THE MECHANISTIC AND VITALISTIC CONCEPTS OF LIFE

(A chemist's view)

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A DISCUSSION of life phenomena from the mechanistic or vitalistic point of view requires that the limits and definitions of these theories be understood.

The distinctive characteristic of the mechanistic theory of life is that in a series of sequential events, the position and the attributes of any particular event in the series may be easily determined. The mechanist has always believed that his conclusions are borne out by the experiences of those sciences which deal more especially with the causal relationships of the ultimate elemental particles of matter: namely, physics and chemistry. He has believed that in the qualitative and quantitative aspects of these sciences he should be able to find a practical basis upon which to construct his theories. It is upon this basis the mechanist proposes to show that life is a purely physico-chemical process, although he recognizes that many of the attributes of life, such as growth, reproduction, heredity, and voluntary acts, are not at present susceptible to the interpretations of these sciences. However, the pure mechanist insists on believing that all of these will ultimately be explained. The mechanist likewise believes that all things, living and non-living, material and otherwise, may be regarded as "material simple" and that the existence of living things must finally be explainable on a physico-chemical causal basis.

The vitalist, on the other hand, believes that permeating material matter there is in reality a psychical agency—an "entelechy" according to Driesch or a soul according to numerous other vitalistic writers. Quite naturally too, it seems to me, we find less agree-

ment regarding the exact definition of vitalism than we do regarding mechanism. In fact, there are at present at least two vitalistic theories advocated which agree in arguing against the strictly physico-chemical basis of life and against the theory that all life is "material simple," but which nevertheless do not agree completely upon other phases of the explanation of the origin of life. Many variations in the interpretation of these two theories of vitalism exist, but in the course of this discussion it is impossible to consider them in detail.

The controversy between the adherents of the mechanistic and vitalistic concepts of life is one of long standing. Its history is associated on the one hand with the names of Descartes, Schwann, and Huxley, who advocated the mechanistic concept of life, and on the other with the names of Aristotle, Hippocrates, and Müller, who, unable to find in the mechanistic physico-chemical basis satisfactory explanation for all that they observed, advocated the vitalistic concept. The question under consideration is likewise a live one, if we can judge from the number of books and articles that have been published recently bearing upon one phase or another of life from a scientific-philosophical point of view. Scientists and philosophers alike have contributed to these writings.

The rise of the mechanistic theory, which was widely accepted during the 18th and up until the middle of the last century, was due in a large part to the fact that during this period physiology, which had had its origin in the practical medicine of Hippocrates, made its most rapid advance. This movement was climaxed in 1859 by Darwin's publication of his *Origin of the Species*. With the publication of this work, it was generally supposed that an explanation of the origin of the transmission from generation to generation of certain structural characteristics had been solved. It was not strange that many persons, and among them many scientists,should immediately assume that it was but a short step from Darwin's interpretation of these structural characteristics to the establishment of the physico-chemical process responsible for the transmission of these structural characteristics from individual to individual. As we now see it, however, the theory gave little, if any, assistance to the interpretation of the process regarding fundamental responsibility for the transmittal of specific characteristics.

In addition to Darwin, many other writers and thinkers of

the present day have added strength to the cause of mechanism. Late in the 19th century, John Tyndall, the famous British natural philosopher, said in the course of an address: "We find in matter the promise and potency of every form of life." The late Loeb, doubtless the most prominent mechanist of our time, speaking of parthenogenesis said: "The process of regeneration was thus revealed as a purely physico-chemical phenomenon, leaving no necessity or room for the postulation of a guiding principle, aside from the purely physico-chemical forces." Among those who have most recently contributed to the mechanistic idea, we find Joseph Krutch. In an article entitled "Conclusions" in the *Atlantic Monthly* for February, 1929, Krutch states that "living is merely a physiological process with only a physiological meaning."

With this rise of mechanism and the increased interest in physiology, physics, and chemistry, it is easy to see how it came to pass that vitalism virtually disappeared during this period. In fact, I believe it is generally conceded that from Darwin's publication of the *Origin of the Species* until perhaps a decade ago, vitalism, except for the fact that it was in the minds of such persons as Driesch and a few others, received very little attention from the thinkers in philosophy, biology, and the physical sciences. More recently, however, and perhaps as a reaction, a very active interest has been revived concerning the explanation of life phenomena.

Indeed, until a short time ago it appeared to many as though the mechanist had furnished rather extraordinary and conclusive explanation of the physico-biological phenomena of life, and that it would be but a short time until the how, the when, and the why of life phenomena itself would be explained. During this time a great impulse was given the idea of determinism (or mechanism) by the work of Loeb, and by the work of other physiologists, both in animal and plant life, and by physicists and chemists, the latter group being especially active in the field of colloidal chemistry. As a result of their research, it was shown that striking instances of life-like phenomena could be produced and that life processes could be imitated and apparently completed by the use of chemical means. Dr. Martin Fischer in his volume *Oedema and Nephritis* showed that certain irregularities that accompany and characterize the production of flowers may be imitated by taking thin strips of gelatin, painting them with an acid, and then dipping them into

water. The places where the acid has been painted on, swell and simulate growth processes. Bechhold in his volume *Colloids in Biology and Medicine* summarizes certain experimental work of Stephane Le Duc, in which Le Duc shows how solutions may be prepared in which inorganic salts agglomerate into structures resembling seaweed, mushrooms, toadstools, etc., and that in some respects the internal structure of these products resembles that of cells in living organisms.

These experiments of Fischer, Le Duc, and others of like kind that are at hand in the literature, have been used by mechanists in support of their thesis. It is true they appear to have produced life-like phenomena. This fact, coupled with the fact that these results have been brought about by physico-chemical agents, has led the mechanist, it seems to me, to erroneous conclusions. True, he has produced through physico-chemical means structures that resemble living things, but it must be borne in mind that the resemblance concerns external structure only. The chemical and physical internal content of Fischer's gelatin, for example, is far different from the chemical and physical composition of the growing plant whose activities he describes. The same is true of Le Duc's experiment in the simulation of the formation of seaweed, etc. Outside of structural formations, these and similar experiments have failed to produce results that have shown the functional attributes associated with life.

This lack of conclusiveness is further apparent in the research of Loeb and his followers, who carried out a very comprehensive study upon the substitution of chemical agents for normal fertilization. Loeb discovered that if the eggs of a sea urchin are placed for a short time in hypertonic sea water and then returned to normal sea water, they will develop. The means by which the solution was rendered hypertonic appears to make no difference in the final results. In fact, Loeb found he could cause the development of the eggs by immersing them in a pure sugar solution of slightly greater osmotic pressure than normal sea water. The fertilization that resulted from the most optimum conditions, however, did not furnish a perfectly true picture of the phenomena of natural fertilization. Nevertheless, the eggs frequently developed into larvae capable of moving about; but they did not live long, they always appeared sickly, and always behaved abnormally. The most outstand-

ing peculiar abnormality of the sea urchin's egg when placed in a hypertonic solution is the fact that it does not form a fertilization membrane.

Loeb, observing this, set about seeking means to induce the formation of such a membrane, and was rewarded by finding a series of agents that would do this. Among these, the monobasic fatty acids, which are soluble in sea water, were found to be very effective. For example, if mature sea urchins' eggs are placed in sea water containing acetic acid and then placed in normal sea water, development of a fertilization membrane occurs in one hundred per cent of the mature eggs. However, eggs that are treated in this manner undergo a few divisions and very soon die. In fact, they die more quickly than unfertilized eggs under the same conditions. The process however affords a membrane similar to that accompanying the process of natural fertilization; and when the two processes of fertilization membrane formation and osmotic pressure treatment are successively carried out, an apparently perfect imitation of natural fertilization is produced, and usually one hundred per cent of the eggs develop and produce normal larvae. The work of Loeb, which has been verified many times and also very largely added to by other investigators, has added great strength to the mechanistic cause. However, the facts remain that although parthenogenesis has apparently produced normal first generations, it has been impossible to carry the process beyond this stage. It is probable that the physico-chemical agents in such cases have released or abnormally catalyzed the reproductive hormone. The essential thing to remember, then, is that the process did not continue into the second generation, although the chemical and physical composition of the larvae must have been nearly the same as the normally produced larvae. Apparently, then, something associated with life processes was lacking, else reproduction would have again occurred.

Another group of scientists feels that if it were possible to get at the intrinsically small particle of matter, both living and nonliving, we might find the explanation of life there. Physical scientists have succeeded in measuring ultramicroscopic organisms of colloidal nature and find them of the approximate dimensions of colloidal inorganic matter. "This result," says Donnan, British physical chemist speaking on the subject *The Mystery of Life* before the British Association for the Advancement of Science, "gives

rise to strange hopes. If we can find a complete continuity of dimensions between living and non-living, is there really any point where we can say that there is life and there is no life?" In reply to this question, may I say I can hardly see how continuity of dimensions may have anything of a fundamental nature to do with life, unless, as I shall point out later, certain functional aspects of matter may be associated with ultimate units of matter.

It is true that the physical characteristics of small colloidal particles, both living and non-living, have many properties in common: both may be precipitated from solutions by various salts, acids, etc., exhibit Brownian movement, and are absorbed by activated carbon. Moreover, there are certain agglutinative reactions of blood particles and bacteria that have their counterpart in the chemistry of inorganic compounds of colloidal nature. However, the fact that these fine particles in living and non-living matter may behave much alike is by no means conclusive proof that they are identical in their intrinsic internal character. These are only a few of the many facts having a bearing on the relationship of living to non-living matter which may be found in the literature of colloidal chemistry.

A generation ago many scientists believed that soon the riddle of life would be solved. They did not understand, however, the nature of the astounding discoveries and advances that were imminent, nor did they realize how meagre the knowledge of the chemist and physicist really was concerning the structure of matter.

The first great upset regarding the insufficiency of the chemist and physicist to explain matter in its ultimate form became apparent in the discovery of radium by Becqueril and Madame Curie. With the discovery of radium and radio active substances, the atomic concept of Dalton was replaced by the electronic conception of matter. This conception is that the atom is composed of a positive nucleus, the proton, which is surrounded by electrons spinning about in orbits. A little later it was observed that as these electrons spin about in orbits, they may under certain influences hop, as it were, from one orbit to another; and it appears from recent research that this atom, composed of proton and spinning electrons, is also being accompanied by a set of waves.

Thus, the further the scientist pushes his investigations, the more he is perplexed by the darkness into which he peers. In fact, the revelations of the past three decades have been so stupendous

that those who understand them best are unwilling to conjecture of their ultimate results. When the physicist sees his concept of position and velocity suddenly swept aside by new relationships and experimental facts; when he sees his time-worn notion that nature is understandable and subject to law shattered into bits as he extends his experimentation; and when he finds that the interaction between the individual intrinsic elemental units of matter of which the physical world is composed cannot be unequivocally predicted—it is as though a leaden twilight had suddenly descended about him.

These new discoveries seem to indicate that in an elemental analysis, when we deal with matter of an atomic or electronic or subelectronic nature, there seems to be considerable evidence of action for which there appears to be no cause. That is, while causality may be applied within wide limits to large bodies, it does not follow that, because an atom behaves in a given manner in one system, it will behave in the same manner again; but only that there is a certain probability that it may do so. In a larger body these small atomic units exist in millions upon millions of numbers and therefore these atomic uncertainty activities complement each other until the large body obeys the laws of physics within limits. Moreover, careful physicists agree that the more they study physical phenomena, the more they are convinced that there is almost no physical law that can be exactly verified.

It is significant, too, that most physical scientists believe that these new discoveries forecast still others of even more fundamental nature. Just what these new considerations may mean as regards the interpretation of life phenomena, no one can foretell. Temporarily at least, since the activities of ultimate particles seem essentially unpredictable, it appears, does it not, that the causality demanded by mechanism is seriously shaken?

The development of the functional activities of living organisms is another phase of this question that is very difficult of explanation. If the mechanist can explain such functional activities as assimilation, growth, consciousness, and reproduction, which have already been mentioned from a physico-chemical point of view, he will have removed the most serious argument against his case, for it is primarily through functional activities that living matter appears to be different from non-living.

For the purpose of our study of this phase of the question, sup-

pose we select a simple unicellular organism, the amoeba. We find that this minute organism possesses certain functional characteristics of form, assimilation, reproduction, growth, response reactions, that thus far have proven impossible of explanation on a physico-chemical basis and that have no counterpart in non-living matter. Although it is subject to the chemical and physical forces of the medium in which it exists, the amoeba maintains its form, is able to conserve the protoplasm of which it is constituted, and reproduces. Moreover, this minute organism without a doubt has as components of its protoplasm some very complex compounds; and it is difficult, is it not, to conceive of these being formed into a stable system from physical forces and chemical substances without the influence of some form of energy to carry on the process. If the amoeba is composed of complex chemical substances, as we believe it is, these are constantly being synthesized from the food ingested, and in this little micro-organism is being carried forward a synthesis that no chemist has yet been able to duplicate.

The living organism, whether of high or low order, selects from those chemical substances surrounding it the material necessary for its sustenance. In living animals of high order, however, two phases of selectivity appear to be operative: namely, selection of the necessary substance from its own digestive tract to reconstitute its physiological being, and the differential selection of the rough foodstuffs. Nowhere in non-living matter do we find a property of selection which eventuates in self-reconstruction or metabolism. It is also very difficult to account for the differential digestive apparatuses and technic of different classes of animals from a purely mechanistic point of view. In short, metabolism—self-reconstruction—the process by which the living organism selects, distributes, and arranges the accumulated components into stable equilibrium, has no counterpart in non-living matter.

Another functional activity thus far defying adequate explanation, and incidentally one which has furnished most of the fireworks for the controversy between the mechanists and the vitalists is "proprioceptiveness,"—the response to environment, environmental sense, the psychic attribute, the consciousness of living matter, or whatever you may call it. The vitalists, for the most part, claim that the most fundamental characteristic of living matter is this "proprioceptive" response to environment. Even in the simplest cell,

they believe, the "proprioceptive" adjustment of the means to an end is the all important characteristic of the phenomenon of life of the cell. In this I believe the vitalists are right, for it is quite impossible, it appears, to understand the phenomenon of the life of any species of living matter without understanding its complete environmental background. It is only through this means, it seems, that it is possible to show why the organism developed in the particular manner in which it did rather than in some other. It is very difficult to see how the various functional attributes could have developed without the presence of this quality of "proprioceptiveness." There seems to be no way, it appears, by which this particular function could be associated with physico-chemical processes alone as they are known.

Suppose we accept the theory that living matter originated from non-living; that first there was a formless universe—a void composed of ether, electrons, protrons, photons, or the elemental stuff of which matter is composed. These elemental units are supposed to have combined into molecules, and molecules into larger masses, until eventually we have comet masses, planet masses, and sun masses. Eventually these were arranged, so this theory says, into solar systems and took their places in the universe. Then on the surface of one of these planet masses, at least on the Earth mass, water condensed, rocks disintegrated, forming carbon dioxide. The nitrogen derived from the atmosphere or from the nitrates combined with hydrogen of the water to form ammonia. Then in time amino acids and other organic acids were formed. These in turn aggregated into larger groups, colloidal particles. Finally these colloidal aggregates agglutinated, and we have a unicellular bit of protoplasm. Thus, this theory says, came about the beginning of living things,—the egg perhaps.

Even if we accept this theory for the formation of the egg, how can we by any possible stretch of the imagination account for the development of the embryo from the egg through its various evolutionary stages from a purely chemical or physical basis, or must it not be accounted for on the basis of its past evolutionary history as well as its present and future functional ends? The anatomist claims that in the development of the embryo he can show the various stages of evolution of the species. Perhaps here we may find the history we are seeking. But the real question is: why

did the embryo develop as it did? An examination of the living embryo will show that it is not alone a collection of protoplasm, muscles, nerves, tissues of various kinds, etc., but that its attributes and functions are coupled with a "proprioceptive" sense. It is, I believe, this "proprioceptive" quality which is responsible for the evolution of the embryo and which is also eventually responsible for the development of its functional activities. Whether this "proprioceptive" sense is associated with the atoms, electrons, molecules, protons, waves, or what not, matters little, for it is but reasonable to believe that in the evolution of the species a certain environmental sense is essential. The living animal organism, the living human body, is more than an aggregation of tissues and bones. It is more than a physical and chemical unit made up of proteins, carbohydrates, fats, and bony structures, etc., for in life it is under the dominance and direction of consciousness.

Moreover, the efforts which living things have put forth have always been to overcome environment. Living matter has always fought to free itself from its surroundings, and its ability thus to strive, it seems to me, presupposes a "proprioceptive" sense. Therefore it appears that it is reasonable to believe that as living things have struggled with environment and thereby developed certain physical attributes, there has also been a concomitant development of the "proprioceptive" qualities. Haldane writing in "Scientific Calvinism" says: "If man has evolved from animals of lower mental organization mainly as a result of natural selection, it is difficult to see why his consciousness should have evolved if it is merely a looker-on in the game and cannot actively influence events." It seems to me that Haldane is right in questioning whether the will and the emotions which have their bases in consciousness may not likewise have evolved and developed. This naturally leads to the question: If consciousness plays such a prominent part in life processes, does it have its inception in the "material simple" of the physical sciences?

Charles Johnson in an article entitled "Conditioned Immortality" ably answers this question, I believe, when he points out that whatever our views of ultimate particles of matter may be, "it is wholly inconceivable" that these particles should be so arranged as to "result in a perceiving consciousness....No philosophic speculation can bridge that chasm. There is, perhaps, one possible loop-

hole: that each electron is endowed with consciousness from the very beginning that consciousness is coeval with these primordial units of being. But if we accept this solution, we thereby admit that the origin of consciousness is an insoluble mystery....If, as we have suggested, there is in each electron and proton some germ of consciousness, then it is a consciousness, beginningless and endless, and without change or the sense of duration—absolute immortality."

Thus it appears impossible to account for such functional activities in living things as assimilation, metabolism, and reproducton; and especially does it seem impossible to account for the "proprioceptive" quality, the quality of consciousness of living things, on a purely physico-chemical basis alone. And, although the physicist, the chemist, the biologist, and the physiologist have been able to probe far into the structure of matter, none have yet been able to discern the hand that starts the physico-chemical engine which has produced life.

You will recall that the theory advocated by Driesch and his followers is constructed upon the idea that at certain critical periods in the development of living things, there is operative a directing influence. Driesch, it has already been stated, calls this force an "entelechy" and claims it controls the physical forces of living matter; in fact, it is assumed to be able to suspend the second law of thermodynamics.

Haldane and his followers, although not accepting Driesch's theory, believe that the functional activities of life are not adequately explained on a physico-chemical basis, and that there is a phenomenon which causes the organization of the essentials of life on a higher level than is possible with physical and chemical forces alone. In fact, they believe that the phenomenon of life is constituted of certain elements that are not subject to physical laws. The exponents of this theory, which had its beginning with Hippocrates, lay great stress upon the "unconscious activities of life as natural processes."

In his recent volume *The Sciences and Philosophy,* we find Haldane setting forth Hippocrates' idea and giving expression of his own approval of the same in the following words: "The coordinated activity manifested in the phenomena of life was regarded by Hippocrates as nothing more than a visible and tangible manifestation of Nature. He found coordination and its maintenance in the as-

pect of nature which he was studying, and refused to be moved by the philosophical atomism of his time...." Continuing, Haldane says: "It seems to me that the attitude of Hippocrates was and is the only possible attitude in scientific biology."

This suggests the possibility that life itself is an intrinsic energy, a part of nature's scheme, with ability to mobilize the forces and elements of nature within wide limits for its own maintenance and evolution. Is this belief not just as sensible as Driesch's entelechies described in his volume *The Science and Philosophy of the Organism,* which he says "are not energies, not forces, not intensities, not constants, but entelechies," for if this so-called entelechy inaugurates action, intensifies action, or suspends action, it must be conceived of as a force or energy of a magnitude and direction sufficient to mobilize the physical and chemical forces and energies at hand for its use? It appears that Driesch has failed to see the significance of his postulation of a controlling "entelechy" in the light of our concept of energetics. It is inconceivable that a scientist would accept such an interpretation of life without many mental reservations. It is doubtless for this reason that actual scientific research workers have chosen to pay little attention to the vitalist's theory of life; that is, they have felt that if the hypothesis of Driesch and his followers was to be accepted as representative of the vitalists, a very distinct limit was placed upon their experimental investigations. Doubtless they are right in coming to this conclusion. There are, for this reason I believe, many among our leaders in science who subscribe to the mechanistic point of view largely because they fear that to do otherwise would be giving expression to a lack of faith in the investigations they are conducting.

Suppose we accept the view of Hippocrates and Haldane, as I understand it, that life is an aspect of nature, that it is a form of energy, an intrinsic part of nature, which has the power to coordinate and maintain itself through the subjugation of the chemical and physical forces with which it is associated. Rignano, the Italian philosopher, predicts the discovery of such a form of energy and designates it as "a vitalistic nervous energy." Such a postulation does presuppose that there is a plan in the universe.

Is there, I wonder, anything strange or unscientific in the idea that living things, the world, and the universe are being shaped toward a definite purpose and end? Even a casual review of life

in its various relationships, such as we have just made, clearly discloses its teleological significance. This teleological aspect of nature manifests itself constantly from the simplest functional activities of living phenomenon to its most complex physiological and psychical attributes. It is difficult to understand how one who has given attention to the apparent order in the cosmic universe, who recognizes evolutionary processes, who knows the experimental facts surrounding heredity, and who subscribes to a perceiving consciousness, can arrive at the conclusion that the Universe, and the Earth with its living things, developed from scattered bits of matter haphazardly thrown together without the interposition of some plan not accounted for by the mechanistic theory.

Perhaps, life itself is an intrinsic energy of the Universe—an energy without mass, without form, without duration; yet a part of the Eternal scheme of things.