methods and impregnated with the fundamental truths of biology."

In the lowest organisms the only obvious phenonema of disease, are such abnormal states of their protoplasm as I have mentioned in the previous chapter. But in the case of the higher organisms—where each of the so-called individuals is really a kind of society, in which a number of mutually dependant cells are bound together, so that whilst each is dependent upon all, yet each has its own special action by which it effects the performance of its own duties—disease may consist either in abnormal states of the protoplasm of the component cells, or in disturbances of their co-ordinating or alimentary machinery or in both. In consequence of such disordered co-ordination, cell-multiplication may arise at a *place* where it has no business, or at a *time* when it ought not to occur, or to an *extent*, which is at variance with the normal formation of the body.

It is to the study of such conditions as these that we must now direct our attention.

The first subject of which I propose to treat, in this connection, is that of generation or reproductive growth in its various aspects. In approaching this subject we must first of all divest ourselves of the ordinary idea that the union of the sexes is the most important and essential thing in the process of reproduction. As I have previously stated the essential thing in reproduction is growth of the organism beyond its individual limit of size, or *cell multiplication.* Impregnation must be regarded merely as one of the many conditions, which determine or affect the process. In all cases reproduction is intimately dependent upon the molecular processes of nutrition.

This simplest mode of reproduction, by cell multiplication, is really the most important and widely spread of all such modes, for in ultimate analysis they can all be reduced to it.

I propose to show that there is no fundamental distinction between the various modes of reproduction—sexual and a-sexual, the process of repair and formation of tissues the reproduction of lost parts, and the various morphological variations, including bud, cancer, and tumour formation.

I maintain that all of these apparently so different phenomena, are merely modifications of one common process, which underlies and is the cause of them all—to wit, reproductive growth, or cell multiplication.

Further, I shall endeavour to show that in all cases the *real meaning* of cell multiplication is the *production of new individuals.*

To this end I shall adduce facts showing that there is no warrant for the belief so generally entertained, that sperm cells and germ cells are fundamentally different from one another, and from all other cells. On the contrary I shall show that they differ from other cells only in this—that they are comparatively *less specialised.*

In the next place I shall give reasons for believing, that every component cell of the multicellular aggregates has the inherent power, under favourable conditions, of developing itself into the form of the parent organism; in short, that each cell is *potentially* the whole organism.

That the degree of development *actually* attained by each cell falls far short of this in most cases, is due to the restraining and modifying influence exerted by the cells of the whole organism on its protoplasm, which is thus compelled to the performance of comparatively subordinate, modified functions. Under these circumstances the primitive force remains latent, but it may often be evolved in varying degrees under favourable conditions, and some-times even to its full extent. Thus there are plants in which any single cell separated from the rest suffices for the reproduction of the whole organism, and among animals nearly similar conditions prevail in the Hydra. These cases will be more fully described further on.

Hence I have arrived at the important conclusion, that the processes of repair and reproduction of lost parts, and the various morphological variations, including bud, cancer and tumour formation, are nothing but more or less abortive attempts of certain cells to reproduce new individuals. Whence it follows that the laws of reproduction are also the laws of cancer and tumour formation, &c.

I state this most emphatically, because the discovery has never before been clearly enunciated, although it has for some time been vaguely foreshadowed. The study of Reproduction and its laws is, therefore, an essential preliminary to the study of the etiology of Cancer and Tumour formation. It is the physiological prototype of these pathological processes.

The simplest living things, such as the *Monera*, reproduce themselves by *Fission* or simple division. When an organism contains a nucleus, its division usually precedes that of the surrounding protoplasm. *Gemmation*, or bud formation, is only a modification of this process.

It appears certain that in the earliest period of the organic history of the world, all organisms propagated themselves in this way, which must therefore be regarded as the original primitive method.

In the lowest organisms, these processes result in the formation of *new individuals* by direct transformation of the germs, as the detached portions of protoplasm are called. In the case of fission, the growth which causes the process is total, affecting the whole protoplasm (vide fig. 1.), so that in most cases neither of the resulting cells can be called the parent of the other.

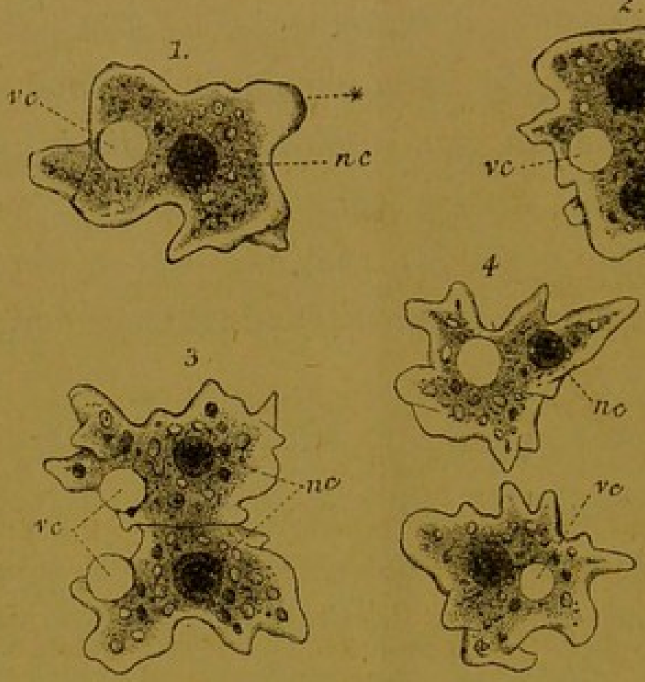

Fig. 1.

Successive stages in the life history of an Amœboid organism, kept under constant observation for three days.—Zeiss D. 3. (After Howes.)
1—The locomotor phase; 2, 3, 4—The reproductive phase in successive stages; 2—Nuclear division; 3, 4—Cell division.
*—Protrusion to form a pseudopodium.
nc—Nucleus.
vc—Contractile vacuole.

But in gemmation, a portion of protoplasm, already more or less developed, separates from the producing individual to form a new being (*vide* figs. 2 and 3).

Here the resulting individuals are of unequal value; the one is the parent of the other. The growth that causes the process is partial, affecting only a portion of the parental organism. Hence the whole difference between fission and gemmation is quantitative merely, and consists in the different amounts of protoplasm, given over by the producing to the produced organisms. In like manner each of the constituent cells of the higher organisms reproduces its kind, whereby the formation and maintenance of their various tissues and organs is ensured.

FIG. 2.

Nos. 1 to 4 cells of ordinary brewer's yeast (torula cerevisiæ), showing stages of bud formation, leading to the formation of branching colonies.—Zeiss D. 4. (After Howes).

No. 1 of the above cells as seen under 1-16th immersion.

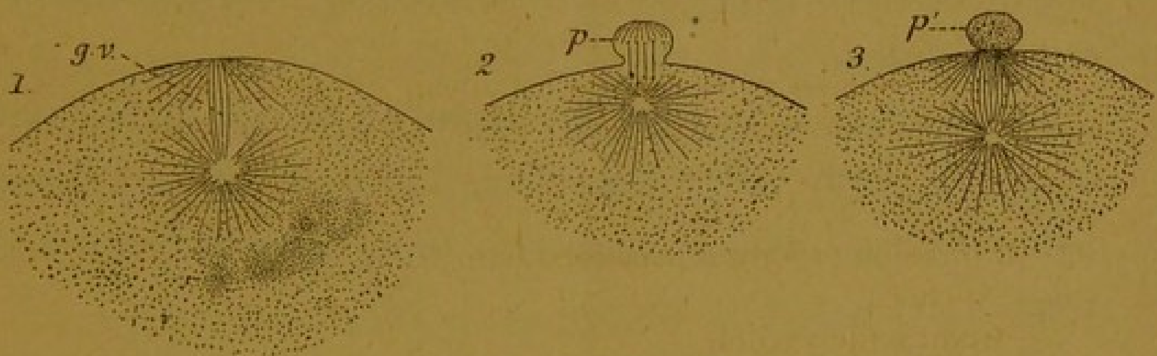

FIG. 3.

Stages in the formation of the first polar cell, by budding, in the ovum of a star-fish. (After Hertwig.)

gv—Germinal vesicle undergoing division transformed into a spindle-shaped system of fibres (karyokinesis.)

p—The polar cell becoming extruded from the surface of the ovum.

p'—The polar cell completely extruded.

Endogenous cell formation, the so-called free cell formation, and the like, are merely modifications of the above processes.

The subject of reproduction by fission and gemmation in the case of the multicellular organisms, will be discussed in a future chapter, when treating of bud formation in general. It will then be shown that each new individual thus separated is the product of the multiplication of but a single parental cell. Between these modes of reproduction and that by " germ buds," there is no real distinction.

In these cases the new individuals thus arising, do not separate from the parental form, until they have undergone considerable or even complete development.

In the case of *spore formation* a *single* cell separates spontaneously from the surrounding cells of the parental organism, and having left this, multiplies by division, and so develops into a new many-celled individual, as among many of the *cryptogamia*, &c.

This mode of reproduction differs from the foregoing only in that separation of the reproductive cell from the parent, takes place before it has become subject to the process of cell multiplication.

In all these cases the development of new individuals from the germ cell takes place independently of other living matter. This is *agamogenesis* or a-sexual reproduction.

Its highest development, spore formation, leads directly to a form of reproduction in which the germ cell cannot develop into a new individual of itself; but must first be fructified by contact with living matter *different* from it—the sperm cell. This is *gamogenesis* or sexual reproduction.

In the lowest organisms gamogenesis has never been observed, and in the highest organisms agamogenesis is absent. It appears to be a general rule throughout both the animal and vegetable kingdoms, that the product of gamogenesis is more highly organised than that of agamogenesis. Hence we are led to infer that a more complex kind of development is initiated by sexual reproduction.

Careful examination of the subject in its different bearings, show that there is no fundamental difference between gamogenesis and agamogenesis, and that the former has originated from the latter at a comparatively late period of the earth's history, in the first instance apparently through spore formation.

The two different generative substances essential for gamogenesis, may be produced either by the same individual (monœcious or hermaphrodite), or by two different individuals (diœcious).

The most ancient primitive form of this process appears to have been through double sexed individuals, as it at present occurs in the majority of plants and in a few animals, such as garden snails and many worms. Some hermaphrodites can fructify themselves, but in most cases copulation, or the reciprocal fructifying of two hermaphrodite individuals is necessary for reproduction. Here we have evident indication of transition to sexual separation, which is universal amongst the higher animals, but occurs only in a few plants, *e.g.*, vallisneria, willows, poplars, &c.

Thus the distinctive feature of gamogenesis under all its different aspects is the coalescence of a detached portion of one organism, with a more or less detached portion of another allied organism, or of two allied unicellular organisms. In a few instances these detached portions are derived from different parts of the same organism.

In its simplest condition—known as *conjugation*—these two factors are apparently similar; but there is usually well marked morphological difference between them. The relatively large and passive factor is the female element the *germ cell*; the relatively small and active factor is the male element, the *sperm cell.* Throughout the whole organic world the germ cell almost invariably maintains the form of a spheroid of protoplasm; but the form of the sperm cell is subject to great modifications, especially in the direction of the development of flagellate processes.

Fructification or impregnation is the result of the union of these two elements; the essential nature of which is the physical admixture of protoplasmic matter derived from two *different* sources. The simple cell—*cytula,*—resulting from the fusion, develops into the new being. This cell must be regarded as an entirely new independent formation, since in it the characters of *both* parents are potential.

Such is the starting point which in the higher plants and animals initiates the evolution of every new individual. Viewed in this light gamogenesis is seen to be nothing but a particular case of cell multiplication, and impregnation merely one of the many conditions which affect the process. As I have previously mentioned, the influence of the sperm cell on the germ cell may be compared to that of a kind of nutriment; but with this proviso, that in this nutriment, no less than in the germ cell, the specific form of the parental organism is involved with all its individual peculiarities.

Thus in every kind of reproduction the essential thing invariably is the detachment of a portion of the parental organism, possessing the capability of more or less independent growth. Such detached portions may consist either of a single cell, or of a group of cells derived from a single cell—variously developed.

Very interesting are the phenomena of *Parthenogenesis* or virginal reproduction, as representing a transition from sexual to a-sexual reproduction. Here germ cells, which often appear to be formed exactly like ova, develop themselves into new individuals, without the influence of any fructifying sperm. It occurs in certain plants and animals, and is probably of the nature of a relapse from the sexual method.

Among our common honey bees a male individual (drone) arises out of the egg of the queen, if it has not been fertilised, a female (queen or working bee) if the egg has been fertilised. This shows there is no such fundamental distinction between gamogenesis and agamogenesis as is commonly supposed.

In true parthenogenesis there occurs along with gamogenesis, in a true ovarium or homologous organ, a form of agamogenesis, exactly like gamogenesis, save in the absence of fertilisation, as in silkworm moths. False parthenogenesis occurs when new individuals arise from *buds* in pseud-ovaria, which are not ova properly so called as in *aphides*.

This process is intermediate between true parthenogenesis and that form of agamogenesis called by Owen *metagenesis*, in which new individuals *bud out*, not from any specialised organs, but from *unspecialised* parts of the parent, which are generally external, but may be internal, as in *distoma*.

We now pass to the very remarkable series of events known as the "*Alternation of generations.*" Until comparatively recently it was believed that in every species the successive generations were always alike—*homogenesis*; but it is now known that this is not always the case—*heterogenesis.*

Many plants and animals produce a generation unlike their parents; these may produce others like themselves, or like their parents, or like neither and so on; but eventually the original form reappears. Here gamogenesis alternates with agamogenesis or parthenogenesis.

Since all gradations between complete alternation of generations and simple agamic budding combined with gamogenesis can be traced in forms now extant, it appears certain that the ancestors of the forms which now exhibit alternation of generations, originally reproduced themselves at the same time sexually and a-sexually, though probably the two modes of reproduction did not take place at the same season.

This subject is so important for the elucidation of my argument, that I must now give two examples of it, in some detail. For this purpose I have in the case of animals, selected the plant lice (*aphides*), because in these insects the whole process has been admirably worked out by Owen, of whose works I shall freely avail myself.

The impregnated ova of the *aphis* are deposited at the close of summer in the axils of the leaves of the plant infested, retaining their vitality throughout the winter, these ova are hatched by the returning warmth of spring: a wingless hexapod larva is the result. In the pseud-ovaria of these imperfect females, there bud forth pseud-ova which rapidly develop into similar imperfect females. At this season no winged males have appeared. This process of agamic multiplication continues throughout the summer. If the external conditions, such as warmth and nutriment, continue favourable, eight or more successive generations may be thus produced. But when the weather becomes cold and the supply of sap fails in the plant, perfect males and females are produced, which by gamogenesis reproduce fertilised ova, thus completing the cycle.

Further experiments have shewn that in such cases the rapidity of the agamogenesis is proportionate to the degree of warmth and nutrition, and that if the temperature and food supply be artificially maintained, the agamogenesis continues throughout the winter. When the favourable conditions have been kept up for several successive years, agamogenesis has likewise continued. In short, it seems probable that this agamic reproduction could be continued indefinitely, if all the requisite conditions be fulfilled.

This connection between reproduction and such diminished nutrition as makes growth relatively slow, was first fully made known by the celebrated German biologist, Caspar Friedrich Wolff, in his *Theoria generationis*. Wolff first shews that the organs of fructification in plants are merely modified leaves. The plants themselves he regards as branched colonies of individuals, of which the leaf-bearing axes are the agamogenetic and the flower-bearing axes the gamogenetic individuals. He next demonstrates that the modifications which leaves undergo in the formation of flowers, are the result of diminished nutrition, leading to imperfect growth. Hence at first, when nutrition is at its best, only leaf-bearing axes or a-sexual individuals are produced. But as we approach the flowering axes, the influence of diminished nutrition shows itself in the production of smaller leaves and shorter internodes. Finally, in the flower itself, the non-development of the terminal internodes, the very stunted modified leaves from which the organs of fructification proceed, and the situation of the whole at the extremity of the axis—far removed from the main channels which supply nutriment—all indicate that extreme diminution of nutrition and approximate arrest of growth which characterises the advent of gamogenesis. In short, the entire structure of the flower suggests that of an abortive sexless axis.

Further, if a plant known to put forth leaves under ordinary circumstances, a certain number of times, for instance, six times, before developing flowers, is set in a very poor soil, not only will its leaves become very small and imperfect, but it will scarcely have put forth leaves three times before fructification occurs. Whereas if the leaves of this same plant are placed in very moist and rich soil, they become larger and more perfectly formed, and instead of developing leaves six times, it will put these forth nine times or more before organs of fructification appear.

Moreover, if whilst fructification is thus delayed by the richness of the soil, the plant is transplanted to a poor soil, flowers immediately appear.

Lastly, if a plant which has already developed the calyx and rudiments of the corolla and anthers in poor soil, is quickly transplanted into rich soil, the anthers can be seen to undergo transformation into petals, in consequence of the excess of nutrition. When the petals and stamens are changed into green leaves the return from gamogenesis to agamogenesis is still more marked.

In accordance with this principle, trees may be made to fruit when quite young, by cutting their roots or confining them in small pots; and luxuriant branches that have had the flow of sap checked by "ringing," soon produce flowers instead of leaves.

Seeing that the action of the sperm cell on the germ cell was the cause of its development—for before it was deficient in this respect—and having in mind the above consideration, Wolff was led to regard the former as nutriment in its highest perfection, supplied to the germ cell from without, instead of through the ordinary channels.

Under what circumstances do single cells develop into new individuals? How have such cells acquired their wonderful properties? And how do they differ from other cells of the organism? These are some of the questions that naturally arise out of such considerations as the foregoing. In answering them it is necessary first of all to bear in mind that simple undifferentiated protoplasm is the proximate source of all growth, reproductive and otherwise. Further, we must remember that by virtue of the laws of heredity, every detached portion of such protoplasm has the inherent power of arranging itself into the form of the organism whence it was derived.

In the simplest living things, as I have previously mentioned, the various functions are exercised equally or nearly so, by all parts of the protoplasmic body; hence when the mass divides each part retains all the functions of the whole, including the reproductive function, and so constitutes a germ whence the entire organism can be reproduced.

The question here presents itself,—how small a portion of the multicellular organisms may contain the force necessary for the reproduction of the species? In the highest organisms which propagate only by gamogenesis, this force is found only in the germ cells (ova), whilst all the other parts of their bodies are destitute of it. In those plants and animals which propagate by buds or sprouts, the germ consists of a mass of cells which may be produced at almost any part of the body of the parent. In some of the lower animals the same reproductive power is possessed by every aggregate of cells. In other lowly organised beings the power of reproducing new individuals is, not merely manifested by separate portions of most parts of the body, but in some cases sub-division, even to the ultimate morphological units, does not destroy this power; isolated cells are, in fact, adequate to propagate the species.

When, therefore, in such organisms, as the *Hydra* and many plants, we see protoplasmic cells — derived from many various parts in the same individual or in different individuals—separating themselves from the rest of the organism and independently developing into new individuals, we may, I think, fairly conclude that every like constituent portion of all organisms, possesses similar power of independent growth and reproduction. Similarly, we may infer that each of the number of cells (blastomeres) into which, in the higher organisms, the germ cell at first divides, also retains all the properties of the germ itself, and is capable of reproducing the entire organism.

Now, if this be so, that every component cell of the multicellular organisms has this inherent power of reproducing the entire individual, how then does it happen that these cells usually remain aggregated together, and unite only in the form proper to the species ?

The answer to this question is threefold.

In the first place, in order that this inherent power may manifest itself the conditions must be favourable to its development. It cannot reasonably be doubted that each unit of an organism acts, by virtue of its polarity, on all the other units, and is reacted on by them. This normal restraining influence, exerted on each cell by all the other cells, in accordance with the specific hereditary tendency of the whole, must be weakened, modified, or withdrawn, before the potential reproductive power can become actual. In the ordinary course of normal life the only cells thus set free are the reproductive or germ cells. But *any* cells, abnormally emancipated from the controlling influence of the whole, may then grow and multiply independently, or with various degrees of dependence, according as the emancipation is complete or more or less incomplete. In lowly organised beings, such as the *Hydra*, this controlling influence is very feeble, so that almost any cell in these creatures may develop itself into a new individual. But in the case of the higher organisms this controlling influence of the whole is much more powerful, except in certain definite localities, hence the formation of reproductive cells is limited in them to special organs, and all their other cells are destitute of this power.

The second factor in the explanation seems to be, that in consequence of the special metamorphosis of their protoplasm, most of the cells of the higher organisms suffer loss or impairment of their reproductive power. In the course of development from originally like units (blastomeres), as the process of division and differentiation proceeds, many cells acquire special functions, and much of the original protoplasm is used up and converted into special tissues. In proportion as the cells are thus specialised, we may infer they lose their primitive general functions. Thus their power of reproducing the whole organism may be greatly reduced or altogether lost, owing to all or the greater part of the original protoplasm being specialised and used up. But in the higher organisms certain cells never attain a high degree of development; they remain in a lowly organised condition and serve, according as they are more or less *unspecialised*, either as germs for reproducing the entire individual, or for forming and maintaining the various tissues and organs. Such cells are found in all growing parts ; they are *the only real cancer and tumour germs*, as I shall hereafter show.

Hence most of the component cells of organisms produce only cells of the same kind as themselves, and are totally incapable of acting as germs of the entire organism, *e.g.*, epithelium cells always reproduce epithelium cells; hence also certain parts of the tentacles of hydras, when cut off, alone of all parts of the body fail to develop into new individuals.

In support of this view it may be mentioned that all kinds of reproductive cells and organs are composed of tissues, remarkable for their low degree of organisation. In plants, as we have seen, they arise at the extremities of axes, where structure is least specialised. The male and female organs at first consist each of a solid bud of similar unspecialised, protoplasmic cells. At this stage their likeness is so great that no distinction of sex can be made in the nascent flower ; it is only subsequently that the difference becomes perceptible. The outermost cells then form the epidermis; and from hypodermal cells, immediately beneath this, the mother cells of the pollen and embryo sac arise. In the lower animals, such as the hydra, sperm cells and germ cells originate from the undifferentiated tissue between the ectoderm and endoderm, *i.e.*, they consist of portions of least specialised structure. In the higher animals, the original primitive origin of the sexual elements is probably similar to that of the hydra, although they appear to arise from modified cells of the cœlomic epithelium, probably as the result of kenogenesis. In either case such cells are lowly organised and very little differentiated.

According to this view, then, the power of reproducing the whole organism will be limited to those cells which have remained unspecialised, and consequently have departed but little from the original primitive type in which the organism commenced its existence.

The more widely diffused such cells are in any given case, the more readily will reproduction by budding or fission take place; the more localised such cells, the more limited the part in which this could occur. Thus, as Mr. Huxley remarks, "the gradual disappearance of agamogenesis in the higher animals would be related with that increasing specialisation of function which is their essential characteristic; and when it ceases to occur altogether, it may be supposed that no cells are left which retain unmodified the powers of the primitive embryo-cell."

In the third place, in order that this inherent power of the cells may manifest itself the external conditions must be favourable to its development.

Granted all of these conditions, and even single epithelial cells from the leaves or stem, as in the case of *Begonia phyl-*

lomaniaca, may become endowed with the power of reproducing the whole organism. Under similar circumstances in many plants and animals, a very small fragment of but little differentiated tissue, may be capable of reproducing a whole organism, like that whence it was derived.

Now if, as I have maintained, sperm cells and germ cells are peculiar only in respect to their low grade of organisation, in which they both resemble unspecialised cells, it follows that they cannot be essentially unlike each other. Many facts point to this conclusion. The most striking are those recorded by Mr. Salter. He has described a monstrosity in two kinds of passion flower and a rose, in which ovules graduated into anthers, and produced pollen in their interior.

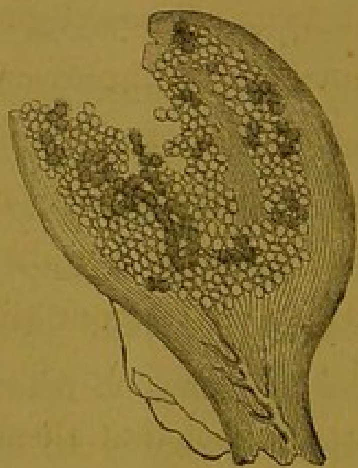

FIG. 4.
Formation of pollen within the ovule of *Passiflora*. (After Salter.)

His description of one of these cases is as follows:—

"The pollen bearing ovules presented various intermediate conditions between anthers and ovules. Commencing at the distal extremity of the carpel was a bilobed anther, and passing in series to the base of the ovary, an antheroid body of ovule-like form, a modified ovule containing pollen, an ovule departing from a perfectly normal condition only in the development of a few grains of pollen in its nucleus, and finally a perfectly normal ovule." He subsequently makes this remark:—"For an ovule to develop pollen in its interior is equivalent to an ovum of an animal body being converted into a capsule of spermatozoa. It is a conversion of germ into sperm, the most complete violation of individuality and unity of sex."

As to the precise circumstances which determine the cells of the homogeneous rudiment of ovules, in one case to form mother cells and pollen grains, and in the other the embryo sac and germ cells, all that can be said is that position and external conditions appear to have some influence. For in all these cases of polleniferous ovules, the ovular structure had been exposed on an open carpel, instead of being confined within the ovary in the usual way.

Thus, then, there is no reason for believing that sperm cells and germ cells are fundamentally unlike one another and unlike other cells. They are simply unspecialised cells which have departed but little from the original general type.

This is borne out by the fact that, throughout the organic world, the less differentiated organisms are those most prone to agamogenesis, that is to say, their individual cells are possessed of a high degree of reproductive power; whereas in the more highly differentiated organisms, the absence of agamogenesis, indicates great falling off in this respect.

In the highest organisms the reproductive cells, even when favourably situated with regard to nutrition, are of themselves incapable of further development. Though unspecialised they have lost the power of growth and development. They have nearly reached a state of equilibrium. I say nearly, because for a time unfertilised ova, even of the higher animals, may undergo similar changes to those which fertilised ova undergo; although these changes soon become lanquid and end in decomposition. Their energy is in fact almost entirely potential. Hence, when left to themselves they disintegrate, and are absorbed or cast out. But by their union a fresh process of cell multiplication is excited, which is the beginning of a new evolution.

Evidently, then, fertilisation does not depend upon any special peculiarities of the sperm cells and germ cells.

How does it happen that some organisms multiply by homogenesis, and others by heterogenesis? Why cannot reproduction be carried on in all cases as it is in many by agamogenesis? What is the real significance of gamogenesis?

Mr. Spencer has asked and essayed to answer these questions as follows, premising that in the present state of biological science, a complete answer is impossible.

From such considerations, as have been previously stated with regard to the relation between nutrition and reproduction, it follows that there is a certain relation between the commencement of gamogenesis and declining growth. We have seen that agamogenesis continues as long as the forces which result in growth are greatly in excess of the antagonistic forces; and that gamogenesis arises when there is an approach to equilibrium between these two sets of forces. Agamogenesis implies by its amount a large excess of nutrition, whilst gamogenesis implies by its amount a small excess of nutrition, the one or the other mode of reproduction occurs according as the external conditions are or are not favourable to nutrition. Generally speaking, only when growth is declining, do sperm cells and germ cells begin to appear; and the fullest reproductive activity arises as growth ceases. The "general law," says Mr. Spencer, "to which homogenesis and heterogenesis conform, thus appears to be that the products of the fertilised germ go on accumulating by simple growth, so long as the forces whence growth results are greatly in excess of the antagonistic forces; but that when diminution of the one set of forces, or increase of the other, causes a considerable decline in this excess, and an approach towards equilibrium, fertilised germs are again produced."

It cannot be said that a decrease of this excess always results in gamogenesis, for some organisms—as the weeping willows—multiply only by agamogenesis, although the same causes of local innutrition are present in them as in other trees. All that can be said is—"That an approach towards equilibrium between the forces which cause growth and the forces which oppose growth, is the chief condition to the recurrence of gamogenesis; but that there are other unknown conditions, in the absence of which this approach to equilibrium is not followed by gamogenesis."

In seeking an answer to the second and third questions, Mr. Spencer points out that as gamogenesis recurs only in individuals approaching a state of organic equilibrium, and as the sperm cells and germ cells thrown off by such individuals are cells in which developmental changes have ended in quiescence, but in which after their union there arises active cell formation, it may be suspected that the approach towards a state of general equilibrium in such gamogenetic individuals is accompanied by an approach towards molecular equilibrium in these cells also. Hence, "the need for this union of sperm cell and germ cell, is the need for overthrowing this equilibrium and re-establishing active molecular change in the detached germ." A result which is probably effected by the mixing, in impregnation, of the slightly different protoplasmic substances of slightly different individuals.

I have already pointed out that the germ of every organism in its earliest stage is a simple protoplasmic cell, that it is by cell multiplication that all the early developmental changes are effected, and that the various tissues and organs of the developed organism are at first cellular.

It now remains for me to call attention to the further important fact, that cell multiplication is the means by which, throughout life, the wonderful processes of repair and reproduction of lost parts are carried on. In the process of repair the undifferentiated cells thus produced, develop, not into new organisms, like the parent organism of which they form a part, but by a modification of their evolution they constantly reproduce the same tissues in the same parts, so that the form of the individual is maintained. Between the processes of reproduction and repair there is then no fundamental distinction, the latter is merely a *modification* of the former. Similarly between the power which makes good an injury, or reproduces a lost part, and that which previously "was occupied in its maintenance by the continual mutation of its particles," there is no real difference. All of these statements are so generally accepted that it is unnecessary here to adduce the proofs of them. Suffice it to say, in the words of Sir James Paget: "The powers of development from the embryo are identical with those exercised for the restoration from injuries; in other words the powers are the same by which perfection is first achieved, and by which when lost it is recovered. . . . . . . It is one and the same power which being maintained continuously from the germ to the latest period of normal life, determines all organic formation."

This capability of repairing injuries and reproducing lost parts is not the exclusive property of living things, for even crystals manifest it, when placed under the same conditions in which they were first formed. In fact, it appears that all bodies having definite form and construction possess the inherent power, under favourable circumstances, of repairing the injuries resulting from the action of external forces.

In order to account for this, we must suppose that by a kind of selective assimilation, the molecules of each part have the power of moulding the adjacent nutritive materials into molecules after their own kind. "Like units," says Mr. Spencer, "tend to segregate, and the pre-existence of a mass of certain units produces, probably by polar attraction, a tendency for diffused units of the same kind to aggregate with this mass rather than elsewhere."

In the case of the reproduction of a lost part, we must assume that the organism, as a whole, exercises some such power over the newly forming part, so as to make it a repetition of its predecessor. "If a leg is reproduced where there was a leg, and a tail where there was a tail, we have no alternative but to conclude that the aggregate forces of the body control the formative processes going on in each part." These processes may, therefore, be regarded as due to forces analogous to those by which a crystal reproduces its lost apex, when placed in a solution like that from which it was formed. In either case, as Mr. Spencer remarks, "a mass of units of a given kind shows a power of integrating with itself diffused units of the same kind; the only difference being that the organic mass of units arranges the diffused units into special compound forms, before integrating them with itself."

This power of repair and reproduction of lost parts varies in different beings: thus, although it is possessed even to the restoration of a lost limb among the lower animals, no such power is possessed by the highest. The general law to which these processes conform, is identical with that which we have seen holds for the process of reproduction. That is to say, this power is greatest where organisation is lowest, and it almost disappears where organisation is highest. Hence it is seen in perfection in those organisms which propagate the species by gemmation and allied methods. The gradual diminution of this power in the higher organisms is likewise due to the same cause which determines abatement of their reproductive power; the using up of the primitive germ protoplasm, in the formation of highly specialised structures, consequent on the physiological division of labour, and, in a less degree, in the growth and maintenance of structures already formed. This power is proportionately much greater in the young than in the old of all species, and it gradually lessens as life advances.

Seeing that the difference between the completeness of repair in early youth and adult age, is so much greater than the difference in adults of different ages, we infer that the capacity is diminished more by development than by mere growth or maintenance. In other words, " to improve a part requires more and more perfect, formative power, than to increase it does."

Hence the larvæ of amphibians, which present many parts that in other animals are developed only in the embryo state, have also a greater power of reproducing lost parts than the perfect animals ; and in the larvæ of insects lost parts are often reproduced, which in the perfect insects cannot thus be replaced.

This rule is equally true even for the most highly organized beings ; thus, in the human species, cases have been recorded of more or less complete reproduction of fingers after injury, in early periods of embryonic life, though nothing of the kind occurs in adults.

Among the polypes, such as the hydra, any minute group of cells separated from the perfect body, suffices for the reproduction of the entire organism.

The well known experiments of Trembley have shewn it to be a matter of indifference whether the hydra is divided longitudinally or transversely, or whether portions are merely cut out of its side ; in all cases the separated fragments grow into perfect polypes. Even if the creature is cut up into a number of small pieces, each of these becomes a perfect hydra, and this process can be repeated over and over again with a similar result. Thus Trembley cut a hydra into four pieces, each became a perfect hydra, and whilst they were growing he cut each of them into two or three. These fractions being on their way to become perfect animals, he again divided, and thus he went on until from one hydra he obtained fifty, each of which developed into a perfect individual.

In such cases it is quite impossible to discern any distinction between the processes of repair and reproduction by gemmation or fission. The identity of these processes is also shown by the fact observed by Trembley, that the supervention of gemmation retards the reproduction after injury.

In the higher actinozoa half an individual will grow into a complete new being; and it has been noticed that, when after injury, the holothurians expel the whole of their viscera, these are in the course of a few months reproduced. Some of the lower annelids, such as *Nais*, may be cut into thirty or forty pieces, and each piece will eventually develop into a new individual.

As we ascend in the scale of organisation, this power though much diminished, is still considerable. In insecta, arachinda and crustacea, entire organs such as extremities, eyes, maxillæ, &c., may be reproduced when detached, but such separated parts never develop into new individuals.

Among the vertebrata in the case of *Fishes* fins are reproduced, but by far the greatest reparative powers are possessed by *Amphibians*. In many of these the reproduction of an entire limb or a tail occurs readily, and this even several times over, though with decreasing completeness. Spallanzani cut off the legs and tail of a Salmander six times, and Bonnett eight times, successively, and they were reproduced. Only the larvæ of the tailless Batrachians, as previously mentioned, and not the adults, are capable of reproducing lost members. In the Triton, Blumenbach has seen even the eyes with cornea, iris, and lens, reproduced within the space of a year. But in the highest animals such complex parts are never reproduced, in these single tissues alone are regenerated.

In *Mammals* and *Birds* the only manifestation of this power is in the healing of wounds, and this is often very imperfect in the case of the higher tissues, such as muscles and nerves. However, at a meeting of the British Association at Hull, in 1853, a thrush was shown, which was said to have thrice reproduced its tarsus after destruction by disease.

Cases have also been recorded of reproduction of supernumerary digits, after amputation, in human beings ; this is remarkable, because, after amputation, the normal digits, it need hardly be said, have no such power of regrowth. The nearest approach to it is seen in the occasional reappearance in man of imperfect nails on finger stumps after amputation. But, according to Sir J. Simpson, in early embryonic life, human beings have considerable power of reproducing lost parts. He has several times observed that arms, amputated *in utero* by bands, &c., have grown again to a certain extent, and in one case the extremity was "divided into three minute nodules, on two of which small points of nails could be detected." These nodules clearly represented fingers in process of regrowth.

The same, or very nearly the same, power is seen in the case of plants. Thus a fragment of a begonia leaf, when placed under appropriate conditions, will develop into a young begonia, and so small is the fragment thus capable of reproducing a complete plant, that as many as a hundred may be produced from a single leaf. Various other plants manifest similar powers of multiplication, and there are well known cases in which a single epithelial cell suffices for reproduction of the whole.

Thus again we arrive at the conclusion that a single cell is adequate for the reproduction of the species.

In the next two chapters I propose to discuss the connection between the above processes, and bud, cancer, and tumour formation, and the relation of these to one another.