PART II.

AN ENQUIRY INTO THE PHYSICAL CAUSES OF LIFE, THE CONDITIONS REQUIRED FOR ITS EXISTENCE, THE EXCITING FORCE OF ITS MOVEMENTS, THE FACULTIES WHICH IT CONFERS ON BODIES POSSESSING IT, AND THE RESULTS OF ITS PRESENCE IN THOSE BODIES.

INTRODUCTION.

NATURE, that word so often spoken as though it referred to a special entity, cannot be for us more than the totality of objects comprising: (1) all existing physical bodies; (2) the general and special laws, which regulate the changes of state and position to which these bodies are liable; (3) lastly, the movement distributed at large among them, which is continually preserved or being renewed, has infinitely varied effects, and gives rise to that wonderful order of things which this totality embodies.

All physical bodies whatever—solid, fluid, liquid or gaseous—are endowed with properties and faculties peculiar to themselves; but as a result of the movement distributed among them, these bodies are liable to different relations and transformations in their state and position. They are liable to contract with one another various kinds of union, combination or aggregation, and then to undergo all kinds of alterations, such as complete or incomplete separation from their other components or from their aggregates, etc.; these bodies thus derive new properties and faculties from the condition in which each of them is placed.

As a further result of the arrangement or position of these same bodies, of their special condition at any period of time, of the faculties possessed by each, of the laws of all the orders which regulate their changes and effects, and, lastly, of the movement which never leaves them in absolute rest, there continually reigns throughout the whole of nature a mighty activity, a succession of movements and transformations of all kinds, which nothing could arrest or annihilate, unless it be the power which has made all things exist.

The idea of nature as eternal, and hence as having existed for all time, is for me an abstract opinion without foundation, finality or probability, and with which my reason could never be satisfied. Since I can have no positive knowledge on this subject, and no power of reasoning about it, I prefer to think that the whole of nature is only an effect: hence, I imagine and like to believe in a First Cause or, in

short, a Supreme Power which brought nature into existence and made it such as it is.

As naturalist and physicist, however, I am only concerned in my studies of nature with the bodies that we know or that have been observed, with the qualities and properties of these bodies, with the relations that they may have to one another under different conditions, and finally, with the effects of these relations and of the diverse movements which are distributed and ever preserved among them.

This method, which is the only one open to us, makes it possible to obtain a glimpse of the causes of those multitudinous phenomena which nature exhibits in her various parts, and to arrive at an understanding of the causes of the wonderful phenomena presented by living bodies, in short, the causes of life.

It is no doubt a very important matter to enquire into the nature of what is called life in a body ; what are the conditions of organisation necessary for its existence ; what is the origin of that remarkable force which gives rise to vital movements so long as the state of organisation allows ; lastly, how the various phenomena resulting from the continued presence of life in a body may achieve their result and endow this body with the faculties observed in it ; but of all the problems which man can suggest these are beyond question the most difficult to solve.

It seems to me that it was much easier to determine the course of the stars observed in space, and to ascertain the distance, magnitudes, masses and movements of the planets belonging to our solar system, than to solve the problem of the origin of life in the bodies possessing it, and, consequently, of the origin and production of the various existing living bodies.

However difficult may be this great enquiry, the difficulties are not insuperable ; for in all this we have to deal only with purely physical phenomena. Now it is obvious that the phenomena in question are, on the one hand, only direct effects of the mutual relations of different bodies, and only the result of an order and state of things which give rise to these relations among some of them ; and, on the other hand, it is obvious that these phenomena result from movements set up in the parts of these bodies by a force whose origin it is possible to ascertain.

These early results of our enquiries are unquestionably of very great interest, and give us a hope of obtaining other results no less important. But however well founded they may be, it will perhaps yet still be long before they obtain the attention which they deserve ; because they have to contend with one of the most ancient preconceptions, they have to destroy inveterate prejudices, and present a new field of study very different from any that we are accustomed to.

It is apparently reflections of this kind which caused Condillac to say that " reason has very little force and makes very slow progress, when it has to destroy errors from which no one is exempt " (*Traité des Sensations*, vol. i., p. 1108).

M. Cabanis unquestionably established a very great truth by a series of unexceptionable facts, when he said that the moral and the physical both spring from a common origin ; and when he showed that the operations called moral are directly due, like those called physical, to the activity either of certain special organs, or of the living system as a whole ; and, finally, that all the phenomena of intelligence and will take their origin from the congenital or fortuitous state of the organisation.

But in order to see more clearly how firmly this great truth is based, we must not confine ourselves to seeking the proofs of it by an examination of the highly complicated organisation of man and the more perfect animals ; proof will be obtained still more easily by studying the diverse progress in complexity of organisation from the most imperfect animals up to those whose organisation is the most complex ; for this progress will then exhibit in turn the origin of every animal faculty and the causes and developments of these faculties. We shall then acquire a renewed conviction that those two great branches of our existence called the physical and the moral, which exhibit two orders of phenomena apparently so distinct, have a common basis in organisation.

This being so, it is in the simplest of all organisations that we should open our inquiry as to what life actually consists of, what are the conditions necessary for its existence, and from what source it derives the special force which stimulates the movements called vital.

As a matter of fact it is only by a study of the simplest organisations that we can attain a knowledge of the true conditions for the existence of life in a body ; for in a complex organisation all the principal internal organs are necessary for the maintenance of life on account of their close connection with other parts of the system, and because the system itself is formed on a plan which requires these organs ; but it does not follow that these same organs are essential to the existence of life in all living bodies whatsoever.

This is very important to remember when we are enquiring what are the real conditions for the constitution of life ; otherwise we might thoughtlessly attribute to some special organ an existence that is indispensable for the manifestations of life.

The peculiarity of vital movements is to be started and maintained by stimulus and not by transmission. These movements are the only ones of this character in nature, except perhaps for those of fermentation ; they differ however from the movements of fermentation in

that they can be maintained almost unchanged for a limited period, and in that they lead to a growth subsequently maintained for some time of the body in which they work, whereas those of fermentation irreparably destroy the body subjected to it and increase up to the limit that annihilates them.

Since vital movements are never transmitted but always stimulated, we must enquire what is their exciting cause, that is to say, from what source living bodies derive the peculiar force which animates them.

Whatever may be the state of organisation of a body and of its essential fluids, active life could assuredly not exist in that body without a special cause capable of exciting its vital movements. Whatever hypothesis we may form in this matter, we are always obliged to recognise that some special cause must be present for the active manifestations of life. Now it can no longer be doubted that this cause which animates living bodies is to be found in the environment of those bodies, and thus varies in intensity according to places, seasons, and climates. It is in no way dependent on the bodies which it animates, it exists before they do and remains after they have been destroyed. Lastly, it stimulates in them the movements of life, so long as the state of these bodies allows ; and it ceases to animate them when that state opposes obstacles to the performance of the movements which it stimulates.

In the most perfect animals this exciting cause of life is developed within themselves, and suffices to animate them up to a certain point ; but it still needs the co-operation of that provided by the environment. In the other animals, and in all plants it is altogether external to them ; so that they can only obtain it from their environment.

When these interesting facts have been ascertained and settled, we shall enquire how the first outlines of organisation come to be formed, how spontaneous generation can have occurred and in what part of the two series of living bodies.

If, indeed, bodies which possess life are really productions of nature, she must have had and still have the faculty of producing some of them spontaneously. She must then have endowed them with the faculty of growth, multiplication and increasing complexity of organisation and the power of varying according to time and circumstances. She must have done this if all those that we now observe are really the products of her power and efforts.

After recognising the necessity for these acts of direct creation, we must enquire which are the living bodies that nature may produce spontaneously, and distinguish them from those which only derive their existence indirectly from her. Assuredly the lion, eagle, butterfly, oak, rose, do not derive their existence immediately from nature ; they derive it as we know from individuals like themselves who transmit it to them by means of reproduction ; and we may be sure that if the entire species of the lion or oak chanced to be destroyed in those parts of the earth where they are now distributed, it would be long before the combined powers of nature could restore them.

I propose then to show what is the method apparently used by nature for forming, in favourable places and conditions, the most simply organised living bodies and through them the most perfect animals ; how these fragile animals, which are the mere rudiments of animality directly produced by nature, have developed, multiplied and become varied ; how at length, after an infinite series of generations, the organisation of these bodies has advanced in complexity and has extended ever more widely the animal faculties of the numerous resulting races.

We shall find that every advance made in complexity of organisation and in the faculties arising from it has been preserved and transmitted to other individuals by means of reproduction, and that by this procedure maintained for very many centuries nature has succeeded in forming successively all the living bodies that exist.

We shall see, moreover, that all the faculties without exception are purely physical, that is, that each of them is essentially due to activities of the organisation ; so that it will be easy to show how, from the humblest instinct, the origin of which can be easily ascertained, nature has attained to the creation of the intellectual faculties from the most primitive to the most highly developed.

My readers must not expect to find here a treatise on physiology : the public is already in possession of excellent works of this character in which I have few alterations to suggest ; but I must marshal together the general facts and well-established fundamental truths on this subject, because I find that their association leads to new light which has escaped those who have occupied themselves with details, and because this light clearly shows us what the bodies endowed with life really are, why and how they exist, and in what manner they develop and reproduce ; lastly, by what methods the faculties observed in them have arisen, and been transmitted and retained in the individuals of each species.

If we wish to grasp the chain of physical causation which brought living bodies into existence, we must pay attention to the principle which I embody in the following proposition :

It is to the influence of the movements of various fluids in the more or less solid substances of our earth that we must attribute the formation, temporary preservation, and reproduction of all living bodies

observed on its surface, and of all the transformations incessantly undergone by the remains of these bodies.

If we neglect this important principle, we become involved in an inextricable confusion, and the general cause of observed facts and objects cannot be perceived; our knowledge of this subject then remains without value, coherence or progress, so that instead of comprehensible truths we shall continue to set up those phantoms of our imagination and that love of the marvellous, in which the human mind takes so much delight.

If, on the other hand, we pay to this proposition all the attention to which its importance entitles it, we shall then see that there naturally flow from it a number of subordinate laws which furnish an explanation of all the well-known facts concerning existence, nature, and the various faculties; and, lastly, concerning the transformations of living bodies, and the other more or less complex bodies that exist.

As to the constant but variable movements of the fluids that I am about to discuss, it seems quite clear that they are permanently maintained on our earth by the influence of the sunlight. Sunlight is incessantly causing modifications and displacements of great masses of these fluids in certain regions of the earth, and forcing them to undergo a kind of circulation and various sorts of movements, so that they are able to produce all the observed phenomena.

To establish the accuracy of this statement, I shall merely have to introduce order into my citation of the facts and their relations, and into the application of these principles to observed phenomena.

In the first place it is necessary to distinguish the visible fluids, which are contained in living bodies and there undergo constant change and movement, from certain other subtle fluids which are always invisible but which animate these bodies and are indispensable to the existence of life.

Next, when considering the effects of the activity of the invisible fluids, to which I refer, on the solid, fluid and visible parts of living bodies, we shall easily discern that the organisation of these different bodies and all their movements and modifications are entirely due to the movements of the various fluids occurring in these bodies; that the fluids in question have by their movements organised these bodies, modified them in various ways and modified themselves also, so as gradually to have produced the state of things now observed.

In short, if we give sustained attention to the various phenomena presented by organisation, and especially to those concerned with the development of that organisation mainly in the most imperfect animals, we shall reach the following convictions:

1. That the entire work of nature in her spontaneous creations consists in organising into cellular tissue the little masses of gelatinous or mucilaginous material which she finds at hand under favourable circumstances; in filling these little cellular masses with fluids and in vivifying them, by setting these contained fluids in motion by means of the stimulating subtle fluids which are incessantly flowing in from the environment;

2. That cellular tissue is the framework in which all organisation has been built, and in the midst of which the various organs have successively developed by means of the movement of the contained fluids which gradually modifies the cellular tissue;

3. That the function of the movement of the fluids in the supple parts of the living bodies which contain them, is to cut out paths and establish depots and exits, to create canals and afterwards various organs; to cause variation in these canals and organs by means of a diversity either in the movements or in the nature of the fluids which produce and modify them; finally to enlarge, elongate, divide and solidify gradually these canals and organs by substances which are formed and incessantly separated off from the essential fluids in movement there; substances of which one part becomes assimilated and united with the organs while the other is thrown out;

4. That, lastly, the function of organic movement is not merely the development of organisation, and the increase and growth of the parts, but also the multiplication of organs and of the function which they fulfil.

After having expounded these great principles which seem to me unquestionable truths although not hitherto recognised, I shall enquire what faculties are common to all living bodies and consequently to all animals; I shall then pass in review the chief of the faculties which are peculiar to certain animals but are not possessed by the rest.

I venture to affirm that grave injury results to the progress of physiological knowledge by the thoughtless supposition that all animals without exception possess the same organs and enjoy the same faculties; as though nature were everywhere forced to employ the same methods to attain her end. Seeing that nothing more than an active imagination is needed for setting up principles if we do not pause to consider facts, it is an easy supposition that all living bodies possess the same organs and hence enjoy the same faculties.

Another subject which I must not neglect in this second part of my work is the question of the immediate results of life in a body. Now I am in a position to show that these results give rise to combinations between principles which, except for this factor, would never have been united together. These combinations accumulate more and more according as the vital energy increases, so that in the most perfect

animals there is a high complexity and great intricacy in the combination of principles. Living bodies thus constitute, by their possession of life, nature's principal means for bringing into existence a number of different compounds which would never otherwise have arisen.

It is vain to imagine that living bodies find ready formed in the substances on which they feed all the material required for building up the various parts of their bodies; they only find in these food substances, materials suitable for entering into the combinations which I have mentioned, and not the combinations themselves.

It is no doubt owing to an insufficient study of the power of life in the bodies which possess it, and the failure to perceive the results of this power, that it has been alleged that living bodies find in their ordinary food the material ready prepared which serves for building up their bodies and that these materials have existed in nature for all time.

Such are the subjects which compose the second part of this work: their importance would no doubt justify considerable expansion; but I have confined myself to a concise exposition of what is necessary in order that my observations may be understood.

CHAPTER I.

COMPARISON OF INORGANIC BODIES WITH LIVING BODIES, FOLLOWED BY A PARALLEL BETWEEN ANIMALS AND PLANTS.

I LONG ago conceived the idea of making a comparison between organised living bodies and crude inorganic bodies. I then noticed the extreme difference existing between these two, and I became convinced of the necessity for examining the kind and amount of this difference. It was at that time the general custom to present the three kingdoms of nature arranged in a line, with class distinctions between them; and the enormous difference apparently was not perceived between a living body and a crude lifeless body.

Yet if we wish to arrive at a real knowledge of what constitutes life, what it consists of, what are the causes and laws which control so wonderful a natural phenomenon, and how life itself can originate those numerous and astonishing phenomena exhibited by living bodies, we must above all pay very close attention to the differences existing between inorganic and living bodies; and for this purpose a comparison must be made between the essential characters of these two kinds of bodies.

COMPARISON BETWEEN THE CHARACTERS OF INORGANIC BODIES AND THOSE OF LIVING BODIES.

1. No crude or inorganic body possesses individuality except in its integral molecule; the solid, fluid or gaseous masses that may be formed by a collection of integral molecules have no limits; and the large or small size of these masses neither adds nor subtracts anything that can alter the nature of the body concerned; for this nature is exclusively dependent on that of the integral molecule of the body.

Every living body, on the other hand, possesses an individuality throughout its mass and volume; and this individuality, simple in some and compound in others, is never confined in living bodies to that of their component molecules.

2. An inorganic body may present a truly homogeneous mass or it may constitute a heterogeneous mass; the aggregation or combination of similar or dissimilar parts can occur without these bodies ceasing to be crude or inorganic. In this respect there is no essential necessity for the masses of this body to be more homogeneous than heterogeneous or *vice versâ*; it is by chance that they are as we observe them.

All living bodies, on the contrary, even those with the simplest organisations, are necessarily heterogeneous, that is to say, composed of dissimilar parts: they have no integral molecules, but are formed from molecules of a different character.

3. An inorganic body may constitute either a perfectly dry, solid mass or a completely liquid mass or a gaseous fluid.

The contrary holds good in the case of all living bodies; for no body can possess life unless it is formed from two kinds of necessarily co-existing parts, the one solid, but supple and capable of holding liquids; the other liquid and contained in the first, but quite independent of the invisible fluids which penetrate the body and develop within it.

The masses which constitute inorganic bodies have no special specific shape; for whether these masses have a regular shape, as in the case of crystals, or whether they are irregular, their shape does not remain permanently the same; it is only the integral molecule which has in each kind an invariable shape.[1]

Living bodies, on the contrary, nearly all exhibit a shape peculiar to their species and one which cannot vary without giving rise to a new race.

4. The integral molecules of an inorganic body are entirely independent of one another; for even when they are combined into a solid, liquid or gaseous mass, each of them continues to exist by itself and to be constituted by the number, proportions, and character of combination of its principles; its existence is neither conditioned nor increased by the similar or dissimilar molecules in its neighbourhood.

The molecules of a living body, on the other hand, and consequently all the parts of that body, are dependent for their character upon one another; because they are all subjected to the influence of a factor

[1] The integral molecules which constitute a compound substance all result from combinations of the same number of principles in the same proportions, with exactly the same character of combination: hence they all have the same shape, density and special properties.

But when any causes have produced a variation either in the number of the component principles of these molecules, or in the proportions of the principles, or in the character of their combination, these integral molecules then acquire another shape, density and special properties: they then belong to another species.

which animates them and gives them activity, and because this factor requires their co-operation for a common end both in the separate organs and in the entire individual; because, moreover, the variations in this same factor work similar effects in the state of each molecule and each part.

5. No inorganic body needs any movement in its parts for its preservation; on the contrary, so long as the parts remain at rest the body is preserved without disintegration and might exist in this condition for ever. But as soon as any factor begins to act upon this body and produce movements and changes in its parts, the body at once loses either its shape or its coherence, if the movement and changes produced in its parts merely affect its mass or some part of its mass; and it loses even its fundamental character or is destroyed, if the movements and changes in question penetrate as far as its integral molecules.

Every body possessing life, on the other hand, is permanently or temporarily animated by a special force, which incessantly stimulates movements in its internal parts and uninterruptedly produces changes of state in these parts, at the same time effecting restorations, renewals, developments and a number of phenomena that are entirely peculiar to living bodies; so that in their case the movements stimulated within them produce disintegration and destruction followed by recuperation and renewal. This prolongs the life of the individual so long as the equilibrium between these two opposed elements is not too rudely disturbed.

6. In all inorganic bodies an increase of volume and mass is always accidental and has no necessary limits. This increase only takes place by *juxtaposition*, that is to say, by the addition of new parts to the external surface of the body in question.

The growth of every living body, on the contrary, is always necessary and limited, and only takes place by *intussusception*, that is to say, by internal penetration, or the introduction into the individual of substances which have to be added to it and make part of it after being assimilated. Now this growth is a true development of parts from within outwards, and is exclusively the property of living bodies.

7. No inorganic body has to feed in order to be preserved; for it need never lose any of its parts, and when it does it has no means of restoring them.

All living bodies, on the contrary, necessarily experience in their internal parts successive and constantly renewed movements, changes in the state of the parts, and, lastly, continual losses of substance through the separations and dissipations involved by these changes. Hence no such body can maintain life if it is not constantly feeding,

that is to say, if it is not incessantly making good its losses by substances introduced into its interior, in short, if it does not take food whenever it needs it.

8. The masses of inorganic bodies consist of separate parts which are united by accident; these bodies are not born, nor are they ever the produce of a germ or bud whose development gives rise to an individual exactly similar to that from which it springs.

All living bodies, on the contrary, are really born, and are the produce either of a germ which has been vivified and prepared for life by fertilisation, or else simply of an expansible bud. In either of these cases new individuals arise exactly like those which have produced them.

9. Lastly, no inorganic body can die, inasmuch as no such body possesses life. Death is a necessary result of the existence of life in a body, for it is only the complete cessation of organic movements, following upon some disturbance which makes these movements henceforth impossible.

All living bodies, on the contrary, are subject to an inevitable death; for it is a property of life or of the movements constituting life in a body, to bring about after a certain period a condition of the organs which makes it impossible for them to carry on their functions, and which therefore destroys the faculty of performing organic movements.

Hence between crude or inorganic bodies and living bodies there exists an immense difference, a great hiatus, in short, a radical distinction such that no inorganic body whatever can even be approached by the simplest of living bodies. Life and its constituents in a body make the fundamental difference that distinguishes this body from all those that are without it.

How great then is the error of those who try to find a connection or sort of gradation between certain living bodies and inorganic bodies!

Although M. Richerand in his interesting *Physiologie* has dealt with the same subject that I am now treating, I have had to reproduce his views together with modifications of my own; since his studies are very important on the subjects which I still have to set forth.

A comparison between plants and animals does not immediately concern my thesis in this Part II.; nevertheless, as such a comparison assists in the general purpose of this work, I propose here to state a few of its most prominent characteristics. But first let us see what plants and animals actually have in common, in their capacity as living bodies.

The only point in common between animals and plants is the possession of life; hence they both fulfil the conditions of its existence, and possess the general faculties to which it gives rise.

Hence in both cases they are bodies composed essentially of two kinds of parts, the one solid but supple and containing; the other liquid and contained, but independent of the invisible fluids which penetrate and develop within them.

All these bodies possess individuality, either simple or compound; have a shape peculiar to their species; are born at the moment when life begins to exist in them or when they are separated from the body whence they spring; are permanently or temporarily animated by a special force which stimulates their vital movements; are only preserved through nutrition which more or less restores their losses of substance; grow for a limited period by internal development; form for themselves the compound substances of which they are made; reproduce and multiply so as to carry on the species like themselves; lastly, all reach a period when the state of their organisation no longer permits of the maintenance of life within them.

Such are the faculties common to these two kinds of living bodies. Let us now compare the general characters by which they are distinguished from each other.

Comparison between the General Characters of Plants and Animals.

Plants are organised living bodies, not irritable in any of their parts, incapable of performing sudden movements several times in succession, and the vital movements of which are only performed by means of external stimuli, that is to say, by an exciting cause provided by the environment and acting chiefly on the contained and visible fluids of these bodies.

In animals, some or all of the parts are essentially irritable, and have the faculty of performing sudden movements which may be repeated several times in succession. The vital movements are in some performed by means of external stimuli, and in others by a force developing within them. The external stimuli and internal stimulating force affect the irritability of the parts, act upon the visible contained fluids and give rise in all cases to the performance of vital movements.

It is certain that no plant whatever has the faculty of suddenly moving its external parts and repeating such movement several times in succession. The only sudden movements that certain plants display are movements of relaxation or collapse of some part (*v.* p. 52); hygrometric or pyrometric movements also are sometimes performed by certain filaments when suddenly exposed to the air. As to the other movements performed by the parts of plants, such as those which make them bend towards the light, those which cause the opening and closing of flowers, those which give rise to the erection

or depression of stamens or peduncles or to the twining of climbing stems and tendrils, finally, those constituting what is called sleeping and waking in plants; none of these movements are ever sudden; they are carried out so slowly as to be altogether imperceptible; and they are only known by their finished results.

Animals, on the contrary, possess the faculty of performing very obvious sudden movements, by means of some of their external parts, and of repeating them several times in succession with or without variation.

Plants, especially those which live partly in the air, grow in a remarkable manner in two opposite directions, in such a way as to exhibit an ascending vegetation and a descending vegetation. These two kinds of vegetation start from a common point which I have elsewhere[1] named the vital knot, because in this point life is specially concentrated when the plant loses its structures, and because the plant only really dies when life ceases to exist in this part. The organisation of this vital knot, otherwise known as the root-collar, is altogether peculiar; from the vital knot the ascending vegetation produces the stem, branches and all the parts of the plant that are in the air; and from the same point the descending vegetation gives birth to roots which are buried in the soil or in water. Finally, in germination, which brings the seeds into life, the early development of the young plant requires ready prepared juices, which the plant cannot yet draw from the soil or from the air; these juices then appear to be furnished by the cotyledons, which are always attached to the vital knot; they suffice for starting the ascending vegetation of the plumule and the descending vegetation of the radicle.

Nothing of the kind is observed in animals. Their development is not limited to two special directions only, but takes place on all sides and in all directions, according to their requirements; finally, their life is never concentrated in an isolated point but is spread throughout the essential special organs, if there are any. In animals in which there are no essential special organs, life is not concentrated in any one part; for when we divide their bodies life is preserved in each separate part.

Plants in general rise perpendicularly, not to the plane of the earth on all occasions, but to that of the horizon; so that according as they grow they shoot upwards towards the sky like a sheaf of rockets in a firework display. Although the twigs and branches which form their tops do not follow the direction of the stem, they always form an acute angle with the stem at their point of insertion. It appears that the stimulating force of the vital movements in these bodies is

[1] *Histoire Naturelle des Végétaux*, édition de Déterville, vol. i., p. 225.

chiefly directed upwards and downwards, and that this is the reason of the peculiar shape and arrangement of these living bodies, in short, of their ascending and descending vegetation. From this it follows that the canals, in which move the essential fluids of these bodies, are parallel to one another and to the longitudinal axis of the plant; for it is always parallel, longitudinal tubes that are formed in their cellular tissue, and these tubes do not diverge except to form the flattened expansions of leaves and petals, or to be distributed in the fruit.

Nothing of all this is found in animals. The longitudinal axis of their bodies is not necessarily directed towards the sky, on the one hand, and the centre of the earth, on the other hand; the force which stimulates their vital movements does not work exclusively in two directions; lastly, the internal canals which contain their visible fluids are turned about in various ways and present no sort of parallelism.

The food of plants consists only of the liquid or fluid substances which they absorb from the environment: this food includes water, atmospheric air, caloric, light, and various gases which they decompose and convert to their own use; hence they never have to carry on digestion, and for this reason they have no digestive organs. Seeing that living bodies themselves elaborate their own substance, it is they which form the first non-fluid combination.

Most animals, on the contrary, feed on substances which are already compound and which they introduce into a tubular cavity suitable to receive them. Hence they have a digestion in order to bring about the complete solution of these substances; they modify existing combinations and load them heavily with new principles; so that it is they which form the most complex combinations.

Lastly, the final residue of destroyed plants is very different from that which emanates from animals, showing that these two kinds of living bodies are indeed of an entirely distinct nature.

In plants, as a matter of fact, solids exist in larger proportion than fluids, mucilage constitutes their softest parts, and carbon predominates among their component principles; whereas in animals fluids are more abundant than solids, gelatine abounds in their soft parts and even in the bones of such as have any, while among their components nitrogen is specially conspicuous.

Moreover, the strata formed out of the residue of plants is chiefly argillaceous and often contains silica, whereas those formed from animals consist either of the carbonate or phosphate of lime.

Some Features of Analogy between Animals and Plants.

Although the nature of plants is very different from that of animals, and although the bodies of the one always possess faculties and even substances that would vainly be sought in the other, the fact remains that they are both living bodies and that nature obviously followed a uniform plan of operations in producing them. In point of fact, nothing is more remarkable than the analogy observed between certain of her operations in these two kinds of living bodies.

In both of them, the most simply organised only reproduce by gemmae or buds. These are reproductive corpuscles which are like eggs or seeds, but require no preliminary fertilisation, and which indeed contain no embryo which has to break through its investments before being able to complete its development. Yet in both animals and plants, when the complexity of organisation was sufficiently advanced to permit of the formation of organs of fertilisation, the reproduction of individuals then became exclusively or chiefly sexual.

Another very remarkable feature of analogy, in the operations of nature, between animals and plants, is the more or less complete suspension of active life, that is to say, of vital movements, which is experienced in certain climates and seasons by a large number of living bodies of both kinds.

In the winter of cold climates, indeed, the woody perennial plants undergo a more or less complete suspension of vegetation, and hence of organic or vital movements; their fluids, which are at these periods less abundant, remain inactive: during these conditions, there occur in the plants no losses or absorptions of food or any alterations or development; in short, their active life is altogether suspended, their bodies become torpid and yet they are not lifeless. Since the truly simple plants can only live for a year, they hurriedly produce their seeds or reproductive corpuscles in cold climates and die on the approach of the bad season.

The phenomena of the more or less complete suspension of active life, that is, of the organic movements composing it, are also witnessed in many animals in very curious forms.

In the winter of cold climates life comes to an end in the most imperfect animals; and among those which retain life, a great many become more or less completely torpid, so that in some all the internal or vital movements are suspended, while in others they still exist but are only performed with extreme slowness. Thus although nearly all the classes contain animals which undergo this more or less complete suspension of active life, it is particularly noticeable in the ants, bees, and many other insects; in the annelids, molluscs, fishes, reptiles (especially snakes), and, lastly, in many mammals such as the bat, marmot, dormouse, etc.

The last feature of analogy that I shall name is no less remarkable; it is this: just as there are simple animals constituting separate individuals, and compound animals adhering together, communicating at their base and sharing a common life such as most of the polyps, so also there are simple plants living as individuals and there are compound plants where several live together, are grafted on to one another and share a common life.

The general rule among plants is to live until they have produced flowers and fruit or reproductive corpuscles. Their lives rarely last for more than a year. Their sexual organs, if they have any, are only of use for a single fertilisation; so that when plants have reached the goal of reproduction (seeds), they die and are completely destroyed.

In the case of a simple plant, death takes place after the production of fruit; and it is difficult, as we know, to propagate it otherwise than by seeds or gemmae.

Annual or biennial plants all appear to be in this position; they are simple plants; and their roots, stems and branches are simply vegetative products; it is by no means every plant however that is in this position, for the greater number of those that are known are in reality compound plants.

Thus, when I see a tree, shrub or perennial, it is not simple plants that I have before me, but a multitude of plants living together upon one another and all sharing a common life.

So true is this that if I were to graft the shoot of a cherry tree on to the branch of a plum tree, and an apricot shoot on to another branch of the same tree, these three species would live together and share a common life while yet remaining distinct.

The roots, trunk, and branches of such a plant consist purely of the vegetable products of this common life, and of separate but adherent plants which live upon it; just as the general substance of a madrepore is the animal product of numerous polyps which live together through successive generations. But every bud in a plant is itself an individual plant, which shares in the common life of all the rest, develops its flower or inflorescence once a year, then produces fruit and may finally give rise to a branch already supplied with other buds, that is, other individual plants. Each of these individual plants either fruits, in which case it does so only once, or produces a branch which gives rise to other similar plants. Any such composite plant is thus a vegetable product, which continues to live after the destruction of all the individuals which have combined to produce it.

By separating off parts of a plant, containing one or more buds or including undeveloped elements, we can form at pleasure a number of new living individuals similar to those from which they are taken, without any necessity for taking the fruit. This in fact is just what horticulturists do when they take slips, layers, etc.

Now just as nature has made compound plants, so too she has made compound animals; and for this purpose she has made no change in the nature of either animals or plants. It is quite as absurd to call compound animals by the name of plant-animals, as it would be to call compound plants by the name of animal-plants.[1]

If the name of zoophyte were given a century ago to compound animals of the class of polyps, the error was excusable; the low state of knowledge then existing about animal nature made this term less obnoxious; but now things have altered, and it cannot be a matter of indifference that a class of animals should receive a name which embodies a false notion of the objects indicated.

Let us now enquire what life is, and what are the conditions for its existence in a body.

[1] When we confine our attention to the substances produced by vegetation or by animals, we often find cases where it is difficult to decide whether they belong to the plant or animal kingdom; chemical analysis of these bodies sometimes decides in favour of animal substances when their shape and organisation are suggestive of true plants. Several genera referred to the family of algae provide examples of this difficulty: it would thus seem to follow that there is an almost imperceptible transition from plants to animals.

I do not think so: on the contrary, I am thoroughly convinced that if it were possible to examine the actual animals which form the membranous or filamentous polyparies so closely resembling plants, the uncertainty as to their true nature would at once be removed.

CHAPTER II.

OF LIFE, WHAT IT CONSISTS OF, AND THE CONDITIONS OF ITS EXISTENCE IN A BODY.

LIFE, said M. Richerand, is a collection of phenomena which succeed one another for a limited period in organised bodies.

He should have said, life is a phenomenon which gives rise to a collection of other phenomena, etc.; for it is not these other phenomena that constitute life, but they are themselves caused by life.

A study of the phenomena resulting from the existence of life in a body provides no definition of life, and shows nothing more than objects that life itself has produced. The line of study which I am about to follow has the advantage of being more exact, more direct and better fitted to illuminate the important subject under consideration; it leads, moreover, to a knowledge of the true definition of life.

Life when studied in living bodies is exclusively due to the relations existing between the three following objects: the parts of the body adapted for containing liquids, the contained liquids moving in them, and the exciting cause of such movements and changes as are carried out.

Whatever efforts we may make by the most profound thought and meditation to decide as to what life consists of, we shall necessarily be compelled to fall back on the principle just enunciated as soon as we pay attention to the teaching of observation on the matter; in fact, life consists of nothing else.

A comparison drawn between life and a watch in active movement is inadequate, to say the least of it; for in the watch there are only two main points to consider: (1) the wheels and machinery of movement; (2) the spring which by its tension and elasticity keeps up the movement so long as that tension continues.

But in a living body, instead of two chief points for study, there are three: (1) the organs or supple containing parts; (2) the essential contained fluids which are always in motion; (3) lastly, the exciting

cause of vital movements, from which arises the action of the fluid on the organs and the reaction of the organs on the fluids. It is then purely from the relations between these three objects that the movements, changes, and all the phenomena of life result.

In order to improve the comparison between a watch and a living body we should have to compare the exciting cause of organic movements with the spring of the watch, and regard the supple containing parts, together with the essential contained fluids, as the machinery of the movement in question.

It will then be clear, in the first place, that the spring (exciting cause), is the essential motive power, without which the whole remains inactive, and that its variations of tension must be the cause of the variations of energy and rapidity of movements.

In the second place, it will be obvious that the machinery of movement (the organs and essential fluids) must be in a state and arrangement suitable for the performance of the movements which it has to carry out; hence, when this machinery gets out of order the effective power of the spring is lost.

From this point of view the parallel is complete; a living body may be compared with a watch; and I can easily show the close accuracy of this comparison by reference to known facts and observations.

As to the machinery of movement, its existence and faculties are now well known, as also most of the laws which control its various functions.

But as to the spring, the essential motive power and originator of all movements and activities, it has hitherto escaped the researches of observers: I believe, however, that I shall be able to describe it in the next chapter, in such a way that it cannot in future be neglected.

But first let us continue the enquiry as to what essentially constitutes life.

Seeing that life in a body results exclusively from the relations existing between the containing parts in an appropriate condition, the contained fluids moving in them, and the exciting cause of the movements, activities and reactions which take place, we may include what essentially constitutes life in the following definition.

Life, in the parts of any body which possesses it, is an order and state of things which permit of organic movements; and these movements constituting active life result from the action of a stimulating cause which excites them.

This definition of life, either active or suspended, includes all the positive facts which have to be expressed in it, and covers all special cases. It appears to me impossible to add or subtract a single word

without destroying the integrity of the essential ideas contained in it; lastly, it is based on the known facts and observations which have reference to this wonderful natural phenomenon.

To begin with, in this definition active life is kept distinct from that life which, without ceasing to exist, is suspended and appears to be maintained for a limited time without perceptible organic movements; and this, as I shall show, is in accordance with observation.

Then it brings out the fact that no body can possess active life except when the two following conditions are satisfied.

The first is the necessity for a stimulating cause which excites organic movements.

The second is the necessity that a body in order to possess and maintain life should be so ordered in its parts as to possess the property of responding to the action of the stimulating cause and of producing organic movements.

In the animals whose essential fluids are quite simple, such as the polyps and infusorians, if the contained fluids of any of these animals are suddenly removed by a rapid desiccation, such desiccation may be carried out without any disintegration of the organs or containing parts of this animal or any destruction of the order existing in them: in this case life is altogether suspended in the desiccated body; no organic movement occurs in it and it appears no longer to be a living body. Yet it cannot be called dead, for its organs or containing parts have retained their integrity, and if the internal fluids are restored to this body, the stimulating cause, assisted by a gentle warmth, soon excites movements, activities, and reactions in its parts and henceforth it returns to life.

The rotifer of Spallanzani, which was several times reduced to a state of death by rapid desiccation, and afterwards restored to life on being plunged into tepid water, shows that life can be alternately suspended and renewed: it is therefore only an order and state of things in a body, by means of which vital movements can occur when stimulated by a special cause.

In the plant kingdom, the algae and mosses exhibit the same phenomena as the rotifer of Spallanzani; mosses rapidly desiccated and kept in a herbarium even for a century may return to life and fresh vegetation, if they are placed in moisture at a moderate temperature.

Complete suspension of vital movements without degeneration of the parts, and hence with a continued possibility of a return of these movements, may also occur in man himself, though only for a very short time.

We learn from observations made on people that have been drowned, that if anyone falls into the water and is pulled out again after an

immersion of three-quarters of an hour or even an hour, he is asphyxiated to the extent that no movement whatever takes place in his organs. Yet it may still be possible to restore him to active life.

If he is left in this condition without any assistance, orgasm and irritability soon become extinct in his internal parts, and thereafter the essential fluids and the softest parts begin to decompose, and this is the sign of death ; but if, immediately after his extraction from the water and before the extinction of irritability, the usual aid is administered to him, if, in short, it is possible by means of the usual stimulants to excite in time contractions in his internal parts, and produce movements in his organs of circulation, then all the vital movements quickly resume their course, and active life no longer remains in suspense but is promptly restored.

But when degenerations and disorders of a living body, either in the order or in the state of its parts, are large enough to prevent these parts from yielding to the influence of the exciting cause and producing organic movements, then life is quickly extinguished, and the body henceforth is no longer included among the living.

From what I have just said, it follows that if in a body any disturbance or degeneration affects the order and state of things which endow it with active life, and if this disturbance is of a nature to prevent the performance of organic movements or their restitution after suspension, the body then loses its life, that is to say, it undergoes death.

A disorder resulting in death may be brought about in a living body through various accidental causes ; but nature becomes the necessary cause at the end of a certain period ; and, in fact, it is a property of life to bring the organs imperceptibly to a condition in which they cannot perform their functions, so that death inevitably ensues ; the reason of this I shall explain.

When therefore we affirm that life, in all bodies which possess it, consists only of an order and state of things in the parts of the body, by which these parts are subject to the influence of a stimulating cause and carry out organic movements, we are not expressing a mere conjecture but a fact universally attested, susceptible of many proofs and never liable to be seriously disputed.

This being so, we are only concerned to know what is the order and state of the parts which make a body capable of possessing active life.

But as no precise knowledge of this subject can be directly acquired, let us first investigate the conditions essential to the existence of this order and state of things in the parts of the body, in order that it may possess life.

Conditions essential to the Existence of the Order and Structure of a Body in order that it may possess Life.

First condition. No body can possess life unless it consists essentially of two kinds of parts, viz. supple containing parts and contained fluid substances.

As a matter of fact, no body that is perfectly dry can be alive, nor can any body whose parts are fluid be in possession of life. The first condition essential to life in a body therefore is that it should consist of a mass with two kinds of parts, the one solid and containing, but soft and more or less cohesive, the other fluid and contained.

Second condition. No body can possess life unless its containing parts are cellular tissue or formed out of cellular tissue.

Cellular tissue, as I shall show, is the matrix in which all the organs of living bodies have been successively formed; and the movement of fluids in this tissue is the means adopted by nature for the gradual creation and development of these organs.

Every living body is thus essentially a mass of cellular tissue in which more or less complex fluids move more or less rapidly ; so that if the body is very simple, that is, has no special organs, it appears homogeneous and consists only of cellular tissue containing fluids which are slowly moving ; but if its organisation is complex, all its organs without exception are invested in cellular tissue down to their smallest parts, and are even essentially formed of it.

Third condition. No body can possess active life except when an exciting cause of its organic movements works within it. Without the impulse of this active stimulus, the solid containing parts of an organised body would be inert, the contained fluids would remain at rest, organic movements would not take place, no vital function would be carried out, and consequently active life would not exist.

Now that we know the three conditions essential to the existence of life in a body it becomes easier for us to ascertain wherein consist the order and state of things necessary to a body for the maintenance of life.

For this purpose, we must not limit our enquiries to living bodies with a highly complex organisation ; for we should never learn from them to what cause life is to be attributed, and we might select at hazard factors of no fundamental importance.

But if we fix our attention on that extremity, either of the animal or plant kingdom, in which are found living bodies with the simplest organisations, we shall notice, in the first place, that in each individual the body consists only of a gelatinous or mucilaginous mass of cellular tissue of the feeblest coherence, the cells of which are in communication,

and the various fluids of which undergo movements, displacements, dissipations, subsequent renewals, changes of state, and finally deposit parts which become fixed there. We shall then observe that an exciting cause of varying activity, but never entirely absent, incessantly animates the very supple containing parts of these bodies, as well as the essential fluids contained in them, and that this cause keeps up all the movements constituting active life, so long as the parts which have to acquire these movements are in a condition to do so.

Inference.

The order of things necessary for the existence of life in a body is then essentially as follows:

1. A cellular tissue (or organs formed of it) endowed with great suppleness and animated by orgasm, the first result of the exciting cause;

2. Various more or less complex fluids contained in this cellular tissue (or in the organs built up from it), and undergoing as a second result of the exciting cause, movements, displacements, various changes, etc.

In animals the exciting cause of organic movements acts powerfully both on the containing parts and on the contained fluids; it maintains an energetic orgasm in the containing parts, puts them in a condition to react on the contained fluids and hence makes them highly irritable; as to the contained fluids, the exciting cause involves them in a kind of rarefaction and expansion, which facilitate their various movements.

In plants, on the contrary, the exciting cause in question only acts powerfully on the contained fluids, and produces in these fluids such movements and alterations as they are adapted to undergo; but its only effect on the containing parts of these living bodies, even on their most supple parts, is an orgasm or slight erethism which is too feeble to permit of any movement or to cause a reaction on the contained fluids or consequently to endow these parts with irritability. The result of this orgasm has been badly named *latent sensibility*; I shall speak of it in Chapter IV.

In animals, which invariably have parts that are irritable, the vital movements are kept up in some solely by the irritability of the parts, and in others by a combination of irritability with muscular activity of the organs themselves.

In fact, in those animals whose very simple organisation only requires slow movements in the contained fluids, the vital movements are carried out exclusively through the irritability of the containing parts and the agitation produced by the exciting cause in the contained fluids. But as the vital energy increases in proportion to complexity of organisation, there soon arrives a time when irritability and the exciting cause are no longer sufficient by themselves for the acceleration needed in the movements of the fluids; nature then makes use of the nervous system which increases the effects of the irritability of the parts by adding the activity of certain muscles; and when this system permits of muscular movement, the heart becomes a powerful motor for accelerating the movement of the fluids; finally, after the establishment of pulmonary respiration muscular movement is once again necessary to the performance of vital movements on account of the alternate dilatations and contractions occurring in the cavity which contains the respiratory organ and without which there could be no inspirations or expirations.

"Doubtless we are not called upon," says M. Cabanis, "to prove again that physical sensibility is the origin of all the ideas and habits constituting the moral existence of man; Locke, Bonnet, Condillac and Helvetius have pushed this truth to the last stage of demonstration. Among educated persons who use their reason there is now no one who can throw the smallest doubt upon the matter. From another standpoint, physiologists have proved that *all vital movements are the result of impressions received by sensitive parts*, etc." (*Rapports du Physique et du Moral de l'Homme*, vol. i., pp. 85, 86).

I too recognise that physical sensibility is the source of all ideas, but I am very far from admitting that all vital movements are the result of impressions received by sensitive parts: that at most can only be true with regard to such living bodies as possess a nervous system; for the vital movements of those which have no such system cannot be the result of impressions received by sensitive parts: this is quite obvious.

If we wish to make a true analysis of life, we must necessarily examine the facts which it presents in all bodies possessing it. Now as soon as we deal with the subject in this way we see that what is really essential to the presence of life in one plan of organisation is by no means essential in another.

No doubt nervous influence is necessary to the maintenance of life in man, and in all animals which have a nervous system; but this does not prove that vital movements, even in man and in animals provided with nerves, are due to impressions made on sensitive parts: it only proves that their vital movements cannot occur without the help of nervous influence.

It is clear from the above exposition that life in general may exist in a body, although the vital movements are not produced by impressions received by the sensitive parts and although there is no muscular activity; it may even exist when the body possessing it has no

irritable parts whose reaction could assist its movements. It is enough, as we see in plants, that a body possessing it should present internally an order and state of things with regard to its containing parts and contained fluids which permit of the excitation of the characteristic movements and changes, by means of a special force.

But if we consider life in special cases, that is, in various selected bodies, we shall then see that whatever is essential to the plan of organisation of these bodies has also become necessary to the maintenance of life in them.

Thus in man and the most perfect animals, life cannot be maintained without irritability of the reacting parts, without the involuntary muscles to keep up the rapid movement of the fluids, without the nervous influence which by quite a different route from feeling provides for the performance of the functions of the muscles and other internal organs; lastly, without the influence of respiration to restore continually the essential fluids which are so rapidly disintegrated in these systems of organisation.

Now this nervous influence, which is undoubtedly necessary, is exclusively that which sets the muscles in action and not that which produces feeling; for it is not by means of sensations that the muscles act. In fact, no feeling whatever is aroused by the cause which produces the movements of systole and diastole in the heart and arteries; and if we do sometimes perceive the beats of the heart it is when they are stronger and more rapid than usual; this muscle, which is the chief motive power of circulation, then strikes neighbouring sensitive parts. Finally, when we walk or perform any action we never feel the movement of the muscles nor the impulse which drives them.

Hence it is not through the medium of feeling that the muscles carry on their functions, although nervous influence is necessary to them. But since nature was obliged, in order to accelerate the movement of fluids in the most perfect animals, to add the muscular movement of the heart, etc., to the irritability which they possess in common with the rest, nervous influence has become necessary to the maintenance of life in these animals. There can, however, be no justification for the statement that their vital movements are only due to impressions received by sensitive parts, for if their irritability was destroyed they would immediately lose their life; and their feeling, if it still survived, could not alone suffice for its preservation. Moreover, I hope to prove in Chapter IV. of this part that sensibility and irritability are not only quite distinct faculties, but that they have not even a common origin and are due to very different causes.

"Living is feeling," said Cabanis: yes, doubtless for man and the most perfect animals and probably too for a great number of invertebrates. But since the faculty of feeling weakens in proportion to the lower development of the system of organs on which it is based and in proportion to the inferior concentration in the cause which makes this faculty active, we must say that life is rudimentary feeling for those invertebrates that have a nervous system; because this system of organs, especially in the insects, gives them only a very dim feeling.

As to the radiarians, if the nervous system still exists in them, it must be very rudimentary indeed and adapted only to the excitation of muscular movement.

Lastly, since it is impossible that the great majority of polyps or any of the infusorians should possess a nervous system, we must say of them and even of the radiarians and worms, that living is not feeling; as we are obliged also to say in the case of plants.

In dealing with nature, nothing is more dangerous than generalisations, which are nearly always founded on isolated cases: nature varies her methods so greatly that it is difficult to set bounds to them.

According as animal organisation becomes more complex, the order of things essential for life does the same, and life is specialised in each of the principal organs. But all specialised organic life depends on the general life of the individual, just as the latter depends on the specialized life of the principal organs, for there is an intimate connection between each organ and the rest of the organisation. The order of things essential to life in any animal is thus only determinable by a description of that order itself.

In accordance with this principle, it is quite clear that in the most perfect animals, such as mammals, the order of things essential to life includes a system of organs for feeling, consisting of a brain, spinal cord, and nerves, a system of organs for complete pulmonary respiration, a system of organs for circulation with a bilocular heart which has two ventricles, and a muscular system for the movement of internal and external parts, etc.

No doubt each one of these systems of organs has its special life, as Bichat has shown: and on the death of the individual, life becomes extinct in them all. Nevertheless none of these systems of organs could preserve its special life independently, nor could the general life of the individual continue if any of them had lost its own.

From this state of affairs, already generally recognised in the case of mammals, it by no means follows that the order of things essential to life in other bodies, includes a system of organs for feeling, another for respiration, another again for circulation, etc. Nature shows us that these various systems of organs are only essential to life in animals where they form a necessary part of the organisation.

These, I think, are truths against which can be set no known facts and no authoritative observation.

The following is a summary of the principles set forth in this chapter:

1. Life is an organic phenomenon which gives rise to many others; this phenomenon results exclusively from the relations existing between the containing parts of the body, the contained fluids moving in them, and the exciting cause of the movements and changes there occurring;

2. Consequently life in a body is an order and state of things which permits of organic movements, and these movements constituting active life result from the action of a cause which excites them;

3. Without the stimulating and exciting cause of vital movements, life could not exist in any body, whatever the state of its parts;

4. The exciting cause of organic movements acts in vain if the state of things in the parts of the organised body is so disordered that these parts can no longer respond to the action of this cause nor produce the special movements called vital. Life would then be extinct in the body, and could no more be restored;

5. Lastly, in order that the relations between the containing parts of the organised body, the fluids contained in them, and the cause which excites vital movements in them, may produce and maintain the phenomenon of life, the three conditions named in this chapter must be completely fulfilled.

Let us now pass to an examination of the exciting cause of organic movements.

CHAPTER III.

OF THE EXCITING CAUSE OF ORGANIC MOVEMENTS.

We have seen that life is a natural phenomenon which itself produces several others, and that it results from the relations existing between the supple containing parts of an organised body and the contained fluids of that body. We cannot conceive the production of this phenomenon, that is to say, the presence and continuance of the movements constituting active life, unless we imagine a special exciting cause of these movements, a force which animates the organs, controls the activities and all the organic functions,—a spring, in short, of which the permanent though variable tension is the driving energy of all vital movements.

There can be no doubt that the visible fluids of a living body and the solid parts which contain them are irrelevant to the cause that we are here seeking. All these parts together constitute the machinery of movement, if I may revert to the parallel already drawn; and it is not the function of any of them to supply the force in question, that is, the motive power or exciting cause of the movements of life.

We may be certain that if there were no special cause to stimulate and maintain orgasm and irritability in the supple and containing parts of animals, and to produce in plants an obscure orgasm by promoting direct movement of their contained fluids, the blood of animals which have a circulation and the transparent whitish serum of those that have not, would remain at rest and would rapidly decompose together with the solid parts.

In the same way, if there were no exciting cause of vital movements, if there were no force or spring to endow a body with active life, the sap and special fluids of plants would remain motionless, would degenerate and be exhaled, and finally compass the death and desiccation of these living bodies.

The ancient philosophers felt the necessity for a special exciting cause of organic movements; but not having sufficiently studied

nature, they sought it beyond her; they imagined a vital principle, a perishable soul for animals, and even attributed the same to plants; thus in place of positive knowledge, which they could not attain from want of observations, they created mere words to which are attached only vague and unreal ideas.

Whenever we abandon nature, and give ourselves up to the fantastic flights of our imagination, we become lost in vagueness, and our efforts culminate only in errors. The only knowledge that it is possible for us to acquire is and always will be confined to what we have derived from a continued study of nature's laws; beyond nature all is bewilderment and delusion: such is my belief.

If it were true that it is really beyond our powers to ascertain the exciting cause of organic movements, it would be none the less obvious that such a cause exists and that it is physical, since we can observe its effects and nature has all the means of producing it. Do we not know that it spreads and maintains movement in all bodies, and that none of the objects submitted to nature's laws really possesses an absolute stability?

I do not wish to go back to the consideration of first causes, nor of all the movements and changes observed in physical bodies of all kinds. We shall confine ourselves to a study of the immediate recognised causes acting on living bodies, and we shall see that they are quite sufficient to maintain in these bodies the movements constituting life, so long as the appropriate order of things is not destroyed.

It would doubtless be impossible to ascertain the exciting cause of organic movement if the subtle, invisible, uncontainable, incessantly moving fluids which constitute it were not disclosed to us in a great variety of circumstances; if we had not proofs that the whole environment in which all living bodies dwell are permanently filled with them; lastly, if we did not know positively that these invisible fluids penetrate more or less easily the masses of all these bodies and stay in them for a longer or shorter time; and that some of them are in a constant state of agitation and expansion, from which they derive the faculty of distending the parts in which they are insinuated, of rarefying the special fluids of the living bodies that they penetrate, and of communicating to the soft parts of these same bodies, an erethism or special tension which they retain so long as their condition is favourable to it.

But it is well known that the question at issue is not insoluble; for no part of the earth inhabited by living beings is destitute of caloric (even in the coldest regions), of electricity, of magnetic fluid, etc. These fluids, some of which are expansive and the others agitated

in various ways, are incessantly undergoing more or less regular displacements, renewals or replacements and perhaps in the case of some of them there may actually be a genuine circulation.

We do not yet know how numerous may be these subtle invisible fluids which are distributed in constant agitation throughout the environment. But we do perceive in the clearest manner that these invisible fluids penetrate every organised body and there accumulate with constant agitation, finally escaping in turn after being retained for a longer or shorter period. They thus stimulate movements and life, when they come in contact with an order of things permitting of such results.

With regard to such of these invisible fluids as chiefly constitute the exciting cause under consideration, two of them appear to us to be the essential elements of this cause, viz. caloric and the electric fluid. They are the direct agents which produce orgasm and the internal movements which in organised bodies constitute and maintain life.

Caloric appears to be that of the two exciting fluids in question which causes and maintains the orgasm of the supple parts of living bodies; and the electric fluid is apparently that which provides the cause of the organic movements and activities of animals.

My justification for this division of the faculties assigned to the two fluids in question is based on the following principles.

In inflammations, the orgasm acquires an excessive energy which is at length even destructive of the parts. This is clearly in consequence of the extreme heat developed in inflamed organs: it is, then, especially to caloric that the orgasm must be attributed.

The rapidity of the movements of caloric throughout the bodies which it penetrates is very far from equalling the extraordinary speed of the movements of the electric fluid. Hence this latter fluid must be the cause of the movements and activities of animals; it must be more particularly the genuine exciting fluid.

It is possible, however, that other active invisible fluids combine with the two already named in the composition of the exciting cause; but what appears to me beyond question is that caloric and electricity are the two chief components, and perhaps even the only components of this cause.

In animals with low organisations, the caloric of the environment seems to be sufficient by itself for the orgasm and irritability of their bodies; hence it arises that in extreme reductions of temperature and in the winters of climates in high latitudes, some entirely perish while others become more or less completely torpid. In these same animals the ordinary electric fluid provided by the environment appears to be sufficient for the organic movements and activities.

The case is different with regard to animals of highly complex organisations: in these, the caloric of the environment merely completes or rather aids and favours the power which these living bodies themselves possess of constantly producing caloric within them. It is probable even that this internally produced caloric has undergone modifications in the animal as a result of which it is specialised; and rendered alone suitable for the maintenance of orgasm; for when the state of the organisation has greatly enfeebled the orgasm and irritability, the external caloric arising either from our fires or from a rise of temperature cannot take the place of internal caloric.

The same observation appears to be applicable also to the electric fluid which excites the movements and activities of animals with highly complex organisations. It appears indeed that this electric fluid, which is introduced through the medium of respiration or of food, has undergone some modification in the animal's interior and become transformed into nervous or galvanic fluids.

As to caloric, it is unquestionably one of the principal elements of the exciting cause of life, and is particularly instrumental in producing and maintaining orgasm, without which life could not exist. So true is this that a great reduction of temperature would exterminate all living bodies long before reaching the point of absolute cold. As a matter of fact, the cold of our winters, especially when it is extreme, causes the death of a great many of the animals exposed to it. But we know that on no part of the earth's surface and at no period of the year do we ever find a total absence of caloric.

Let me repeat that without a special exciting cause of orgasm and vital movements—without the force which alone can produce such movements—life could not exist in any body. Now this exciting cause has nothing to do with the visible fluids of living bodies, nor with the solid containing parts of these bodies. This is a fact that can no longer be questioned since it is justified by all observation.

This same exciting cause is also the cause of fermentation, the manifestations of which it alone brings about in all compound non-living matter, whose parts are favourable to it. Thus in great reductions of temperature the activities of life and fermentation are suspended more or less completely, in proportion to the intensity of the cold.

Although life and fermentation are two very different phenomena, they both derive from the same origin the movements by which they are constituted; and in both cases it is necessary that the state of the parts, whether of the organic body capable of life or of the inorganic body capable of fermentation, should be favourable to the performance of these movements. But in bodies possessing life, the existing order and state of things are such that every decomposition of principles

is subsequently made good by new and closely similar combinations as a result of continued movements, whereas in the unorganised or disorganised fermenting body, the decompositions which occur cannot be made good by a continuance of fermentation.

As soon as an individual dies, its body, which is then disorganised in reality though often not in appearance, immediately joins the class of bodies liable to fermentation, particularly as regards the more supple of its parts. The exciting cause which gave it life then hastens the decomposition of such of its parts as are capable of fermentation.

We learn then from the principles set forth above that the exciting cause of vital movements must necessarily be sought in the invisible, subtle, penetrating and ever active fluids with which the environment is always supplied; and that the chief element of this cause is the element which maintains an orgasm essential to the existence of life, and, in fact, that it is no other than caloric; as the following observations will further bring out.

I need not cite any special instances on this subject, since the general fact concerned is well known. We are aware that a certain quantity of heat is generally necessary to all living bodies and especially animals. When it is reduced below a certain point, the irritability of animals becomes less intense, their organisation less active and all their functions flag or are performed slowly, especially in those animals where there is no production of internal caloric. When it becomes still further reduced, the most imperfect animals die and a great many of the rest fall into a torpid lethargy and undergo a suspension of life; it cannot be doubted that they would in turn all lose their lives, if this reduction of heat were to be carried much further in the environment.

When the temperature rises, on the contrary—that is, when the heat increases and is distributed everywhere—we constantly notice, if this state of things continues, that life revives and seems to acquire new strength in all living bodies, that the irritability of the internal parts of animals rises proportionally in intensity, that the organic functions are carried on with more energy and promptitude, that the various stages of life succeed each other with greater rapidity, and that life itself comes sooner to an end, but that the new generations are more frequent and abundant.

Although heat is everywhere necessary for the maintenance of life especially in animals, its intensity should not much exceed certain limits; for if it did animals would suffer greatly from it, and in the case of the highly complex would be exposed at the slightest cause to rapid diseases, which would quickly result in death.

We may then be sure that not only is heat necessary to all living

bodies, but that when it reaches a certain degree without exceeding the proper limits, it markedly animates all the activities, is favourable to reproduction and appears to expand life everywhere in a wonderful way.

The ease, rapidity, and abundance with which, in tropical countries, nature produces and multiplies the simplest animals are facts in support of this statement. The multiplication of these animals is in fact specially noticeable in favourable times and places, that is to say, in hot climates and in the case of countries of high latitudes in the warm season, especially when there are other conditions favourable to fertility.

Indeed at certain times and in certain climates, the earth (especially at its surface where caloric always accumulates the most) and the body of the waters teem with animated molecules, that is to say, with animalcules of extremely varied genera and species. These animalcules, like many other imperfect animals of different classes, reproduce and multiply with an astonishing fertility—far greater than that of larger animals with a more complex organisation. So rapid are the results of this prodigious fertility, that matter seems to become everywhere animalised. Hence, if it were not for the huge immolation which overtakes the animals of the first orders of the animal kingdom, they would soon overwhelm and perhaps extinguish the more perfect animals of the later classes and orders of this kingdom—so great is the difference between them in the capacity and ease of multiplication !

The above statement as regards the necessity for animals of a caloric distributed throughout the environment, and varying within certain limits, is entirely applicable to plants ; but in their case heat only maintains life under certain necessary conditions.

The first and most important condition is that the roots of the plant should have constant access to moisture ; for the greater the heat, the more necessary does water become to the plant, to make good the heavy losses of its fluids due to transpiration ; and the less the heat, the less it needs moisture, which would then be injurious to its preservation.

The second condition for the elaboration of its products by a plant, is that the plant in addition to heat and water should also have plenty of light.

The third, lastly, makes it dependent upon air, from which it probably appropriates oxygen and the other gases which it finds there, immediately decomposing them and making use of their principles.

From the above statement, it is quite clear that caloric is the first cause of life, in that it produces and maintains orgasm without which

no living body could exist. In this it succeeds so long as the state of the parts of the living body does not prevent it.

We find, moreover, that this expansive fluid, especially when its abundance gives it some intensity of action, is the principal factor in the enormous multiplication of living bodies of which I have just spoken. Hence it is universal that in the hot climates of the earth the animal and plant kingdoms exhibit an extremely remarkable wealth and abundance, whereas in the frozen regions of the earth they only exist in a state of the greatest poverty.

A further fact in favour of the principle just established is that there is a great difference between the summer and winter of our own climates as regards the number of animals and plants.

Although caloric is really the first cause of life in the bodies which possess it, yet it could not alone account for its existence nor keep up the movements which constitute it ; there is needed in addition, especially for animals, the influence of a fluid to excite their acts of irritability. Now we have seen that electricity possesses all the properties necessary for constituting this exciting fluid, and that it is distributed sufficiently widely notwithstanding its variations, to ensure that living bodies shall always be provided with it.

It may be that some other invisible fluid combines with electricity in making up the cause which is able to excite vital movements and all the organic activities ; this is quite possible, but I see no need for supposing it.

It seems to me that caloric and the electric substance together are quite sufficient to constitute the essential cause of life, the one by setting the parts and internal fluids in a proper condition for the existence of life, and the other by arousing in the course of its movements through the body the various stimuli which give rise to the organic activities and the active part of life.

If we were to try to explain how these fluids work, and to determine definitely the number of those that enter into the composition of the exciting cause of all organic movements, we should be abusing the power of our imagination and arbitrarily creating explanations which we have no means of verifying.

It is enough to have shown that the exciting cause of the movements which constitute life does not reside in any of the visible fluids in the interior of living bodies, but that it takes its origin as follows :

1. From caloric, which is an invisible penetrating, expansive, ever active fluid that percolates slowly through the supple parts, distending them and making them irritable ; and that is constantly being dissipated and renewed and is never entirely absent from any body that possesses life ;

2. From the electric fluid, either the ordinary electric fluid in the case of plants and imperfect animals, or the galvanic fluid for those with very high organisation;—a subtle fluid, moving with extraordinary speed, which instigates sudden local dissipations of the caloric which distends the parts, and thus excites acts of irritability in the non-muscular organs, and movements in the muscles when it extends its action to them.

If the two fluids named above thus combine their special activities, there must ensue in the case of organised bodies submitted to their influence, a powerful cause or force which works effectively, and is controlled by the organisation,—that is, by the regular shape and arrangement of the parts,—and keeps up movements and life so long as there exists in these bodies an order of things which allows of such effects.

This apparently is the mode of action of the exciting cause of life; but it cannot be regarded as established, until it is possible to find proofs of it. The two named fluids may be the only principles contributing to the production of this cause; but that again is a belief of which we cannot be certain. What is quite positive in this respect is that the source, from which nature derives this cause and the resulting force, is to be found in the subtle invisible fluids among which the two just named are unquestionably the chief.

I shall confine myself to the statement that the active and expansive fluids, composing the exciting cause of vital movements, penetrate into or are constantly developing in the bodies which they animate, pass all through them, while harmonising their movements with the nature, order and arrangement of the parts, and are then constantly being exhaled by an imperceptible transpiration. This fact is unquestionable and sheds the brightest light over the causes of life.

Let us now enquire into the special phenomenon that I call orgasm in living bodies, and afterwards into the irritability which this orgasm produces in animals, where the nature of their bodies permits it to be highly developed.

CHAPTER IV.

OF ORGASM AND IRRITABILITY.

It is not the special affection called orgasm that we are now about to discuss, but the general condition known under the same name and characteristic of the supple internal parts of animals during life; a condition which is natural to them, since it is essential to their preservation, and which necessarily comes to an end at or soon after death.

It is certain that, among the solid internal parts of animals, those that are supple are animated throughout life by an orgasm or peculiar kind of erethism, from which they derive the faculty of collapsing and being promptly restored on the receipt of any impression.

An analogous orgasm also exists in the most supple of the solid parts of plants, so long as they are alive; but it is so faint that the parts endowed with it do not derive therefrom any faculty for immediate restoration, after the impressions that they have received.

The orgasm of the supple internal parts of animals contributes to some extent to the production of their organic phenomena; it is maintained by an invisible, expansive, penetrating fluid (possibly several), which slowly passes through the parts affected and produces in them the tension or sort of erethism just mentioned. The orgasm resulting from this state of things in the parts, is maintained throughout life with a strength that is proportional to the favourable disposition of the parts; it is the stronger according as they are more supple and less dried up.

It is this same orgasm, the necessity for which has been recognised for the presence of life in a body, that some modern physiologists have looked upon as a kind of sensibility; hence they have alleged that sensibility is a property of all living bodies, that such bodies are both sensitive and irritable, that all their organs are impregnated with these two necessarily co-existing faculties, in short that they are common to every living thing both animal and plant. Cabanis, who shared this opinion with M. Richerand and apparently others, said indeed that sensibility is the general fact of living nature.

M. Richerand, however, who has in particular developed this opinion in the prolegomena of his *Physiologie*, admits that the sensibility, which gives us the power of receiving sensations and depends on nerves, is not the same thing as that more general kind of sensibility for which no nervous system is necessary. For the former he suggests the name of perceptibility and for the latter that of latent sensibility.

Since these two faculties are different in their origin and results, why should we give a new name to the phenomenon, long known as sensibility, and transfer the name of sensibility to a more recently observed phenomenon of altogether special nature ? Surely it is more convenient to give a particular name to the general phenomenon on which life depends : and this is what I have done by calling it orgasm.

It is probable that without orgasm (latent sensibility), no vital function could go on ; for wherever it exists, there can be no true inertia in the parts ; they are no longer merely passive. This is the element of truth in the idea that all the living parts feel and act in their own way, that they distinguish among the fluids which bathe them whatever is suitable for their nutrition, and that they separate from them those substances which affect their special type of sensibility.

Although we are not definitely aware how each vital function is performed, we should not gratuitously attribute to the parts a knowledge and power of choice among the objects which they have to separate out, and retain or evacuate. We should rather reason thus :

1. The organic movements aroused are simply due to the action and reaction of the parts ;

2. From these actions and reactions it follows that the state and nature of the parts undergo alterations, decompositions, new combinations, etc. ;

3. As a result of these alterations, there occur secretions which are favoured by the width of the secretory canals ; depots are established which are sometimes kept isolated and sometimes attached to these same parts ; lastly, there are various evacuations, absorptions, resorptions, etc.

All these operations are mechanical and subject to physical laws ; they are carried out by means of the exciting cause and of orgasm, which keeps up the movements and activities ; so that by these means and by the shape, arrangement and situation of the organs, the vital functions are varied and controlled, and each works in its special way.

The orgasm dealt with in this chapter is a definite fact, which whatever we call it can no longer be neglected. We shall see that it is very weak and faint in plants where its powers are very limited, but

that in animals on the contrary it is very conspicuous ; for it produces in them that remarkable property called irritability by which they are distinguished.

Let us first study it in animals.

Of Animal Orgasm.

By animal orgasm, I mean that curious condition of the supple parts of a living animal, in which there exists at every point a peculiar tension, of such strength that the parts are able immediately to react to any impression that they may experience, and do in fact react on the moving fluids which they contain.

This tension, the degree of which varies in the different parts, constitutes what physiologists call the tone of the parts ; it seems to be due as I have already said to the presence of an expansive fluid which penetrates these parts, remains in them for a certain period and keeps their molecules separated to some distance from one another though without destroying their coherence ; some of the fluid suddenly escapes on any contact, leading to a contraction, but it is promptly restored again.

Thus at the moment of the dissipation of the expansive fluid distending any part, this part subsides on itself as a result ; but it is promptly restored to its previous distention by the arrival of new expansive fluid. Hence it follows that the orgasm of this part gives it the property of reacting on the visible fluids which affect it.

This tension in the soft parts of living animals does not go so far as to break up the cohesion of their molecules, or to destroy their adhesiveness, agglutination and firmness, so long as the intensity of orgasm does not exceed a certain point. But the tension prevents the falling together and collapse of the molecules which would occur if this tension did not exist ; for the soft parts do actually subside in a remarkable way as soon as the tension is removed.

Indeed among animals, and even among plants, the extinction of orgasm, which only occurs on the death of an individual, gives rise to a relaxation and subsidence of the supple parts, making them softer and more limp than in the living state. This has given rise to the belief that these limp parts found in old people after death have escaped the rigidity which gradually comes over the organs during life.

The blood, and especially the arterial blood, of animals whose organisation is highly complex, itself possesses a sort of orgasm ; for it is during life suffused with various gases which develop within it and become modified there. Now these gases may also contribute to the stimulation of the organic acts of irritability, and consequently

to the vital movements, when the blood affected flows to the organs.

The excessive tension of orgasm under certain conditions in some or all of the soft parts of an individual, although not great enough to break up the cohesion of those parts, is known under the name of erethism. When it is very strong it produces inflammation, whereas when the orgasm is extremely reduced, though not to the point of disappearance, it is generally designated by the name of atony.

The tension which constitutes orgasm may vary within certain limits, without on the one hand destroying the cohesion of the parts, or on the other hand ceasing to exist. This variation renders possible those sudden contractions and distensions which occur when the cause of orgasm is momentarily removed and then restored. This seems to me to be the chief cause of animal irritability.

The cause which produces orgasm, or that peculiar tension of the supple internal parts of animals, is no doubt an element in what I have called the exciting cause of organic movements. It is to be found principally in caloric, either in that provided by the environment, or in this combined with the caloric that is constantly being produced in the interior of many animals.

Indeed an expansive caloric is continually emanating from the arterial blood of many animals, and constitutes the principal cause of the orgasm in their supple parts. It is especially in the warm-blooded animals that the continual emanation of caloric becomes remarkable. This expansive fluid is constantly being dissipated from the parts which it distends, but it is as constantly being renewed by the emanations always being given off from the animal's arterial blood.

An expansive fluid, similar to that which we are discussing, is distributed throughout the environment and incessantly provides for the orgasm of living animals, either by completing what was wanting to the internal caloric, or achieving it alone.

As a matter of fact, the caloric of the environment assists more or less in the orgasm of the most perfect animals and suffices by itself for that of the rest; it is especially the cause of orgasm in all animals which have no arteries or veins, that is to say, no circulatory system. Hence all organic movement becomes gradually weaker in these animals, according as the temperature of the environment becomes lower; and if this reduction of temperature continues indefinitely their orgasm is extinguished and they die. We have only to recall the torpidity that overtakes bees, ants, snakes and many other animals when the temperature falls below a certain point, and we shall then be in a position to judge whether my statement has not some foundation.

The reduction of temperature which causes many animals to become

torpid works this result by weakening their orgasm and hence by slackening their vital movements. If this reduction of temperature goes too far, I have already observed that it extinguishes the orgasm and causes the death of the animal; but I may remark on this subject, with regard to the effects of cooling, not carried far enough to kill the individual, that there is a certain peculiarity in the case of warm-blooded animals and perhaps of all animals that have nerves: it is as follows.

It is known that no very great fall of temperature is required to bring about the torpid state of apparent sleep in certain mammals, such as marmots, bats, etc. If the heat returns, it penetrates, revives, awakes, and restores them to their usual activity; but if on the contrary the cold increases still further after these animals have become torpid, they do not pass imperceptibly from their condition of apparent sleep into death. If the increase of cold is considerable, it causes an irritation in their nerves which awakes and agitates them, and revives their organic movements and hence their internal heat. If the increase of cold then continues, it soon throws them into a state of disease, ending in death unless heat is quickly restored to them.

Hence it follows that, for warm-blooded animals and perhaps for all animals with nerves, a mere weakening of their orgasm may reduce them to a torpid state. In this case the orgasm is not totally destroyed, since if the cold were great enough for that purpose, it would begin by irritating them, giving them pain and end by killing them.

In the case of animals without nerves, it seems that a reduction of temperature sufficient to weaken their orgasm and make them torpid, may if it increases result in their passing through their stage of lethargic sleep to that of death, without any temporary return of activity.

Those who imagine that the first result of a moderate degree of cold is to slacken the respiration, have mistaken the effect for the cause. Thus the torpid state, into which various animals fall when the temperature is lowered, has been attributed to a direct slackening of the respiration of these animals; whereas in point of fact the slackening of respiration is itself due to another effect of the cold, namely, the enfeeblement of their orgasm.

As regards animals which breathe with lungs, those that fall into a torpid state in certain degrees of cold doubtless undergo a considerable slackening of respiration; but here it is clearly only the result of a great enfeeblement in their orgasm. Now this enfeeblement slackens all the organic movements and all the functions. It diminishes also the production of internal caloric and the losses which these animals are subject to, during their customary activity. Their need for restoration during their lethargy is thus very slight or next to nothing.

Animals breathing with lungs undergo alternate swellings and contractions of the cavity containing their respiratory organ. Now these movements are carried out with greater or less facility, according as the orgasm of the supple parts is more or less energetic. Thus several mammals, such as the marmot and dormouse, and many reptiles, as the snakes, fall into a torpid state on certain reductions of temperature, because they then have a greatly weakened orgasm, from which results secondarily a slackening of all their organic functions including that of respiration.

If this decline in the energy of their orgasm did not take place, there would be no reason why any less air should be breathed by these animals when it is cold. In bees and ants which breathe by tracheae and undergo no alternative swellings and contractions, it cannot be said that they breathe less when it is cold; but there are sound reasons for the belief that their orgasm is then greatly enfeebled, and thus accounts for the torpid state which they undergo in these conditions.

Finally, in warm-blooded animals their internal heat is almost entirely produced within their bodies, either as a result of the decomposition of air in respiration as is generally held, or because it is constantly given off from the arterial blood while changing into venous blood, as I myself believe; in either case the orgasm gains or loses energy, according as the internal caloric increases or diminishes in quantity.

As regards the explanation which I am giving of orgasm, it is a matter of indifference whether the caloric produced in the interior of warm-blooded animals, is the result of the decomposition of air in respiration or is an emanation from the arterial blood as it changes into venous blood. If, however, it is desired to consider this question, I should put forward the following suggestions:

If you drink a glass of spirits, the resulting warmth that you feel in your stomach assuredly does not spring from increased respiration. Now if caloric may be given forth from this liquor as it undergoes changes in your organ, so too it may be exhaled from your blood when it undergoes changes in its component parts.

In fever when the internal heat is greatly increased, it is observed that respiration is also faster, and hence it is inferred that the consumption of air is greater. This supports the view that the internal caloric of warm-blooded animals results from the decomposition of the respired air. I know of no experiment to show definitely whether the consumption of air during fever is really greater than in health. I doubt whether it is so; for if respiration were faster in this diseased condition it may be compensated for by each inspiration being less, owing to the constraint of the parts. What I do know is that when

I have some local inflammation like a boil or any other inflamed tumour, caloric issues in extraordinary abundance from the blood of the parts affected. Yet I do not see how any increase of respiration can in this case have given rise to the local concentration of caloric; I should say on the other hand that the blood, being compressed and concentrated in the diseased part, is liable to disturbances and decompositions (as also the supple parts containing it) which involve the productions of the observed caloric.

I cannot admit that atmospheric air includes in its composition a fluid, which when freed is an expansive caloric; I have elsewhere stated my views on this matter. In point of fact, I believe that air is composed of oxygen and nitrogen; and I know that it contains caloric within it, because absolute cold does not exist anywhere on our earth. I am fully convinced that the component fluid which when freed is changed into expansive caloric was previously a constituent part of our blood; that this fluid in combination is always being partially set free and that by its liberation it produces our internal heat. Evidence that this internal heat does not come from our respiration is furnished by the fact that if we were not constantly making good the losses in our blood by means of food, and hence of a chyle always being renewed, our respiration would not restore to our blood the qualities which it must possess for the maintenance of our existence.

The utility of respiration to animals is not in question; by this method their blood derives a restoration which they could not do without; and the belief appears to be justified that it is by appropriating oxygen from the air that the blood derives one of its most necessary restorations. But in all this there is no proof that caloric comes from the air or its oxygen, rather than from the blood itself.

The same thing may be said with regard to combustion: the air in contact with burning substances may be decomposed, and its disengaged oxygen may be fixed in the residue of combustion; but that is no proof that the caloric then produced comes from the oxygen in the air rather than from the combustible substances, with which I hold that it was previously combined. All the known facts are better and more naturally explained on this latter assumption than on any other.

However this may be, the positive fact remains that in a great many animals an expansive caloric is constantly being produced within them, and that it is this invisible penetrating fluid which maintains the orgasm and irritability of their supple parts; while in other animals orgasm and irritability are chiefly the result of the caloric of the environment.

To refuse to recognise the orgasm of which I have spoken, and to regard it as a hypothetical fact, that is to say a product of the imagination, would be to deny to these animals the existence of that *tone* in the parts which they possess throughout life. Now death alone extinguishes this tone, as also the orgasm which constitutes it.

Plant Orgasm.

In plants the exciting cause of organic movements seems to act chiefly on the contained fluids, and sets them alone in motion; while the cellular tissue of the plant, whether simple or modified into vasculiform tubes, only acquires from it an ill-defined orgasm giving rise to a very slow general contractility, which never acts in isolation or suddenly.

If, during the warm season, a plant grown in a pot or box needs watering, we notice that its leaves, the ends of its branches and young shoots hang down as though about to fade: yet life still continues to exist in them; but the orgasm of the supple parts is then greatly enfeebled. If this plant is watered, we see it gradually erect its drooping parts and show an appearance of life and vigour which it did not present when it had no water.

This restoration of the vigour of the plant is doubtless something more than a mere result of the introduction of new fluids into the plant. It is also the result of a revived orgasm, since the expansive fluid causing this orgasm penetrates the parts of the plant with much greater ease when the juices or contained fluids are abundant.

The ill-defined orgasm of living plants thus causes a slow general contractility in their solid parts, especially in the newest,—a sort of tension which various facts justify us in accepting, although there are no sudden movements. This plant-orgasm does not endow the organs with any faculty for instantaneous reaction on contact with objects which might affect them, and hence it has no power of causing irritability in the parts of these living bodies.

It is not true indeed, as has been alleged,[1] that the canals in which move the visible fluids of these living bodies are sensitive to impressions of stimulating fluids, or that they become relaxed or distended by a prompt reaction in order to achieve the transport and elaboration of their visible fluids;—in short they have no true tone.

Finally, it is not true that the peculiar movements observed at certain periods in the reproductive organs of various plants, nor the movements of leaves, petioles or even the small twigs and plants called sensitive, are the product and proof of an irritability existing

[1] Richerand, *Physiologie*, vol. i., p. 32.

in these parts. I have observed and watched these movements and am convinced that they have nothing in common with animal irritability. See what I have already said, pp. 51-53.

Although nature has doubtless only one general plan for the production of living things, she has everywhere varied her means, when diversifying her productions, according to the circumstances and objects on which she worked. But man is always striving to confine her to the same methods; for the idea that he has formed of nature is still indeed far from that which he ought to entertain.

How great are the efforts that have been made to discover sexual reproduction everywhere throughout the two kingdoms of living bodies; and in the case of animals to attribute to all of them nerves, muscles, feeling and even will, which is necessarily an act of intelligence! How profoundly different nature would be, if she was really limited in the ways that we imagine!

We have just seen that orgasm has very different degrees of intensity, and consequently has effects that vary according to the nature of the living bodies in which it occurs, and that in animals alone does it give rise to irritability. We now have to enquire into the nature of this remarkable phenomenon.

Irritability.

Irritability is the faculty possessed by the irritable parts of animals, of producing sudden local manifestations which may occur at any point on the surface, and may be repeated as often as the exciting cause acts upon the susceptible regions.

The manifestations consist in a sudden contraction and shrinkage of the irritated point, a shrinkage characterised by the closing in of neighbouring points upon that which is affected, but soon followed by a contrary movement, that is to say by a distension of the irritated point and neighbouring parts; so that the natural condition of the parts distended by orgasm is promptly re-established.

I said at the beginning of this chapter that orgasm is formed and maintained by caloric, that is a penetrating expansive invisible fluid which passes slowly through the soft parts of animals and produces in them a tension or kind of erethism. Now if some impression is made upon any such part so as to instigate a sudden dissipation of the invisible fluid distending it, the part immediately shrinks and contracts: but if a new supply of expansive fluid is instantly developed and distends it afresh, it then reacts immediately and so produces the phenomenon of irritability.

Lastly, since the parts in the neighbourhood of the point affected themselves suffer a slight dissipation of the expansive fluid distend-

ing them, their consecutive shrinkage and restoration throw them momentarily into a condition of quivering.

Thus a sudden contraction of the part affected, followed by an equally sudden distension which restores the part to its original condition, constitutes the local phenomenon of irritability.

The production of this phenomenon does not need any special organ; for the state of the parts and the instigating cause are sufficient in themselves; it is in fact observed in the simplest of animal organisations: moreover the impression giving rise to the phenomenon is not conveyed by any special organ to a centre of communication or nucleus of activity; the whole process is confined to the immediate site of the impression; every point of the surface of irritable parts is capable of producing it and of repeating it always in the same way. This phenomenon is obviously quite different from that of sensations.

From these principles it will be clear that orgasm is the source from which irritability arises; but this orgasm exhibits very different degrees of intensity, according to the nature of the bodies in which it is produced.

In plants, where it is ill-defined and devoid of energy, and where it works extremely slowly in causing the shrinkages and distensions of the parts, it has no power to produce irritability.

In animals on the contrary, where orgasm is highly developed on account of the nature of their body-substance, it rapidly produces the contractions and distensions of the parts on the stimulus of the exciting causes; in them it constitutes a marked irritability.

Cabanis, in his work entitled: *Rapports du physique et du moral de l'homme*, has endeavoured to prove that sensibility and irritability are phenomena of the same nature and have a common origin (*Histoire des sensations*, vol. i., p. 90); his intention no doubt was to reconcile what we know of the most imperfect animals with the ancient and universally received belief that all animals without exception possess the faculty of feeling.

The arguments adduced by this savant for showing the identity of nature between feeling and irritability, appear to me neither clear nor convincing; hence they do not affect the following propositions by which I distinguished these two faculties.

Irritability is a phenomenon peculiar to animal organisation, requiring no special organ, and continuing to subsist some time after the death of the individual. This faculty may exist just the same whether there are or are not any special organs, and it is therefore universal for all animals.

Sensibility on the contrary is a phenomenon peculiar to certain animals; it can only be manifested in those which have a special organ essentially distinct, and adapted solely for producing it; and it invariably ends with life or even slightly before death.

We may be sure that feeling cannot occur in an animal without the existence of a special organ adapted for producing it,—that is without a nervous system. Now this organ is always quite discernible; for it cannot exist without a centre of communication for the nerves, and hence could not remain unperceived when it is present. This being so, seeing that many animals have no nervous system, it is obvious that sensibility is not a faculty common to all animals.

Finally, feeling as compared with irritability presents in addition this distinctive peculiarity, that it comes to an end with life or even a little before; whereas irritability is still preserved some time after the death of the individual, and even after it has been divided into fragments.

The time during which irritability is preserved in the parts of an individual after death varies no doubt with the system of organisation of that individual; but in all animals it is probably true that irritability continues to be manifested after the cessation of life.

In man the irritability of his parts scarcely lasts more than two or three hours after death, or even less, according to the cause of death: but thirty hours after having removed a frog's heart it is still irritable and capable of producing movements. There are insects, in which movements are manifested still longer after they have been deprived of their internal organs.

From the above account, we see that irritability is a faculty peculiar to animals; that all animals possess it in a high degree in some or all of their parts and that an energetic orgasm is the source of it: we see moreover that this faculty is entirely distinct from that of feeling; that the one is of very different character from the other, and that since feeling can only result from the functions of a nervous system provided as I have shown with its centre of communication, it only occurs in those animals which possess the required system of organs.

Let us now consider the importance of cellular tissue in all kinds of organisation.

CHAPTER V.

OF CELLULAR TISSUE, REGARDED AS THE MATRIX IN WHICH ALL ORGANISATION HAS BEEN CAST.

As we observe the facts presented to us in the various parts of nature, it is curious to remark how the simplest causes of observed facts are often those which remain the longest unperceived.

It is no new discovery that all the organs of animals are invested by cellular tissue, even down to their smallest parts.

It has indeed been long recognised that the membranes which form the investments of the brain, nerves, vessels of all kinds, glands, viscera, muscles and their fibres, and that even the skin itself are all the produce of cellular tissue.

Yet in this multitude of harmonious facts, nothing more appears to have been seen than the mere facts themselves; and no one that I know of has yet perceived that cellular tissue is the universal matrix of all organisation, and that without this tissue no living body could continue to exist.

Thus when I said [1] that cellular tissue is the matrix in which all the organs of living bodies have been successively formed, and that the movement of fluids through it is nature's method of gradually creating and developing these organs out of this tissue, I was not afraid of coming upon any facts which might testify to the contrary; for it is by examining the facts themselves that the conviction is acquired that every organ whatever has been formed in cellular tissue, since it is everywhere invested with it even down to its smallest parts.

Hence we see that in the natural order, both of animals and plants, those living bodies whose organisation is the simplest and which are consequently placed at one extremity of the order, consist only of a mass of cellular tissue in which there are to be seen neither vessels, nor glands nor any viscera; whereas those bodies, whose organisation

[1] Opening address of the course of invertebrate animals delivered in 1806, p. 33. Since the year 1796, I have stated these principles in the early lessons of my course.

is the most complex and which are therefore placed at the other extremity of the order, have their organs so deeply imbedded in cellular tissue that this tissue always forms their investments and constitutes for them a bond of communication. Hence the possibility of those sudden metastases, so well known to those who practice the art of medicine.

Compare the very simple organisation of the infusorians and polyps, presenting nothing more than a gelatinous mass of cellular tissue, with the highly complex organisation of the mammals, which still presents a cellular tissue though enveloping a large number of different organs; you will then be in a position to judge whether the principles, which I have drawn up on this important subject, are merely the results of an imaginary system.

Compare in the same way in plants the very simple organisation of the algae and fungi with the more complex organisation of a big tree or any other dicotyledonous plant, and you will perceive that the general plan of nature is everywhere the same, notwithstanding the infinite variations of her individual operations.

Take for instance the algae which grow under water, such as the widely spread *Fucus* which constitutes a great family with different genera, and such as the *Ulva*, *Conferva*, etc.; their scarcely modified cellular tissue is conspicuous enough to prove that it alone forms the whole substance of these plants. In several of these algae, the movements of the internal fluids in this tissue have not yet given rise to any signs of a special organ, and in the others they have only traced out a few canals through which food is supplied to those reproductive corpuscles, which botanists take for seeds because they often find them invested in a capsular vesicle in the same way as the gemmae of many known examples of *Sertularia*.

We may then convince ourselves by observation that in the most imperfect animals, such as the infusorians and polyps, and in the least perfect plants, such as the algae and fungi, there sometimes exists no trace of any vessels and sometimes only a few rudimentary canals; lastly, we may recognise that the very simple organisation of these living bodies consists only of a cellular tissue, in which slowly move the fluids which animate them; and that these bodies being destitute of special organs only develop, grow, and multiply or reproduce themselves by a faculty of growth and separation of reproductive parts; for they possess this faculty in a very high degree.

In plants indeed, even including those with the most perfect organisation, there are no vessels comparable to those of animals which have a circulatory system.

Thus the internal organisation of plants really consists only of a

cellular tissue more or less modified by the movement of fluids, a tissue which is very slightly modified in the algae, fungi and even the mosses, whereas it is much more modified in the other plants and especially in the dicotyledons. But everywhere, even in the most perfect animals, there is really nothing in their interior but a cellular tissue modified into a large number of different tubes, most of which are parallel to one another in consequence of the ascending and descending movement of the fluids. Yet the structure of these tubes is not comparable to that of the vessels of animals which possess a circulatory system. Nowhere do these vegetable tubes intertwine or form those special groups of vessels, folded and interlaced in infinite variety, that we call conglomerate glands in animals which have a circulation. Finally in all plants without exception, there is no special organ within their bodies: there is nothing but more or less modified cellular tissue, longitudinal tubes for the movement of fluids, and harder or softer fibres also longitudinal, for strengthening the stem and branches.

If we admit on the one hand that every living body whatever is a mass of cellular tissue, in which are embedded various organs of a number proportionate to the complexity of organisation; and if on the other hand we also admit that all bodies contain within them fluids that move faster or slower according as the state of organisation allows of a more or less active or energetic life, we are forced to the conclusion that it is to the movement of fluids in the cellular tissue that we have primarily to attribute the formation of every kind of organ in the midst of this tissue, and hence that each organ must be invested by it both in its gross outlines and in its most minute parts, as indeed we actually find.

With regard to animals, I have no need to show that in various of their internal parts the cellular tissue is squeezed aside by the moving fluids, which open a passage through it; and that in these regions it has been forced back upon itself; it has then been compressed and transformed into investing membranes round about these running streams of fluid; while on the outside these living bodies are incessantly compressed by the environing fluids (either water or atmospheric fluids) and modified by external impressions and by deposits upon them. Their cellular tissue has thus come to form that universal investment of every living body, that is called skin in animals and bark in plants.

I was then fully justified when I said "that the function of the movement of fluids in the supple parts of living bodies, and especially in the cellular tissue of the simplest among them, is to carve out routes, places of deposit and exits, to create canals and thereafter diverse organs, to vary these canals and organs in accordance with the diversity of the movements or character of the fluids causing them, finally to enlarge, elongate, divide, and gradually solidify these canals and organs. This is effected by the substances which are incessantly being formed in the fluids, and are then separated from them, and in part assimilated and united to the organs, while the remainder is rejected" (*Recherches sur les corps vivants*, pp. 8 and 9).

I was equally justified when I said "that the state of organisation in every living body has been gradually acquired by the increasing influence of the movement of fluids (firstly in the cellular tissue and afterwards in the organs formed in it), and by the constant changes in the character and state of these fluids owing to the continual wastage and renewals proceeding within them."

Lastly, I was authorised by these principles in saying "that every organisation and every new shape, acquired by this agency and contributing circumstances, were preserved and transmitted by reproduction, until yet further modifications had been acquired by the same method and in new circumstances" (*Recherches sur les corps vivants*, p. 9).

It follows from the above that the function of the movement of fluids in living bodies, and consequently of organic movement, is not merely the development of organisation, for this development continues so long as the movement is not weakened, through the hardness which overtakes the organs during life; but that this movement of fluids has in addition the faculty of gradually increasing the complexity of organisation and of multiplying the organs and their functions according as new modes of life or new habits acquired by individuals stimulate it in various ways, create a necessity for new functions, and consequently for new organs.

Let me add that the faster the movement of fluids in a living body, the more does it complicate the organisation, and the greater the branching of the vascular system.

It is from the uninterrupted co-operation of these factors and of long periods of time, combined with an infinite variety of environment, that all the orders of living bodies have been successively formed.

Vegetable Organisation is also cast in a Cellular Tissue.

Imagine a cellular tissue in which, for various reasons,[1] nature could not establish irritability, and you will have an idea of the matrix in which all vegetable organisation has been cast.

If we then reflect that the movements of fluids in plants are only

[1] Chemical analysis has shown that animal substances abound in nitrogen, while vegetable substances are destitute of this material or contain only very small proportions of it. Hence there is a distinct difference between animal and vegetable substances: now this difference may be the reason why the factors which produce orgasm and irritability in animals cannot establish these faculties in living plants.

excited by external influences, we shall be convinced that in this kind of living bodies life can only have a feeble activity, even in times and climates when vegetation is rapid; and consequently that their complexity of organisation is necessarily confined within very narrow limits.

Infinite pains have been taken to become acquainted with the details of plant organisation: search has been made in them for peculiar or special organs of the same kind as some of those known in animals; and the results of all these researches have done no more than show us that the containing parts consist of a more or less compressed cellular tissue, with elongated cells that communicate with each other by pores and by vascular tubes of various shape and size, mostly having lateral pores or sometimes clefts.

All the details ascertained on this subject furnish little in the way of clear general ideas, and the only ones which we need recognise are as follows:

1. Plants are living bodies with less perfect organisation than animals and with less active organic movements; their fluids move more slowly and the orgasm of the containing parts is very faint;

2. They are essentially composed of cellular tissue; for this tissue is to be found in every part of them, and indeed it is found almost by itself and with very slight modifications in the simplest of them (algae, fungi and probably all the agamous plants);

3. The only change undergone by cellular tissue in monocotyledons and dicotyledons as a result of the fluids moving within them, consists in the transformation of certain parts of this cellular tissue into vascular tubes of varied size and shape open at the extremities, and mostly having lateral pores.

Let me further add that since the movement of fluids in plants is either upwards or downwards their vessels are naturally almost always longitudinal, and approximately parallel to one another and to the directions of the stem and branches.

Lastly, the outer part of that cellular tissue, which constitutes the bulk of every plant and the matrix of its low organisation, is squeezed and compressed by the contact, pressure and collision of the environment, and is thus thickened by deposits and transformed into a general integument[1] called bark which is comparable to the skin of animals. Hence we may understand how the external surface of this bark, being even more disorganised than the bark itself by the causes named,

[1] If the stems of palms and some ferns appear to have no bark, it is because they are only elongated root collars, the exterior of which shows a continuous succession of scars left by old leaves that have fallen; this prevents the possibility of a continuous or uninterrupted bark; but it cannot be denied that each separate part of this exterior has its special bark, although more or less imperceptible on account of the small size of these parts.

comes to constitute that outer pellicle called epidermis both in animals and plants.

If then we study plants from the point of view of their internal organisation, all that we can find is, among the simplest, a cellular tissue without vessels but variously modified and stretched or compressed according to the special shape of the plant; and in the more complex, an assemblage of cells and vascular tubes of various sizes, mostly with lateral pores, and a varying number of fibres, resulting from the compression and hardening that a portion of the vascular tubes has undergone. This is all that the internal organisation of plants presents, as regards their containing parts; even their pith is no exception.

But if we study plants from the point of view of their external organisation, the most general and essential points to observe are as follows:

1. Their various peculiarities of shape, colour and consistency, both in them and their parts;

2. The bark which invests them, and gives communication by pores with the environment;

3. The more or less complex organs which develop on the exterior in the course of the plant's life, and serve for reproduction; they perform their functions once only, and are highly important in the determination of the characters and true affinities of each plant.

It is then in the study of the external parts of plants, and especially in that of their reproductive organs, that the means must be sought for describing the characters of plants and determining their natural affinities.

Since the above exposition is a positive result of knowledge acquired by observation, it is obvious that on the one hand the true affinities among animals can only be determined by their internal organisation, which provides the only features of real importance; and that on the other hand these affinities cannot be similarly determined among plants, as regards any of the divisions which mark their classes, orders, families and genera. In their case affinities can only be determined by a study of their external organisation; for their internal organisation is insufficiently complex, and its various modifications too vague, to provide the means for fulfilling this purpose.

We have now seen that cellular tissue is the matrix, in which all organisation was originally cast; and that it was by means of the movement of the internal fluids of living bodies that all their organs were created in this matrix and out of its substance. We have now to enquire briefly whether we are justified in attributing to nature the power of forming direct generations.

CHAPTER VI.

OF DIRECT OR SPONTANEOUS GENERATION.

LIFE and organisation are products of nature, and at the same time results of the powers conferred upon nature by the Supreme Author of all things and of the laws by which she herself is constituted: this can no longer be called in question. Life and organisation are thus purely natural phenomena, and their destruction in any individual is also a natural phenomenon, necessarily following from the first.

Bodies are incessantly undergoing transformations in their condition, combination and character; in the course of which some are always passing from the inert or passive condition to that which permits of the presence of life in them, while the rest are passing back from the living state to the crude and lifeless state. These transitions from life to death and from death to life are evidently part of the immense cycle of changes of every kind to which all physical bodies are liable as time goes on.

Nature, as I have already said, herself creates the rudiments of organisation in masses where it did not previously exist; subsequently, use and the vital movements cause the development and increasing complexity of the organs (*Recherches sur les corps vivants*, p. 92).

However extraordinary this proposition may appear, we shall be obliged to abandon any opinion to the contrary if we take the trouble to examine and reflect seriously upon the principles which I am about to advance.

The ancient philosophers had observed the power of heat, and noted the extreme fertility which it confers on the various parts of the earth's surface in proportion to its abundance; but they omitted to reflect that the co-operation of moisture is the essential condition for making the heat so fertile and necessary to life. Since however they perceived that life in all living bodies derives its support and activity from heat, and that the privation of heat everywhere results in death, they concluded with justice not only that heat was necessary for

the maintenance of life, but that it could even create both life and organisation.

They recognised then that direct generations do occur, that is to say, generations wrought directly by nature and not through the intermediary of individuals of a similar kind: they called them somewhat inappropriately spontaneous generations; and perceiving as they did that the decomposition of animal or vegetable substances provided nature with conditions favourable to the direct creation of new organisms, they wrongly imagined that such organisms were the produce of fermentation.

I am in a position to show that the ancients were not mistaken when they attributed to nature the faculty for direct generation; but that they were very much mistaken in applying this moral truth to a number of living bodies, which neither are nor can be produced by this sort of generation.

As a matter of fact, sufficient observations had not then been collected on this subject; and it was not known that nature, by means of heat and moisture, directly creates only the rudiments of organisation. This direct creation is confined to those living bodies which are at the beginning of the animal and vegetable scales, and perhaps of some of their branches. Thus the ancients, of whom I speak, thought that all the animals with low organisations—which they called for this reason imperfect animals—were the result of these spontaneous generations.

Lastly, since natural history in those times had scarcely advanced at all, and very few facts had been observed as to the productions of nature, the insects and all the animals then designated as worms were generally regarded as imperfect animals, which are born in favourable times and places, as a result of the action of heat on various decaying substances.

It was then believed that putrid flesh directly engendered larvae, which were subsequently metamorphosed into flies; that the extravasated juice of plants, which, as a result of pricks by insects, gives rise to gall nuts, directly produced the larvae which are transformed into *Cinips*, etc., etc.: all of which is without foundation.

Thus the mistake of the ancients in assuming direct generations in cases where they do not occur, was propagated and transmitted from age to age; it was bolstered up by the erroneous beliefs named above, and became the cause of a new mistake for moderns after they had recognised the old one.

When people perceived the necessity for collecting facts and making precise observations as to what actually occurs, the mistake into which the ancients fell was disclosed: men famous for their attainments and powers of observation, such as Rhedi, Leuwenhoek, etc., proved

that all insects without exception are oviparous or sometimes apparently viviparous, that worms are never found to appear on putrid meat, except when flies have been able to deposit their eggs on it; and lastly that all animals, however imperfect they may be, themselves have the power of reproducing and multiplying the individuals of their species.

But unfortunately for the progress of knowledge we are nearly always extreme in our opinions, as we are in our actions; and it is only too common for us to compass the destruction of an error, and then throw ourselves into the opposite error. How many examples I might cite in illustration, even in the present state of accredited opinions, if such details were not foreign to my purpose!

It was thus proved that all animals without exception have the power of reproducing themselves; it was recognised that the insects and all the animals of the later classes only do so by the method of sexual generation; bodies resembling eggs had been seen in the worms and radiarians; and lastly the fact had been verified that the polyps reproduce themselves by gemmae or kinds of buds. Hence the inference was drawn that the direct generations attributed to nature never take place, but that every living body springs from a similar individual of its own species, by a generation that is either viviparous, oviparous or even gemmiparous.

This conclusion is erroneous in being too universal: for it excludes the direct generations wrought by nature at the beginning of the animal and vegetable scales, and perhaps also at the beginning of certain branches of those scales. Moreover, supposing that the bodies, in which nature has established life and organisation directly, obtain at the same time the faculty of reproducing themselves, does it necessarily follow that these bodies spring only from individuals like themselves? Unquestionably no; and this is the mistake into which we have fallen, after recognising that of the ancients.

Not only has it been impossible to demonstrate that the animals with the simplest organisation, such as the infusorians and among them especially *Monas*, and also the simplest plants such perhaps as the *Byssus* of the first family of algae, have all sprung from individuals similar to themselves; but moreover there are observations which go to show that these extremely small and transparent animals and plants, of gelatinous or mucilaginous substance, of very slight coherence, curiously ephemeral, and as easily destroyed by environmental changes as brought into existence, are unable to leave behind them any permanent security for new generations. It is on the contrary far more probable that their new individuals are a direct result of the powers and faculties of nature, and that they alone perhaps are in this position. Hence we shall see that nature has played only an

indirect part in the existence of all other living bodies, since they are all derived one after the other from the original individuals; meanwhile in the course of long periods, she wrought changes and an increase of complexity in their organisation, and ever preserved by reproduction the modifications acquired and the development attained.

If it is admitted that all natural bodies are really productions of nature, it must be quite clear that in bringing the various living bodies into existence, she must necessarily have begun with the simplest, that is with those which are in truth the veriest rudiments of organisation and which we scarcely venture to look upon as organised living bodies. But when by means of the environment and of her own powers, nature has set going in a body the movements constituting life, the repetition of these movements develops organisation in it and gives rise to nutrition, the earliest of the faculties of life; from the latter soon arises the second of the vital faculties, namely, growth of the body.

Excess of nutrition in causing growth of this body prepares in it the material for a new being with a similar organisation; and thus provides it with the power to reproduce itself. Hence originates the third of the faculties of life.

Finally, the continuance of life in a body gradually increases the hardness of its containing parts and their resistance to the vital movements: it proportionally enfeebles nutrition, sets a limit to growth, and finally compasses the death of the individual.

Thus as soon as nature has endowed a body with life, the mere existence of life in that body, however simple its organisation may be, gives birth to the three faculties named above; and its subsequent stay in this same body slowly works its inevitable destruction.

But we shall see that life, especially in favourable conditions, tends incessantly by its very nature to a higher organisation, to the creation of special organs, to the isolation of these organs and their functions, and to the division and multiplication of its own centres of activity. Now since reproduction permanently preserves all that has been acquired, there have come from this fertile source in course of time the various living bodies that we observe; lastly, from the remains left by each of these bodies after death, have sprung the various minerals known to us. This is how all natural bodies are really productions of nature, although she has directly given existence to the simplest living bodies only.

Nature only establishes life in bodies that are at the time in a gelatinous or mucilaginous state, and that are sufficiently soft to respond easily to the movements which she communicates to them by means of the exciting cause that I have spoken of, or of another stimulus which I shall hereafter endeavour to describe. Thus every germ, at

the moment of its fertilisation, that is at the instant when by an organic act it is rendered suitable for the possession of life, and every body which derives immediately from nature the rudiments of organisation and the movements of the most elementary life, are at that time necessarily in a gelatinous or mucilaginous state; although they are yet composed of two kinds of parts, the one containing and the other contained, the latter being essentially fluid.

Comparison between the Organic Act called Fertilisation, and that Act of Nature which gives rise to Direct Generations.

However little we may know of the two phenomena that I am now about to compare, it is quite obvious that they are related, for the results accruing from them are almost identical. Indeed the two acts in question both give origin to life; or give it the power of establishing itself in bodies where it was not previously found, and which could not possess it except through their agency. Thus a careful comparison between them cannot but enlighten us to a certain extent on the real nature of these acts.

I have already said [1] that in the reproduction of mammals, the vital movement in the embryo appears to follow immediately upon fertilisation; whereas in oviparous animals there is an interval between the act of fertilising the embryo and the first vital movement induced by incubation; and we know that this interval may sometimes be very long.

Now during this interval the fertilised embryo cannot yet be reckoned among living bodies; it is ready no doubt for the reception of life, and to that end requires only the stimulus of incubation; but so long as organic movement has not been originated by this stimulus, the fertilised embryo is only a body prepared for the possession of life and not actually possessing it.

If the fertilised egg of a fowl or any other bird is preserved for a certain time without incubation or any increase of temperature, it is not found to contain a living embryo; in the same way, the seed of a plant, which is really a vegetable egg, does not enclose a living embryo unless it has been exposed to germination.

Now if, owing to special circumstances, there occurs no incubation or germination to start the vital movement in the egg or seed, the result is that after a period, dependent on the species and the environment, the parts of this fertilised embryo degenerate; the embryo, since it has never actually had life, will not suffer death; it will

[1] *Recherches sur les corps vivants*, p. 46.

merely cease to be in a condition for receiving life and will ultimately decompose.

I have already shown in my *Mémoires de Physique et d'Histoire naturelle*, p. 250, that life may be suspended for some time and afterwards resumed.

I here wish to observe that preparation for life may be made either by an organic act, or by the direct agency of nature without any such act; so that certain bodies, without possessing life, are yet made ready for its reception by an impression, which does no doubt trace out in these bodies the earliest outlines of organisation.

What indeed is sexual reproduction but an act for achieving fertilisation? What again is fertilisation but an act preparatory to life, an act in short which disposes the parts of a body for the reception and enjoyment of life?

We know that in an unfertilised egg we yet find a gelatinous body which presents a complete external resemblance to a fertilised embryo, and is indeed nothing else than the germ previously existing in the egg although it has not been fertilised.

Yet what is the unfertilised germ of an egg but an almost inorganic body,—a body not prepared internally for the reception of life and incapable of acquiring life even by the most complete incubation?

The fact is generally known that every body which receives life, or which receives the first outlines of organisation preparing it for the possession of life, is at the time necessarily in a gelatinous or mucilaginous state; so that the containing parts of this body have the weakest coherence and the greatest flexibility possible, and are consequently in the highest possible condition of suppleness.

This must necessarily have been the case: the solid parts of the body must have been in a state closely allied to fluids, in order that the disposition, which makes the internal parts of the body ready for life, may be easily achieved.

Now it seems to me certain that sexual fertilisation is nothing else than an act for establishing a special disposition in the internal parts of a gelatinous body; a disposition which consists in a particular arrangement and distension of the parts, without which the body in question could not receive life.

For this purpose it is enough that a subtle penetrating vapour, which escapes from the fertilising material, should be insinuated into the gelatinous corpuscles capable of receiving it; that it should spread throughout its parts and by its expansive movement break up the adhesion between these parts, and so complete the organisation already begun and dispose the corpuscles for the reception of life, that is of the movements constituting life.

It appears that there is this difference between the act of fertilisation which prepares an embryo for the possession of life, and the act of nature which gives rise to direct generations; that the former acts upon a small gelatinous or mucilaginous body, in which the organisation was already outlined, whereas the latter is only carried out upon a small gelatinous or mucilaginous body, in which there was no previous trace of organisation.

In the first case, the fertilising vapour which penetrates the embryo merely breaks asunder by its expansive movement the parts which in the rudiments of organisation ought no longer to adhere together, and arranges them in a particular way.

In the second case, the subtle surrounding fluids, which are introduced into the mass of the small gelatinous or mucilaginous body, enlarge the interstices within it and transform them into cells; henceforth this small body is only a mass of cellular tissue, in which various fluids can be introduced and set in motion.

This small gelatinous or mucilaginous mass, transformed into cellular tissue, may then possess life, although not yet having any organ whatever; since the simplest living bodies, both animal and plant, are really only masses of cellular tissue which have no special organs. On this subject, I may observe that, whereas the indispensable condition for the existence of life in a body is that the body shall be composed of non-fluid containing parts and of contained fluids moving in these parts, the condition is fulfilled by a body consisting of a very supple cellular tissue, the cells of which communicate by pores: the possibility of this is attested by the fact.

If the small mass in question is gelatinous, it will be animal life that is established in it; but if it is simply mucilaginous, then vegetable life only will be able to exist in it.

With regard to the act of organic fertilisation, if you compare the embryo of an animal or plant that has not yet been fertilised with the same embryo after it has undergone this preparatory act of life, you will observe no appreciable difference between them: because the mass and consistency of these embryos are still the same and the two kinds of parts which compose them are extremely vaguely marked out.

You may then conceive that an invisible flame or subtle and expansive vapour (*aura vitalis*) which emanates from the fertilising material, and which penetrates a gelatinous or mucilaginous embryo, that is, enters its mass and spreads throughout its supple parts, does nothing more than establish in these parts a disposition which did not previously exist there, break up the cohesion at the proper places, separate the solids from the fluids in the way required by the organisation, and dispose the two kinds of parts in this embryo for the reception of the organic movement.

Lastly, you may conceive that the vital movement, which follows immediately on fertilisation in mammals but which is on the contrary only set up in oviparous animals and in plants by incubation of various kinds for the former and by germination for the latter, must subsequently develop by slow degrees the organisation of individuals endowed with it.

We cannot penetrate farther into the wonderful mystery of fertilisation; but the principle which I have just set forth is indisputable, and rests on definite facts which I think cannot be called in question.

It is important then to note that, in a different state of affairs, nature in her direct generations imitates her own procedure for fertilisation which she employs in sexual generations; and that for this purpose she does not require the assistance or produce of any pre-existing organisation.

But we must first remember that a subtle penetrating fluid in a more or less expansive condition, and apparently very analogous to the fluid of the fertilising vapours, is distributed everywhere throughout the earth, and that it provides and ever maintains the stimulus which like orgasm is at the base of every vital movement; so that we may rest assured that in places and climates where the intensity of action of the fluid is favourable to organic movement, this movement never ceases until the changes which come over the organs of the living body no longer permit these organs to lend themselves to continuous movement.

Thus in hot climates where this fluid abounds, and especially in places where a considerable dampness acts as a co-operating agency, life seems to be born and multiply everywhere; organisation is formed directly in any appropriate mass where it did not previously exist; and in those where it did exist, it develops rapidly and runs through its various stages in each individual with very remarkable speed.

It is known indeed that in very hot times and climates, the more complex and perfect the organisation of animals may be, the more rapidly does the influence of a high temperature make them traverse the various stages of their existence; this influence accelerates the various stages and the termination of their life. It is well known that in tropical countries, a girl becomes nubile very early, and that she also reaches very early the age of decay or senility. It is, lastly, an admitted fact that intensity of heat increases the danger of the various known diseases, by causing them to run through their stages with astonishing rapidity.

From these principles, we may conclude that any great heat is

universally injurious to animals living in the air, because it greatly rarefies their essential fluids. It has thus been noted that in hot countries, especially at the time of day when the sun is most powerful, the animals appear to suffer, and hide themselves so as to avoid too strong a glare.

Aquatic animals, on the other hand, derive from heat, however great it may be, results that are invariably favourable to their movements and organic development. Among them, it is especially the most imperfect such as the infusorians, polyps and radiarians that benefit the most, since the condition is advantageous to their multiplication and reproduction.

Plants, which only possess a faint and imperfect orgasm, are in absolutely the same condition as the aquatic animals of which I have spoken: for, however great the heat may be, so long as these living bodies have enough water at their disposal, they vegetate all the more vigorously.

We have now seen that heat is indispensable to the most simply organised animals; let us enquire if there are not grounds for the belief that it may itself, with the co-operation of a favourable environment, have fashioned the earliest rudiments of animal life.

Nature, by means of heat, light, electricity and moisture, forms direct or spontaneous generations at that extremity of each kingdom of living bodies, where the simplest of these bodies are found.

This proposition is so remote from the current notion on this matter, that for a long time to come it is likely to be rejected as an error, and even to be regarded as a product of imagination.

But since men who are free even from the most ubiquitous prejudices, and who are observers of nature, will sooner or later perceive the truth contained in this proposition, I wish to contribute towards their perception of it.

I believe I have shown by a collection of comparative facts, that nature under certain circumstances imitates what occurs in sexual fertilisation and herself endows with life isolated portions of matter which are in a condition to receive it.

Why indeed should not heat and electricity, which in certain countries and seasons are so abundantly distributed throughout nature, especially at the surface of the earth, not work the same result on certain substances of a suitable character and in favourable circumstances, that the subtle vapour of the fertilising substances works on the embryos of living bodies by fitting them for the reception of life?

A famous savant (Lavoisier, *Chimie*, vol. i., p. 202) said with truth that God, when he made light, distributed over the earth the principle of organisation, feeling and thought.

Now light is known to generate heat, and heat has been justly regarded as the mother of all generations. These two distribute over our earth at least, the principle of organisation and feeling; and since feeling in its turn gives rise to thought as a result of the numerous impressions made on its organ by external and internal objects through the medium of the senses, the origin of every animal faculty may be traced to these foundations.

This being the case, can it be doubted that heat, that mother of generations, that material soul of living bodies, has been the chief means employed directly by nature for working in appropriate material the rudiments of organisation, a harmonious arrangement of parts, in short, an act of vitalisation analogous to sexual fertilisation?

Not only has the direct formation of the simplest living bodies actually occurred, as I am about to show, but the following principles proves that such formations must still be constantly carried out and repeated where the conditions are favourable, in order that the existing state of things may continue.

I have already shown that the animals of the earliest classes (infusorians, polyps, and radiarians) do not multiply by sexual reproduction, that they have no special reproductive organ, that fertilisation does not occur in them and that consequently they lay no eggs.

Now if we consider the most imperfect of these animals, such as the infusorians, we shall see that in a hard season they all perish, or at least those of the most primitive orders. Now seeing how ephemeral these animalcules are, and how fragile their existence, from what or in what way do they regenerate in the season when we again see them? Must we not think that these simple organisms, these rudiments of animality, so delicate and fragile, have been newly and directly fashioned by nature rather than have regenerated themselves? This is a question at which we necessarily arrive, with regard to these singular creatures.

It cannot then be doubted that suitable portions of inorganic matter, occurring amidst favourable surroundings, may by the influence of nature's agents, of which heat and moisture are the chief, receive an arrangement of their parts that foreshadows cellular organisation, and thereafter pass to the simplest organic state and manifest the earliest movements of life.

If it is true that unorganised and lifeless substances, whatever they may be, could never by any concurrence of circumstances form directly an insect, fish, bird, etc., or any other animal which has already a complex and developed organisation; such animals certainly can only derive their existence through the medium of reproduction, so that no fact of animalisation can concern them.

But the earliest outlines of animal organisation, the earliest acquisition of a capacity for internal development, namely, by intus-susception, lastly, the earliest rudiments of the order of things and of the internal movement constituting life, are formed every day under our very eyes, although hitherto no attention has been paid to it, and give existence to the simplest living bodies which are placed at one extremity of each organic kingdom.

It is useful to note that one of the conditions, essential to the formation of these earliest outlines of organisation, is the presence of moisture and especially of water in a fluid mass. So true is it that the simplest living bodies could not be formed or perpetually be renewed except in the presence of moisture, that none of the infusorians, polyps or radiarians are ever met with except in water; so that we may regard it as an undoubted fact that the animal kingdom originated exclusively in this fluid.

Let us continue the enquiry into the causes which have created the earliest outlines of organisation in suitable masses, where it did not previously exist.

If, as I have shown, light generates heat, heat in its turn generates the vital orgasm that is produced and maintained in animals, where the cause of it is not within them; thus heat may create the earliest elements of orgasm in suitable masses, which have attained the earliest stages of organisation.

When we remember that the simplest organisation needs no special organ distinct from other parts of the body and adapted to a special function (as is made clear by the simplification of organisation observed in many existing animals), we can conceive that such organisation may be wrought in a small mass of matter which has the following qualification.

The body that is most fitted for the reception of the first outlines of life and organisation is any mass of matter apparently homogeneous, of gelatinous or mucilaginous consistency, and whose parts though cohering together are in a state closely resembling that of fluids, and have only enough firmness to constitute the containing parts.

Now the subtle expansive fluids, distributed and constantly moving throughout the environment, incessantly penetrate and are dispersed in any such mass of matter; in passing through it they regulate the internal arrangement of its parts; they convert it into the cellular state; and they make it fit for continually absorbing and exhaling the other environmental fluids which may penetrate within it, and are capable of being contained there.

We have indeed to distinguish the fluids, which penetrate living bodies, in two categories:

1. *Containable fluids*, such as atmospheric air, various gases, water, etc. The nature of these fluids does not permit them to pass through the walls of the containing parts, but only to go in and escape through the exits;

2. *Uncontainable fluids*, such as caloric, electricity, etc. These subtle fluids are naturally capable of passing through the walls of investing membranes, cells, etc., and hence cannot be retained or preserved by any body, except for a brief period.

From the principles set forth in this chapter, it appears to me certain that nature does herself carry out spontaneous or direct generations, that she has this power, and that she utilises it at the anterior extremity of each organic kingdom, where the most imperfect living bodies are found; and that it is exclusively through their medium that she has given existence to all the rest.

To me then it seems a truth of the highest certainty, that nature forms direct or so-called spontaneous generations at the beginning of the plant and animal scales. But a new question presents itself: is it certain that she does not give rise to similar generations at any other point of these scales? I have hitherto held that this question might be answered in the affirmative, because it seemed to me that, in order to give existence to all living bodies, it was enough for nature to have formed directly the simplest and most imperfect of animals and plants.

Yet there are so many accurate observations, so many facts known, which suggest that nature does form direct generations elsewhere than at the beginning of the animal and vegetable scales, and we know that her resources are so wide and her methods so varied in different circumstances, that it is quite possible that my view, according to which the possibility of direct generations is limited to the most imperfect animals and plants, has no true foundation.

Why indeed should nature not give rise to direct generations at various points in the first half of the animal and plant scales, and even at the origin of certain separate branches of these scales? Why should she not establish, in favourable circumstances, in these diverse rudimentary living bodies, certain special systems of organisation, different from those observed at the points where the animal and vegetable scales appear to begin?

Is it not plausible, as able naturalists have believed, that intestinal worms which are never found except in the body of other animals, are direct generations of nature; that certain vermin, which cause diseases of the skin or pullulate there as a result of such diseases, also have a similar origin? And why should not the same hold good among such plants as moulds, the various fungi, and even the lichens, which

are born and multiply so abundantly on the trunks of trees and on rocks favoured by moisture and a mild temperature?

Doubtless as soon as nature has directly created an animal or plant, the existence of life in this body not only endows it with the faculty of growth, but also with that of separating off some of its parts, and in short of forming granular corpuscles suitable for reproducing it. Does it follow that this body which has just obtained the faculty of propagating individuals of its own species must necessarily have sprung itself from corpuscles similar to those that it forms? This is a question which in my opinion is well worthy of examination.

Whether the kind of direct generations, here referred to, do or do not actually take place, as to which at present I have no settled opinion, it seems to me certain at all events that nature actually carries out such generations at the beginning of each kingdom of living bodies, and that she could never, except through this medium, have brought into existence the animals and plants which live on our earth.

Let us now pass to an enquiry as to the immediate results of life in a body.

CHAPTER VII.

OF THE IMMEDIATE RESULTS OF LIFE IN A BODY.

THE laws controlling all the transformations that we observe in nature, although everywhere the same and never in contradiction with one another, produce very different results in living bodies from what they cause in lifeless bodies. The results indeed are quite opposite.

In the former, by virtue of the order and state of things characteristic of living bodies, these laws are constantly striving and succeeding in forming combinations between principles which otherwise would never have been joined together, and in complicating these combinations and adding to them a superfluity of constituent elements; so that the totality of living bodies may be regarded as an immense and ever active laboratory from which all existing compounds were originally derived.

In the latter, on the contrary, that is to say in bodies without life, where there is no force to harmonise their movements and maintain their integrity, these same laws are incessantly tending to decompose existing combinations, to simplify them or reduce the complexity of their composition; so that in course of time they disengage nearly all their constituent principles from their state of combination.

This line of thought leads to developments, which when thoroughly understood and applied to all the known facts, cannot but show more and more the truth of the principle which I have been setting forth.

This course of study however is very different from that which has hitherto occupied the attention of savants; they had observed that the results of the laws of nature in living bodies were quite different from those produced in lifeless bodies, and they attributed the curious facts observed in the former to special laws, although in reality they are only due to the difference of the conditions between these bodies and in bodies that are destitute of life. They did not see that the nature of living bodies, that is, the state and order of things which produce life in them, give to the laws which regulate them a special direction,

strength and properties that they cannot have in lifeless bodies; so that, by their omission to reflect that one and the same cause necessarily has varied effects when it acts upon objects of different nature and in different conditions, they have adopted for the explanation of the observed facts a route altogether opposite from what they ought to have followed.

It has indeed been said that living bodies have the power of resisting the laws and forces to which all non-living bodies or inert matter are subject, and that they are controlled by laws peculiar to themselves.

Nothing is more improbable, and nothing moreover is so far from being proved as this alleged property of living bodies for resisting the forces to which all other bodies are submitted.

This doctrine, which is very widely accepted, and is to be found set forth in all modern works on this subject, appears to me to have been invented in the first place to escape from the difficulty of explaining the causes of the various phenomena of life, and in the second place to afford some explanation of the faculty which living bodies possess of forming for themselves their own substance, of making good the wastage undergone by the material composing their parts, and lastly of giving rise to combinations which would never have existed without them. Thus in the absence of any solution, the difficulty has been shelved by the invention of special laws, without any effort being made to ascertain what they are.

In order to prove that bodies possessing life are subject to a different set of laws from that followed by lifeless bodies, and that the former possess in consequence a special force of which the chief property is said to be their release from the sway of chemical affinities, M. Richerand cites the phenomena presented by the living human body, viz.: "the decomposition of food by the digestive organs, the absorption of their nutritive material by the lacteals, the circulation of these nutritive juices in the blood, the changes which they undergo in the lungs and secretory glands, the capacity for receiving impressions from external objects, the power of approaching or flying from them, in short all the functions carried on in the animal economy." In addition to these phenomena, this savant names as more direct proofs, sensibility and contractility, two properties with which are endowed the organs that carry out the functions of the animal economy (*Éléments de Physiologie*, vol. i., p. 81).

Although the organic phenomena just mentioned are not universal to living bodies nor even to animals, they are yet characteristic of a great number of the latter and of the living human body; and they do undoubtedly show the existence of a special force animating living bodies; but this force in nowise results from laws peculiar to these

bodies; it finds its origin in the exciting cause of vital movements. Now this cause, which in living bodies may give rise to the force in question, could not produce it in crude or lifeless bodies, nor could it animate them, even though it acted upon them to the same extent.

Moreover, the force in question does not altogether withdraw the various parts of living bodies from the sway of chemical affinity; and M. Richerand himself agrees that there occur, in the living machinery, effects that are quite obviously chemical, physical, and mechanical; but these effects are always influenced, modified, and weakened by the forces of life. To M. Richerand's reflections on this subject I may add the remark that the decompositions and alterations produced in living bodies by chemical affinities which tend to break up the state of things adapted for the maintenance of life, are incessantly being repaired, although more or less completely, by the results of the vital force which acts on these bodies. Now in order to bring this vital force into existence and endow it with its recognised properties, nature has no need of special laws; those which control all other bodies are amply sufficient for the purpose.

Nature never uses more complex methods than necessary: if it was possible for her to produce all the phenomena of organisation by means of the laws and forces to which all bodies are universally subjected, she has doubtless done so; and did not create laws and forces for the control of one section of her productions, opposite to those that she uses for the control of the rest.

It is enough to know that the cause, which produces the vital force in bodies whose organisation and structure permit that force to exist and excite the organic functions, could not give rise to any such power in crude or inorganic bodies, where the state of the parts does not permit of the activities and effects observed in living bodies. This cause, of which I have just spoken, only produces in the case of crude bodies or inorganic substances a force which incessantly works towards their decomposition, and which regularly achieves it by mingling its effects with that of the chemical affinities, when the closeness of their combination does not prevent it.

There is then no difference in the physical laws, by which all living bodies are controlled; but there is a great difference in the circumstances under which these laws act.

The vital force, we are told, keeps up a perpetual struggle against the forces which lifeless bodies obey; and life is only a prolonged combat between these different forces.

For my own part, I see in both cases only one force, which is synthetic in one order of things and analytic in another. Now since the conditions

established by these two orders of things are always combined in living bodies, though not in the same parts at the same time, and since they follow each other in turn as a result of the incessant changes wrought by the vital movements, there does exist in these bodies throughout life a perpetual struggle between those conditions which make the vital force synthetic, and those others, always being renewed, which make it analytic.

Before developing this doctrine, let us consider several principles which should not be lost sight of.

If all the activities of life, and all the organic phenomena, without exception, are merely the result of the relations existing between the containing parts in an appropriate state and the contained fluids set in movement by a stimulating cause, the effects named below must necessarily ensue from the existence of this order and state of things in a body.

In point of fact as a result of these relations and of the movements, actions and reactions produced by the stimulating cause, there do incessantly occur the following events in all bodies possessing an active life :

1. Changes in the state of the containing parts of this body (especially the most supple), and in that of its contained fluids ;
2. Real losses in these containing parts and contained fluids, caused by the changes wrought in their state or nature ; losses which give rise to deposits, dissipations, evacuations and secretions of substances, some of which can be no more utilised, while others may be turned to various purposes ;
3. The constant need for making good the losses undergone ; a need which perpetually requires the introduction of new and suitable substances into the body, and which is actually assuaged by food in animals, and by absorptions in plants ;
4. Lastly, various kinds of combinations, which the conditions and results of the various activities of life are alone able to bring about ; combinations which, but for these results and conditions, would never have occurred.

Thus throughout life in a body, combinations are incessantly formed which are as heavily loaded with principles as the organisation of the body is adapted for ; and among them also, decompositions are always taking place, and ultimately destructions which perpetually give rise to the losses experienced.

This is the main positive fact, that is always confirmed by a close observation of vital phenomena.

Let us now return to the study of the two important principles of which I spoke above, and which furnish us to some extent with the key

to all the phenomena connected with complex bodies. These principles are as follows :

The first deals with a universal and ever active factor, which more or less rapidly destroys all existing compounds.

The second concerns a power which is incessantly forming combinations, increasing their complexity and adding new principles to them, according as the circumstances are favourable.

Now although these two powers are in opposition, they both derive their origin from laws and forces which are certainly not opposed, but which work out very different effects on account of the very different circumstances.

I have already established the fact in several of my works,[1] that, by means of nature's laws and forces, every combination and every compound substance tends to be destroyed ; and that this tendency is greater or less, faster or slower in its realisation, in proportion to the nature, number, proportions, and closeness of combination between the principles composing it. The reason of this is that some of these principles in combination have been forced into that condition by an external force, which modifies them while fixing them ; so that these principles have a constant tendency to liberate themselves ; a tendency to which they give effect, on the advent of any favouring factor.

Hence, but little attention is necessary to convince us that nature (the activity of movement established in all parts of our earth) works unceasingly towards the destruction of all existing compounds, the liberation of their principles from the combined state by constantly bringing forward factors which make for such liberation, and the restoration of these principles to that state of freedom, in which they recover their special faculties and which they tend to preserve for ever ; this is the first of the two doctrines enunciated above.

But I have shown at the same time that there also exists in nature a peculiar, powerful, and ever active cause, which has the faculty of forming combinations, of increasing and varying them, and which incessantly tends to add to them new principles. Now this powerful cause, which is comprised by the second of the two doctrines cited, resides in the organic activity of living bodies, where it is always forming combinations that would never have existed without it.

This special cause is not found in any laws adapted to living bodies, and opposite to those which regulate other bodies ; but it takes its origin in an order of things essential to the existence of life, and especially in a force which results from the exciting cause of organic movements. Hence the special cause, which builds up the complex

[1] *Mémoires de Physique et d'Histoire naturelle*, p. 88 ; *Hydrogéologie*, p. 98 *et seq.*

substances of living bodies, is due to the sole condition capable of giving it existence.

In order to be understood, I should mention that two hypotheses have been tried with a view of explaining all the facts bearing on existing compounds and their transformations, and on the elementary combinations that we can ourselves form, break up and then re-establish.

The one generally received is the hypothesis of affinities: it is well known.

The other, which is my own special theory, rests on the assumption that no simple substance whatever can have a tendency of its own to combine with any other, that the affinities between certain substances should not be regarded as forces but as harmonies which allow of the combination of these substances, and lastly, that they can never combine except when constrained by a force external to themselves, and then only when their affinities or harmonies permit of it.

According to the received hypothesis of affinities, to which chemists attribute active special forces, the whole environment of living bodies tends to their destruction; so that unless these bodies possessed within them a principle of reaction, they would soon succumb to the action of surrounding substances. For this reason men have been unwilling to admit the fact that there exists an exciting force of movements in the environment of every body, living or inanimate; and that among the former it succeeds in setting up the phenomena which they present, whereas among the latter it brings about a series of changes permitted by the affinities and finally destroys all existing combinations. The supposition is preferred that life only maintains and develops that series of phenomena found in living bodies, because these bodies were subjected to laws that were altogether peculiar to them.

It will no doubt be recognised some day that affinities are not forces, but that they are harmonies or kinds of relationships between certain substances, which enable them to enter into a more or less close combination through the agency of a general force outside themselves which constrains them to it. Now since the affinities vary between different substances, those substances which displace others from their combinations only do so because they have a greater affinity with certain of the principles in those combinations; they are assisted in this act by that general exciting force of movements and by that which works for the approximation and union of all bodies.

As to life, all that ensues from it during its residence in a body results, on the one hand, from a tendency of the constituent elements of compounds to free themselves from their state of combination, especially

those which have been forced into it, and, on the other hand, from the results of the exciting force of movements. It is indeed easily perceived that in an organised body, this force regulates its activity in all the organs of the body, that it preserves harmony in its activities through the connection of these organs, that so long as they maintain their integrity it everywhere makes good the wastage wrought by the first cause, that it profits by the changes taking place in the compound moving fluids to appropriate from these fluids the assimilated substances which they carry and to fix them in their right positions, lastly, that by this order of things it always conduces to the preservation of life. This same force also conduces to growth of the parts in a living body; but this growth soon comes to an end in almost every part, for a special reason which I shall state in its proper place; and it then endows the body with the faculty of reproducing itself.

Let me repeat then that this singular force, which is derived from the exciting cause of organic movements, and which in organised bodies brings about the existence of life and produces so many wonderful phenomena, is not the result of any special laws but of certain conditions and of a certain order of things and acts which give it the power of producing such effects. Now among the effects to which this force gives rise in living bodies, we must include that of building up diverse combinations, of making them more complex, of loading them with such principles as can be forced into combination, and of incessantly creating substances which, but for it and but for the combination of circumstances in which it works, would never have existed in nature.

It is true that the trend of arguments, generally received by the physiologists, physicists and chemists of our century, is very different from that of the principles which I have set forth and developed elsewhere.[1] It is however not my purpose to endeavour to change this tendency of thought, and thus convert my contemporaries; but I was obliged to state here the two doctrines concerned, because they complete the explanation that I have given of the phenomena of life, and because I am convinced of their accuracy, and know that without them we shall always have to imagine for living bodies laws contrary to those which regulate the phenomena of other bodies.

It appears to me beyond question, that if we enquire sufficiently as to what happens in the objects concerned, we shall soon be convinced:

That the organic functions of all living beings confer on them the faculty, in some cases (plants) of forming direct combinations, that is, of uniting free elements after modification, and of immediately pro-

[1] *Hydrogéologie*, p. 105.

ducing compounds; in other cases (animals) of modifying these compounds and altering their character by the addition of new principles to a remarkable extent.

I must then again impress the fact that living bodies form for themselves, by the activity of their organs, the substance of their bodies and the various secretions of their organs; and that they neither find this substance ready formed in nature, nor the secretions, which come purely from them alone.

It is by means of food, which animals and plants are obliged to use for the preservation of their life, that the organs of these living bodies work their effects. These effects consist in a modification of the food resulting in the formation of special substances, which would never have existed without this cause, and in building up by perpetual alterations and renewals of these substances, the entire body which they constitute, as also its products.

Whereas all animal and vegetable substances are composed of principles in very complex combinations, and many of which have been forced into these combinations, man has no power to do the like; all that he can do is to decompose, alter, or destroy them, or to convert them into various special combinations, always less and less complex. It is only the movements of life that can produce these substances.

Thus plants, which have no intestinal canal nor any other organ for digestion, and which consequently use for food only fluid substances or substances whose molecules are not aggregated (such as water, atmospheric air, caloric, light, and the gases that they absorb), yet form out of such material, by means of their organic activity, all the juices that are proper to them, and all the substances of which their body is composed; that is, they form for themselves the mucilages, gums, resins, sugar, essential salts, fixed and volatile oils, feculae, gluten, extractive and woody matter; all of them substances arising direct from immediate combinations, and none of which can ever be formed by art.

Plants certainly cannot take from the soil by means of their roots the substances which I have just named: they are not there, and those which are there are in a more or less advanced condition of degradation or decomposition; lastly, if there were any in a state of complete integrity, plants would not be able to make use of them without having previously decomposed them.

Plants then have formed directly the substances to which I refer; but when they are outside plants, these substances can only be useful as manure; that is to say, only after being altered in nature, broken up, and having undergone the necessary degradation to fit them for

manure, the essential function of which is to keep up a favourable moisture round about the roots of plants.

Animals cannot build up direct combinations like plants: hence they use compound substances for food; they have to carry out digestion (at least nearly all of them), and they consequently have organs for this purpose.

But they also form for themselves their own substance and secretions: now for this purpose they are not obliged to use as food either these secretions, or a substance like their own: out of grass or hay the horse forms by the action of its organs its blood and other humours, its flesh and its muscles, the substances of its cellular tissue, vessels and glands, its tendons, cartilages and bones, and lastly the horny matter of its hoofs, and the hair of its body, tail and mane.

It is then in forming their own substance and secretions, that animals build up to a high degree the combinations that they produce, and give to these combinations the astonishing number of principles that enter into animal substances.

Let us now remark that the substance of living bodies, as also the secretions which they produce by their organic activity, vary in quality according to the following circumstances:

1. The actual nature of the living being which forms them: thus vegetable productions are in general different from animal productions; and among the latter the productions of vertebrates are in general different from those of invertebrates.

2. The nature of the organ which separates them from other substances after their formation: the secretions of the liver are not the same as those of the kidneys, etc.

3. The vigour or debility of the organs of the living being and of their action: the secretions of a young plant are not the same as those of the same plant when it is very old; nor are those of a child the same as those of a grown man.

4. The integrity of the organic functions: the secretions of a healthy man cannot be the same as those of a diseased man.

5. The abundance of caloric which is continually formed on the surface of the earth although in quantities varying in different climates, and which favours the organic activity of the living bodies which it penetrates; or the rarity of caloric, as a result of which this organic activity is greatly enfeebled: as a matter of fact in hot climates the secretions formed by living bodies are different from those that they produce in cold climates; and in cold climates again the secretions of these bodies differ among themselves, according as they are formed in the hot season or during the rigours of winter.

I shall not here further emphasise the fact that the organic action

of living bodies incessantly builds up combinations, which would not have arisen without it: but I shall again repeat that if it is true, as can hardly be doubted, that all compound mineral substances such as earths and rocks, and all metallic, sulphurous, bituminous, saline substances, etc., arise from the remains of living bodies,—remains which have undergone successive decompositions on and under the surface of the earth and waters; it is equally true to say that living bodies are the original source from which all known compound substances have arisen. (See my *Hydrogéologie*, p. 91 *et seq.*)

It would thus be a vain task to try to make a rich and varied collection of minerals in certain regions of the earth, such as the vast deserts of Africa, where for many centuries there have been no plants and only a few stray animals.

Now that I have shown that living bodies form their own substance for themselves as well as the various matters that they secrete, I must say a word about the faculty of feeding and growing which all these bodies possess within certain limits, since these faculties again are the result of vital activities.

CHAPTER VIII.

OF THE FACULTIES COMMON TO ALL LIVING BODIES.

It is a well-known and established fact that living bodies have faculties which are common to all of them and belong to them as a consequence of life itself.

But I think that little attention has been paid to the fact that those faculties common to all living bodies do not need any special organs as a basis, whereas those faculties which are peculiar to certain bodies only, are necessarily based on some special organ capable of producing them.

Doubtless no vital faculty can exist in a body without organisation; and organisation is itself simply a collection of organs in combination. But those organs, whose combination is necessary for the existence of life, are not peculiar to any one portion of the body they compose; they are, on the contrary, distributed throughout this body, and they bring life to every part of it, as also the essential faculties which spring from life. Hence the faculties common to all living bodies are exclusively due to the same causes which lead to the existence of life.

The case is different with the special organs that give rise to the faculties belonging only to certain living bodies: life can exist without them; but when nature achieved their creation, the chief of them have so close a connection with the order of things existing in the body, that they then become necessary for the maintenance of life in that body.

Thus it is only in the simplest organisations that life can exist without special organs; these organisations are then incapable of producing any other faculty than those common to all living bodies.

On starting an investigation as to the essential properties of life, we must distinguish the phenomena belonging to all bodies which possess life, from those which are peculiar to some of those bodies: and since the phenomena presented by living bodies are a measure of

their faculties, we may usefully adopt this method of distinguishing the faculties common to all from those that are peculiar to some.

The faculties common to all living bodies,—that is, the only faculties that they have in common, are as follows :

1. Feeding, by means of incorporating food substances ; the continual assimilation of a part of these substances ; lastly, the fixation of the assimilated substances, which repair at first plentifully and afterwards less completely the loss of substance which these bodies undergo at all periods of their active life.

2. Building up their bodies ; that is to say, forming for themselves the substances of which they are made by means of materials which only contain the principles of these substances, and which are mainly supplied in the form of food.

3. Developing and growing, up to a certain limit which varies according to the species ; this growth being more than a mere aggregation of matter added externally.

4. Lastly, reproducing themselves, that is producing other bodies which are exactly like them.

Whether a living body, animal or plant, has a very simple or very complex organisation, whatever may be its class, order, etc., it necessarily possesses the four faculties enumerated above. Now since these faculties are the only ones common to all living bodies, they may be regarded as constituting the essential phenomena presented by these bodies.

Let us now enquire how much we can ascertain with regard to nature's methods for the production of these phenomena.

If nature only creates life directly in bodies which did not previously possess it ; if she only creates the simplest type of organisation (Chapter VI.) ; lastly, if she only maintains organic movements by means of an exciting cause of these movements (Chapter III.) ; we may ask how the movements kept up in an organised body, can give rise to the nutrition, growth and reproduction of that body, and at the same time confer on it the faculty of forming its own substance for itself.

I have no desire to provide an explanation of all the details of this wonderful work of nature ; for such an attempt would expose us to the probability of error and might discredit the main truths yielded by observation. I believe that the question propounded above is sufficiently answered by the following observations and reflections :

The activities of life, or the organic movements, necessarily produce alterations of state both in the containing parts and in the contained fluids of a living body, as a result of affinities and of the decomposition of principles previously in combination : such decomposition being

due to these organic movements and the penetration of subtle fluids. Now from these alterations which give rise to various new combinations, there result different kinds of substances ; some of which are dissipated or evacuated as the vital movement continues, while others are merely separated from parts, which do not thereby suffer any fundamental change. Among these separated substances some are deposited in particular parts of the body or are reabsorbed through canals and serve certain purposes ; such are lymph, bile, saliva, the generative substance, etc. ; but the rest acquire a special character, and are carried off by the general force which animates all the organs and drives all the functions, and are then fixed in similar or corresponding parts, either solid or supple and containing. They make good the wastage of these and enlarge their size, in proportion to their abundance and the possibilities of the case.

It is therefore by means of these assimilated substances, which have become adapted to particular regions, that nutrition is carried out. Nutrition, the first of the faculties of life, is thus essentially a mere restoration of the losses undergone ; it is merely a means for reversing the tendency towards decomposition, which all compound substances are liable to. Now this reformation is achieved by means of a force which conveys the newly assimilated substances to their destined positions, and not by any special law, as I have already endeavoured to show. In fact, each kind of part in the animal body appropriates and stows away, by a true affinity, the assimilated molecules capable of being incorporated with it.

But nutrition is more or less abundant according to the state of organisation of the individual.

During youth, nutrition is exceedingly abundant in all organised living bodies ; and it then does more than repair losses, for it adds to the size of the parts.

Indeed in a living body all the newly formed containing parts are extremely supple and of weak consistency, as a result of the causes of their formation. Nutrition under these conditions is carried on so easily as to be excessive. Not only does it completely make good the losses ; but by an internal fixation of assimilated particles, it adds successively to the size of the parts and gives rise to growth of the young individual.

But after a certain period, varying with the organisation in each race, the parts, including even the most supple parts of this individual, lose much of their suppleness and vital orgasm ; and their faculty of nutrition is then proportionally diminished.

Nutrition in this case is limited to the restoration of losses ; the body maintains a stationary condition for some time ; it is indeed in the

height of its vigour, but it grows no more. Now the surplus of the parts prepared, being of no further use for nutrition or growth, is destined by nature to another purpose, and becomes the source through which she arranges for the reproduction of new individuals like the others.

Hence reproduction, the third of the vital faculties, derives its origin like growth from nutrition, or rather from the materials prepared by nutrition. But this faculty of reproduction only acquires intensity when the faculty of growth begins to decline: this fact is confirmed by common observation, since the reproductive organs (sexual parts) both in plants and animals only begin to develop when the growth of the individual is nearing an end.

I should add that, since the materials prepared for nutrition are assimilated particles of as many different kinds as there are parts in the body, the union of these diverse particles left over from nutrition and growth constitute the elements of a very small organised body, exactly similar to that from which it sprang.

In a very simple living body with no special organs, when nutrition has attained the limit of growth for the individual, the excess is then diverted to the formation and development of a part which thereupon separates from the organism and continues to live and grow, constituting a new individual like the old one. Such indeed is the method of reproduction by fission and by gemmae or buds, which occurs without any need for a special organ.

Ultimately after a still longer period—a period that varies even in the individuals of one race according to their habits and climate—the most supple parts of the living body acquire so great a rigidity and suffer so great a diminution of orgasm, that nutrition thereafter repairs the losses only incompletely. The body then gradually wastes away; and if some slight accident or some internal disorder, that the diminished vital forces cannot cope with, do not put an end to the individual, its increasing old age is necessarily terminated by a natural death which supervenes when the existing state of things no longer permits of the performance of organic movements.

This rigidity of the soft parts, which increases during life, has been denied on the ground that after death the heart and other soft parts of an old man shrink more and become more flaccid than in a child or young man who has just died. But the fact has been overlooked that orgasm and irritability which still continue sometime after death, lasts longer and is more intense in young individuals than in the old, among whom these faculties are greatly weakened and are extinguished almost simultaneously with life. This cause alone gives rise to the observed effects.

This is the place to show that nutrition cannot be carried out, without slowly increasing the consistency of the parts restored.

All living bodies, and especially those in which internal heat is developed and maintained throughout life, continually have a part of their humours and even of their bodily tissue in a real state of decomposition; hence they are incessantly undergoing real losses, and it cannot be doubted that it is to the effects of degradations of the solids and fluids of living bodies, that the various substances formed in them are due. Of these, some are secreted and deposited or retained, while others are evacuated by various routes.

These losses would soon lead to degeneration of the organs and fluids of the individual, if nature had not given to living bodies a faculty essential to their preservation: that of making good the losses. Now as a result of these continuous losses and repairs, it follows that after a certain period the body cannot have in its parts any of the molecules which originally composed it.

It is known that the repairs are effected by means of nutrition; but they are more or less complete according to the age and state of the organs of the individual, as I remarked above.

Besides this inequality in the relation of losses to restorations according to the ages of the individuals, there exists another which is very important, and which yet appears to have received no attention. It concerns the constant inequality between the substances assimilated and fixed by nutrition, and those which are liberated as a result of the continual degradation above mentioned.

I have shown in my *Recherches* (vol. ii., p. 202) that the cause of this inequality is as follows:

Assimilation (the nutrition resulting from it) always provides more solid principles or substances, than are removed or dissipated by the losses.

The successive losses and repairs, which never cease in living bodies, have long been recognised; and yet it is only during the last few years that the conviction has grown that these losses are due to degradations continually being undergone by the fluids and even the solids of the body. Some people still have a difficulty in believing that the formation of the various secretions is the result of these degradations and changes or combinations always going on in the essential fluids of living bodies: but this fact I have already established.[1]

Now if it is true, on the one hand, that the losses of the body consist less of solid, earthy and concrete substances than of fluid substances and especially volatile substances; and if, on the other hand, it is also

[1] *Mémoire de Physique et d'Histoire naturelle*, pp. 260-263; and *Hydrogéologie*, pp. 112-115.

true that nutrition gradually provides the parts with more solid substances than fluid and volatile substances ; it will follow that the organs will gradually acquire increasing rigidity, making them less fitted for carrying out their functions, as is actually the case.

It is far from being true that the whole environment of living bodies tends to their destruction, as is repeated in all modern physiological works. I am convinced that, on the contrary, they only maintain their existence by means of external influences, and that the cause leading to the death of the individuals is within them and not without them.

Indeed I see clearly that this cause is due to the difference between the substances assimilated and fixed by nutrition, and those thrown out or dissipated by the continual wastage to which living bodies are subject, since volatile substances are always the first and the easiest to be freed from their state of combination.

I see, in short, that this cause, which brings about old age, decrepitude, and finally death, resides in the progressive hardening of the organs ; a hardening which gradually produces rigidity, and which in animals reduces to a corresponding extent the intensity of orgasm and irritability, stiffens and narrows the vessels, and imperceptibly destroys the action of the fluids on the solids, and *vice versâ*. Lastly, it disturbs the order and state of things necessary to life, which ultimately is entirely extinguished.

I believe I have proved that the faculties common to all living bodies are those of feeding ; of building up for themselves the various substances of which their bodies are composed ; of developing and growing up to a certain limit that varies in each case ; of propagating, that is, of reproducing other individuals like themselves ; lastly, of losing their life by a cause that is within themselves.

I shall now examine the faculties that are peculiar to some living bodies ; and shall confine myself, as I have just done, to an exposition of the general facts without any attempt to enter into the details that may be found in works on physiology.

CHAPTER IX.

OF THE FACULTIES PECULIAR TO CERTAIN LIVING BODIES.

JUST as there are faculties common to all bodies that enjoy life, as I have shown in the preceding chapter, so too we find in certain living bodies faculties peculiar to themselves and not shared by the rest.

We are now confronted with a circumstance of capital importance, to which the utmost attention should be paid if further progress is to be made in natural science ; it is this.

It is quite clear that both animal and vegetable organisation have, as a result of the power of life, worked out their own advancing complexity, beginning from that which was the simplest and going on to that which presents the highest complexity, the greatest number of organs, and the most numerous faculties ; it is also quite clear that every special organ and the faculty based on it, once obtained, must continue to exist in all living bodies which come after those which possess it in the natural order, unless some abortion causes its disappearance. But before the animal or plant which was the first to obtain this organ, it would be vain to seek either the organ or its faculty among simpler and less perfect living bodies ; for neither the organ nor its faculty would be found. If this were otherwise, then all known faculties would be common to all living bodies ; every organ would be present in each one of these bodies, and there would be no progress in complexity of organisation.

It is, on the contrary, well established that organisation exhibits an obvious progress in complexity, and that all living bodies do not possess the same organs. Now I propose to show that, from want of sufficient study of nature's order in her productions and of the remarkable progress that occurs in complexity of organisation, naturalists have made altogether fruitless attempts to trace in certain classes, both of animals and plants, organs and faculties which could not possibly be there.

We must then first determine the point in the natural order, say of

animals, at which some organ began to exist, in order to save ourselves from seeking that organ in much earlier points of the order. Otherwise science would be retarded by our hypothetically referring to parts with which we are little acquainted, faculties which they could not have.

Thus several botanists have made useless attempts to find sexual reproduction in agamous plants (the cryptogams of Linnæus), and others have thought that they had found, in what are called the tracheae of plants, a special organ for respiration. In the same way several zoologists have wanted to prove the existence of lungs in certain molluscs, a skeleton in star-fishes, gills in jelly-fishes : lastly, a learned society has this year set, as a prize subject, the question whether there exists a circulation in radiarians.

Such attempts prove indeed how little we are yet impressed by the natural order of animals, by the progress in the complexity of their organisation, and by the general principles which result from the knowledge of that order. In a matter of organisation, moreover, when the objects dealt with are very small and unknown, people think they actually see what they want to see, and they thus find whatever they want : as, for instance, already happens in the arbitrary reference of faculties to parts of whose nature and function we are ignorant.

Let us now enquire what are the chief faculties peculiar to certain living bodies and let us see at what point in the natural order of animals and plants each of these faculties, with its attached organ, began to exist.

The chief of the faculties peculiar to certain living bodies, and consequently not shared by the rest, are as follows :

(1) The digestion of food ;
(2) Respiration by a special organ ;
(3) The performance of acts and movements by muscular organs ;
(4) Feeling, or the capacity for experiencing sensations ;
(5) Multiplication by sexual reproduction ;
(6) A circulation of their essential fluids ;
(7) The possession of a certain degree of intelligence.

There are many other special faculties, of which examples are found among living bodies and especially among animals ; but I shall confine myself to the consideration of these few, because they are the most important, and because what I have to say about them is sufficient for my purpose.

The faculties which are not common to all living bodies are based in every case without exception on special organs which cause them, and hence on organs that are not possessed by all living bodies ; and

the acts which make up these faculties are functions of those organs.

I shall consequently not enquire whether the functions of such organs are being performed uninterruptedly or only intermittently, nor shall I consider whether these functions subserve the preservation of the individual or of the species, nor whether they act as links between the individual and surrounding bodies that are foreign to it. I shall merely state briefly my views on the organic functions which give rise to the seven faculties named above. I shall prove that each of them is limited to particular animals, and cannot be common to the entire animal kingdom.

Digestion. This is the first of the special faculties, and is possessed by the greater number of animals. It is at the same time an organic function carried on in a central cavity of the individual ; a cavity which, although varying in shape in different races, is generally like a tube or canal, which is sometimes open at one of its extremities only, and sometimes at both.

This function, which acts only on compound substances, called alimentary substances and not a part of the individual, consists firstly in destroying the aggregation of the component molecules of the alimentary substances, introduced into the digestive cavity ; and then of changing the state and properties of these molecules, in such a way that part of them become fitted for the formation of chyle, and for renewing or restoring the essential fluid of the individual.

Various liquids, delivered into the digestive organ by the excretory ducts of various glands in the neighbourhood, liquids which are chiefly poured forth when digestion has to be performed, facilitate in the first place the dissolution, that is to say, the destruction of the aggregation of the molecules of the food substances ; and then contribute to bringing about the changes which these molecules have to undergo. Thereafter, such of the molecules as have been adequately altered and prepared, are suspended in the digestive and other liquids, and penetrate through the absorbent pores of the walls of the alimentary or intestinal tube into the lacteals or subordinate canals, and there constitute that precious fluid which is destined to restore the essential fluid of the individual.

All the molecules or coarser parts, which are of no use for the formation of chyle, are afterwards rejected from the alimentary cavity.

Thus the special organ of digestion is the alimentary cavity, whose anterior opening by which food is introduced bears the name of mouth, while that of the posterior extremity, when there is one, is called the anus.

It follows from the foregoing that no living body, which lacks an alimentary cavity, ever has any digestion to perform; and since all digestion works on compound substances and breaks down the aggregation of the food molecules into solid masses, it results that such living bodies as have no digestion, can only feed on fluid, liquid or gaseous material.

This applies to all plants; they have no digestive organ, nor as a matter of fact do they have any digestion to perform.

Most animals, on the contrary, have a special organ for digestion; but this faculty is not, as has been alleged, common to all animals, and cannot be cited as one of the characters of animality. The infusorians indeed do not possess it; and we should vainly seek an alimentary cavity in a monas, volvox, proteus, etc.; there is none to be found.

The faculty of digesting is then only common to the greater number of animals.

Respiration. This is the second of the faculties peculiar to certain animals, for it is less general than digestion; its function is carried on in a distinct special organ, which varies greatly in different races and different requirements.

This function consists in a restoration of the essential fluid, which in these individuals becomes too rapidly degraded; a restoration for which the slower alternative of food is not sufficient. The restoration in question is effected in the respiratory organ by means of the contact of a special fluid that is breathed in, and decomposes and communicates restorative principles to the individual's essential fluid.

In those animals whose essential fluid is quite simple and only moves slowly, the degradation of this fluid is also slow, and then the method of food alone suffices for the restorations; the fluids capable of providing certain necessary restorative principles penetrate into the individual by this route and also by absorption; and their influence is sufficient without any need for a special organ. Hence the faculty of breathing by a special organ is not necessary to these living bodies. This is the case with all plants and also with a considerable number of animals, such as those that compose the class of infusorians and that of polyps.

The faculty of breathing then should only be attributed to those living bodies that possess a special organ for the purpose; for if those which have no such organ require for their essential fluid any influence analogous to respiration (which is very doubtful), they apparently derive it through some slow general route like that of food or of absorption through external pores, and not by a special organ. Hence these living bodies do not breathe.

The most important of the restorative principles furnished by the

fluid breathed to the animal's essential fluid, appears to be oxygen. It is liberated from the respired fluid, combines with the essential fluid of the animal, and restores to the latter qualities which it had lost.

There are, as we know, two different respiratory fluids which provide oxygen for breathing. These fluids are air and water; in general they are the media in which living bodies are immersed, or by which they are surrounded.

Water indeed is the respiratory fluid of many animals which live permanently in its depths. It is believed that this fluid does not decompose when giving up oxygen; but that it always has a certain amount of air mixed up with it; and that it is this air which is decomposed in the act of breathing, and thus provides oxygen for the essential fluid of the animal. This is the way in which fishes and many aquatic animals breathe; but this respiration is less active, and yields its restorative principles more slowly, than that which takes place in free air.

Free atmospheric air is the second respiratory fluid, and that which is breathed by a large number of animals which live permanently in it or within reach of it: it is promptly decomposed in the act of breathing, and thereupon yields up its oxygen to the essential fluid of the animal. This kind of breathing, which is characteristic of the most perfect animals and many others, is the most active: and its activity is proportional to the development of the organ in which it is carried out.

It is not enough to discuss the existence of a special organ for breathing; we must pay attention to the character of this organ, in order to judge of the height of the animal's development, by means of the faster or slower recurrence of the necessity for restoring its essential fluid.

In proportion as the essential fluid of animals becomes more complex and animalised, the degradations which it suffers during life are greater and more rapid, and the restorations required gradually develop in proportion to the changes experienced.

In the simplest and most imperfect animals, such as the infusorians and polyps, the essential fluid is so elementary, so little animalised, and becomes so slowly degraded, that the restorations of the food are sufficient. But soon afterwards, nature begins to require a new method for preserving the essential fluid of animals in a proper condition. It is then that she creates respiration; but at first she only sets up a very weak and inactive respiratory system,—that namely furnished by water, which has itself to convey its influence to every part of the animal.

Nature subsequently varies the type of respiration in accordance with the progressive increase of the requirement. She makes this

function ever more active, and ultimately endows it with the highest energy.

Since water-born respiration is the least active, let us examine it first. We shall find that water-breathing organs are of two kinds, which again differ as regards activity; we shall afterwards note the same thing in the case of air-breathing organs.

Water-breathing organs are divided into water-bearing tracheae and gills, just as air-breathing organs are divided into air-breathing tracheae and lungs. It is indeed quite obvious that water-bearing tracheae are to gills what air-breathing tracheae are to lungs. (*Systéme des Animaux sans Vertebrés*, p. 47.)

Water-bearing tracheae consist of a certain number of vessels which ramify and spread in the animal's interior, and open on the outside by a number of small tubes which absorb the water: by this means water continually enters by these tubes, undergoes a kind of circulation all through the animal's interior, carries the respiratory influence there, and appears to issue forth again through the alimentary cavity.

These water-bearing tracheae constitute the most imperfect, the least active, and the earliest respiratory organ created by nature; that moreover which appertains to animals whose organisation is so low that their essential fluid still has no circulation. Striking examples are found in the radiarians, such as the sea-urchins, star-fishes, jelly-fishes, etc.

Gills are also a water-bearing organ, which may moreover become accustomed to breathing free air; but this respiratory organ is always isolated either within or without the animal, and only occurs in animals whose organisation is sufficiently advanced to have a nervous and a circulatory system.

Trying to find gills in radiarians and worms merely because they breathe water, is like trying to find lungs in insects because they breathe air. The air-breathing tracheae of insects constitute therefore the most imperfect of the air-breathing organs; they extend throughout all parts of the animal, carrying with them the valuable influence of respiration; whereas lungs, like gills, are isolated respiratory organs which at their highest development are more active than any other.

For the thorough appreciation of the foregoing doctrine, some attention must be given to the two following principles.

Respiration, in animals which have no circulation of their essential fluid, is carried out slowly without any perceptible movement, and in a system of organs which is distributed to almost every part of the animal's body. In this type of respiration, the respired fluid itself conveys its influence to the parts; the animal's essential fluid goes nowhere in advance of it. Such is the respiration of the radiarians and worms, in which water is the respired fluid; and such again is the respiration of the insects and arachnids, in which the respired fluid is atmospheric air.

But the respiration of animals, which have a general circulation, is of a very different type; it is effected more rapidly, it gives rise to special movements which in the highest animals become regular, and it is carried out in a simple, double or compound organ that is isolated and does not spread throughout the body. The essential fluid or blood of the animal then goes beyond the respired fluid, which only penetrates as far as the respiratory organ: the blood therefore has to undergo in addition to the general circulation a special circulation that I may call respiratory. Now since it is sometimes only a part of the blood that travels to the organ of respiration before being despatched throughout the animal's body, and since in other cases the whole of the blood passes through this organ before its journey in the body, the respiratory circulation is accordingly said to be either complete or incomplete.

Now that I have shown that there are two quite different types of respiration in those animals which have a distinct respiratory organ, I think that the name of general respiration may be given to the first type, such as that of the radiarians, worms, and insects; and that the name of local respiration should be applied to the second type, which belongs to animals more perfect than insects, including perhaps the limited respiration of arachnids.

The faculty of breathing is thus peculiar to certain animals; and the nature of the organ by which they breathe is so well adapted to their needs and to the stage of development of their organisation, that it would be very unreasonable to expect to find in imperfect animals the respiratory organ of more perfect animals.

The Muscular System. This confers upon the animals which possess it, the faculty of performing actions and movements, and of controlling these activities either by the inclination due to habit, or by the inner feeling, or, lastly, by the operations of the intellect.

Since it is admitted that no muscular activity can occur without nervous influence, it follows that the muscular system must have been formed after the rise of the nervous system, at all events in its first outlines. Now if it is true that that function of the nervous system, of which the purpose is to dispatch the subtle fluid of the nerves to the muscular fibres or bundles and set them in action, is much simpler than that other function of producing feeling (as I hope to prove), it must follow that as soon as the nervous system had reached the stage of a medullary mass in which terminate the various nerves, or as soon as it was provided with separate ganglia sending

out nervous threads to various parts, it was henceforth capable of giving rise to muscular excitation without however being able to produce the phenomenon of feeling.

From these principles I believe I am justified in drawing the conclusion that the formation of the muscular system is subsequent to that of the earliest stages of the nervous system, but that the faculty of carrying out actions and movements by means of muscular organs is in animals prior to that of experiencing sensations.

Now since the origin of the nervous system is anterior to that of the muscular system, and since its functional existence only dates from the time when it was composed of a main medullary mass from which issue nervous threads, and since no such system of organs can exist in animals with organisations as simple as the infusorians or most polyps, it clearly follows that the muscular system is peculiar to certain animals, that it is not possessed by all, and yet that the faculty of acting and moving by muscular organs exists in a greater number of animals than does the faculty of feeling.

For deciding as to the presence of a muscular system in animals in doubtful cases, it is important to consider whether there are in these animals any points of attachment for muscular fibres, of a certain strength or firmness; for, being constantly under stress, these points of attachment become gradually stronger.

It is certain that the muscular system exists in insects and all animals of subsequent classes; but has nature established this system in animals that are more imperfect than insects? If she has, it can hardly be (as far as the radiarians are concerned) anywhere but in the echinoderms and fistulides: it cannot be in the soft radiarians: perhaps there are rudiments of it in the sea-anemones; the coriaceous substance of their bodies makes this belief plausible, but its presence cannot be supposed in the hydra nor in most other polyps, and still less in the infusorians.

It is possible that, when nature set out to establish some special system of organs, she selected conditions favourable to their creation; and that consequently there are several interruptions in our scale of animals near the point at which the system is established, and due to the existence of cases in which its formation was impracticable.

Attentive observation of the operations of nature in the light of these principles will doubtless teach us many things that we do not yet know on these interesting subjects, and may perhaps disclose the fact that although nature was able to begin the muscular system with the radiarians, yet the worms which follow them are still devoid of it.

If this principle is well-founded, it will confirm what I have already urged with regard to worms, viz.: that they appear to constitute a special branch of the animal chain that has started afresh by spontaneous generation (Chapter VI., p. 247).

The plainly marked and well-known muscular system in insects is everywhere found afterwards in animals of the following classes.

Feeling is a faculty which must take the fourth rank among those that are not common to all living bodies; for the faculty of feeling appears to be still less general than those of muscular movement, respiration and digestion.

We shall see farther on that feeling is only an effect; that is to say, the result of an organic act and not a faculty inherent in any of the substances, which enter into the composition of a body that can experience it.

None of our humours and none of our organs, not even our nerves, have the faculty of feeling. It is only by an illusion that we attribute the singular effect, that we call sensation or feeling, to a definite part of our body; none of the substances composing this part does or can really feel. But the very remarkable effect called sensation or, when more intense, pain, is the product of the function of a very special system of organs, the activity of which is dependent on the circumstances which provoke it.

I hope to prove that this effect, constituting feeling or sensation, is an undoubted result of an affective cause which excites action in any part of the special system of organs adapted to it; this action by a repercussion, that is swifter than light and affects every part of the system, delivers its general effect in the common nucleus of sensation and the sensation is then propagated to the point of the body that was affected.

I shall endeavour to describe in the third part of this work, the wonderful mechanism of the effect which we call feeling: I shall here merely remark that the special system of organs for producing such an effect, is known under the name of the nervous system; and I may add that this system only acquires the faculty of giving rise to feeling, when it is so far developed as to have numerous nerves meeting in a common nucleus or centre of communication.

It follows from these principles that no animal, which does not possess a nervous system of the kind named, can experience the remarkable effect in question, nor consequently can it have the faculty of feeling. *A fortiori*, any animal which does not have nerves, terminating in a main medullary mass, must be destitute of feeling.

The faculty of feeling therefore cannot be common to all living bodies, since it is universally admitted that plants have no nerves and can therefore have no feeling. It has however been held that this faculty is common to all animals; this is clearly a mistake, for all

animals neither have nor can have nerves; moreover, those in which nerves are just arising, do not yet possess a nervous system that fulfils the conditions for the production of feeling. It is probable indeed that, in its origin or primitive imperfection, this system has no other faculty than that of exciting muscular movement. The faculty of feeling therefore cannot be common to all animals.

If it is true that every faculty that is limited to certain living bodies is based upon a special organ, as is everywhere found to be the case, it must also be true that the faculty of feeling, which is clearly limited to certain animals, is exclusively the product of a special organ or system of organs, whose activities produce it.

According to this principle, the nervous system constitutes the special organ of feeling when it is composed of a single centre of communication and of nerves terminating it. Now it seems probable that it is only in the insects that the nervous system attains a development sufficient for the production of feeling, although still of a vague kind. The faculty recurs in all animals of later classes in a regular progress towards perfection.

But in animals less perfect than insects, such as worms and radiarians, if we do find traces of nerves and separated ganglia, there are strong reasons for the presumption that these organs are only adapted to the excitation of muscular movement, the simplest faculty of the nervous system.

Finally, in animals still more imperfect, such as the majority of polyps and all the infusorians, it is quite certain that they cannot possess a nervous system capable of giving them the faculty of feeling, nor even that of moving by muscles: for them, irritability alone takes its place.

Thus feeling is not a faculty common to all animals, as has been generally held.

Sexual Reproduction. This is a special faculty which is in animals nearly as general as feeling; it results from an organic function, not essential to life, the purpose of which is to attain the fertilisation of an embryo which then becomes fitted for the possession of life, and for constituting after development an individual like that or those from which it sprang.

This function is performed at particular periods, sometimes regular and sometimes not, by the co-operation of two systems of organs called sexual, one being the male organs and the other female.

Sexual reproduction is observed in animals and plants, but it is limited to particular animals and plants and is not a faculty common to all these living bodies; nature could not have made it so, as we shall see.

In the production of living bodies, both animal and plant, nature was originally obliged to create the simplest organisation in the most fragile bodies, where it was impossible to establish any special organs. She soon had to endow these bodies with the faculty of multiplying, for otherwise she would everywhere have been occupied with creations, and this is beyond her power. Now since she could not give her earliest productions the faculty of multiplying by any special system of organs, she hit upon the plan of giving it through the medium of growth, which is common to all living bodies. She conferred the faculty of undergoing divisions, at first of the entire body, and afterwards of certain projecting portions of the body; in this way were produced gemmae and the various reproductive bodies, which are only parts that grow out, become separated, and continue to live after their separation, and which need no fertilisation, form no embryo, develop without the rupture of any membrane, and yet after growth resemble the individuals from which they spring.

Such is the method employed by nature for the multiplication of those animals and plants, to which she could not give the complicated apparatus of sexual reproduction; it would be in vain to seek any such apparatus in the algae and fungi, or in the infusorians and polyps.

When the male and female organs are united in the same individual, that individual is said to be hermaphrodite.

In this case a distinction must be drawn between perfect hermaphroditism, which is sufficient to itself, and that which is imperfect and not sufficient to itself. Indeed many plants are hermaphrodites, in which the individual suffices to itself for fertilisation; but in animals, which combine the two sexes, it is not yet proved by observation that the individuals are sufficient to themselves; and it is known that many truly hermaphrodite molluscs none the less fertilise one another. It is true that, among hermaphrodite molluscs, those which have a bi-valve shell and are fixed, like oysters, must apparently fertilise themselves: it is however possible that they may fertilise one another mutually through the medium in which they are immersed. If this is so, there are among animals only imperfect hermaphrodites; and it is known that, among vertebrates, there are not even any true hermaphrodites at all. Perfect hermaphrodites will thus be confined to plants.

The character of hermaphroditism consists in the combination of the two sexes in one individual, but it seems that the monoecious plants constitute an exception; for although a monoecious shrub or tree carries both sexes, its individual flowers are none the less unisexual.

I may remark in this connection that it is wrong to give the name

of *individual* to a tree or shrub or even to herbaceous perennials; for a tree, shrub, etc., is in reality a collection of individuals which live on one another, communicate together, and share a common life, in the same way as the compound polyps of madrepores, millipores, etc.; as I have already proved in the first chapter of this second part.

Fertilisation, the essential result of an act of sexual reproduction, must be divided into two different kinds, one of which is higher or more eminent than the other, since it belongs to the most perfect animals (mammals). This comprises the fertilisation of viviparous animals, while the other, which is inferior and less perfect, includes that of oviparous animals.

The fertilisation of viviparous animals immediately vivifies the embryo exposed to it, and this embryo forthwith continues to live, and feeds and develops at the expense of its mother, with which it remains in communication up to birth. No interval is known between the act which prepares it for the possession of life and the reception of life itself; moreover, this fertilised embryo is enclosed in a membrane which contains no stores of food within it.

The fertilisation of oviparous animals, on the other hand, only prepares the embryo for the reception of life, but does not actually confer life. Now this fertilised embryo of oviparous animals is enclosed with a store of food in investments, which cease to communicate with the mother before being separated from her; and it only receives life when a special factor, which may come sooner or later according to circumstances, or may not come at all, communicates to it the vital movement.

This special factor, which confers life on the embryo of an oviparous animal after it has been fertilised, consists as regards animals' eggs in a mere rise of temperature, and as regards the seeds of plants in the co-operation of moisture with a gentle penetrating warmth. In birds' eggs, for instance, incubation causes this rise of temperature, and in many other eggs a gentle warmth of the atmosphere is enough; lastly, circumstances that favour germination vitalise the seeds of plants.

But eggs and seeds adapted for giving existence to animals and plants must of necessity contain a fertilised embryo enclosed in investments, whence it can only emerge after breaking through them: such eggs and seeds are therefore products of sexual reproduction, since reproductive bodies otherwise originating do not have any embryo enclosed in investments which have to be broken through at the outset of development. Gemmae and the more or less oviform reproductive bodies of many animals and plants cannot assuredly be compared with them: it would be a waste of time to search for sexual generation where nature has had no means for establishing it.

Sexual reproduction is thus peculiar to certain animals and plants: consequently the simplest and most imperfect living bodies cannot possess any such faculty.

Circulation. This is a faculty which only exists in certain animals, and which is much less general in the animal kingdom than the five others of which I have already spoken. This faculty springs from an organic function whose purpose is the acceleration of the movements of the essential fluid of certain animals,—a function which is performed by a special system of organs adapted to it.

This system of organs is essentially composed of two kinds of vessels, viz. arteries and veins, and almost always in addition a thick and hollow muscle, which occupies about the centre of the system, which soon becomes the principal motive power of it, and which is called the heart.

The function carried out by this system of organs consists in driving the animal's essential fluid, which is here known by the name of blood, from an almost central point occupied by the heart (when there is one), through the arteries into every part of the body; whence it returns to the same point by the veins, and is then dispatched anew throughout the body.

It is this movement of the blood, always being driven into every part and always returning to its starting point throughout the duration of life, that has received the name of *Circulation.* It should be qualified as *general* in order to distinguish it from the respiratory circulation, which is undertaken by a special system likewise composed of arteries and veins.

Nature, when initiating organisation in the simplest and most imperfect animals, was only able to give their essential fluid an extremely slow movement. This no doubt is the case in the very simple and scarcely animalised essential fluid that moves in the cellular tissue of infusorians. But afterwards she gradually animalised and developed the essential fluid of animals in proportion as their organisation became more complex and perfect; and she accelerated its movement by various methods.

In the polyps, the essential fluid is nearly as simple and has scarcely more movement than that of the infusorians. The regular shape of the polyps, however, and especially their alimentary cavity begin to furnish means to nature for somewhat increasing the activity of their essential fluid.

She probably took advantage of this in the radiarians, to establish in their alimentary cavity the centre of activity of their essential fluid. The expansive surrounding subtle fluids, in fact, which constitute the exciting cause of these animals' movements, penetrate chiefly

into their alimentary cavity; and by their incessant expansions have greatly developed this cavity, have induced the radiating form of these animals both internally and externally, and moreover cause the isochronous movements observed in the soft radiarians.

When nature had established muscular movement, as she has in the insects and perhaps even a little before, she had a new means for increasing the movement of their serum or essential fluid; but on reaching the organisation of the crustaceans, this means no longer sufficed, and a special system of organs had to be created for accelerating the essential fluid or blood of these animals. It is indeed in the crustaceans that we find for the first time a complete general circulation; for this function is only rudimentary in the arachnids.

Every new system of organs acquired is permanently preserved in subsequent organisations; but nature continues to work towards its gradual perfection.

The general circulation is thus at first provided only with a heart with one ventricle, and indeed in the annelids even a heart is unknown: it is at first accompanied only by an incomplete respiratory circulation, viz. one in which all the blood does not pass through the organ of respiration before being despatched to the parts. This is the case with animals which have imperfect gills; but in fishes, where the branchial respiration is perfect, the general circulation is accompanied by a complete respiratory circulation.

When nature subsequently created lungs for breathing, as she did in the reptiles, the general circulation was of necessity accompanied only by an incomplete respiratory circulation; because the new respiratory organ was still too imperfect, and because the general circulation still had a heart with only one ventricle and also because the new fluid breathed is by itself more effectively restorative than water, so that a complete respiration was not needed. But when nature reached that perfection of pulmonary respiration seen in the birds and mammals, the general circulation came to be accompanied by a complete respiratory circulation; the heart necessarily had two ventricles and two auricles; and the blood gained its highest velocity; the high animalisation became capable of raising the animal's internal temperature above that of the environment, and, lastly, the blood became subject to rapid decomposition requiring corresponding restoration.

The circulation of the essential fluid of a living body is then an organic function peculiar to certain animals: it first becomes complete and general in the crustaceans, and is afterwards found gradually becoming more perfect in animals of the following classes; but it would be vain to seek it in the less perfect animals of the anterior classes.

Intelligence. Of all the faculties peculiar to certain animals, this is the one that is the most limited as regards the numbers which possess it, even in a very imperfect form; but it is also the most wonderful, especially when highly developed; and it may then be regarded as the high-water-mark of what nature can achieve by means of organisation.

This faculty arises from the activities of a special organ which can alone produce it, and which is itself highly complex when it has acquired all the development of which it is capable.

As this organ is actually distinct from that which produces feeling although unable to exist without it, it follows that the faculty of performing acts of intelligence is not only not common to all animals but is not even common to all those that can feel; for feeling may exist without intelligence.

The special organ in which are produced the acts of the understanding appears to be only an accessory of the nervous system; that is, a part added on to the brain, and containing the nucleus or centre of communication of the nerves. The special organ in question is thus adjacent to the nucleus; the nature of the substance of which it is composed appears moreover to differ in no way from that of the nervous system; in it alone, however, acts of intelligence are performed; and it is a special organ, for the nervous system may exist without it.

In the third part I shall take a general survey of the probable mechanism of the functions of this organ. In vertebrates it is confused with the medullary mass under the name of brain, although it only consists of the two wrinkled hemispheres which cover it over. It is sufficient here to note that of those animals which have a nervous system, it is only the most perfect that actually possess the two cerebral hemispheres; probably all invertebrates, except perhaps some of the last order of molluscs, are destitute of it, although a great many of them have a brain to which run directly the nerves of one or more special senses, and although this brain is generally divided into two lobes separated by a furrow.

In accordance with this view the faculty of performing acts of intelligence has only just begun in the fishes or, at the earliest, in the cephalopod molluscs. It is in these animals in a state of extreme imperfection; some development has been achieved in the reptiles, especially in the later orders; much more has been made in the birds, and the faculty reaches its highest point in the latest orders of mammals.

Intelligence is then a faculty limited to certain animals which are able to feel; but the faculty is not common to all those that possess feeling: indeed, as we shall see, among the latter, those that have no

special organ for performing acts of intelligence can only have simple perceptions of the objects which affect them, but can form no idea of them, do not make comparisons or judgments, and are guided in all their actions by their habitual needs and inclinations.

Summary of Part II.

By confining myself in the nine preceding chapters solely to the observations with which I was concerned, I have avoided entering into a quantity of details which are doubtless very interesting, but may be found in the good works on physiology already accessible to the public: the principles which I have advanced appear to me sufficient to prove:

1. That life in every body which possesses it consists only of an order and state of things, by which the internal parts can be influenced by an exciting cause and perform movements called organic or vital, from which are produced according to the species the recognised phenomena of organisation;

2. That the exciting cause of vital movements is external to the organs of all living bodies; that the elements of this cause are always found, although in varying abundance, wherever there is life; that it is provided to living bodies by the environment either in whole or part; and that without this same cause no such body could possess life;

3. That every living body whatever is necessarily composed of two kinds of parts, viz.: containing parts consisting of a very supple cellular tissue, in which and out of which every kind of organ has been formed; and visible contained fluids capable of moving about and of undergoing various changes in their condition and nature;

4. That animal nature does not differ essentially from vegetable nature as regards the special organs of these two kinds of living bodies, but chiefly as regards the nature of the substances of which they are composed: for the substance of every animal body is such that the exciting cause can establish in it an energetic orgasm and irritability; whereas the substance of all vegetable bodies merely gives the exciting cause the power of setting in motion the visible contained fluids, while only permitting in the containing parts of a faint orgasm, not enough to produce irritability or to cause any sudden movements by the parts;

5. That nature herself produces direct or so-called spontaneous generations by creating organisation and life in bodies which did not previously possess them; that she must of necessity have this faculty in the case of the most imperfect animals and plants at the beginning of the animal and vegetable scales, and also perhaps of some of their branches; and that she only performs this strange phenomenon in

tiny portions of matter, gelatinous in the case of animals and mucilaginous in the case of plants, transforming these portions of matter into cellular tissue, filling them with visible fluids which develop within them, and setting up in them various movements, dissipations, restorations and alterations by means of the exciting cause provided by the environment;

6. That the laws which control the various transformations in bodies, of whatever nature they may be, are everywhere the same; but that these laws in living bodies work results altogether opposite to those achieved in crude or inorganic bodies, because in the former they find an order and state of things which give them the power to produce all the phenomena of life, while in the latter they find a very different state of things and produce very different effects: so that it is not true that nature has special laws for living bodies, opposite to those which control the transformations observed in lifeless bodies;

7. That all living bodies of both kingdoms and all classes have certain faculties in common; these are the property of the general organisation of such bodies, and of the life which they contain; hence these faculties, common to all living things, need no special organ for their existence;

8. That in addition to the faculties common to all living bodies, some of these bodies, especially among animals, have faculties peculiar to themselves and not found among the rest; but these special faculties are in every case the product of a special organ or system of organs, so that no animal without that organ or system of organs can possibly possess the faculty which it confers on those that have it; [1]

9. Lastly, that the death of every living body is a natural phenomenon, which necessarily results from the presence of life and is brought about by natural causes, unless some accidental cause intervenes first; this phenomenon is nothing else than the complete cessation of vital movements, resulting from some disturbance in the order and state of things necessary for the performance of these movements; in animals with highly complex organisations, the principal systems of organs possess to some extent a life of their own, although closely bound up with the general life of the individual. The death of an animal thus takes place gradually in the separate parts, so that life becomes succes-

[1] In this connection I may observe that plants in general have no special organs within them for particular functions. Every part of a plant contains the organs essential to life, and may therefore either live and vegetate separately, or as a result of grafting share with another plant a life common to both; lastly, from this order of things in plants it follows that several individuals of the same species, or even only of the same genus, may live on one another in the enjoyment of a common life.

I may add that the latent buds found on the branches and even the trunk of woody plants are not special organs, but the rudiments of new individuals, awaiting favourable conditions for their development.

sively extinct in the principal organs in a regular and constant order; and the moment at which life ceases in the last organ is that which completes the death of the individual.

On such difficult subjects as those of which I have been treating, we are closely confined within the limits of knowledge and to the sphere of what we can learn from observation. Everything has reference to the conditions essential to life in a body; conditions established in compliance with facts which prove their necessity.

If things are not really as I have described, or if it is held that the conditions named and the admitted facts which testify to the true foundation of these matters, are not adequate proofs to justify us in admitting them, we shall then have to abandon altogether the enquiry into the physical causes which give rise to the phenomena of life and organisation.

PART III.

AN ENQUIRY INTO THE PHYSICAL CAUSES OF FEELING, INTO THE FORCE WHICH PRODUCES ACTIONS, AND, LASTLY, INTO THE ORIGIN OF THE ACTS OF INTELLIGENCE OBSERVED IN VARIOUS ANIMALS.