

CHAPTER II.

Nature of Life and Vital Action—Difficulties in dealing with the Subject—Theories of the Nature of Vital Action—Definitions of Life—Conditions for Vitality—Essential Conditions—Protoplasm : its Nature and Relations—Physical Theory of Life—Theory of a “Vital Force”—Subsidiary Conditions for Vitality—Organisation—Air—Temperature—Light—Water—“Death”—“Potential” Vitality—Revitalisation and its Significance.

HAVING thus disposed of the Inorganic Series, we may now give our undivided attention to the field which the biologist claims as peculiarly his own. We have seen that of the natural groups into which the objects of the universe are divided, one set or group—the Organic Series—is separated from the second group—the Inorganic Series—by several well-defined characteristics. These characteristics we are further accustomed to observe and recognise, as collectively dependent upon the possession of “vitality” or “life.” And the bent of our present inquiries leads us in a most natural sequence to notice and discuss, as plainly and as shortly as possible, the nature and tendency, as well as the relative merits, of some recent speculations and theories regarding “vital force,” or, as we are better accustomed to call it, “life.”

The discussion of such a subject is, however, not without its difficulties and disadvantages ; difficulties lest the teacher should be led to lean more strongly to one side than to the other, and so, losing his place as an impartial reciter of facts, become a partisan and special pleader ; and disadvantages no less, because the question involves so much that is hypothetical, that it may be no easy task to fairly, honestly, and impartially state the case for both sides of the question. Still, to slur over the topic would of necessity be worse than to be discursive or even par-

tial; and to leave the student without at least putting him in possession of facts as they stand, would be to neglect the most important of the principles and theories with which the biologist has to deal: Since questions concerning the nature of life and vital action are, at the present time, of the fullest and deepest import to every student of the great life-sciences. Newspaper and magazine literature teems with discussions respecting the life-theories of the past as compared with those of the present; and, if only to enable us to keep abreast with the tendencies of everyday life and thought, the present subject demands somewhat extended notice and comment.

The opinions of the earlier workers in biological science regarding the nature of life need not be discussed at any length in considering the question in its more modern aspects, and under the light of modern research. In this, as in very many other matters, the ancients were quite content to theorise, and to conceal, under the idea of an abstract term or name, their ignorance of the cause or source of any given action or series of phenomena. The ancient theories of the origin and nature of life embody much that is mythical and fabulous, yet we may trace through the mist of superstition and ignorance a few beams of the true light, struggling and feeble, no doubt, but asserting their power and presence as auguries of the higher hopes and certainty of the future.

Passing over the dark ages of history, in which knowledge, social, political, or scientific, gained little or nothing that was new or useful, we step at once, in the consideration of life-theories, into the arena and sphere of modern thought. A transition this, comparable, in detail and results, only to the rapid change from the gloom and darkness of a dungeon to the bright sunlight of the full and brilliant day. With the advent of what may be termed the philosophical era of thought, matters biological, along with the condition of science in general, underwent a very great, and at the same time beneficial change. New theories and ideas rapidly supplanted the old time-honoured thoughts, which, from sheer staid age and

respectability, had assumed an importance not to be lightly estimated or set aside. And, as is usual in such revolutions, whether in the world of active physical life or in that of mental toil, the change wrought, amidst much that was really good, not a little harm. Nor can the chronicler or historian avoid taking cognisance of the important fact, that the iconoclasm in the matter of "life-theories," amongst many other results, has tended to produce serious discord in the scientific world, and has trammelled and clogged the thought and energies of workers in other fields besides our own. The history of modern progress in biological thought and science will be found to be throughout a record of hot contention, arising chiefly from the battle of theories, and from the conflict of opposing ideas.

Treading so closely, as we do in the present case, on the confines of the "unknowable," the amount of speculation which has been indulged in respecting life-theories has loaded the biological mind with a most unprofitable burden ; and we do not all possess the time, many have not the inclination or even the ability, to assume the office of scientific threshers, and riddle out the scanty grains of pure corn from amongst the mass of useless chaff which lies around us and impedes our way. To use mere hypothesis as a clue and guide to the unravelling of a perplexing and unexplained series of phenomena, is a perfectly justifiable and legitimate procedure ; but, at the same time, it is one which must be very carefully distinguished from another and most unwarrantable aspect and fallacy of speculative reasoning, that of employing a mere theory as if it were based on ascertained fact ; or, as if the hypothesis involved in itself facts and laws which have as yet to be ascertained, and to the knowledge of which it is the true office of speculative reasoning to lead. As has well been expressed by a distinguished thinker, "Let it not be imagined that we undervalue the assistance which science often receives from the wildest speculations, so long as these are not elaborately enunciated as *a priori* laws, but are confined to their only legitimate use, the suggestion

of new methods of interrogating nature by experiment. By all means let philosophic minds indulge in any vagaries they may choose to foster, but let these be carefully distinguished from facts established by experiment, and kept as private magazines, from which, when required, may be extracted an idea leading to an experimental research." Very necessary is it, therefore, for the student to bear in mind the caution to be careful and discriminating in all matters involving much speculative reasoning, and in no case more than in the present can the advice be strongly insisted upon.

If, in imagination, we address the query "What is life?" to an audience composed of the leaders of biological thought in our day, we should find the scientific world, so addressed, to divide itself, according to the reply given to our question, into two great sects or schools. On the one side the "vitalists" would be ranged, and the answer of this first school of thought would assume somewhat of the following character. They maintain that life or vitality is a something—call it a "force" or "principle" if we will—entirely distinct and separate from the matter through which its actions are manifested. The distinct entity of life or vital force, therefore, constitutes the chief idea in the theory of this first sect or party.

On the other side, the school of the "physicists" would be perceived, and to our question this second body would reply, that they regard life as a mere "form of energy," analogous in its operation and relations to the ordinary physical forces which operate on the world around us; and in support of this latter view, it is maintained that in the substance known as "protoplasm," the "basis," or "matter of life," has been found the necessary material in which all the properties, and indeed the source, of vital action and power may be said to reside. Life or vitality, thus viewed, is merely a property of the protoplasm, similarly as we ascribe ordinary physical properties to inorganic and inert substances.

Modifications of these chief and leading ideas will also be found to hold a place in the category of modern life-

theories ; but our present aim will be most readily and satisfactorily fulfilled if we briefly examine each of these theories, together with the conclusions which may be deduced from our considerations.

And at the outset we must carefully distinguish between the significance and meaning of the terms "physical" and "vital ;" since, concerning the use and application of these two words much confusion and misunderstanding have existed. By the term "vital" we mean to indicate those properties or actions which are inevitably connected with the possession of life, or which are distinctive of living beings. And by "physical" actions, properties, or forces, we mean to express those phenomena which are seen exemplified in inorganic bodies, or in the non-living matter of which the world is composed. These latter forces are manifested from without, generally with distinctly appreciable effects, and under conditions readily ascertainable by scientific inquiry. Such forces or their effects, seen in gravitation, heat, light, electricity, magnetism, etc., afford examples of ascertained "physical" forces. The force or principle, on the contrary, whereby a living organism is enabled primarily to exist, and thereafter to maintain that existence, exemplifies actions and phenomena which may be considered as essentially distinct from the preceding forces and actions, and which, therefore, we denominate "vital." These definitions simply express the leading and single significance of the terms, apart from their scientific or ultimate relations. And by thus defining them, we do not mean to imply that all the forces exerted in or through the living body are necessarily "vital," or that there is no correlation between the physical and vital forces. These latter considerations may be reserved for a later period in our studies ; but it will be found of great assistance to the clear understanding of the subject, if the relative and primary significance of each term be distinctly perceived and borne in mind.

Numerous definitions of life have from time to time been framed, but, as might be expected, these merely formal expressions are limited to the enumeration or exposition

of the effects, rather than of the intimate cause or essential conditions of vitality. And from the nature of the case, in that nothing definite or certain is known of the force or principle they attempt to define, mere definitions of life or of vital force teach us little or nothing concerning the exact or primary nature of life. Indeed, several of the definitions have long ago, and on grounds we shall presently notice, been disallowed as incorrect.

Beclard, for example, defines life as "organisation in action." Duges tells us that life is the "special activity of organised bodies." Carpenter defines life as "the state of action peculiar to an organised body or organism." Bichat maintains that life is "the sum total of the forces which resist death." Treviranus held that "life is the constant uniformity of phenomena, with diversity of external influences." Lawrence informs us, that life consists "in the assemblage of all the functions or purposes of organised bodies, and in the general result of their exercise;" whilst, lastly, we may add the philosophical definition of Spencer, who reduces his ideas of vital action to the statement, that life is "the continuous adjustment of internal relations to external relations."

These definitions, as a whole, therefore deal with the effects of vitality rather than with vitality itself. Such a result will, doubtless, be considered as inevitable in the present state of our knowledge; but we cannot avoid the fact that the knowledge we do possess does not warrant us in attempting to define, or, what is much the same thing, to limit, our ideas of the vital principle.

The first three definitions are rendered useless by the consideration, that they involve the idea of *organisation* as being indissolubly connected with life, or even as being the *cause* of life. We shall hereafter have occasion to notice that exactly the opposite of this latter assertion is true,—organisation being a *result*, and not a cause, of life.

Leaving mere definitions, then, as of little or no assistance in framing a strict, or even abstract, idea of the nature of life, we may next turn our attention to the

facts upon which the respective theories of vital force are built up. Both hypotheses start with the full recognition of the differences which separate the organic from the inorganic world. They disagree only as to the nature of the cause from which these differences take origin; that cause, in the opinion of the vitalist, residing in a force or principle possessing a distinct entity from matter, and, in the opinion of the physicist, consisting in a peculiar exhibition of physical force,—a form of energy, differing only in degree and direction from other forms of energy affecting ordinary inorganic material.

Our first inquiry may appropriately be directed to the investigation of those conditions which appear more or less essential to the exhibition of vitality. Modern research has demonstrated that a common medium or substance exists, through which the phenomena of life are invariably exhibited. This "basis," or "matter of life," is therefore common to living organisms of every grade and kind. The highest plant or animal has thus a community of substance and relationship with the lowest plant or animal, in respect of this common material of which the bodies of both are composed. They differ from each other only in the degree to which development has carried out the ulterior processes of organisation, and formation of organs and parts.

The recognition of this "basis," or universal "matter of life," naturally simplified, and at the same time gave a definite starting-point, for further investigation. And the chief difference of opinion among modern theories of the nature of vitality, relates as to whether this basis or matter of life is to be considered the essential cause and origin, or merely as the result and medium for the exhibition of vital force.

It is, however, but fair to state, that some biologists are by no means disposed to agree with the statement of the universal nature claimed for the substance we have alluded to as the "basis" or "matter of life." And in this latter view it is maintained, that the "life-basis" is itself preceded by simpler forms of the living material, or

that it is by no means of uniform and universal character throughout the organic series. Still, practically, the greater weight of authority is in favour of the recognition of this common life-basis; and if we regard the term "matter of life" as including allied and nearly-related forms of living matter in its primary state, we may dispose of or modify these objections so as not essentially to interfere with the argument about to be stated.

A second consideration of importance lies in the fact that vitality very generally appears to require, as conditions for its manifestation, the presence of light, of air, of a certain temperature, of water, and in most cases, though not in all, of a greater or less degree of organisation.

Of these two great classes of conditions for the exhibition and maintenance of vitality, the first, consisting in the presence of a "life-basis," may very properly be termed an *indispensable* condition; and those just enumerated under the second head may be termed *subsidiary* conditions, inasmuch as, most, if not all, of these latter conditions may, in certain cases, be dispensed with or be absent, and yet life or vitality be manifested as if they were present. Such instances, however, are of an exceptional kind.

The presence of a life-basis, or "*materies vitæ*," constitutes therefore the indispensable condition for the exhibition of vital phenomena. This basis is found in the substance, now well known under the various names of "sarcode," "protoplasm," or "bioplasm,"—the last of these names being that which is most in accordance with strict scientific requirements. This matter of life is present wherever life or vitality is seen. It constitutes the primary or ultimate tissue or substance of which the bodies of living beings, without exception, are composed; its simple and primitive state, as already remarked, being witnessed in the lower forms of life, whilst, by a subsequent process of elaboration and development, the complicated structure of the higher organism is evolved

from this primary material. Thus the germ of the lowest plant or animal, and the germ of the highest organism of either series, are primarily and essentially the same, in respect of the protoplasm of which each is composed; and the differences which, in the after-history of either organism, are to be perceived, thus depend on the mould, and on the causes which determine the conformation of the mould, and not on the common clay or material from which both are cast.

The chemist has told us very succinctly the chemical relations of this "protoplasm." Its nature, briefly stated, is that of an albuminous substance, analogous to the albuminoid matter we familiarly see in white of egg. It belongs to a group of substances to which the term "proteine" compounds has been applied, and of this group the "bioplasm" or "life-basis" constitutes the typical example, around which the other forms of albuminous matter are classed and arranged. The exact composition of this protoplasmic material has formed subject-matter for considerable discussion; the so-called "proteine" compounds of Mulder being held to consist of an elementary substance known as "proteine," in combination with phosphorus and sulphur. There can, however, be little doubt that the typical form of protoplasmic material essentially consists of the four elements, carbon, hydrogen, oxygen, and nitrogen, united together in very high combining proportions, and after a very complicated fashion. And any further information as to the chemico-physical properties or relations of "protoplasm," may be summed up by stating, that the "proteine" compounds coagulate at a temperature of from 40° to 50° Centigrade, and that if electrical currents be sent through a protoplasmic mass, it very generally and at once contracts under this latter influence.

Protoplasm, after a merely superficial consideration of its relations, stands primarily to living beings as a conductor does to the electric fluid, or as air is related to the sounds it conveys. Life appears to require for its exhibition and manifestation this albuminous compound,

just as electricity or sound require conduction for their due manifestation. Whether or not the relation just indicated has a deeper meaning than a merely metaphorical one, will form the subject of after considerations.

Lastly, we must bear in mind the fact already insisted upon, that the term "protoplasm" is *generic* in its significance, that is, it must be viewed as including different *kinds* of albuminous matter, concerning the identity of which with the typical matter known as protoplasm, chemists and physicists are by no means agreed. And if to these considerations we add the fact, that in many instances certain forms of mineral matter, as well as other substances of alien kind, may be found associated apparently in the most fixed and intimate manner with the bioplastic material, we shall have completed all that need be said with regard to the first and indispensable condition for the manifestation of life or vital force.

It is thus of the highest importance to gain a correct idea of the nature of this protoplasmic life-basis, since the chief points of controversy in the contest between the life-theories of the present day, may safely be said to rest upon the relative interpretation of the relations which exist between the protoplasm and the vital phenomena it exhibits. Both vitalist and physicist may be held as agreeing in the universal nature of this "matter of life;" but they differ widely in their respective interpretation of the relation which protoplasm bears to vital force, or at least to the phenomena known to be perceptible in, and peculiar to living material. In the case of the vitalist this protoplasm is held to be merely the medium for the exhibition and manifestation of an entirely independent force, to which the name of "vital" force is applied; whilst in the physicist's view, the protoplasm of itself, and in virtue of physico-chemical properties and laws, originates the phenomena which he considers we wrongly denominate as "vital"—that is, as being dependent upon the assumption of a new, special, and independent force or principle.

As the chief facts and features of the physicist's theory have been succinctly stated by Professor Huxley in his address on the "Physical Basis of Life," the arguments for or against the purely physical nature of vital phenomena have generally been delivered in support of or against the views expressed in the paper just referred to. And a primary idea in the line of reasoning adopted by the physicist, consists in the assumption that because this protoplasm or universal matter of life is composed of carbonic acid, water, and ammonia—or more ultimately of carbon, hydrogen, oxygen, and nitrogen—these elements may, in logical sequence, be considered as giving origin to the phenomena of vitality which that protoplasm manifests. Life or vital action is thus assumed to arise from the union or combination of the protoplasmic elements. Or to use Huxley's own words, "carbon, hydrogen, oxygen, and nitrogen, are all lifeless bodies. Of these, carbon and oxygen unite in certain proportions, and under certain conditions, to give rise to carbonic acid : hydrogen and oxygen produce water : nitrogen and hydrogen give rise to ammonia. These new compounds, like the elementary bodies of which they are composed, are lifeless. But when they are brought together, under certain conditions they give rise to the still more complex body, protoplasm, and this protoplasm exhibits the phenomena of life."

Then we are furnished with a further and analogical example of this synthesis or building up of protoplasmic or living material. Hydrogen and oxygen unite in certain proportions to form water, and water exhibits many interesting and peculiar properties both in a liquid and in a solid state. "We call these," says Huxley, "and many other strange phenomena, the properties of the water, and we do not hesitate to believe that, in some way or another, they result from the properties of the component elements of the water. We do not assume that a something called 'aquosity' entered into and took possession of the oxide of hydrogen as soon as it was formed, and then guided the aqueous particles to their places in the facets of the

crystal, or amongst the leaflets of the hoar-frost.
 What justification is there, then, for the assumption of the existence in the living matter of a something which has no representative, or correlative, in the not living matter which gave rise to it? What better philosophical status has 'vitality' than 'aquosity'?"

These sentences, quoted from Huxley's address, will serve to convey, at once simply and shortly, the leading ideas in the physicist's theory of the nature and origin of vital action and phenomena. Life, according to the physicist, can thus arise *de novo*. He would expect the exhibition of vital phenomena to follow the combination of carbon, hydrogen, oxygen, and nitrogen, just as surely as water results from the union of hydrogen with oxygen. And we have therefore no more right, according to the line of reasoning thus laid down, to say that any principle, termed "vitality" or "vital force," influences the matter of life, than we have to assert that something, which might similarly be termed "aquosity," entered the water, and directed its particles to form, it may be, an ice-crystal, or the delicate tracery imitative of vegetation which appears on our windows during the winter season. Such a theory is purely "physical" in every sense of the term. Life thus reduced, is viewed simply as a property of its basis or material, and exists or appears in virtue of chemico-physical actions or laws. In other words, vitality is a mere *result*, inevitable or incidental to the formation of protoplasm.

If such be the physicist's views of the nature and origin of vital action, let us now attend shortly to the theory and views of his opponent, the vitalist. Is the instance and comparison of "vitality" with the presumed "aquosity" a strictly parallel one, and, if not, in what does the misconception lie? Or, lastly, and in connection with the preceding points, is the vitalist fully or at all justified in asserting that protoplasm is the *cause* of vitality; and is not protoplasm merely a *condition*—invariable and indispensable, it may be, but still merely a condition—under which vitality is manifested? If these points be

susceptible of proof from the vitalist's side, it is thus possible that the physicist has been confusing cause with effect, and, as a result, involving himself in much misconception and error.

So far, the point at issue concerns the view which is to be taken of the connection between life and its basis ; and hence the vitalist denies that protoplasm exists as the *cause* of vitality, and views the life-basis as merely an indispensable condition or medium for the exhibition of vital force. He thus assumes the existence of a principle—the vital force—which the physicist totally ignores. The combination of elements to form protoplasm, on the part of the physicist, neither necessitates nor demands any new or independent principle ; which latter, however, the vitalist maintains and upholds as the chief standpoint of his theory.

Thus the vitalist observes and knows that the body of the lower animal or plant is composed simply and entirely of a minute speck or particle of structureless, unorganised protoplasm ; and, despite this barren simplicity of structure, it lives, moves, nourishes, reproduces itself, and, in short, performs all the functions of life as perfectly in its way as the highest organism. We have already seen that, in virtue of the life it possesses, it differs very materially from the inorganic things by which it is surrounded. And as it differs of itself from unorganised or lifeless objects, so also it differs from them in respect of the laws and conditions to which it is subject. It is in itself the seat of actions very different from the physical or chemical actions which affect inorganic matter from without ; and we have no warrant for the assumption that any combination of purely chemical or physical forces could inaugurate, produce, or maintain, the series of phenomena we see exhibited in the humblest organism as a direct result of the possession of vitality or life.

No physicist has yet been able to produce any such combination of physical actions, nor even to hope for such a result, and, in the face of this fact, the term "vital" must be properly retained, with all the significance which

we are accustomed to regard as associated with it. The term "vital" thus stands expressive and indicative of a series of actions which fall without the boundaries of chemical or physical science, just as they exist independently of physico-chemical nomenclature.

But, apart from considerations respecting the nature of vital phenomena, the question of cause and result, or of the relations in point of *time*, between vitality and protoplasm, affords subject-matter for argument against the physicist's views. We cannot tell at what period in the history of the protoplasmic germ or animalcule it becomes possessed of life, or is "vitalised." Certain it is, that protoplasm becomes possessed of life only through the medium or influence of pre-existent life; and the question as to whether the basis or its vitality has precedence, may be debated in favour of the vitalist's views. Or, to place the question in its widest phase, we may most safely, and with least fear of being controverted, assume that vitality, self-originated or acquired, in all likelihood precedes the mass it invests; and in this view we regard the vital force as standing to protoplasm in the relation of a cause and not of a result.

It is also worthy of remark, that much confusion has arisen in discussions respecting the present subject, from the variable and widely-different senses in which the mere term "protoplasm" has been used. In many instances, no distinction is drawn between living protoplasm and dead protoplasm; and, as may readily be conceived, endless misconception has arisen from this careless and unspecific use of the term. To argue of inert, dead, or non-living albuminous material, as of living protoplasm, involves a very transparent, but at the same time a very serious, absurdity.

We may conceive it possible that the chemist in his laboratory might build up for us, by the exercise of his synthetical art, a protoplasmic compound; just, indeed, as Huxley tells us, that when the requisite compounds of carbon, hydrogen, oxygen, and nitrogen, are brought together, "they give rise to the still more complex body,

protoplasm, and this protoplasm exhibits the phenomena of life." When "brought together," the compounds of these four elements might, and probably would, produce protoplasm; but are we justified in assuming that *living* protoplasm would result from the artificial combination? It can be said, neither in the order of logic nor in the sequence of natural and reasonable phenomena, that the protoplasm of the laboratory should be living protoplasm, or that it should exhibit the simplest vital phenomena whatever. And in thus glossing over the changes and actions, be they simple or intricate, which are necessary to convert the dead albuminous matter into living protoplasm, the physicist takes an illogical leap over a wide gulf, at which a consideration of the sequence thus described compels us to draw rein. There is a very significant break in the order so narrated; and this break intervenes between the artificial formation of the dead protoplasm, and the exhibition by such artificially-formed material of truly "vital" phenomena.

Thus, then, the constructive art of the chemist might bring together the elements of protoplasm, but he would reach the utmost limit of his power with the manufacture of a dead and inert compound. We still require a something more to make the inert material exhibit the complicated phenomena, which, even in the microscopic germ or animalcule, are to be perceived, and which are thus characteristic of the truly living organism. This "something" the vitalist holds is the "vital principle" or "vital force;" a term often questioned as to its status or right of admission into scientific terminology, but which the physicist is not entitled to expunge, and for which he is unable to provide a due, equivalent, or sufficient substitute.

But further, the consideration, that in our researches we never meet with an instance capable of demonstration, of lifeless matter springing of itself into living material, affords an argument of some weight in favour of the theory of the existence of a "vital force." The dead protoplasm is always dead to us, and the conversion of

such lifeless material into living tissue can only be accomplished by the agency of an organism already living or vital. Pre-existent vitality is thus the sole and only source of vital activity and impulse, and our inability to explain the conditions under which vital force is thus transmitted does not invalidate the assumption of its existence. And granting, for the sake of argument, that it were possible to reach back through the ages of the past to those primitive germs or atoms, from which, according to the ideas of the evolutionist, all subsequent forms of life have been developed, the same question of antecedent vitality would await our consideration of these supposed primeval protoplasmic germs. It would be impossible, even in dealing with bodies of so primitive and simple a nature, to decide the question of the origin and of the circumstances of that origin, relatively to the period at which vitality manifested itself in their history.

To quote the words of M. Dumas from his "Faraday" eulogium :—"This subject remains what it was—inaccessible, closed. Life is still the continuation of life ; its origin is hidden from us as well as its end. We have never witnessed the beginning of life ; we have never seen how it terminates.

"Every organised being is born of a germ ; every plant from a seed ; every animal from an egg. The physiologist has never seen the birth of a cell, excepting by the intervention, or as the produce of a mother-cell.

"The chemist has never manufactured anything which, near or distant, was susceptible even of the appearance of life. Everything he has made in his laboratory belongs to 'brut' matter ; as soon as he approaches life and organisation he is disarmed."

The parallelism between the synthetical formation of water, by bringing oxygen and hydrogen in certain proportions together, and the relations of protoplasm to vitality, is not a strict parallelism, if indeed it can be considered a parallelism at all. In the production of water after this fashion, we do not assume the existence or need of any new force. The hydrogen combines with

the oxygen to form water, in virtue of the ascertained laws of chemical affinity. But with the protoplasm, and its composition and formation, the case is widely altered, and possesses little or nothing in common with the production of water. We may manufacture our protoplasm, just as we may manufacture water. But we cannot explain *how* that protoplasm may become disposed to exhibit vital phenomena; nor can we account for or trace the origin of these phenomena, although we can with certainty and precision explain, by aid of physics, the conditions under which an ice-crystal may be formed, or an imitation forest produced upon our window-panes by the hoar-frost. We thus require and demand the existence of a new and independent force to make the inert protoplasm *live*, in the sense that even the lowest organism lives. Hence the term "vitality" cannot be set aside as an unphilosophical and incorrect expression. "Vitality," in this view, has a "philosophical status," whilst "aquosity" has no status at all.

Lastly, and by way of a final and useful thought, in judging of matters so intimately involving the distinctions between the known and "unknowable," we should bear in mind the fact, that even had we no idea of the relations of protoplasm, or had we, in point of fact, no protoplasm at all, the presumption of the existence of a "vital force" in living beings would not be lessened or affected by such a consideration. The limits and relations of the most common forces and actions, in so matter-of-fact a study as that of physics, are not always demonstrable. We do not now doubt the existence of an electrical force or a magnetic force; yet, but a few years ago, ordinary speculation as to the relations which these forces are now ascertained to possess with the external world would have been condemned, or at any rate have been subjected to criticism of a very searching kind. Yet we cannot maintain that the relations of electricity or of magnetism were the less real because of our former inability to measure or estimate them.

Or, further, if we had had no telescopes to investigate

the relations of the planets, and especially of the more obscure heavenly bodies, these relations, or the mere existence of these bodies for that matter of it, would not, on account of our ignorance, have been the less real. And so is it with "vital force." Because we cannot demonstrate its nature, origin, or actual relations, we are not entitled on that account to assume its non-existence. Just as physical forces and actions operate independently of our means for observing them, so vital force may be, and undoubtedly is, exercised, and operates, under conditions which we are unable to limit or determine. As every fact or circumstance is not at first or necessarily explicable, so also the conditions on which the circumstance depends may be insusceptible of explanation; yet it would be obviously irrational to question the fact because the explanation was not forthcoming. And in the case of the argument against the existence of a "vital force," a great amount of comment has been made on the alleged absurdity of assuming the existence of a principle, the conditions of which we cannot determine, and the relations of which we are unable to define. Let protoplasm as a life-basis and as a medium for the manifestation of vital phenomena be even removed, and vital force will still exist; just, indeed, as surely as ordinary physical forces would continue, without the media for their active conduction or exhibition.

Such may be regarded as a brief statement of the leading ideas in the respective theories which, in the present day, occupy the biological mind with reference to the nature and origin of the wondrous cycle of phenomena and actions, we collectively designate under the term "vitality," or "life." And although neither hypothesis can lay claim to having satisfactorily explained the entire circumstances and surroundings of this great biological problem, the "vitalist" theory appears to be that most worthy of support and belief. There is doubtless much that is inexplicable involved in the idea of a "vital force," but the assertion that the use of such a term is a mere cloak to our ignorance, does not bear weight when we

consider that other and professedly more rational hypotheses leave us as ignorant of the origin or nature of vital phenomena as before. If the theory of the vitalist be one insusceptible of demonstration, the hypothesis of the physicist, in spite of its matter-of-fact tendencies, tells us nothing new, since its explanation is insufficient to account for the cause and nature of even the simplest of vital actions.

Whilst thus giving countenance to the vitalist belief, we by no means wish to assert that the labours of the physicist have been of no avail or advantage. On the contrary, we cannot but feel deeply imbued with the belief, that to the labours of workers in this school of biological thought we owe many and great advances, which of late years have been made in investigations into subjects bearing intimately upon the question we have been discussing. Thus, through the efforts of vitalists and physicists in their researches into the intimate structure of the lower forms of life, we have been led to recognise the universality of protoplasm and allied substances, and from facts and information thus obtained we have been enabled to make wide generalisations, of great and useful import in the study of the life-sciences at large.

And chiefly through labours of this kind we have added largely to our stores of knowledge respecting the conditions of life in the lowest organisms. Thus, seeing this "matter of life" in its simple jelly-like state, giving origin in one case to the curious fabric of a sponge, or in another case building up the beauteous and complicated shell of a chalk animalcule; observing it taking upon its apparently simple self the onerous duties which are subserved by all the organs and tissues of the higher organism; watching it thus constituting, *per se*, a living being, able perfectly to nourish itself, reproduce itself, and to maintain all the relations which ordinarily exist between the living organism and the sphere it inhabits—observing these multifarious duties devolving upon, and performed by a medium so simple and structureless, we may well stand amazed at, and puzzled to account for,

the origin and exhibition of such wondrously complicated powers.

Whilst thus we are forced to admit our ignorance of the origin of such phenomena, we yet find in the theory of a "vital force" possessing an entity distinct from matter, as satisfactory a hypothesis as in the present order of things we are entitled to expect or believe. What life in its essential part is, we therefore do not know, nor may we with assurance predict that the higher knowledge of the future will render the problem of living and being any the less mysterious or inexplicable. We can make no limitation to scientific inquiry. We cannot wish to bind or curb the tendency of that freedom and energy of thought which has already accomplished so much for the good of mankind at large. But, at the same time, we cannot understand how we shall readily arrive at a knowledge of what appears to be within the confines of the unknowable, and of what, from its very nature, must fall beyond our utmost ken.

In concluding the considerations relating to the nature of life and vitality, we have to notice, very briefly, the second set of conditions which we have already observed to be more or less essential to vital manifestation. The presence of protoplasm, or of a distinct "life-basis," forms, as we have seen, the first and indispensable condition for vitality. The second set of conditions, to which we may now direct attention, are termed *subsidiary* conditions, since part or all of these latter may be suppressed, and yet vitality be perfectly exhibited and maintained in their absence. Regarding the merits and place of most of these subsidiary conditions, biologists are very generally agreed, although much yet remains to be ascertained regarding the various and modifying circumstances which affect the stability of these latter conditions of life.

The presence of a greater or less degree of *Organisation*, may appropriately form the first consideration to which attention may be directed. The relations of organisation to vitality have been, and indeed still are, subject to much misconception. We have already noticed that not

a few definitions of life hinge upon the recognition of organisation as a *cause* of life. Such expressions as "the special activity of organised bodies," and "organisation in action," assert a belief in the constant and invariable presence of organised structures, tissues, or parts, as necessary for, and indeed as a cause of, the manifestation of vital action.

By organisation we mean—as indeed the mere significance of the term would imply—the possession by a living being of definite structural parts or organs, bearing distinct and fixed relations to each other. Most animals and plants are "organised" in this sense of the word, but at the same time it is to be borne in mind, that there are very many lower forms in both kingdoms, which, if the above definitions of life were held as true, would fall without the pale of the organic or living series. In other words, we have animals and plants existing and living, without being in the least degree organised.

The *Amœba* (Fig. 1, *a b*), found in stagnant water, or any one of the *Foraminifera* or their allies (Fig. 2, *a b c*),

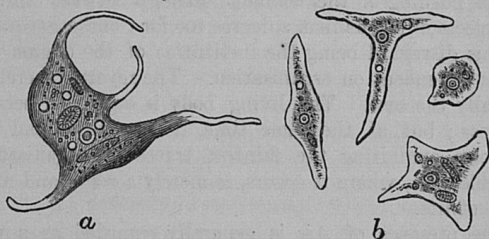


Fig. 1. RHIZOPODA.

a, *Amœba radiosa*, showing pseudopodia, contractile vesicles, nucleus, and food-vacuoles ; *b*, *Amœba diffluens* in various stages of contraction.

exemplify animal forms in which few or no traces of organisation are to be perceived. These organisms are closely related to each other, the bodies of both consisting of minute masses of granular sarcode or protoplasm, which to all intents and purposes is void of any definite structure, and consequently destitute of anything meriting the name of

organisation. Yet each little particle of sarcode constitutes a perfect being. It lives, moves, grows, and reproduces itself, and, as in the case of the *Foraminifera* (Fig. 2), may even manufacture shells of exquisite beauty and design.

Hence the immeasurable difference and distinction between the broad comparison of a piece of mechanism, such as a watch, and a living being or organism. The various parts or "organs" of the watch possess each a distinct relation to one another; just, indeed, as the organs of the higher animal or plant exist in definite combination to perform all the functions of life. But if we extend the comparison to include all animals and plants, the parallelism between the mechanical and the vital organisation at once fails. In the humble, structureless animalcule, the functions of life are carried on without any distinctive organs or parts to perform the work. The essential feature of the watch—complex mechanism—is exactly what is wanting in the *Amœba* and allied forms.

A disregard of this consideration has therefore resulted in the pushing of the common analogy between animals and pieces of mechanism a degree too far; one consequence of this disregard being the institution of the dogma that life is dependent on organisation. The reverse, therefore, is really the case. The living body is organised because it lives; but, at the same time, it may exist and live without exhibiting the faintest traces of organisation. Organisation, where it occurs, is merely a *result* and not a *cause* of life.

The presence of *Air* is generally regarded as a very constant subsidiary condition for vital activity. Perhaps this fact would be more correctly stated by asserting that certain *gases* appear necessary and generally essential to the maintenance or exhibition of vital action. Oxygen gas is thus regarded as needful for the due maintenance of animal existence, whilst carbonic acid gas is essential to the life of the plant. Certain exceptions to these general rules occur in the case of many of the lower members of both kingdoms; some of the lower plants being

capable of existing in an atmosphere of oxygen, whilst some *Protozoan* forms appear to flourish amid carbonic acid gas. These latter facts will, however, be more fully and appropriately noticed when we consider the relations of the animal and plant worlds.

A certain degree of *Temperature* is also looked upon as usually necessary for the maintenance and exhibition of vitality ; but throughout both animal and plant kingdoms the variations in the degree of heat and cold suited to the existence of the contained organisms are so numerous and marked, that it is almost impossible to pronounce

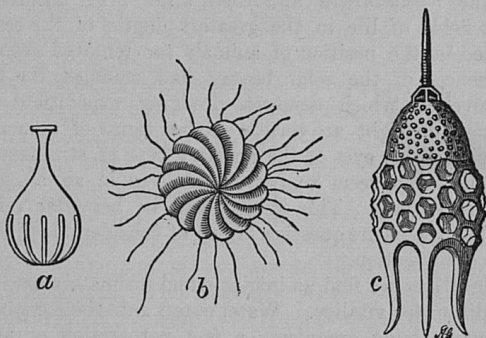


Fig. 2. FORAMINIFERA AND RADIOLARIA.

a, *Lagena striata*, a monothalamous or single-chambered *Foraminifer* ; b, *Polystomella crista*, with pseudopodia emitted through "foramina" or apertures in the shell ; c, *Podocyrtes Schomburgkii*, a *Radiolarian* form.

definitely on this head. The limits of ordinary vitality are said to exist between freezing point and about 130° Fahrenheit ; but we are well aware that a temperature far below the former, and also much above the latter, does not necessarily or at all interfere with the development of life in lower organisms.

The effect of *Light* in the manifestation of vitality is to be regarded as of considerable importance, although, like the preceding condition, it does not appear to be absolutely or invariably necessary that the living organism should be

exposed to its influence. As regards the plant creation, light is certainly the great agent by which the subtle chemistry of vegetation, to be afterwards noticed, is set in operation and carried on; but we have also to bear in mind that, as before, the lower groups of plants and animals present instances of exceptions to this rule. Not a few animals occupying a high place in the created scale live and grow in the dark; these cases, however, generally exhibiting that want of colour, and other abnormal or unusual conditions, which appear to result from non-exposure to the influence of sunlight.

The *Foraminifera* and their allies (Fig. 2), forming vast fields of life in the greatest depths of the sea, are placed in the position of animals far removed from the influences of the solar beam; and amongst the latest discoveries which deep-sea dredging expeditions have brought to light are certain higher forms of animal life, provided with eyes of the ordinary type of structure, and which would seem to pass their lives in an altogether abnormal state. This subject will be hereafter referred to, but the entire question is one of considerable difficulty and complication.

In *Water* we find an intrinsic and intimately-associated condition for vitality. Water enters into the composition of every living organism; a fact not strange or new to us when we recollect the composition of protoplasm itself. Accordingly, wherever we find the "matter of life," we have a certain proportion of water present as a component and constant part of the protoplasm.

Viewed apart from this consideration, however, we generally find that water bears a close and most important relation to the vital processes, and, as a consequence, to the mere exhibition of vitality also. Yet, as before, vitality may exist without the presence of water, although, as will be presently explained, the conditions of such vitality are of an abnormal and unusual kind.

The consideration of life-theories, and of the concomitant questions which are naturally related to such a subject, would be incomplete if we did not notice the use

and significance of the term "death," and also the occurrence of certain conditions included under the general term of "altered" vitality.

By the "death" of an organism, we mean the cessation of vital activity, and the consequent suspension of the processes and actions which the living body, in virtue of its vitality, evinces and exhibits. A period this, in its existence, marked by its surrender to those physical and chemical forces, which the possession of vitality enabled it to avail itself of or to resist. The dead protoplasm, that is, protoplasm *minus* vital force, is thus subject to the same actions that affect ordinary inorganic or non-living material. The living protoplasm, in virtue of its life, is lifted, as it were, above inorganised matter, and endowed with all those characteristics which we have observed to mark the presence of vitality.

The term "altered" or "potential" vitality refers to certain conditions, under which the active exhibition of vital force may, for a longer or shorter period, be suspended. This condition is typically seen in the seeds of plants, which may be kept for centuries in a dry and parched condition, and which, on being placed in the soil, at once revive and give origin to their usual forms of plant structure. The vitality in such a case is throughout inherent in the seed, and appears to be in a condition analogous to that seen in a half-drowned person, whose animation or vitality is said to be "suspended." Such vitality, therefore, we term "dormant," "potential," or "altered," and numerous examples of this condition occur in both the animal and vegetable worlds.

The *Rotifera* or "wheel animalcules" (Fig. 3, A B), tiny and microscopic inhabitants of all our pools, may be dried up or desiccated from the water by the heat of the sun, and be blown about by the wind as mere dust-specks. In this mummified condition they may exist even for years, yet upon the addition of a little moisture they resume all the functions of life with renewed vigour.

And such a statement is to be regarded as the more

wondrous, when we consider that the *Rotifera* are creatures of very complicated organisation (Fig. 3).

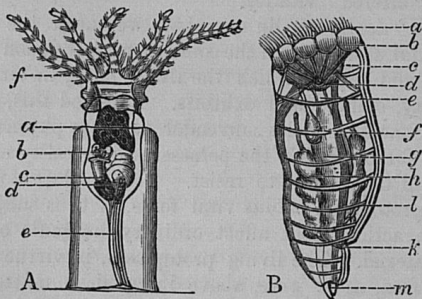


Fig. 3. ROTIFERA.

- A, *Stephanoceros Eichornii* (greatly magnified): a, pharynx; b, gizzard; c, stomach; d, ovary; e, foot; f, tentacles. B, Anatomy of *Hydatina senta* (female) (magnified): a, cilia; b, ciliated discs; c, muscles of jaws; d, nervous ganglia; e, gullet; f, salivary gland; g, stomach; h, ovary; k, anus; l, vascular system; m, terminal appendages.

We must, however, carefully distinguish between the terms "revive" and "revitalise." Much confusion has existed from the indiscriminate use of these terms, and a clear idea of their true meaning and significance cannot be better conveyed than by the words of Dr. Lionel Beale, who says — "To revive and revitalise are two very different things. That which is not dead may be revived, but a thing that is dead cannot be revitalised. The animalcule that can be revived has never been dead. The half-drowned man who revives has never died. The difference between the living state and the dead state is absolute, not relative. The matter from which life has once departed cannot be made to live again."