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ORDINARY MEETING, APRIL 5, 1880.

H. CADMAN JONES, ESQ., M.A., IN THE CHAIR.

The minutes of the last meeting were read and confirmed, and the following elections were announced :—

MEMBER :—The Rev. Canon W. Ince, D.D., Regius Professor of Divinity, Oxford.

ASSOCIATE :—Rev. G. Weaver, South Africa.

The following paper was then read by the Rev. T. M. Gorman, M.A., the author being unavoidably absent :—

LIFE AND ITS PHYSICAL BASIS. By H. ALLEYNE NICHOLSON, M.D., D.Sc., F.R.S.E., Professor of Natural History in the University of St. Andrews.

“Ante omnia itaque scire convenit, quid sit illud quod vulgata appellatione Vita dicitur? In quo consistat formaliter? Circa quid versetur et occupetur tam materialiter seu subjective, quam finaliter et objective?”*

THE whole subject of the nature of life and of the connection between vitality and the matter by which it is manifested, is one of such vastness and complexity that it would be impossible to treat it adequately, save in a special and extended treatise. Upon the present occasion, I need hardly say, I shall attempt nothing further than to give a brief and general sketch of the fundamental phenomena manifested by living beings, and of the more important considerations which, it appears to me, should guide us in arriving at some

* G. E. Stahl, *Theoria Medica Vera*, Ed. by Choulant. 1831. P. 253.

judgment as to the essential nature of that which we call "life." The mere historical retrospect of the various views which have been at different times entertained and published as to the nature of vitality, however brief and bald, would occupy no inconsiderable time, and I shall content myself here with a short discussion of the latest phases into which this question has entered; while I must entirely omit all considerations relating to the subject, still a contested one, of the *origin* of living matter.

We are, in fact, enabled with advantage to eschew all formal review of the theories and controversies of the older writers upon this subject, by taking as the basis of our argument the now universally admitted fact that what we in general language call "life," is manifested only by the particular form of matter to which the now familiar name of "protoplasm" is applied. Living bodies, however simple, are probably always in part composed of other substances than protoplasm; and when at all complex they unquestionably are so. Still, it is certain that the phenomena to which the term "vital" can reasonably be applied, are invariably associated with the larger or smaller quantity of protoplasm present in the living organism. This, to use the apt phrase of Professor Huxley, is the "physical basis" of life; and though opinions may differ as to the ultimate nature of the connection between this matter and the phenomena of vitality, it is necessary, in the first place, to very shortly consider the chief facts which we may be said to actually know about protoplasm, and to indicate any important points on which our knowledge is still defective.

The first accurate knowledge which we may be said to possess as to protoplasm dates from the earlier part of this century, when Dujardin* pointed out that various of the lowly organised animals now included in the sub-kingdom *Protozoa* are composed of a semi-fluid, apparently structureless, contractile substance, which he designated by the well-known name of "sarcode." The name of "protoplasm" was, ten years afterwards, given by Von Mohl † to a similar substance found in the interior of the cells of plants; and, still later, Max Schultze ‡ accomplished a still further advance by

* *Recherches sur les Organismes inférieurs: Ann. des Sci. Nat.*, Tom. V. 1835.

† *Vermischte Schriften, Botan. Inhalts.*, 1848.

‡ *Organismus der Polythalamien*, 1854; *Müller's Archiv*, 1861; *Das Protoplasma der Rhizopoden*, 1863.

showing that the "sarcode" of the *Protozoa*, and the "protoplasm" of plants were essentially identical in their nature. Since the publication of Schultze's well-known works upon the *Rhizopoda*, protoplasm has been studied by a host of observers, notably by E. Brücke,* Haeckel,† Kühne,‡ Huxley,§ Allman,|| Francis Darwin,¶ and Beale;** and numerous points regarding the place which it fills in the organism have been brought to light.

As before said, it is now universally admitted that protoplasm constitutes that element of the animal and vegetable body, with which the essential phenomena of vitality are more directly connected, and it is therefore important that we should be acquainted with its more important physical and chemical properties. As regards its *physical* characters, protoplasm presents itself as a semi-fluid viscous body, transparent, and either quite homogeneous or minutely granular. In no case known to us has the microscope revealed any actual *structure* in protoplasm, and its *molecular* constitution is, of course, beyond all investigation by means of any instruments at present available. Though during life usually semi-fluid—its precise consistence depending upon the amount of water with which it is combined—protoplasm is coagulated by exposure to a temperature of about 50° C., and it further possesses the singular property of being more or less deeply reddened when submitted to the action of a solution of carmine.

Regarded *chemically*, we may consider protoplasm as being a mixture of albuminoid bodies, or proteine-substances, with water, and probably a variable amount of mineral substances in addition. It is, therefore, a member of that great group of organic compounds which are known generally as the "nitrogenous," or "azotised" substances; and it may be said, roughly, to be a compound of carbon, hydrogen, oxygen, and nitrogen, and consequently to more or less closely approximate to albumen in its chemical composition. It must be admitted, however, that we have no absolutely accurate analysis to fall back upon in dogmatising as to the composition of protoplasm; that we cannot assert from positive knowledge that the protoplasm of animals is precisely identical in chemical composition

* *Elementar-Organismen Wiener Sitzungsberichte*, 1861.

† *Die Radiolarien*, 1862.

‡ *Protoplasma und die Contractilität*, 1864.

§ *The Physical Basis of Life. Lay Sermons*, 1872.

|| *Ann. Nat. History*, 1864.

¶ *Quart. Journ. Microscopical Science*, 1877.

** *Protoplasma*, 1874. Also in numerous other works and memoirs.

with that of plants; and that we do not even know for certain that the protoplasm of different kinds of animals is absolutely the same. It must also be added that we are still ignorant of the precise vital and physiological relations between protoplasm and chlorophyll, the well-known green colouring-matter of plants, which plays a most important part in the life of the plant, and which, when present at all, is always associated with protoplasm. We must remember, therefore, that though it is convenient to apply the general name of "protoplasm" to the apparently identical living matter of all animal and vegetable organisms, we can only *infer* that this substance is really identical in all the cases where we meet with it, and that the at present ascertained facts do not warrant us in asserting positively that it has a definite and invariable chemical composition.

If protoplasm were an inorganic substance, we should have exhausted its essential characters in describing its physical properties and its chemical composition. We have, however, next to glance at what have been called the "vital" properties of protoplasm; and here we come at once upon a point which we shall have to consider again, and which has been, I think, too much neglected in all the discussion and controversy which has taken place in connection with this substance. I do not think, namely, that sufficient distinction has been generally made between *dead* protoplasm and *living* protoplasm; and I am decidedly of opinion that, with our present knowledge, an unwarrantable conclusion has been arrived at by those observers—and they are very numerous and influential—who have always conducted their argument upon the basis that the difference between the two is merely a difference of *state*. The physical properties of protoplasm—as above enumerated—have been determined by an examination of protoplasm in both its dead and its living condition, and these, therefore, may be considered as real and inherent properties of this substance. On the other hand, the chemical composition of protoplasm can only be determined by an examination of *dead* protoplasm, and we are by no means without examples of the almost instantaneous chemical alterations which are apt to supervene in highly complex organic compounds when the organism passes into that condition which we know as "death." We are not, therefore, justified in making the positive assertion that living protoplasm has precisely the same chemical composition as dead protoplasm—as far as the constitution of the latter may be said to be at all accurately known to us. We may infer that the protoplasm of the body—if really a definite chemical compound—remains unchanged after death, until

such period as actual decomposition of the tissues sets in ; but assuredly we do not *know* this as a matter of fact, and any reasoning based upon an assumption that this is the case must be regarded as being, in the meanwhile, open to doubt.

Whatever may be thought as to the validity of the above argument in relation to the chemical properties of protoplasm, no hesitation at all can be entertained as to its force so far as the so-called "vital" properties of this substance are concerned. These properties—as their very name implies—are not, and never can be, known, except as manifested by *living* protoplasm. I do not say that it may not be ultimately proved that they are "properties" of protoplasm, as protoplasm pure and simple, whatever its state may be, and that in the one case they are simply dormant or potential properties, while in the other they are active and visible ones. I do not say that we may not ultimately have sufficient proof to establish the thesis that dead protoplasm and living protoplasm are one and the same substance, with no other difference than that dead protoplasm is in a statical, and living protoplasm in a dynamical condition. I do say, however, that we have not at present a shadow of actual *proof* to support such a thesis, and that it is begging the entire question at issue to speak of the "vital properties" of protoplasm at all. If there be—as for all that science has yet proved there may be—any truth, or kernel of truth, at the bottom of the old vitalistic theories, then, however modified a shape these theories may assume, it will remain true that the so-called "vital properties" of protoplasm are properties which belong to it in virtue of its being *alive*, and not in virtue of its having the physical and chemical properties of the substance known under this name.

I shall return to the point here alluded to again, and we may pass on now to briefly consider what the so-called "vital properties" of protoplasm actually are. In other words, what are the essential phenomena manifested by a living mass of protoplasm ; and in what respects do these phenomena differ from those exhibited by all known aggregates of purely inorganic matter, or by dead bodies in general ? In order to arrive at clear ideas upon this subject, we may with advantage briefly glance at the phenomena exhibited by a "cytode," by an independent "cell," and by any complex organism, whether animal or vegetable.

What is known as a "cytode" is a minute microscopic mass of protoplasm, which is not bounded by a definite or rigid outer envelope or "wall," and which does not possess in its interior the structure known as a "nucleus." It is in the form of a cytode, or a simple mass of indifferentiated and

non-nucleated protoplasm that the simplest of all living beings present themselves, and it is in the animal kingdom that we find these to occur; the least highly organised plants being so far differentiated as to assume the form of a true "cell." As examples of "cytodes" leading an independent existence we may take the small and often microscopic animals known as the *Monera*, and we may select *Protomyxa* as a type of these. In *Protomyxa* we find the entire organism to consist of an irregular or shapeless mass of orange-red protoplasm, which attains a diameter of as much as half an inch, and has the consistence of jelly. It is found in the sea, floating in the open ocean, attached to the dead shells of oceanic molluscs. The simple, structureless sarcode which forms the body possesses no nucleus, but exhibits numerous vacant oval or spherical spaces, which are, probably, small collections of water taken in during the process of ingestion of the food, and enclosed in the soft protoplasm. At any rate, these "vacuoles," as they are called, are certainly not to be regarded as being in any way of the nature of distinct organs or structures. There is no definite wall or outer envelope to the protoplasm; there is no "nucleus" or central body; and the structure known as the "contractile vesicle" of the higher *Protozoa* is similarly wanting. The structureless being thus constituted is, however, highly irritable, and responds readily to external stimuli, this feature being especially manifest in the method in which food is taken into the body. The ingestion of nutritive matter is effected, namely, by the production at all the free surfaces of the animal of numerous long branched filaments or streams of the soft and diffuent protoplasm, which radiate outwards from the central mass, and to some extent interlace with one another. These prehensile processes of protoplasm can be produced at any point of the surface, and can be again withdrawn, to melt undistinguishably into the soft sarcode of the body, being, therefore, purely temporary and provisional structures. Whenever any particle of nutritive material comes in contact with one of these branching filaments it is seized at once; and by the contraction and withdrawal of the filament, it is securely lodged within the central body-substance, to undergo there the process of digestion. The temporary and adventitious filaments of protoplasm above alluded to are known by the name of "pseudopodia;" and, in one form or another, they are present in all the members of that great group of the *Protozoa*, which naturalists know by the name of the *Rhizopoda*. Beyond the pseudopodia, *Protomyxa* possesses no organs of any kind, and the former have no real title to such a designa-

tion, as they have no permanent existence. There are no digestive organs, no circulatory system, no nervous system, no reproductive organs. As in all living beings, the processes of growth and the maintenance of the body are effected by intussusception and assimilation: that is to say, foreign matter is conveyed from the exterior to the interior of the animal, and is then submitted to certain influences by which it is "assimilated," or made like to the matter composing the animal which it is about to nourish. Finally *Protomyxa* has the power of reproducing itself by a process of "encystation," quite similar to what is known to occur in various of the higher *Protozoa*. It is unnecessary to enter here into the details of this process, but it consists essentially in the assumption by the adult organism of a quiescent stage, in which its pseudopodia are all withdrawn, and the protoplasm becomes surrounded by a thick hyaline capsule or cyst. The contained protoplasm ultimately breaks up into a number of minute spherical balls, without any outer envelope, which are liberated by the rupture of the outer cyst, and after a short period of independent life are developed into as many new individuals.

In such a Moner as *Protomyxa* we find the very simplest expression of the great equation of life, and, as before remarked, no type of structure so simple and so undifferentiated is to be found elsewhere among animals, or, except temporarily, in the vegetable kingdom. All other animals and all adult plants consist of single or aggregate masses of protoplasm in the form of "cells," properly so called. What is termed a "cell" is, as is well known, a mass of protoplasm, usually of a more or less definite shape, typically spheroidal, enclosing in its interior a distinct vesicular, or solid, variously-shaped body, which is shown by the readiness with which it is stained by carmine to be also of a protoplasmic nature, and which is termed the "nucleus." Such a nucleated mass of protoplasm constitutes a single "cell," and it may or may not be enclosed in a thinner or thicker external covering, which differs in consistence, and often in chemical composition, from the protoplasmic contents, which may be rigid or flexible, and which is known as the "cell-wall."

A single independent cell may alone constitute an individual animal or plant; or an animal or vegetable may be an aggregate of cells, variously disposed, and variously modified; or, lastly, an animal may be an aggregate of cells, of which some form the actual tissues, and have definite places and relations with one another; while others are locomotive, and, from one point of view, semi-independent. We may briefly consider cases of each of these conditions. As an example of the case

where a single individual animal is constituted by a single cell, we may take the *Amæba* or Proteus-Animalcule. This little microscopic creature, so common in water holding organic matter in solution, consists of a minute mass of protoplasm, which does not possess any rigid, well-defined, or unyielding outer investment, but is so far differentiated that it can be clearly distinguished into an outer transparent layer, or "ectosarc," and an inner more fluid and mobile molecular layer, or "endosarc." Not only is this differentiation of the protoplasmic body a distinct advance upon what obtains in the *Monera*, such as *Protomyxa*, but there is now the further feature that there exists in the endosarc a solid granular "nucleus." In addition, also, to numerous fluid-cavities or "vacuoles," we now meet with a permanent internal circulatory organ, in the form of what is known as a "contractile vesicle." This is a little cavity or vesicle, holding a fixed position, filled with a colourless fluid apparently derived from the digestion, and exhibiting rhythmical movements of contraction and dilatation. It may, in fact, be regarded as a rudimentary heart. No mouth is present, nor are there any digestive organs; while the nervous and reproductive systems are wholly undeveloped. Owing to the absence of a hard outer covering, the soft protoplasm of the body is amenable to the slightest external stimulus, and can be protruded from all points of the surface in the form of temporary outward prolongations or pseudopodia, which are used as organs of prehension, and are employed by the animal as the agents whereby it obtains its food. The pseudopodia of the *Amæba* are, in fact, precisely similar in their essential structure and function to the structures known by the same name in the *Protomyxa*, but they are now comparatively few in number, and are blunt and finger-shaped in form. The *Amæba* can reproduce itself either by an actual division of its substance into two portions, each of which ultimately becomes an independent being, or by means of a process of "encystation," and endogenous division, the little sarcode-spherules formed within the parent cyst being ultimately set free by the rupture of the latter to give origin to new individuals.

Nearly allied to the *Amæba* are the wonderful organisms known as *Foraminifera* and *Polycystina*, which among other peculiarities, exhibit the feature that the soft sarcode of the body, undifferentiated as it is, has the power of secreting hard structures of the nature of a skeleton, often of surpassing beauty and not unusually of mathematical regularity. In the case of the *Foraminifera*, which are so abundant in our present oceans, and enter so largely into the composition of the

earth's crust, the skeleton is generally composed of carbonate of lime, while in the *Polycystina* it is of pure glassy flint. The structure of the animal is in both cases very similar to that of the *Amœba*; but the pseudopodia are excessively long and filamentous, and in the case of the *Foraminifera* they largely inosculate and interlace with one another, so as to give rise to a regular network, while in the *Polycystina* they usually stand out like rays, without much anastomosis. In both cases, also, there is seen in the pseudopodia a very singular phenomenon, which is not known in the case of the pseudopodia of the *Amœba*, and which has a singular interest as showing the highly irritable condition of undifferentiated protoplasm in certain instances. If, namely, we observe the pseudopodia of one of the *Foraminifera*, or *Polycystina*, under sufficiently high powers of the microscope, we discover that these apparently structureless filaments of sarcode are really largely made up of very minute molecules or granules, which are in a condition of constant movement or circulation, streaming out from the central mass of protoplasm, and then returning again into it. A similar circulation of molecules is well known as occurring in the protoplasm of many vegetable cells, and the movements, though their precise origin and cause are unknown, are probably really of a similar nature in all cases in which they have been noticed. We may conclude, indeed, with much probability, that this cyclosis or circulation of minute particles is a property of living protoplasm in one of the conditions in which this presents itself to our notice.

As an example of a single cell constituting an individual plant, we may select the cell of Yeast plant (*Saccharomyces cerevisie*). If a minute fragment of yeast be examined microscopically under suitable conditions, it is seen to consist of a vast number of independent rounded cells, each of which may be regarded as a separate plant. Each cell—as can be well demonstrated by staining with carmine—consists of a central mass of living protoplasm, with a more or less clearly-defined internal nucleus, and surrounded by an apparently structureless external transparent layer, or “cell-wall.” The cell-wall is composed of the characteristically but not exclusively vegetable substance, *cellulose*, and it is formed by the central mass of protoplasm as a kind of excretion or exudation, being truly in itself more or less entirely devoid of life, and consisting of what Dr. Beale has termed “formed material.” The yeast cell imbibes its own proper nutriment by endosmose through the porous wall, which is thinnest in the young cells and becomes gradually thicker with age. It has, further, the power of reproduction by the development of gemmæ or buds.

derived from the central protoplasm, and ultimately detached to form new individuals.

Owing to the comparative density and rigidity of its cell-wall, the protoplasm of the yeast plant does not give rise to outward processes, or "pseudopodia," though it may, as above observed, give forth external buds. For the same reason, the protoplasm of vegetable cells in general is usually devoid of any power of thrusting out pseudopodia. Amœboid and moving filaments of protoplasm have, however, been shown by Mr. Francis Darwin* to be emitted from the cells of the glandular hairs of the Common Teasel (*Dipsacus sylvestris*), and to differ in no essential respect from the "pseudopodia" of the Rhizopods. Moreover, it is well known that the protoplasm in the interior of many vegetable cells, though confined by an unyielding envelope, is capable of "rotation" as a whole, or of exhibiting a circulation of granules similar to that seen in the pseudopodia of the Foraminifera. Lastly, in certain of the life-stages of some of the lower plants (*Myxomycetes*) we really meet with wall-less masses of protoplasm, which are capable of thrusting out pseudopodia, and are in all essential respects morphologically similar to *Amœba*.

In the case of the higher and more complex plants, as also in the more highly-organised animals, the ovum, or earliest rudiment of the future organism, has invariably the form of a single simple cell, the essential part of which is a central mass of protoplasm. In these cases, however, the unicellular structure is soon lost; new cells are produced in larger or smaller numbers by processes well known to physiologists; some of these cells may undergo considerable secondary modifications, and ultimately the organism comes to consist of an aggregate of cells, all of which may more or less entirely retain their primitive form, or many of which may be highly specialised and developed into various complex tissues. It should also be noted that in addition to the tissues, as ordinarily understood, the body of an animal may contain a great number of cells which float freely in a fluid (the blood), and are not in any direct connection with one another. Lastly, while the cells of the higher animals, as a rule, resemble those of the great majority of plants in having firm walls, which allow of no changes of form, nor of outward protrusion of protoplasmic filaments, there are cases, even amongst the highest animals, in which we meet with wall-less masses of protoplasm, which contain distinct nuclei, and are capable of manifold mutations of shape. The pigment cells of the skin of the frog, of cuttle-fishes, and of

* *Quart. Journ. Microscop. Science*, 1877, p. 245.

various other animals, supply good examples of such cells; but the most striking instance is that afforded by the "white corpuscles" of the blood. If, namely, we examine the blood of man, or of any of the higher vertebrates, under a sufficiently high magnifying power, and with suitable precautions, we shall observe that it contains floating in it a number of minute masses of naked protoplasm, which are provided with a nucleus, but are destitute of a proper cell-wall. These are the so-called "white corpuscles," and they are now well known as exhibiting the surprising phenomenon that they throw out external filaments, or processes of their own protoplasmic substance, which can be thrust out at any point of the surface, and can be again retracted, and which precisely resemble the "pseudopodia" of such a Rhizopod as the *Amæba*. Moreover, not only is the life of the "white blood-corpuscles" in one sense a semi-independent one, but these little aggregations of protoplasm are capable of using the pseudopodia just as the *Amæba* does, not only for locomotion but also for the purpose of obtaining food. Thus, by adding a little vermilion, or aniline-blue, or milk, to a drop of blood, the white corpuscles can be observed under the microscope to take in the particles of these substances by means of the pseudopodia, and then in some cases to discharge them again, in a manner precisely similar to that observable in the *Amæba*.

Before proceeding further it should be noted, that all forms of vital activity, of whatsoever nature, are attended with a certain disintegration and destruction of the living matter, or protoplasm, of which the organism is composed. In the case of the microscopic unicellular organisms, this constant destruction of life-matter can be inferred rather than actually demonstrated; but in the higher animals and plants it can be shown that the vital processes resolve themselves, roughly speaking, into the constantly-proceeding destruction of old cells, and the corresponding production of new cells to take the place of the former.

Having now considered some of the principal forms in which protoplasm presents itself for our examination, and some of the chief phenomena which it manifests when alive, we may here briefly summarise the essential phenomena manifested by all living bodies, as opposed to those which are dead.

1. All living beings may be regarded as essentially larger or smaller aggregates of a substance of extreme chemical complexity, which is, during life, in a condition of continual flux and constant change affecting its minutest parts. In

spite, however, of the excessively unstable chemical equilibrium of living protoplasm, the living body is enabled to maintain its stability and its average condition for a longer or shorter period, which is normally constant, or approximately so, for each organism. This is due to the fact that every mass of living protoplasm has the power of taking in from the exterior certain foreign materials, and of "assimilating" these, or of converting these into new protoplasm capable of replacing the loss and destruction of this substance due to the act of living. In this connection, however, we must notice the remarkable fact that the assimilative powers of vegetable and animal protoplasm differ in a very remarkable manner. Thus the protoplasm of plants, when associated with the green colouring-matter known as "chlorophyll," has the power of decomposing carbon dioxide in the presence of sunlight; and all plants possess the power of building up new protoplasm out of the inorganic substances, ammonia, carbon dioxide, and water. On the other hand, no known animal can thus synthetically construct protoplasm out of merely inorganic materials, but all require to be supplied with ready-made protoplasm as food. The true significance of this fact cannot, with our present knowledge, be rightly estimated; but it is deserving of especial notice, as showing that though the protoplasm of animals and that of plants are, so far as we know, structurally and chemically identical, there nevertheless exists a vast and most important difference in the vital functions which each is able to discharge in the economy.

2. All masses of living protoplasm, whether these are independent organisms, or form parts of an organic whole, have certain *active* relations with their surroundings. This is especially seen in the power of *movement* exhibited by protoplasm in all its forms (when free to move) in response to certain external or internal stimuli. This "irritability," or the power of *actively* responding to stimulation, is a feature entirely confined to living protoplasm, and is not exhibited by any of the multifarious forms of dead matter, all of which are *passive*, and merely exhibit appropriate *reactions* when influenced by external forces.

3. Lastly, living protoplasm has the unique power of reproducing itself by the process of detaching a portion of its own substance, which, under suitable conditions, will become developed into a new living being, resembling that by which it was originally given off.

Having now briefly glanced at the principal phenomena

manifested by living matter, we may next consider what we actually mean when we speak of "life" or "vitality;" and this, though apparently a simple matter, is really one about which considerable differences of opinion have prevailed. As for definitions of life, many such have been framed by eminent philosophers, and would be quoted if any advantage were derivable therefrom. As an old definition we may take that of Treviranus, who defines life as "the constant uniformity of phenomena with diversity of external influences." As a modern definition that of Mr. Herbert Spencer may be selected, who considers life to be "the definite combination of heterogeneous changes, both simultaneous and successive, in correspondence with external coexistences and sequences." When we come, however, to examine these and other short definitions of life, we shall generally find that they practically amount to stating, in terse phraseology, that life or vitality is the sum of the phenomena manifested by a living being; in other words, that life is life. It appears to me, however, that there is, or ought to be, in any satisfactory definition of life, the underlying conception that life is something more than the mere sum of the *phenomena* of a living being; and that it is, in fact, the *force* or *aggregate of forces* to the operation of which these phenomena are due. Life, in fact, is the force or group of forces in virtue of which protoplasmic matter, under given conditions, passes through a succession of changes, which correspond with, and are determined by, internal and external impressions, and follow one another in a more or less definite and determinable sequence.

Leaving, however, short definitions on one side, we may see what more particularly are those phenomena of living beings in virtue of which we ascribe to them the possession of "life," and distinguish them fundamentally from all forms of dead matter. So far as this point is concerned, it is at once evident that a living body is only thereby distinguishable from a dead one that it performs the three great physiological functions previously enumerated; or that, at any rate, it has the *power* of discharging these functions under appropriate conditions and stimuli. Every living body nourishes itself, and maintains its existence as an individual, in spite of the constant destruction of the matter of which it is composed. Every living body has certain active relations with the external world. Every living body can reproduce itself. It cannot be doubted, however, that the most striking phenomena of a living body, or at least those which are most obviously opposed to what we see in merely dead matter, are those which arise from its having active

relations with its surroundings. Upon this subject Treviranus* expresses himself as follows:—

“Under the term ‘life’ we form for ourselves a conception of a condition of activity. We speak of an animal or a plant as being ‘living’ so long as we can still detect in it signs of growth and movement, and therefore of activity. But at the same time we conceive of this activity as being something which originates in the body to which we ascribe life, from the interior and not *ab extra*. The sea, when disturbed by storms, also exhibits activity, but we do not for this reason ascribe ‘life’ to it. We do not do this, because its every movement is the result of the application of an external force. Every movement, then, which originates in extraneous forces and is merely imparted to the body, we term a ‘mechanical’ movement; and those movements which occur as the manifestations of life, are distinguished from those which are merely mechanical, by the fact that they find their starting-point in internal and not in external causes. Easy, however, as it may appear at first sight to separate mechanical from vital movements, nevertheless a closer examination shows us that the above-mentioned ground of distinction is an insufficient one. If the living body were an entirely isolated system, which contained in itself the source and spring of all its movements, then, certainly, it would be easy to draw the line between mechanical and vital movements. But, all the manifestations of vital activity are products of an interaction between the living body and the outer world, and this is precisely the case also with mechanical movements. A mass which has been set in movement by an external impulse, does not less react against the impelling body, than does the muscle-fibre against the stimulus which calls forth its contractility. What, then, is the distinctive character between the interaction which gives rise to the mechanical movement, and that by which the vital movement is originated? In this lies the first of the difficulties which we have to combat in forming a conception of life.”

It is not necessary to pursue further the line of argument indicated above. For our present purpose, it is sufficient to assume that all bodies in a state of active vitality are characterised by their power of maintaining a stable condition in the face of the agencies whereby their substance is constantly being disintegrated; that they make certain active responses to external and internal stimuli, and have other than merely passive relations with the external world; and, lastly,

* *Biologie*, vol. i., p. 16. 1802.

that they can detach portions of their own substance which may be developed into new individuals. How, then, do we explain the fact that living bodies exhibit these phenomena, so different in their essence to anything observable in dead matter? In other words, what is the nature of "life," and what is its connection with the matter by which it is manifested?

In dealing with this question,* we have two classes of theories to consider—namely, the *physical* or *material*, and the so-called *vitalistic*. It is not meant by this that there are only two theories commonly held as to the nature of life, but simply that all existing theories, however diverse, may be reduced to one or other of these categories. First, as to the *physical theories*. The ordinary physical phenomena of matter appear beyond question to be due simply to movements taking place in the ultimate molecules of which matter is composed. These movements may vary in amount and in kind, and may thus give rise to the most diverse phenomena, but they are all essentially of the same nature. Hence, so far as dead matter is concerned, there is no impropriety in saying that force is simply an *affection* of matter. You *might* have the matter without the force; but you cannot have the force, or its resultant phenomena, without the matter.

The advocates of the physical doctrine of life stretch this admission beyond the limits here assigned to it, and embrace in its scope all the phenomena of vitality. On this theory all vital actions are reduced to molecular movements of the protoplasm of which the living body is composed. The properties of living beings are asserted to be "as much dependent upon the mere qualities and nature of the material aggregate which displays them, as the properties of a metal, or the properties of a crystal, are the results of the nature and mode of collocation of the atoms of which these bodies are composed."—(Bastian.) On this view, therefore, "Life" is merely a form of energy or *motion*, and the vital forces of the organism are merely correlates of the ordinary physical forces. To put it in another form, the mechanical, chemical, and physical phenomena of the organism are wholly the result of transformations of the *heat* which it receives from the sun, and the *energy* stored up in its *food*.

As opposed to the doctrines of the physical school, we have the views held by the so-called "vitalists." In its crudest

* The following remarks as to the physical and vitalistic theories of life are taken from the inaugural lecture to the class of Natural History in the University of St. Andrews, delivered in 1875.

form this doctrine was held by the ancient philosophers of Greece, who believed that life was an independent principle, capable of being added to and again removed from ordinary matter. Later, it was held that in some central spot in the living organism there existed some kind of guiding, directing, and all-pervading power, or "vital principle," capable of "influencing all the organs and tissues of the body in much the same way as the master builder controls and directs the operations of his workmen."—(Beale.) Later still, again, it has been held that there is inherent in the protoplasm of the *living* body a peculiar power, which, for want of a better term, may be called "vital force," and which disappears from the organism when death takes place. This power is supposed to be in association with every particle of living matter, and is believed to be independent of the correlated series of physical and chemical forces. It is asserted to be superior to the ordinary forces of the universe in *kind* and *order*, and to control and regulate these. There is thus no reason to regard it as a mere "aspect" of matter, or as necessarily ceasing to exist when separated from the material substratum with which alone we know it to be associated.—(Beale.)

The vitalistic doctrine of life admits of various modifications and diverse reservations; but all forms of this doctrine agree in believing that there exists in the living organism something which is not merely a form of one of the ordinary physical or chemical forces, but is superior to these. On the other hand, all modifications of the physical doctrine of life agree in believing that the forces displayed by the living body are nothing more than the ordinary correlated forces of the universe in another form.

We may now compare these theories a little more minutely. In the first place, it is to be at once admitted that a large proportion of the phenomena exhibited by every living being are clearly physical and chemical, and are therefore due to the action of the ordinary correlated forces. Here is where the real difficulty of the case arises. It is impossible to deny that *many* of the actions of animals are purely or mainly physical and chemical. The point is—are *all* the actions of the living organism of this nature, or are *some* of them due to something else, distinct from the physico-chemical forces of the correlated series? Every one acquainted with the modern doctrine of the "conservation of energy" will admit at once that the mechanical and chemical forces of the organism are derived entirely from the transformation of the ordinary physical forces. Digestion is carried on by a modification of ordinary chemical affinity. Animal heat is derived from chemical com-

bination. The force with which muscular movements are effected is derived from the energy stored up in the food on which the animal lives. All the forces of our globe, of *this* kind, are derived from the sun, and in *this* sense we may safely accept Tyndall's dictum, that our future Shakespeares are "potential in the fires of the sun." If we have no sun, assuredly we shall have no Shakespeares, for life can only be carried on by the transformation of energy primarily derived from the sun. So far, the advocates of the physical doctrine of life are clearly correct, and stand within their rights. The question, however, is whether *all* the energies of plants and animals are either chemical or physical? and to this question an answer in the negative may be safely returned. On this point the advocates of the vitalistic doctrines are fundamentally right, if not right in details. Animals and plants exhibit phenomena which can *not* be explained simply by reference to the known chemical and physical forces of the universe.

As has been more or less dimly discerned by many investigators, and has been specially insisted upon by Mr. Croll,* the real problem is not as to the *nature* of the molecular movements of protoplasm which give rise to vital phenomena, but as to the nature of the cause which *determines* these movements. Indeed, the same may be said of the molecular movements of matter which constitute the ordinary physical and chemical forces of the universe. Heat, electricity, magnetism, and the like, are merely different kinds of movement taking place amongst the same particles of matter. The fundamental question is not "What is the particular force in action, or upon what does its exertion depend? but rather, What is it that causes the force to act in the particular manner that it does act?" It is quite true that the human mind is incapable of conceiving of force as acting *at all*, unless as acting in a particular *direction*. The force cannot be *produced* without at the same time being *determined* in space and in time; but what accounts for its production will not account for the direction it may take. The explosion of the gunpowder is a sufficient cause for the movement of the bullet, but it is clearly no cause for the bullet travelling eastwards rather than westwards.

Here we appear to reach the kernel of the matter at issue. The living organism, however simple, constitutes a system or vehicle for the action of the chemical and physical forces of

* "What Determines Molecular Motion?—the Fundamental Problem of Nature." James Croll, *Philosophical Magazine*, 1872. A most admirable and thoughtful disquisition on the determining causes of the molecular movements of both dead and living matter.

the universe. We can account for the existence and ultimate constitution of these forces, no better, and no worse, in the case of the living organism, than we can in the case of ordinary non-living matter. The sole question is—Do these forces act in the living organism otherwise than they do in dead matter; and, if so, what is it that causes this different action, and *determines their direction*?

That the physical and chemical forces act differently in the living body to what they do in dead matter seems to be sufficiently proved by the fact, that whilst the matter of life (“protoplasm”) is apparently identical in composition in all living beings, the vital phenomena exhibited are of the most varying character. No one can produce any adequate distinction between the protoplasm of a man and that of a sponge; but no one will deny that the vital phenomena exhibited by these organisms are of an extraordinarily different nature. With identity of force, and of the vehicle through which that force acts, we have therefore a marvellous diversity of results, and this diversity can only be due to differences in the cause which *determines* the molecular movements of protoplasm.

The advocates of the physical theory of life have endeavoured to evade this difficulty by assuming the existence of an inherent “*directive force*,” either in the protoplasm itself, and constituting one of its natural properties, or in the “sun-force” which that protoplasm receives, directly or indirectly. We hear a great deal about “molecular organisation,” “atomic machinery,” being “built up by sun-force,” “formative power of matter,” and the like; and these, as Fluellen has it, are indeed “prave ’ords;” but they are nothing more than words, and a little observation and reflection will show us the fallacy of all this. Given a steam-engine and coals, you still require something to direct its action, and you cannot find that something in the dead machine or in the fuel. You get a certain amount of “power” or force,” but that is all; and you may use that power in an almost infinite variety of ways by *directing* it in different directions. It is only a *man*, however, who can determine the course which the power of the steam-engine shall take. To use a somewhat similar illustration of Dr. Carpenter’s, you may go to any large manufacturing town, and you may hire or purchase a room “with power,” as the phrase goes. What is it that you buy in such a case? Surely you do not purchase the power to do any particular thing, such as to weave cloth or to print books? On the contrary, you simply buy so much bare *force*, and it is for *you* to direct that force by suitable machinery into any

channel that you may wish, and thus to render it available for the special purpose you may have in view.

When the advocates of the physical theory of life speak of protoplasm assuming the marvellous forms of organised beings by means of an inherent power of its own, they are employing a scientific fallacy. It is all very well to tell us that the forces which reside in living protoplasm are but the forces, physical and chemical, that rule amongst the particles of dead matter, and are therefore derived from the sun. So they are; nobody would think of denying it. The question to be solved is simply whether these forces constitute *all* that exists in living protoplasm, and to which its vital activity is due? The supporters of the physical theory of life say that they do, but in so saying they are proceeding upon the most improbable of assumptions. The vital phenomena manifested by even the simplest mass of living protoplasm are out of all proportion in extent and variety to the external stimuli, which form the starting-point of most of these phenomena; and the same stimulus may give rise to very different phenomena in different masses of protoplasm, or in the same mass at different times. As has been well pointed out by Mr. Croll, however, nothing could be more unfounded than the assumption that the power which *directs* the molecular movements of protoplasm in one path rather than another, is itself the very molecular movements in question. When protoplasm is said, by its intrinsic "directing power," to determine the motions of its molecules, and force these into certain paths or modes of motion, we are practically told that the *production* of force and the *determination* of force are the same thing, and that the action of a force can be determined by the same force. Without entering into the argument on this point, it may be said at once, however, that it can be logically demonstrated that "the production of motion and the *determination* of motion are absolutely and essentially different," and that "the action of a force cannot be determined by a force, nor can motion be determined by motion."

Before attempting to come to any conclusion as to the essential nature of life, we may shortly consider one or two further points as to the connection which has been supposed to subsist between life and its physical basis or protoplasm, and also the extent to which vital phenomena may be supposed to be connected with *organisation*. As regards the first of these subjects, high authorities have at the present day declared themselves in favour of the view that life is merely a *property* of protoplasm. In other words, it is asserted that life is the result of the combined properties of the elements which unite to form

protoplasm, just as the properties of water are the resultant of the combined properties of its constituent hydrogen and oxygen; and it is alleged to be just as absurd to set down the phenomena of life to an assumed "vital force," as it would be to ascribe the properties of water to an assumed "aquosity." Now it appears to me, that in considering such an assertion, there are two important points to bear in mind. In the first place, it seems clear that in speaking of life as a "property" of protoplasm, we are really using a phrase which might admit of more than one interpretation. What in the case of a lifeless body are understood as its "properties," are either certain inherent *qualities* (as learned by our sensations), or else they are certain *reactions*, which are of constant and invariable occurrence whenever the body in question is acted upon in a particular manner. From the point of view here taken, however, life consists of *actions* as well as of reactions, and to speak of the former as being "properties" of protoplasm is simply to beg the entire question at issue; while it may be presumed that even the most ardent advocates of the physical theory of life would not be prepared to assert that life is an *inherent quality* of protoplasm.

In the second place, the assertion that life is merely a "property" of protoplasm, is one which ignores the difference between *dead* protoplasm and *living* protoplasm. Even as regards the phenomena of irritability and contractility—as manifested in the protrusion of pseudopodia by all naked masses of living protoplasm—it is certain that we have to deal with something which cannot be justly spoken of as a property of protoplasm. On the contrary, the manifestations of irritability are in the most obvious manner directly dependent upon the fact that the protoplasm is in that peculiar condition to which we apply the term "*living*." Irritability and contractility are not inherent properties of protoplasm *quâ* protoplasm; and those who make such an assertion must be taken as maintaining the thesis that protoplasm has no existence in its *dead* state, and that we are only acquainted with it in its *living* condition. Considering, however, that the greater part of our entire knowledge of protoplasm, as an actual substance, is based upon the observation and examination of *dead* protoplasm, that we are still ignorant of its composition as a definite chemical compound, and that there is not a particle of scientific evidence to show that the protoplasm of a dead animal is in any way physically or chemically different from that of the same animal when alive, until, at any rate, decomposition has occurred—considering these things, we may well maintain that the assertion that life is a

“property” of protoplasm is at present wholly unproved, and, upon the face of it, very unlikely.

We may fairly assert, on the other hand, that the phenomena of vitality are due to the fact that living protoplasm is temporarily the seat of forces which do not reside in dead protoplasm; and the *onus* of proving the contrary rests clearly with those who assert that all protoplasm is, *ex hypothesi*, in a state of active or potential vitality. Upon quite as good grounds might it be said that man is composed of some forty chemical elements, combined with water in various proportions, and that the properties of the resulting compound are not only that of digesting, respiring, moving, &c., but also of thinking, speaking, writing books, building ships, and the like. These, however, are the properties—in a loose sense of this word—of the *living* man, in spite of the fact that the dead body cannot be shown to differ in chemical composition from the living one, until a certain period after death has elapsed. All such arguments ignore the effects of *form* and *collocation* as vehicles for transmitted forces.

Again, assuming with modern physiologists and naturalists that the protoplasm of all living beings is essentially identical, it is clear that only such vital phenomena can be said to be “properties” of protoplasm—in any sense, or upon any theory—as are manifested by protoplasm in all organisms and under all conditions. Even then, if we were to admit the propriety of considering living protoplasm at all in connection with such an argument, we should still have to face the difficulty that the vital phenomena of different organisms differ, as one may say, immeasurably, while the protoplasm remains the same. This is an insuperable obstacle to our accepting the theory that life is a “property” of protoplasm; for though a sponge and a man both “live,” in the strict sense of the term, there is fixed between the vital phenomena of the two (including their mental processes under this head) an absolutely impassable gulf.

It should not be overlooked, however, that there is a theory first propounded by Dr. Fletcher,* and subsequently developed by Dr. Drysdale,† which would escape the difficulty above pointed out by the assumption that protoplasm really has *no* existence except in the *living* body. Upon this theory, the living matter of the organism (protoplasm) is not only “in a somewhat different chemical state from that in which it

* *Rudiments of Physiology*. 1835.

† *The Protoplasmic Theory of Life*. 1874.

exists after death," but its constituent elements are "in a state of combination not to be called chemical at all in the ordinary sense, but one that is utterly *sui generis*." In fact, "no albumen, fibrin, myosin, protagon, or fats exist at all in the living matter," but "the sum of the elements of all these is united into a compound, for which we have no chemical name, and of the complex mode in which the atoms are combined we can form no idea; and it is only at the moment of death that those chemical compounds, with which we are familiar, take their origin." It would be impossible here to enter into any further exposition of this ingenious theory, or to attempt to criticise it. As before remarked, it evades the difficulty which has been above pointed out; but it must be noted that it only does so at the expense of having to assume the existence in the living body of an entirely hypothetical form of matter. Whether or not such a matter really exists, it is clearly something very different to that which is ordinarily known as "protoplasm;" and it may, perhaps, be questioned whether it is not, from a philosophical point of view, much the same thing to postulate a form of matter "of the complex mode in which the atoms are combined we can form no idea," as to assume the presence in the living organism of the much-ridiculed "vital force."

It remains only to say a few words as to the supposed relations between life and *organisation*. It has been commonly assumed that an animal lives because it is "organised," or consists of various definite organs, each of which discharges its appropriate function in the economy. Upon this view an animal is a kind of a machine, and "life" is the product of the working of its parts. Modern naturalists and physiologists are, however, tolerably agreed that though the *specialisation* of the vital functions can only be carried out by a correspondingly specialised set of organs in the animal, the essential phenomena of vitality are manifested by naked, and to all appearances structureless protoplasm. The existence of animals like the *Monera*, which are absolutely devoid of anything which could strictly be called "organisation," but which, nevertheless, discharge all the fundamental functions of life, is sufficient proof that vitality is essentially independent of organisation or structure. Recently, however, it has been maintained by one of our most illustrious naturalists* that the protoplasm of different organisms, though to all appearances identical, is really different in its "molecular constitution."

* Professor Allman, *Inaugural Address to the British Association*, Sheffield, 1879.

Upon this point, Professor Allman observes, that to suppose that "all protoplasm is identical where no difference cognisable by any means at our disposal can be detected, would be an error. Of two particles of protoplasm, between which we may defy all the powers of the microscope, all the resources of the laboratory, to detect a difference, one can develop only to a jelly-fish, the other only to a man; and one conclusion alone is here possible—that deep within them there must be a fundamental difference which thus determines their inevitable destiny, but of which we know nothing, and can assert nothing beyond the statement that it must depend on their hidden molecular constitution. In the molecular condition of protoplasm there is probably as much complexity as in the disposition of organs in the most highly differentiated organisms; and between two masses of protoplasm indistinguishable from one another there may be as much molecular difference as there is between the form and arrangement of organs in the most widely separated animals or plants."

There is, doubtless, much that is attractive in this theory, that the "molecular constitution" of protoplasm differs in different organisms, and that to variations in this respect are due the striking differences in the vital phenomena which they exhibit. Not only is this theory a fascinating one, but it would even find some sort of support in the well known phenomenon of "allotropism" amongst inorganic substances. It must be borne in mind, however, that it is only a theory, and that nothing like positive proof can be brought forward in its favour. If such differences in molecular constitution really exist in the protoplasm of animals and plants, they must be as endless as are the variations in the degree and kind of the vital phenomena which these exhibit, while, in any case, they are purely hypothetical. It should also be borne in mind that this theory is only a revival, in a subtler form, of the hypothesis that life is the result of organisation; for it cannot be denied that "molecular constitution" is only a kind of "organisation" upon such a lilliputian scale that it cannot be demonstrated even by the microscope, and can only be grasped by the "scientific imagination."

In the above connection there is one point which deserves a passing notice. It has, namely, been commonly assumed that as the life of a Moner or a unicellular organism is seated in a single, often microscopic spherule of protoplasm, so a complex, multicellular organism, may be properly regarded as a mere collection of such units, and its life as a mere agglomeration of the functions and activities of these. It is true, no doubt, that in one of the higher animals or plants, each

individual cell or cytode has, in a certain limited sense, and in a certain limited degree, its own independent life, its own period of active existence, its own proper work and function. It is no less true, however, that each and all of the cells of a compound and complex organism draw their life from that of the whole. To assert that the life of a higher animal is the mere added-up total of the lives of the component cells which form the individual, is to entirely ignore the all-important effects which flow from collocation and relative arrangement. Just as well might we assert that there is no difference between a heap of bricks and a house, or that a statue is nothing more than a block of marble, *plus* the aggregate mechanical energy of the blows of the sculptor with his mallet. Moreover—and here we touch the root of the matter—collocation would alone be powerless to produce the varied and wonderfully complex vital phenomena of the higher organisms, and cannot but be itself the result of some directing and unifying power, which we must suppose to be present, in greater or less degree, in all forms of life.

What, then, is this directive force? It is the old "vital force" of the vitalists, but the title is a bad one, and has necessarily led to much and inevitable misconception. No scientific observer at the present day can accept the assumption that there exists any peculiar physical force which can be added to and again taken away from matter, and upon the presence or absence of which depends the animated or lifeless condition of the organism. No scientific observer, further, will feel disposed to deny that a very large number of the processes which go on in the living body, and which have usually been called "vital," are really the result of the ordinary physico-chemical forces modified by the peculiarities of the medium through which their operation is determined. At the same time, I, for one, find it impossible to believe that all the so-called "vital" phenomena of even the simplest of living beings depend upon the action of the known physical and chemical forces upon the peculiar kind of matter which we term "protoplasm." In all living beings, I must assume the existence of some directing power, which, after all, is no more hypothetical than is the supposed peculiar "molecular constitution" of Professor Allman, or the complex chemical constitution, of which "we can form no idea," of Dr. Fletcher and Dr. Drysdale. When we come to think of the vital phenomena of the *higher* animals, I hold the hypothesis of an inner directing power to be absolutely inevitable; but if we admit such an idea for man, we must equally admit it, with the necessary modifications, for the Moner. I will not use in

this connection the well-worn and much abused terms of "material" or "immaterial," in speaking of this admittedly inferential directive power in the organism. Professor Tyndall has demanded recognition for a very similar or identical agency under the name of "formative power." Besides, it is for the physicist to give some definition of "matter" which is not based simply upon its *phenomena*, before he is entitled to demand that one should define that which is *not* matter. I cannot, however, fail to recognise that there exists in every living being some actual force independent of and superior to the protoplasm of which its substance is composed. By this force all the activities of the living organism are controlled and directed, and we must suppose that it differs in degree, if not in kind, in different organisms. To designate such a force as "vital" is but to use a term which we cannot philosophically define; but of its actual existence we can nevertheless have no doubt. It is, in fact, the indwelling *psyche* which forms the real essence of all forms of living matter, from the humblest alga up to man himself, and without which "life," in its proper sense, would have no existence. What may be the essential nature of this *psyche*, how far it may differ in fundamental constitution in different organisms, and in what manner it is united with the protoplasm of the material body and is enabled to influence this, are questions which, if answerable at all, belong to the domain of the psychologist and not to that of the naturalist. If, however, it can be shown to have a real existence, then we shall have accomplished a part of what I hold to be one of the most pressing duties of the present generation, by linking on, so far as may be, the clear-sighted scientific knowledge of to-day to the elaborate and often self-evolved theories of the past, retaining what may appear good in these, and welding them into a homogeneous whole with modern ideas.

The CHAIRMAN.—I am sure we are all much indebted to Professor Nicholson for the very valuable paper he has sent to us, and we can only regret that it has been impossible for him to read it in person, in consequence of his being obliged to be at Edinburgh University taking the duties of Sir C. Wyville Thomson. All will concur in thanking Mr. Gorman for the very clear and able manner in which he has read the paper. (Hear, hear.) Those present can now offer any remarks upon the subject of the paper.

Mr. J. E. HOWARD, F.R.S.—I am glad to be able to give a general assent to the conclusions of the writer of this paper; but could have wished that in giving a sketch of the fundamental phenomena manifested by living beings, he had not shown so much deference to the palpably false statements

of some modern writers. In order to form a true conception of these, it is necessary to scrutinise very closely the terms which they employ. The definitions of *protoplasm* involve this fallacy, that whilst spoken of as one thing or substance, it is at the same time, according to the same authors, many things or substances, to which the same remarkable, and indeed incredible, properties are attached. As if we were to say that "clay" was a substance universally admitted to produce bricks, and also potter's-ware and porcelain: and, ignoring the brickmaker or the potter (whilst theorising further on this fundamental basis of brickmaking), were to conclude that without possessing any actual structure in itself, it manifested brickmaking properties, or porcelain-producing properties, by virtue of its being "brought from a statical into a dynamical condition."

If we apply to the brickmaker, he would tell us that our definition of "clay" (to begin with) was very imperfect; and that, without having at his disposal a mixture of various earths (best known to himself), "with water, and a variable amount of mineral substances in addition," he could not produce *bricks* at all. He would further inform us, that "molecular movements" had never come within the compass of his observation—that, on the contrary, much horse or donkey-power was needed to effect the mixture. As to any inherent properties of the "clay" to form itself into bricks, he would be lost in wonder whether you were after all sane, or whether much learning had made you mad.

Turning to the porcelain manufacturer, he would tell us that "clay" might very likely be well described (see Johnson's Dictionary) as an "unctuous and tenacious earth, such as will mould into a certain form," but that the term could only be very loosely used of the "highly complex" matter which would alone serve his turn. After showing you the elaborate contrivances for preparing the material, he would let you see the workmen engaged in the various manipulations of his art, and would probably acquaint you with the difficulty he found in causing his plans to be perfectly carried out by his men. He would then show you his designing-rooms, and perhaps say, "I flatter myself that I have here in my employ the most perfected taste and the highest skill that can be met with in the trade; but it is astonishing, and you would scarcely credit, how highly I have to pay for all this *mind* employed in my service."

Now, if we consider Nature, we find that she makes her bricks so economically as never to lose any part of her material—turning everything to account. She is never disturbed by adverse combinations of her under-workmen nor troubled with their insubordination.

But, as a porcelain-maker, she is unrivalled; for she can communicate to her little lumps of soft sarcode (undifferentiated as they are), (p. 274), the power of secreting hard structures formed out of *chalk* or pure glassy-flint of surpassing beauty, and not unusually of mathematical regularity. To what schools she sends these sarcodes to acquire this *perfection of taste* and this *fondness for mathematical regularity* we are not informed; but can at all events display our wisdom by calling them *Foraminifera* and *Polycistina*.

As to the God that made them we do not recognise His existence, and are ignorant that professing themselves to be wise, certain persons became *fools*, which is a name likely to last as long as the scripture from which it is taken and is the proper distinctive term to be applied to *us*, if we are guilty of such egregious folly.

Admitting that life ordinarily requires for its manifestation that great group of organic compounds which are known generally as the nitrogenous or azotised substances, and that these more or less closely approximate to albumen in chemical constitution, we may (if we like) apply the term *protoplasm* with the same amount of accuracy (or inaccuracy) as in the former case we use the word clay. But take away *life* and you have nothing but a *caput mortuum* as a residuum. The carbon, hydrogen, oxygen, nitrogen, the iron silica, &c., are all there, but there is no longer any power of organization. The brickmakers, the porcelain-makers, the designers, are all gone and Nature takes care that this refuse shall be disposed of in other ways.

“Imperious Cæsar, dead and turned to clay,
Might stop a hole to keep the wind away.”

The albumen and proteine substances in an egg illustrate this part of my meaning. Every one knows that they are *not* dead refuse matter; although unless quickened into independent life they speedily *become* so, and are resolved into other chemical compounds. And the *life*, whence comes it? Certainly not from some inherent “molecular movements of extreme chemical complexity!”

I have shown in my “Addendum to the Contrast between Crystallization and Life” how this subject is intentionally mystified, for the object of maintaining the doctrine of *evolution*; and how, whilst it is admitted that the cell theory is misleading, it is again and again brought to the front. To assert a fallacy and to re-assert it, in spite of all argument which *cannot* be faced but *must be* ignored—this passes for *science!* And we must get rid of *fanaticism in science* as well as in religion, if there is to be any reconciliation between them; for in all cases fanatical adherence to a system leads to a want of truthfulness of statement, and whilst it enlists partisans destroys all accuracy of research.

I cannot but regret that in the midst of so much that is excellent, as a *résumé* of the present state of scientific knowledge, Dr. Nicholson should have failed to define a more striking point than any of the three which he has recorded (at pp. 277, 278) in discussing the essential phenomena of all living bodies as opposed to those that are dead.

Kant has well said that “the cause of the particular mode of existence of a living body *resides in the whole*”; and Müller, that “there is in living or organic matter a *principle* constantly in action, the operations of which are in accordance with a rational plan, so that the individual parts which it creates in the body are adapted to the design of the whole—and *this it is which distinguishes organism.*”

It is this principle, residing in the whole, to which our author gives the

name of *psyche*, to which I by no means object,* but on the contrary gladly take it as the basis of what I have further to say, with this preliminary observation, that we have here passed the bounds of all possible scientific investigation; seeing we have to do with that which is not ponderable or visible, nor can in any way be brought within the cognizance of our senses. The mind can only grasp it as a living *idea* caused to inhere in each organism, and to build up and maintain that organism according to the preconceived plan of the Creator.

How else can we explain the phenomena of life? How conceive of the possibility of its commonest manifestations? Why should a crab, which has lost its claw, reproduce a crab's claw rather than a human hand? The notion of the infinite variety of created things arising from the qualities of protoplasm is (as I have shown) absurd; and, moreover, this variety is produced (as Huxley has so well shown †) as if by an invisible artist shaping the organism from the very commencement according to its "kind"; "fashioning" in continuance its members when as yet there was none of them; and in the meantime, leaving tokens in each case of the links which connect each individual with the grand whole; so that all is shown to be the evolution of the harmony existing in the infinite Λόγος or Word, of which all creation is but (as it were) the expression.

The *psyche*, whilst it inheres in the organism, dominates and turns to its own end all chemical forces. Take away the *psyche* and in the moment all is reversed. The torch no longer burns but is at once extinguished.

I may add that according to the belief and experience of mankind in all ages, this *psyche* is not necessarily dependent on or even connected with *protoplasm*.

In propounding the opposite doctrine, contrary to all evidence, *Positivism* proves itself an Impostor, and should be dealt with accordingly.

Rev. C. L. ENGSTRÖM.—The Rev. J. H. Barker has asked me to read the following communication; the views are his own, and, as only the reader, it is unnecessary for me to say whether I agree with them or not:—

"While I fully acknowledge the formidable difficulties surrounding the subject of this able and interesting paper,—difficulties which might well deter any but the acutest intellect from attempting to grapple with them,—I may yet, as one of the oldest members of this Institute, claim the privilege of making a few remarks upon it. The mystery of *Life* is a subject upon which I have bestowed much thought; and I entirely concur with the author of this paper, that the solution (or even partial solution), of the problem 'is one of the most pressing duties of this generation.' I would begin by expressing my conviction that it is hopeless to expect to

* But, if we have ψυχή feminine, we must also have ἕρος masculine, or our 'idea (being thus differentiated in nature), would be incomplete. The French term "*puissance formatrice*" is liable to no such objection.

† See "The Contrast between Crystallization and Life," *Transactions*, Vol. VIII., p. 194.

arrive at any satisfactory conclusion in the matter, without a vast extension of our ordinary notions as to the *variety* of creation in two particular directions :—(1) As to the extent to which the imponderable or æthereal forms of matter are involved in the structure and functions of living things ; and (2) As to the existence and almost boundless variety of *psychical entities*, as forming constituent parts of *animal* organisms, the latter being more strictly than the former individual *creations* ; but both, of course, products of the same Infinite Power and Wisdom, and formed to carry out the purposes of His beneficence. In a matter of this kind, hypothesis is unavoidable ; but, as it has been well observed, hypothesis, if duly guarded, is a necessary and most useful precursor of ascertained truth. And the supposition that a “world of mind” exists, having at least as wide a range as that which science recognises as the world of matter, is one which is in perfect harmony with the patent facts of our own consciousness, and of our surroundings.

“After specifying two classes of theories on the subject of Vitality, Dr. Nicholson points out (p. 283) the importance of distinguishing between the *production* and *direction* of *force* in living beings, and that what accounts for the one does not necessarily account for the other. He had just before granted to the advocates of the materialistic theories, that *many* vital phenomena are due to ordinary physico-chemical forces, but denied that *all* could be so accounted for. This truth (which rescues us from being reckoned as mere pieces of machinery) may, I submit, be best explained upon a principle which I strongly hold,—that *all* force is, properly speaking, the *acting of will* ; and that we have here the simultaneous and concurrent action of *two* wills, a higher, which originates and directs the force that produces the physical and molecular motions, and a lower (created) mind and will, which has been endowed with a limited control over, and direction of, the physical forces of matter, whether gross or æthereal. The term ‘created mind’ here used I regard as equivalent to the author’s *psyche* (p. 291). It is not necessary to suppose that this mind is always *conscious* of its own actions, or that it always acts from purpose. This cannot be said even of the *human* mind. And though to draw a distinct line of demarcation between the operations of the two forces, the *physical* and the *psychical*, is clearly beyond our power, this does not forbid the recognition of both as factors in vital movements.

“To refer, then, only to theories alluded to in the paper before us:—the author points out (pp. 269, 270) the absurdity of assuming the identity of the chemical characters of *living* and *dead* protoplasm, and the fallacy of arguments based upon this assumption. And this, coupled with the obvious fact that no proof has been, or indeed can be, given, of the chemical condition and composition of *living* protoplasm, entirely vitiates many of the conclusions of the materialistic school of philosophers.

“Mr. H. Spencer’s definition of ‘life’ (p. 279) as ‘a combination’ of certain phenomena, is quite inadequate, because it specifies no producing cause for the combination. Mr. Bastian (p. 281) places all vital action on the level of chemical and mechanical phenomena. But does this writer undertake

to tell us what is the originating and directing power in these *latter* phenomena? What if they are to be ascribed to the constant working of the 'higher Will,' both as to the production and direction of these forces, while the former include the action of the *psyche* also? And even if it be admitted, that the hypothesis alluded to in this connexion,—viz., that vital force is a transformation of solar energy 'stored up' in vegetation, and thence transferred to the animal system,—is as true as it appears to me doubtful, this would only remove the vivifying power a step or two back, and virtually lodge it in the hands of Him who makes the sun to shine.

"As to the now fashionable doctrine of the *storage* of solar energy in food and fuel, based, as it appears to be, on the analogy of *potential* force latent in a bent metallic spring, or in a condensed volume of elastic gas, the two cases are so different, that they do not admit of comparison. It appears to me that according to the theory referred to on the first part of page 282, 'life' is a power associated temporarily with matter, superior to physical and chemical forces, and controlling them, and not necessarily ceasing to exist when separated from matter. This comes very near to the idea of a 'psychical entity, distinct from matter,' and approximates closely to Dr. Nicholson's *psyche*. For while at p. 283 he calls the living being 'a vehicle for the action of the chemical and mechanical forces of the universe,' at p. 290 he speaks of 'mere *collocation* of materials as being wholly powerless to construct definite organisms; this very *collocation* being itself the result of some directing and unifying power, which we must suppose to be present in a greater or less degree in all forms of life.'

"A little further on he considers the hypothesis of an inner directing power inevitable, 'alike in man and in the Moner.' These large results, however, can hardly be ascribed to the *psyche*. I think, therefore, we must understand the Professor as admitting the presence of *one Power* alike in all organisms, viz., that of God. I would add that this would also be a sufficient answer to Professor Tyndall's demand for an agency, under the name of 'formative power.' The presence of such a power (using the term in its concrete rather than its abstract sense),—the presence of such a power does not, of course, forbid the exercise of *will* on the part of the living beings. They are, doubtless, quite compatible, within the limits assigned to the *psyche* by its Maker.

"The case of vegetable life is so far simpler than that of animals, that no *psyche* can reasonably be predicated as dwelling in plants; and yet something like it is found there also, which seems, at least, to control the chemical and mechanical forces of Nature. But is this a necessary deduction? May it not with equal reason be inferred, that in this department of living nature, the *only will* concerned is that of the great Ruling Mind? For the purpose of clothing the earth with plants in all their beautiful variety, and providing food for the animal world, that Supreme Will forms from dead matter the definite compound we call protoplasm, employing aethereal agencies in the construction and development of all their tissues and varied products; and their life or death is the continuance or cessation

of that action in any cell, or aggregate of cells, which form an individual plant.

"Here, as in the case of animals, only to a far greater extent, the life and development and variation of plants, are placed by the Creator within the power of man, not to originate a single living atom, but only to modify (within certain limits) the results of the various processes.

"Thus, after all, the life both of plants and animals, must be ultimately traced to Him who is 'the Author and Giver of life.'"

Professor O'DELL.—I regret that I had not the advantage of seeing a proof of Professor Nicholson's paper before I came here, as I should then have been able to have discussed it better. Nevertheless, I think the whole matter lies in a nutshell, the pith and marrow of the question being simply—Is there life independent of matter? We need not go to inferior organisms for the answer; let us seek it in ourselves. I will give a very simple illustration, which I think will prove that life exists independently of matter and of mind too. You put your fingers on the keys of a piano, and, being a good and perfect player, you produce most excellent and harmonious music. Stand away from the instrument, and it is to all appearance quite dead: there is no music there; no manifestation of harmony. But does that prove that you are dead? Does it prove that you have ceased to exist? By no means. Well, it is the same with the human mind. There is the body and there is the brain, and if the brain does not manifest its power and thought, its reflective and perceptive abilities, it is not because the mind is dead, but that it has ceased to act upon the corporeal body. It cannot be proved that the mind* is dead because there is no manifestation of the mental abilities. I will give you another illustration. Take the same piano, unstring it, or damage it in some way. Let the same pianist try to play upon it, and the result is that you hear the most inharmonious sounds. Do you say the pianist is affected? By no means. You have the same pianist, with the same ability; but he does not produce the same sounds. So if any of you should meet with an accident, or be thrown upon a bed of sickness: you are living, but you may not manifest intelligence,—the mind still exists, though you may only manifest such an amount of intelligence, or want of intelligence, as you would look for in an idiot. I think these illustrations will suffice to show that the mind may exist quite apart from the body, and quite independently of any material existence.

Dr. HOGGAN.—It is always a hazardous thing to attempt to criticise the writings of so scientific a man as Professor Nicholson; but all I have to say is in the same direction as he has gone himself. I desire to direct my observations especially to one theory which is receiving general support at present amongst our greatest minds, namely, that life is merely the sum total, as expressed by Professor Nicholson, of the vitality of individual cells—in other words, that it is simply organisation in action. Now, we know very well, that in the human body we have really two different forms of life

* Soul or life.

represented—namely, the life we speak of as “the spirit,” and the life which each individual cell has for itself. But if life is merely the result of the vitality of all these individual cells, it ought, if all these cells remain in action, to be maintained in the body after what we call death. We know, however, that this is not the case; although a man dies, all the cells in his body may still retain their individual life. We can prove this in many ways. Half-an-hour after death we can electrify the nerves so that a stimulus may be conveyed to the muscles, and they will contract and exhibit the same sort of action that is going on in life. Again, if we take the cells, with proper precautions we may see them working as rapidly and with as much life as ever, although the spirit has left the body for ever. It is evident from this that the vitality of the cells of our body is not our life; and if we reverse the matter, we may say that the cells can live independently of the original life by which they were produced. Suppose we go to a surgical operation. We can take the skin from a man’s arm and use it on a patient who requires a new nose, whereby we may grow a million of cells in what is taken from the body of one man and transferred to that of another. Here, you will see, there has been a complete change, the living cells taken from one person and transferred to another, being not entirely dependent on one life for their life. Doubtless the individual cells die a certain time after life has left the body, just as if we had a pet canary that was left without the necessaries of life, and died in consequence; but when transferred, as I have pointed out, they live and manifest all the phenomena of life. It would, however, be ridiculous to say that their life is the result of the sum total individually of our own. If we endeavour to find out what it is that keeps those cells in life, it is in reality the food we take. After a certain time, when food is not supplied, they die as the canary does when it is neglected. But if we wish to find out what is the nature of the directing force of which Professor Nicholson speaks, we find that we can really form no conception of it. It is spoken of as a “force” or “power”; but I do not think that these are the terms to apply. It is, in fact, merely an agent, just as the wind is an agent to blow away a straw or the dust. It is the Creator who stands behind and originates the directing power. We see but the phenomena connected with matter. We know that the earth and the planets are moving in their prescribed cycles, and that they have done so for ages, and we speak of such things as due to repulsion and attraction; but there is something behind which keeps propelling the earth and the planets through space, and it may be that the same power which guides the stellar systems also guides each individual cell, and that to it the action of life in the body is also attributable. What I want to say is this, that all the definitions of life remind one of the celebrated dictum that “language was given to enable us to conceal our thoughts,” although in the language used by different philosophers I find not so much that they wish to conceal their thoughts as that they desire to conceal their ignorance. The truth is, that we have not got a step further, notwithstanding all the philosophers who have given us the results of their science and knowledge—we have not

arrived at a more satisfactory opinion yet as to what life is, or how it gets where it is found, than is obtained from the account given by the historian of creation, who tells us that man having been made, God "breathed into his nostrils the breath of life."

Captain F. PETRIE.—Before this discussion closes, I would venture to refer to Professor Lionel Beale's most valuable Address, as President for 1879-80 of the Royal Microscopical Society. In that Address he treats of the phenomena of living matter, and after a careful examination of the subject concludes thus :—

"I venture to throw the most important conclusions into the form of propositions.

"The phenomena of living matter are not due to the properties of the matter. Vital actions are of an order absolutely distinct from any known physical actions.

"Life force, or power, has not been, and cannot be, evolved in any way from matter only, nor is it a consequence of changes occurring in matter ; but, on the contrary, life influences and determines changes in the matter, which changes are quite peculiar.

"The vital phenomena of the lowest simplest forms of living matter are of the same general nature as those of the highest, and are as far removed as are the latter from any kind of physical change.

"The assertion that any low forms of life are near to, or establish any transition towards, the inorganic, is not justified by any facts known to science.

"The attempts made to make the public believe that the so-called properties of living matter belong to the same order or category as that in which known properties of known forms of non-living matter can be included, are not to be justified by an appeal to facts, and are therefore contrary to the principles of science.

"Every vital phenomenon is absolutely different in its nature from every physical (mechanical or chemical) action. There is no analogy whatever between the two sets of phenomena.

"The present state of knowledge justifies the conclusion that no form of living matter existing at present, nor any one which existed in the past, directly originated from non-living matter, or in any way derived its powers or properties from the non-living."

The meeting was then adjourned.

ADDENDUM.

The closing observations of Professor G. G. STOKES, F.R.S., in his Address as President of the British Association for the Advancement of Science, in 1872, may not be out of place here. He said :—

"What this *something*, which we call Life, may be, is a profound mystery. We know not how many links in the chain of secondary causation may yet

remain behind ; we know not how few. It would be presumptuous indeed to assume in any case that we had already reached the last link, and to charge with irreverence a fellow-worker who had attempted to push his investigations yet one step further back. On the other hand, if a thick darkness enshrouds all beyond, we have no right to assume it to be impossible that we should have reached even the last link of the chain, a stage where further progress is unattainable ; and we can only refer to the highest law at which we stopped to the fiat of an Almighty Power. To assume the contrary as a matter of necessity, is practically to remove the First Cause of All to an infinite distance from us. The boundary, however, between what is clearly known and what is veiled in impenetrable darkness is not ordinarily thus sharply defined. Between the two there lies a misty region, in which loom the ill-discerned forms of links of the chain which are yet beyond us : but the general principle is not affected thereby. Let us fearlessly trace the dependence of link on link as far as it may be given us to trace it, but let us take heed that in thus studying second causes we forget not the First Cause, nor shut our eyes to the wonderful proofs of design which, in the study of organized beings especially, meet us at every turn."