ered, in physics for instance, and suppose further that men had set about, as indeed they have, to try all sorts of "fool experiments"; then, in view of the infinite multiplicity of things which they might have tried, what is the probability that they would have discovered all or nearly all of the fundamentally new facts which twenty years ago were yet to be brought to light? According to the theory of probability, this chance is practically nil. Let us put with this result the further fact that for many hundred years men had been looking at phenomena with care and had not found the important facts discovered in this twenty-year period. Then, in view of all this we can only conclude that it is extremely probable that there is yet an unlimited, or at least a very great, number of fundamental facts still to be discovered. We can hardly refuse to draw the further conclusion that all we know at present is only a mere fragment of what we shall ultimately find out.

We can indicate the immediate prospect more precisely by a consideration of the present state of physics which I believe now stands in an enviable position with respect to all science and all philosophy—in fact, with respect to every body of doctrine whose development makes for human progress. In recent years it has undergone a marvelous rejuvenation, into the detail of which we can not now enter. It requires no eye of prophecy to see that this is certain to make itself felt in valuable advances in astronomy and geology and to lead the way to new and fundamental conquests in chemistry and biology. All branches of the sciences of phenomena should sit at the feet of the new physics in order to get in touch with her most recent discoveries and to carry them over to their consequences in other special domains of research.

All indications point to magnificent conquests of research in the immediate future and for many years to come. An analysis of the past gives us a strong assurance that there are many important things yet to be discovered. The progress of the preceding decade shows that we have in hand tools that have been effective, and we can hardly suppose that they have just now finished their work when we consider the sort of achievements which have just been made. Notwithstanding that the war in Europe will cut off many young men of enthusiasm and power and hinder the work of all investigators on that continent, it is yet true that there is an enthusiastic body of workers, especially in America, still carrying on their silent conquests which will take a place alongside the great achievements of the race. It is a pleasure to know that there is such an organization as this society to foster a work of this sort. I am glad that so many of us have entered upon the undertaking already and I hope that young men and women of promise will see a possibility of labor toward the good of the whole future of mankind and will lay their lives and their energies upon the altar of service in science.

R. D. Carmichael

THE PHILOSOPHY OF BIOLOGY: VITALISM VERSUS MECHANISM[1]

In comparison with mathematicians and physicists, biologists have contributed little to philosophical literature, notwithstanding the close relations existing between their science and philosophy. The most notable instance of recent years has been Driesch, whose attempts at philosophical commentary and interpretation seem, however, to have given on the whole little satisfaction to either biologists or philosophers. Bergson—"the biological philosopher," as Driesch calls him—bases much of his doctrine on biological data, and the use of such data appears to be becoming more frequent among philosophers. Lately professed biologists have shown somewhat more tendency to enter the field of philosophical discussion; and it is remarkable that when they do so they often adopt a vitalistic point of view. Haldane's "Mechanism, Life and Personality" is one recent illustration of this tendency, and the present book of Johnstone's is another.

[1] "The Philosophy of Biology," by James Johnstone, D.Sc., Cambridge University Press, 1914.

As the author himself explains, the point of view and methods of treatment are largely those suggested by Driesch and Bergson. The book is not long; there are eight chapters entitled, respectively, the Conceptual World, the Organism as a Mechanism, the Activities of the Organism, the Vital Impetus, the Individual and the Species, Transformism, the Meaning of Evolution, the Organic and the Inorganic; there is also an appendix with a brief account of the chief principles of energetics. In the table of contents is given a concise yet complete and connected summary of each chapter. This makes it unnecessary for the reviewer to summarize the whole book, and this review will be confined chiefly to a criticism of the author's main contentions and especially of the arguments by which he seeks to support his vitalistic thesis.

The first chapter discusses the relation of conceptual reasoning to reality. The author agrees with Bergson in regarding intellect as essentially a biological function, which reacts in a characteristic manner on the flux of reality and dissociates this more or less arbitrarily into detached elements; the aim of this dissociation is practical—namely, to facilitate definite or effective action on the part of the organism. Scientific method follows an essentially similar plan; our scientific descriptions and formulations of natural processes are conceptual schemata; their correspondence with real nature is inevitably inexact; they necessarily simplify and diagrammatize. In reality, however, nature can not be regarded as a composite of separate processes, individually susceptible of exact description in intellectual terms, and interconnected in ways which are similarly definite and quantitatively determinable; it is rather a continuous or flux-like unitary activity, exhibiting a progressive and irreversible trend; hence actual duration is distinct from the conceptual time of physicists. Now the intellect, in making its characteristic conceptual transformation, neglects or ignores or even falsifies much of the essential character of reality. This is how it becomes possible to view the living organism as a mechanism: the physiologist substitutes for the real living organism the conception of a system of physico-chemical processes, conceived as interconnected in a definite way; by doing so he is enabled to view the organism as essentially a physico-chemical mechanism; but we must note that the conceptual elements out of which he builds up his scientific view of the organism inevitably determine the nature of this end-conception, which is physico-chemical or mechanistic only because his method does not permit him to regard the organism as anything but a summation or integration of the physico-chemical processes that form the elements of his synthesis. As a result, however, he really misses what is most distinctive of living beings, and reaches a point of view which is not only inadequate for scientific purposes—as shown by the failure of physico-chemical analysis in the case of many vital processes—but in its very nature far removed from the actuality itself.

This is the fundamental criticism which the author makes of the accepted scientific methods of investigating life-phenomena. In the remainder of his book he interprets the characteristics of the organism and of the evolutionary process from this general or Bergsonian point of view. He sees operative in life a distinctive agency, corresponding to the "élan vital" of Bergson or the entelechy of Driesch, which acts typically in a direction contrary to that characteristic of inorganic processes; these latter tend toward homogeneity and dissipation of energy; in living organisms, on the contrary, evolution tends toward the production of diversity, and the tendency of entropy to strive toward a maximum may be compensated or even reversed by vital activity. "Life, when we regard it from the point of view of energetics, appears as a tendency which is opposed to that which we see to be characteristic of inorganic processes. . . . The effect of the movement which we call inorganic is toward the abolition of diversities, while that which we call life is toward the maintenance of diversities. They are movements which are opposite in their direction" (page 314). It is here that the author's views become most seriously open to scientific attack; the evidence that the second law of thermodynamics does not always apply to life-processes is certainly inadequate; there is exact experimental evidence that the first law (that of conservation) holds for organisms; and the storing of solar energy by chlorophyll is in no sense evidence that the second law is evaded. There seems in fact to be a fundamental misconception in this part of the author's argument. He holds that life may play the part of the Maxwellian demon under appropriate circumstances (page 118), and defends this view on the ground that the laws of molecular physics are statistical in their nature and might be different if it were possible to control the movements of individual molecules; such control, it is implied, is possible to the vital entelechy. It seems to the reviewer, however, that the application of the second law to gases or solutions implies simply a tendency of the freely moving molecules to uniform distribution; the resulting homogeneity can be prevented only by adding energy to, or abstracting it from, part of the system; even Maxwell's demon has to work a partition which resists the impact of the faster molecules—a consideration which shows that any coordination or sorting of molecules would in itself involve the performance of work. Johnstone's supposition, however, is that the vital entelechy can, without altering the total energy of the system, control or direct the otherwise uncoordinated motions of the individual molecules; and that the purposive or directed character of the individual organism's life, and also of the whole organic or evolutionary process, is conditional on the existence of such an agency, and is indeed the characteristic expression of its activity. He thus maintains, in effect, that physiological processes are unintelligible unless we can assume the existence of some such directive agency peculiar to life, which can vary the nature, intensity and direction of the physico-chemical processes and coordinate them in the interest of the organism. This "entelechy" is what imparts their distinctive quality to life-phenomena.

It has long seemed to the reviewer that failures or deficiencies in the physiological analysis of complex or delicately adjusted functions form no sufficient ground for rejecting such methods of investigation as in their nature inadequate. Vitalists, however, are fond of this kind of attack; and both Haldane and Johnstone adduce instances which they believe make it incredible that physico-chemical processes, unguided by an entelechy, could ever form the basis of vitality. At present our knowledge of the physiology of embryonic development and of certain types of form-regulation is especially defective; and such phenomena are cited more frequently than any others as proving the inadequacy of physico-chemical analysis. Driesch's "logical proof of vitalism," quoted in the present book, is an instance of this tendency; even relatively simple processes like muscular contraction and nerve conduction remain largely mysterious, and we find also scepticism as to the possibility of any satisfactory account of these processes in physico-chemical terms (*cf.* page 100 of the present book).

A twofold reply to this type of vitalistic argument may be given. First, it is to be noted that the failure of physico-chemical analysis is often due to mere complexity of condition. But complexity, as such, does not introduce any essentially new problems; it simply makes more difficult, and may for a time make impossible, the task of analysis. Provided that the more elementary processes forming a complex process are characterized by *constancy* in their nature and in the conditions of their occurrence, any degree of complexity in the total process is possible. Ordinary experience with complex artificial systems, of a mechanical or other kind, verifies this contention; we find that there is no limit other than that set by practical expediency to the complexity of a system whose component parts operate and interact in a constant manner. In all such cases smaller and simpler parts are taken as units from which higher compound units are built up, and these secondary units are then similarly utilized for the construction of more complex systems; these may be still further combined, and so on. The one indispensable condition is that there should be an essential invariability in the operation and interaction of the parts of the system. Similarly with life and its manifestations: the complexity of organisms and of organic processes, so far from making us despair of the adequacy of physico-chemical analysis in dealing with vital phenomena, seems in fact to the reviewer the surest witness to their essential adequacy. For these vital processes, however complex and mysterious, are unfailingly *constant* in their normal manifestation; one has only to reflect on what is continually happening in the body of a healthy man in order to realize this; and the stability of conditions thus shown surely has the same basis as have the stability and constancy of the simpler non-vital processes which we everywhere find as components of the vital. The basis of this stability is simply the exactitude with which natural processes repeat themselves under identical conditions.[2] If this were not the case, how could a physico-chemical system of the vast complexity of (*e. g.*) the human organism ever exhibit stable existence or constant action? It is impossible to doubt that the constancy with which complex physiological processes operate is conditional on the constancy of the simpler component processes—those which form the subject-matter of physico-chemical science. Constancy in the character, mode of action, and interconnection of the component substances and processes is evidently indispensable to the constancy or stability of the product of their integration, the living organism. We find in fact that mysterious and unintelligible physiological processes, *e. g.*, the regeneration of the lens in the eye of a salamander, recur under appropriate conditions with the same constancy as the simplest and most intelligible, say the formation of a retinal image by that same lens. It is clear that if we admit the adequacy of physico-chemical methods in the one case we must be prepared to do so in the other.

Second, it is to be noted that the organic processes show evidence by their very limitations that the underlying mechanisms are strictly physico-chemical in character. Thus vitalists call especial attention to the instances of development and form-regulation which have so far baffled all attempts at physico-chemical analysis. "Does not this mean," Johnstone asks, "that in biology we observe the working of factors which are not physico-chemical ones?" The limits to the regulative power are less frequently cited by vitalists; yet surely evidence of this kind is equally relevant. Why, if an entelechy can restore the amputated arm of a salamander, can not it perform a similar miracle in the case of a man? The fact is that nothing is proved by citing such cases. But on the whole they seem clearly to imply that the properties of the organism are throughout the properties of physico-chemical systems, differing from inorganic systems simply in their complexity. The reviewer knows of no facts which, viewed without prepossession, necessitate or even unequivocally favor the contrary view. Those vitalists who maintain that material systems are incapable, without the aid of an entelechy, of developing the characteristics of life—and who even hold that fundamental physical laws like the second principle of energetics are evaded by organisms—must adduce evidence of a less doubtful kind in support of their thesis. The peculiarities which organisms exhibit appear to the reviewer to lead to precisely the contrary conclusions, and to indicate that stable and constantly acting physico-chemical systems may exhibit a degree of complication, both of composition and of behavior, to which literally no limits can be assigned.

Another mode of reasoning popular among vitalists, and equally fallacious from the physico-chemical standpoint, is that an entelechy can, without the performance of work, guide or coordinate toward a definite end processes which themselves require the performance of work. This view implies that in the organism molecular movement may be directed, retarded, or accelerated at the will of the entelechy. But in Newton's first law of motion it is surely made clear that any deviation in the move-

[2] Just why there is such repetition is rather a philosophical than a scientific question; but it seems probable that it is at bottom an expression of the homogeneity of the conditions of natural existence, space and time.

ment of a particle from a straight line, or any retardation or acceleration of its motion, involves work in precisely the same sense as does the initiation of the movement. Now it is evident that guidance or regulation of the sequence of events in any material system must involve one or other of these kinds of processes. In other words, it is physically impossible for any agency to modify the processes in any material system without modifying the energy-transfers in that system, and this can be done only by the introduction of compensating or reinforcing factors of some kind—*i. e.,* by altering the energy-content of the system—which is equivalent to the performance of work. One is forced to conclude that all such attempts at the solution of biological problems are based on fundamental misunderstandings. Dogmatism must be avoided in scientific criticism; nevertheless it seems to the reviewer that the following general considerations are incontrovertible, and that they are quite inconsistent with the type of vitalism represented by Driesch and Johnstone. First, the organism is a system whose development and continued existence are *dependent* on the rigid constancy of physico-chemical modes of operation; here, if anywhere in nature, stability of the internal or vital conditions is indispensable; otherwise it is inconceivable that the complex living system could persist, and maintain its characteristic activities and often delicate adjustment to the surroundings. Clearly the numerous and diverse processes whose integration constitutes life could not deviate far from a definite norm without fatal derangement of the whole mechanism. Second, the basis for this regularity is the regularity of physico-chemical processes in general. These, the more closely they are subjected to scientific scrutiny, appear the more definite and constant in their character: this conclusion is not—as many philosophical critics of scientific method maintain—an illusion resulting from the inherently classificatory nature of intellectual operations; it is simply a matter of observation and experimental verification. Repeat the conditions of a phenomenon and the phenomenon recurs. We find this to be equally the case in living organisms and in non-living systems; and it appears to be as true of psychical as of physical phenomena. The difficulty in dealing with organisms is to secure exact repetition of conditions, because organisms are in their nature complex, and complexity means a large number of factors which may vary. Regularity, in fact, may be said to be of the very essence of vital processes; special devices for securing regularity (*e. g.,* constancy of body-temperature, of the osmotic pressure and reaction of the tissue-media, etc.) are highly characteristic of organisms. It would seem that an entelechy disturbing this regularity, however intelligently, would be not only superfluous but detrimental. Moreover, we must always remember that unequivocal evidence for the existence of such an agency is quite lacking.

Thus there seems to be no valid reason to believe that organisms differ essentially from non-living systems as regards the conditions under which the processes underlying vitality take place. The *conditions* of natural existence and happening appear everywhere and at all times to be homogeneous, whatever existence itself may be. This conclusion seems unavoidable to the impartial observer of natural processes; the repetition so characteristic of nature is apparently an expression of this central fact. The flux-like character of natural existence, so insisted upon by Bergson and the other Heracleiteans, is to be admitted only in a highly qualified sense. Repetition and the existence of discontinuities and abrupt transitions are equally characteristic; and all of the evidence of physical science goes to show that a repetitious or atomistic construction lies at the very basis of things. So far from the intellect arbitrarily imposing a diagrammatic uniformity and repetition upon a nature which in reality is a progressive flux and never repeats itself—to the student of natural science it appears rather true that the conceptualizing characteristic of the reasoning process is itself one expression of this fundamental mode of natural occurrence—that it is, in fact, the derivative of a peculiarity which pervades nature throughout. Such a view, if well established, would refute the contention that scientific methods, being intellectual in their character, necessarily involve a falsification; and would dispose of attempts to discredit physiological analysis on the ground that life transcends intellect and hence is properly to be investigated by other than scientific methods.

The attempt to find in organisms evidence of special agencies not operative in the rest of nature seems to the reviewer to show less and less promise of success as physico-chemical and physiological science advances. Thus the author's attempt to limit the applicability of the second law of energetics to the non-living part of nature is quite unjustified by the evidence which he presents. The interception and accumulation of a portion of the radiant energy received by the green plant, in the form of chemical compounds of high potential, is in no sense an infringement of the second law; as well might one hold that the partial transformation of radiant energy into potential energy of position, as seen, *e. g.*, in the accumulation of glaciers, is an instance of this kind. The partial transformation of energy at low potential into energy at high potential is in fact a frequent occurrence; thus the temperature of an electric arc far exceeds that of the furnace which generates the current; similarly the animal organism utilizes energy derived from oxidation of carbohydrates and proteins to build up compounds of much higher chemical potential, viz., the fats. If living organisms—systems which are specially characterized by utilizing chemical energy as the main source of their activity—exhibit such tendencies, there is in this fact nothing anomalous from the point of view of physical science. To say on the basis of this kind of evidence that "life appears as a tendency which is opposed to that which we see to be characteristic of inorganic processes" (page 314) is surely unwarranted from any point of view.

This review is not necessarily an attack on vitalism, but only on certain current forms of vitalism. It can scarcely be denied that there is something distinctive about life; but at the present advanced stage of physical science it seems futile to argue that the vital process is the expression of an agency which is absent from non-living material systems. Viewed temporarily or historically, the vital is seen to develop out of the non-vital; many of the steps in this process are still obscure; but with the progress of science it becomes more and more evident that the development is continuous in character. Hence, if we are to account for life, we must equally account for non-living nature. Now since nature exhibits itself as coherent throughout, we must conclude that in its inception[3] it held latent or potential within itself the possibility of life. This is not entirely an unbased speculation; even in the character of the chemical elements life is foreshadowed in a sense, as shown in Henderson's recent interesting book.[4] In a recent discussion,[5] in some respects related to the present, the reviewer has called attention to one implication of the scientific view of nature and the cosmic process. If we assume constancy of the elementary natural processes, and constancy in the modes of connection between them—as exact observation forces us to do—there seems no avoiding the conclusion that—given an undifferentiated universe at the outset—only one course of evolution can ever have been possible. Laplace long ago perceived this consequence of the mechanistic view of nature, and the inevitability of his conclusion has never been seriously disputed by scientific men. Nevertheless, this is a very strange result, and to many has seemed a *reductio ad absurdum* of the scientific view as applied to the whole of nature. The dilemma can be avoided only if we recognize that the question of ultimate origins is not, strictly speaking, a scientific question at all; and in saying this there is implied no disparagement of scientific method. As an object of scientific investigation nature has to

[3] I do not use this term necessarily in a historical sense, but rather in the sense of ultimate origin of whatever kind,—which it may well be necessary to conceive as extra-temporal.

[4] "The Fitness of the Environment," Macmillans, 1913.

[5] SCIENCE, N. S., 1913, page 337.

be accepted as we find it; and why it exhibits certain apparently innate potentialities and modes of action which have caused it to evolve in a certain way is a question which really lies beyond the sphere of natural science. Such considerations, if they do not exactly remove the vitalistic dilemma, yet separate sharply the scientific problems which organisms present from the metaphysical questions to which the phenomena of life—more than any others—give rise. If we consider the organism simply as a system forming a part of external nature, we find no evidence that it possesses properties that may not eventually be satisfactorily analyzed by the methods of physicochemical science; but we admit also that those peculiarities of ultimate constitution which have in the course of evolution led to the appearance of living beings in nature are such that we can not well deny the possibility or even legitimacy of applying a vitalistic or biocentric conception to the cosmic process considered as a whole.

Although disagreeing with the author's main contentions, the reviewer wishes to recognize the merits of the book as an interesting, enthusiastic and ingenious contribution to the literature of its subject. We have noted some errors in matters of biological detail, but these are not such as to affect the main argument. The brief account of certain physiological processes seems somewhat out of date; the account of the nerve impulse is unsatisfactory, and certainly few physiologists now hold that a muscle is a thermodynamic machine in the sense conceived by Engelmann; there is some evidence of unfamiliarity with biochemistry; the term "animo-acid" instead of amino-acid recurs a number of times, a mis-spelling perhaps appropriate to a book which is really a modern plea for animism.

Ralph S. Lillie

Clark University,
October 12, 1914

THE COMMITTEE OF ONE HUNDRED ON SCIENTIFIC RESEARCH

On the invitation of the chairman of the executive committee of the Committee of One Hundred on Scientific Research of the American Association for the Advancement of Science, there was held at his house on the evening of November 28 a meeting of the executive committee and of some members of the subcommittees and of the general committee resident in or near Boston. There were present Mr. Charles W. Eliot, president of the association and chairman of the committee, Mr. E. C. Pickering, chairman of the executive committee, and Messrs. E. W. Brown, J. McKeen Cattell, W. T. Councilman, Charles R. Cross, Reid Hunt, Richard C. Maclaurin, A. A. Noyes, Theodore W. Richards, Elihu Thomson and Arthur G. Webster.

Plans for the work of the committee were discussed, and preliminary reports were presented from four of the subcommittees, as follows: Research funds, by Mr. Cross; research work in educational institutions, by Mr. Cattell; the selection and training of students for research, by Mr. Brown, and improved opportunities for research, by Mr. Richards.

In addition to the subcommittees whose membership has been announced, the committee on improved opportunities for research has been completed, and consists of Messrs. Theodore W. Richards, chairman, W. T. Councilman, Richard C. Maclaurin, T. H. Morgan and E. H. Moore. The subcommittee on the selection and training of students for research has also been formed, and consists of Messrs. E. W. Brown, chairman, Ross K. Harrison, George A. Hulett and W. Lindgren. Subcommittees have been authorized on research institutions, research in industrial laboratories, research under the national government, research on the Pacific coast and research in the south, but these committees have not yet been completely organized.

Reports from subcommittees will be presented at the meeting of the Committee of One Hundred, which will be held in the Houston Club, University of Pennsylvania, Philadelphia, at 2 o'clock, on the afternoon of December 28.

J. McKeen Cattell,
Secretary