*Meeting of the Aristotelian Society at 21, Gower Street, W.C. 1,
on December 5th, 1921, at 8 P.M.*

III.—ON THE LIMITATIONS OF A KNOWLEDGE OF NATURE.

By JAMES JOHNSTONE.

SOMETIME about the beginning of the eighteenth century, and during the last ten years of his lifetime, Newton spoke to a friend about his work: "I know not," he said, "how it may seem to the world but, as to myself, I seem to have been only as a boy playing on the seashore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me." These words, I take it, were, in a way, an admission of cessation of individual effort. By reason of his resolute and disciplined imagination, his genius for experiment and the mighty mathematical weapons that he had made, Newton had found a way. He thought about truth as lying there, spread out, so to speak, and waiting to be discovered and the means whereby that discovery was to be made were known to him. He knew that what he had found was only an infinitesimal part of all that was accessible by application of his methods. But there is only so much dynamic mental quality in any man, a little more or a little less as we vary from each other, and this can be "intended" to the investigation of nature, the pursuit of pleasure or the acquisition of wealth, and it can be exhausted. In little over forty years Newton, like his great predecessor, Descartes, had spent his creative energy, and the undiscovered, but discoverable ocean of truth was still there.

By the time that these words were spoken the course that physical and natural science was to follow during the next century and half had already been marked out by three great men: Galileo, to an extent which has only been appreciated by

some of us as the result of the relativity discussions of the last few years ; Descartes, by the exercise of an "inventiveness" which, as Clerk Maxwell said, "knew no bounds" ; and Newton himself, who had found the way. Throughout that century and half one seems to trace little or no really creative scientific thought but only a successful working out of the great ideas of the seventeenth century. From these came our conceptions of matter, inertia and force ; the laws of motion ; the theory of universal gravitation ; the description of the Solar system ; the notion of the ether as the locus and substance of physical change ; the ideas of illimitable space and uniformly flowing infinite time ; the Cartesian mechanism of life and the restricted theory of relativity. About the middle of the nineteenth century new ideas did come : perhaps the notion of natural selection was really new—I do not know—perhaps we had in that idea, the first clear distinction between statistical and individual results—a distinction that does not yet seem fully to be realized and employed in biological science. And then, a little later, we had from the mathematical investigators, of whom J. Clerk Maxwell is the type, the germinal work that was to bring about a revolution in knowledge.

Throughout those two centuries scientific men employed the inventions of Galileo, Descartes and Newton. Physics and natural science (which has always clung to the skirts of physics) explored the seashore, described and catalogued the pebbles and shells and now and then ventured out on the ocean. The eighteenth and nineteenth centuries elaborated the methods of the seventeenth, employing them in ways that were certainly unanticipated by Descartes and Newton—one wonders what the great French philosopher would have thought about the modern mechanistic conception of life, as it has been stated by Jacques Loeb ! It has been noted that as the methods of the seventeenth century became exhausted so did the materialistic science of the nineteenth seem to approach

finality and tend to become complete and rounded-off, in a sense. Perhaps one may be quite wrong but it does appear as if the natural science of the latter third of the last century regarded its framework as sound and entirely satisfactory and one gets suggestions of that kind from some of Huxley's essays. What was the good of quarrelling about the unknowable? The speculative game was drawn and what was left for Science was the work of strengthening the framework and filling in the details.

Perhaps this hard nineteenth century materialism had its work to do in the evolution of social and political liberty. It had to assert itself as a way of interpreting the meaning of the "passage of nature" and of searching out the origin and destiny of man. Medieval doctrines of social and economic privilege had to be destroyed. Perhaps that work is not yet fully accomplished and while that is so science will remain materialistic. There is still a fraudulent and grotesque spiritualism to be detected; a muddled vitalism to be replaced by something sounder and a prematurely formulated "Eugenics," that may be utilized to maintain caste and social disability, to be sifted clear from humbug. We may leave materialistic biology to these tasks.

Two centuries later than Newton a modern thinker,* writing while a revolution in scientific thought was being effected, refers to "the passage of nature which is only another name for the creative force of existence." "This operative presence" he says, "which is now urging nature forward must be sought for throughout the whole, in the remotest past as well as in the narrowest breadth of any present duration. Perhaps also in the unrealized future. Perhaps also in the future which might be, as well as in the future which will be. It is impossible to

* A. N. Whitehead, in *The Concept of Nature*, Cambridge University Press, 1920, p. 73.

meditate on time and the mystery of the creative passage of nature without an overwhelming emotion at the limitations of human intelligence."

I place this saying over against the well-known words of Newton because the two utterances illustrate very well the change in our attitude towards what is meant by scientific discovery. But I must make it clear what I mean by the "passage of nature" because this is a notion far less subtle than that indicated by Mr. Whitehead. And I think that a candid and impartial survey of the speculative biology of the late nineteenth and twentieth centuries must force one to the recognition of a *twofold* passage of nature. Perhaps this is indicated even in Huxley's contrast of the cosmic and ethical processes but it is expressed, with the utmost clearness, in Bergson's vital impetus as opposed to the tendency of matter to pass into the inert condition. I take it that the fundamental concept of physical science is the second law of energetics—the universal augmentation of entropy—and I assume (though it is difficult to be sure) that nothing in the most modern results of mathematical relativity tends, in the least, to weaken this great conception. Nature, then, has direction, or passage, which is such that all that we recognize as physical change tends continually to diminution: the Universe, regarded as a physical mechanism is one that is running down, or in Bergson's term, *detending*. This is the one aspect of the passage of nature.

To the biologist, however, it can only be one aspect. I am well aware that the entropy-increase law is a statistical one and that it can only hold true for organic entities which are above certain limiting magnitudes: for Maxwell's demons the law would have a double sign and the entropy of an isolated system would increase or decrease with equal probability. The biologist must recognize that, even in organic systems, entropy tends always towards augmentation but surely he misunderstands the meanings of reproduction and adaptation if he does not see that what he calls life is the incessant attempt of certain

physico-chemical systems that we call organisms to resist the increase of entropy. There is, therefore, a passage of nature which is not that tending to inert-materiality (that is, to statistical inertia) but which is the opposite to this passage and is what one must understand by life in the physical sense. I am not sure whether we ought to insist on this two-fold passage of nature or, perhaps, regard it as a double aspect, in some way or other, of the same condition. Is life something that resists the passage of inorganic nature, or is inorganic nature already inert and extended, while living systems pass through it? Perhaps one inclines to think about a two-fold passage because of some mental constraint that tends always to a dualism of one kind or another.

I suppose that biologists must accept the main result of generalized relativity: "the differentiation of the one quality of extension into time and space," but I confess that it is very difficult to do so. It seems to me that for speculative physiology space-time cannot be completely isotropic—the x , y , z and t -dimensions cannot be of the same quality. I take it that our notion of space rests entirely on our degrees of freedom of bodily mobility. I can move backwards and forwards, and from side to side with equal facility but not nearly so easily can I move upwards and downwards. And the equal freedom of mobility in the x , y -plane is only possible because I can turn my body round a vertical (z)-axis in one direction or the other with equal facility but even then the turning movement from left to right is not quite the same as that from right to left but differs in some subtle way. And, of course, the difficulty of generating the z -dimension depends on the condition that our freedom of mobility is restricted because we move in a gravitational field. Only since we have become enabled to dispense (in thought) with the gravitational field as something physically unique has our space become truly isotropic.

Such as we are, however, the space-dimensions are not entirely isotropic and far less so is the t -dimension when

compared with the x , y , z -ones. The quality of duration I take to be entirely different from the others and we must, I think, regard it, with Bergson, as the cumulative continuity of life. It is a passage as well as the persistence of that which, in a sense, has passed. It is life-extension but it does not seem to me to be capable of "extensive abstraction" in Mr. Whitehead's sense. The passage is not a uniform one (though I confess I find it difficult to say exactly what is meant by uniformity in a durational passage).*

Obviously we do not obtain the conception of a moment of organic duration by the method of extensive abstraction, for this "moment" depends on what Bergson calls the "rhythm of duration": thus the "event-particle" in the conscious life of a boy of fifteen is not the same as in the man of fifty, nor does it appear to be the same in the ephemeral insect as it is in the long-lived reptile. The matter, however, is much too difficult to be pursued here.

It is also necessary that I should deal with the purely biological conception of variability. In general we mean by a variation a deviation from a morphological type, but I generalize the notion so as to include also deviations of functioning, acting, response and mentality, perceiving no essential differences between these organic activities. The organic "type," whether it be that of form, or behaviour, or mentality is, of course, only a convenient abstraction, but the general notion of "types" has brought with it the conception of variability. It is very convenient, in our description of nature, to speak of specific types and then of variations or departures from them. Observations and experiments, we say, "ought" to give unique values but for the accompanying errors of methods. So, also,

* "Time" in the sense of life-extension I regard as "humped" in the "neighbourhood" of a conscious entity in somewhat the same way as Mr. Eddington regards space as being "humped" or "peaked" in the neighbourhood of a material particle.

we postulate organic types which are accompanied by variations in the same way that experimental results are attended by error. Then we search (rather unsuccessfully, it must be admitted) for the "cause" of variability. Obviously, this conception of variability is the consequence of our adoption of the logical category of determinism.

Now there are organic activities that have all the appearance of spontaneity—whether these are truly spontaneous or not I do not argue—but there are also many activities which we call responses to events that occur "in the environment." These we can investigate and we can endeavour to establish a relation of functionality, in the mathematical sense, between the environmental "stimulus" and the organic response. It would be easy, I think, to make a series of such responses, beginning with tropistic ones, passing through reflexes in the decerebrate animal, reflexes in the intact one, and ending with those responses which we call "intelligent." In the various terms of such a series there will be "more or less" determinism, if one may say so without being misunderstood. At the one extreme we find (as in a tropism, or taxis) a degree of functionality which approximates closely to the behaviour of a compass needle in a variable magnetic field, and at the other we find that apparently capricious behaviour or functioning which must be so annoying to physiologists. I suppose that there must either be determinism, or no determinism, and so I have simply to reject the validity of this concept (except as a working method, of course) even at the risk of being exposed to the dreadful accusation of throwing overboard scientific method altogether!

One other thing I must endeavour to make clear—the distinction between the organic variations that are called "fluctuations" by biologists and those others that are called "mutations." The former are individual and acquired while the latter are congenital and are transmitted by heredity—they are not acquired. In the lower animals fluctuations, or

acquirements, do not materially influence the process of transformism and what are of significance from that standpoint are mutations, which do lead to transformism. In man, of course, certain fluctuations persist by reason of tradition: they are not bodily variations but means of action by tools (using the term "tool" in its most general significance). Now the distinction between fluctuations and mutations is evidently one that depends upon our distinction between a racial and individual life-passage. Life is, of course, a continuous career in the morphological sense: what is discontinuous in it is the personal passage which is marked by memory, blame, merit and responsibility—sin, if you like. The mutational variation belongs then to the racial passage and it is an acquirement of this continuous life-career; the fluctuating variation arises in the discontinuous personal life-passage, or career.

I return now, after this digression, to the saying of Newton. The ocean of undiscovered knowledge must, to him, have been like the material oceans explored by the voyagers of his century: they were unknown but whatever was there did not depend, in itself, in the least upon the vessels and instruments of navigation; it was only *revealed* by those methods. So, to Newton, physical laws were there waiting to be discovered, so to speak, but even if they were to remain undiscovered they would still be there. Without doubt he could have made most of the discoveries of the eighteenth century and perhaps those of the nineteenth up to the time of Clerk Maxwell had he been capable for a long period of that sustained intension of mind of which he spoke, for (I take it) those discoveries were implicit in the creative work of his early lifetime.

But were the later physical and biological results of the later nineteenth and the twentieth century there in the same sense as were, for instance, planetary theory and tidal dynamics? Were the quantum hypothesis of radiation and

our present-day notions of atomic structure present already in Newton's undiscovered ocean of truth? Could these conceptions have been deduced by him by a sufficient intending of mind from the mathematical, physical and dynamical relationships known to him? I take it that they could not and that only by the creative thought of Newton's nineteenth century successors did these parts of the ocean of truth *actually come into existence*.

Otherwise it would appear that there was mental determinism and that Clerk Maxwell, Hertz, Planck, Einstein, J. J. Thomson and others thought as they did think *because* Newton's mind worked in the way *it* did. And nothing in the results of modern biology seems to suggest that. I have referred already to the way in which mutations of form arise with all the appearance of spontaneity or lack of causation. It must have occurred to many biologists to attempt to predict the evolutionary career of some organic stock or other but beyond suggesting that certain specific forms are in process of extinction, or that some bodily parts of an organic species are becoming vestigial and tend to disappear nothing of the sort has, I believe, been attempted. No biologist has ventured to predict the appearance of a mutation—the essential step to a process of transformism. Now one admits the incredible complexity of the physico-chemical systems in which such mutations arise and we may well despair of laying bare the physical antecedents of a mutation—supposing that there *are* such. But the overwhelming impression that most biologists have, in thinking about these matters at all, is that of the spontaneity of appearance of the mutation. I admit that there is evidence that environmental changes may *induce* mutations; expose an organism to some environmental stimuli and mutations may arise but what we have to deal with here are active, functional adaptations of the organism, ways in which it *responds* to the external change. But that the particular nature of the response is a function, in the mathematical sense, of the particular

change in the environment does not seem to be established, nor do I think that it is likely.

Probably we must generalize "responses" in the widest possible way. I have argued elsewhere that the most various kinds of behaviour are of essentially the same organic nature. An "adaptation," I take it, is not merely a change in colour or form that renders an animal less conspicuous to its enemies or prey, or confers upon it some useful means of finding food or shelter, or of avoiding its foes. These changes are of much significance in hypotheses of the means of transformism and so they are the things that we usually think about when we speak of adaptations. But temporary variations of functioning (such as the process of sweating when one becomes warm) are also adaptations. So is the behaviour of a man who takes an umbrella with him on an unpromising morning, or that of the skipper of a vessel when he shortens sail in anticipation of bad weather.

Again the invention and use of a new tool is an adaptation and so also is the discovery of a new mathematical device (say tables of logarithms). It is quite true that some of these organic modes of behaviour are transmitted by heredity so that they become integral in the life-processes of the race while others would disappear on the death of the individual in which they are evolved. That, however, is because the one kind of adaptation (mutations) is characteristic of the racial life passage (it is germinal) while the other appears in the individual life-passage (it is somatic). It would disappear if it were not preserved by tradition.

So I can make no essential distinction between morphological or "organic" adaptations of functioning and those changes of ways of mental operation that we call scientific discoveries. The strengthening of the muscles of the fingers and wrists of a pianist; the formation of a skin callus on some part of the hand in consequence of the persistent holding of a tool; manual dexterity in some repetitional mechanical operation;

facility in arithmetical work; the finding of some new mathematical relationships (say Maxwell's four thermodynamic potentials) and so on—all these seem to me to be processes that have the same significance. In each of them there is something creative or new, some means whereby the organism becomes the better able to oppose the tendency to inert-materiality. This is, of course, pure Bergsonism: Maxwell's thermodynamic functions or the Christoffel "tensor analysis" are means of acting on nature. Sooner or later, someone endeavours to give even the most abstruse of mathematical results a "physical meaning", and sooner or later also, these results receive "applications" in industry. All "intended" thinking, I take it, aims at establishing inter-connexions between events in nature, All general discoveries are mental adaptations—something really new in organic behaviour.

And if that is so we must, I think, regard Newton's ocean of truth as amorphous in structure. The relations that are to be discovered in it are only *in* it in the sense that they come into existence with the thought that makes the relations. Our knowledge of nature, as Eddington says, is a knowledge of form and not of content, but even the form is carved out from a nature that may have any forms—or as many as are implicit within the limitations of the human mind. At any moment in human history, then, our description of nature is complete, that is to say, what more is in it than that which we know has still to be made by us. I feel that, as I have stated this there is something paradoxical in it, but my meaning will, I trust, be plain.

Finally, I return to Mr. Whitehead's saying—perhaps that which is urging nature forwards is in the future as well as in the present and past; and in the future that may be as well as in future that will be. I take this to be literally true. The impetus is certainly in the remotest past as well as in the present, since we inherit modes of acting on nature which have "passed" only in the sense that they came into existence one

after the other in "time," but which nevertheless endure in that they constitute our present life-mechanisms. The impetus is in the future that will be, surely, because many of the things that we do are done in order that some change, or condition clearly thought about but which has not yet happened, or does not yet exist, will come about as the result of our acting. So from the wolf we have bred the sheep dog and we are rearing rustless wheat and potatoes that are immune to disease. These organisms were not *discovered* in nature nor did they exist there in the literal sense—they were made, if my interpretation of the meaning of mutations is a right one. The impetus is in the future that may be, because in seeking for something we make something else. There is an ideal communistic state that may be and that is ardently desired by some. In seeking to make it our present-day idealists are, without doubt, making some other society, the form of which is not discoverable.