II.—LIFE AND MECHANISM.¹

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It is a proposition very generally accepted by physiologists, that all organic processes could, had we means sufficiently delicate to investigate them, be reduced to series of causes and effects; or, which comes to much the same, that all that ultimate analysis can reveal in these processes, is matter acting as a 'vehicle' of energy. The present article will be devoted to an examination of this proposition in the light of biological facts, and to an endeavour to show that, however great a relative value it may have, it is in fundamental respects inconsistent with these facts.

I shall assume at starting that the proposition just referred to is true, and, as a consequence, use the language of physical science in referring to biological phenomena. I shall then proceed to show that the consistent application to these phenomena of physical conceptions leads to difficulties from which the only escape lies in substituting conceptions and language entirely different, and whose nature will appear in the course of the discussion.²

For physical science a steam-engine is an arrangement of matter into which energy passes from surrounding objects, and out of which, in a different form, the same energy is returned. It will therefore serve the purposes of our discussion to compare a steam-engine so conceived with a living organism. Energy enters the organism in the form of the potential energy which is present in a chemically unstable mixture of oxygen and various forms of food. Similarly the potential energy of an unstable mixture of oxygen and coal enters a steam-engine. From both the steam-engine and the organism this same energy is given off again in the form of heat and mechanical motion. So far the analogy between the steam-engine and the organism is complete.

¹ The greater part of this article is based on a paper read before the Edinburgh Royal Medical Society, March 9, 1883.

² In reviewing *Essays in Philosophical Criticism* (*Nature*, Aug. 23, 1883), Mr. Romanes objects to discarding the conception of cause and effect as applied to the phenomena of life. It is no doubt true that physiology, in so far as it is an abstract science, ought not to regard life under any other conception. In the sequel, however, it will be shewn that there is an absolute necessity for discarding the conception of cause and effect if we are to attain to an idea of the nature of life which is not both abstract and self-contradictory.

But let us carry our inquiry a little further. The energy which leaves the machine is dissipated on the surroundings in a manner which, so far as our conception of the machine is concerned, has no reference to the future maintenance of its mechanism in action. When the fuel is finished, the machine cannot replace it, but simply runs down. If, now, we turn to the organism, we find that the energy which leaves it is by no means dissipated at random on the surroundings. On the contrary it is a characteristic fact that a part at least of that energy is so expended as directly or indirectly to bring about the maintenance of the organism in activity. The surroundings, in fact, are so acted on as to be caused to direct to the organism a supply of potential energy sufficient to make up for what has been spent. A man, for instance, will always direct his labour into some productive channel. Thus in agriculture his labour is expended in so acting on the land as to cause it to yield to him various forms of food. By producing clothing and erecting shelter for himself he in a less direct manner causes his surroundings to conduce towards maintaining his body in activity. Similar facts may be observed in the case of any of the lower organisms, and are characteristic of everything living.

Here, then, we have reached something in which an organism differs from an ordinary machine. There is nothing in all this, however, to lead us to suppose that organisms are not machines; though it is necessary to assume that they are so constructed as automatically to supply themselves with food and perform other actions necessary to their being kept in motion. It is, for instance, quite easy to suppose that the *Paramecium* is such a machine. The *Paramecium*, which is one of the Infusoria, has a ciliated channel passing a short way into its interior. The cilia move in such a way as to direct a current of water, and whatever it may contain, into and out of this gullet. Nutritive particles which are in this way brought within reach are seized upon and used as food. It is quite possible, surely, to imagine a machine constructed on the model of the *Paramecium*, and renewing its supply of fuel in the same way as the *Paramecium* renews its supply of food. And in the case of higher organisms it seems reasonable to suppose that the difference is only a difference in the degree of complication and delicacy of the mechanisms involved.

We may, for instance, compare the method by which the *Paramecium* procures its food with that employed by a frog. The frog lives to a large extent on flies. These it catches by jumping at them and at the same time darting out its

tongue. There appears to be every reason to suppose that in the case of the frog we have to deal with a mechanism, just as in the case of the *Paramœcium*; though in the frog this mechanism must be assumed to be much more delicate and complicated. The step from the frog to man is scarcely so great as that from the *Paramœcium* to the frog. So far, then, as the facts have been examined, they seem entirely consistent with the hypothesis that the organism is only a machine so peculiarly constructed as to be capable of keeping itself in action automatically.

But there is another point of difference between an organism and an ordinary machine. This lies in the power which the organism possesses of adapting its actions to unusual circumstances. What I mean is well illustrated by the experiments which Darwin made with a view to testing the intelligence of earthworms.

Earthworms are in the habit of stopping up the mouths of their burrows with leaves, leaf-stalks, or other convenient materials. It is evident that some leaves can be most conveniently dragged into a burrow by their tip, while in the case of others of a different shape it will be more convenient to make use of some other part, as the stalk. Consequently, in laying hold of one part rather than another, the animal may display more or less intelligence. In order to exclude the hypothesis that a special inherited instinct determines the worms to select the most convenient part of each special kind of leaf, Darwin tested them with leaves of foreign trees, and triangles of paper. At the end of the account of his observations he says (*Vegetable Mould*, &c., p. 98):—

“To sum up, as chance does not determine the manner in which objects are drawn into the burrows, and as the existence of specialised instincts for each particular case cannot be admitted, the first and most natural supposition is that worms try all methods until they at last succeed; but many appearances are opposed to such a supposition. One alternative alone is left, namely that worms, although standing low in the scale of organisation, possess some degree of intelligence. This will strike every one as improbable; but it may be doubted whether we know enough about the nervous system of the lower animals to justify our natural distrust of such a conclusion. With respect to the small size of the cerebral ganglia, we should remember what a mass of inherited knowledge, with some power of adapting means to an end, is crowded into the minute brain of a worker-ant.”

In these experiments the worms display intelligence in the fact that they do not mechanically employ one constant means in dragging objects into their burrows, but tend to use just the particular means suited to the particular circumstances of each case. That is to say, the intermediate steps in the process are in each particular case determined with reference to the final result. Hence we cannot simply say

that the result is determined by, or is the effect of, the process, for it appears to be just as true that the process is determined by the result. Now this being so, it appears to me that the analogy between the nervous system and a machine can no longer by any possibility be held to. The action of a machine is determined from behind. That is to say, every one of its movements can be traced back to a cause antecedent in time, and in this way explained. But this is not true of the movements which we have been considering in the case of the earthworm; for the apparent cause appears to be as much effect as cause of the apparent effect. I shall, however, return to this matter presently.

Such behaviour as that of the earthworm in these experiments is only one example of a kind of behaviour which may be observed in the case of other organisms. Since the word 'intelligent' carries with it a reference to consciousness, I shall call this kind of behaviour 'purposive' rather than 'intelligent'.

But it is not only where the nervous system is concerned that purposive behaviour may be observed; for such behaviour is evident enough in the case of other tissues. Attention has been drawn elsewhere¹ to the significance of what occurs in the healing of wounds, especially among the lower animals. And it was pointed out that in the case of, say, the reproduction, after amputation, of the limb of a newt, it is not possible to explain on mechanical principles the behaviour of the cells which are concerned in the process. As the phenomena referred to may be passed over without their significance being realised, it may be well to indicate more particularly in what respects they are significant.

Let us suppose that the limb is amputated half way up the thigh: the cells near the surface of the stump work together by dividing and developing in various ways, so as to reproduce the limb. Supposing now that the line of amputation is oblique or irregular, this does not affect the result. The cells concerned in the process allow for the irregularity. If, for instance, two-thirds of the extensors of the knee, half of the thigh bone, and a third of the hamstring muscles, are amputated, the missing part of each of these structures is nevertheless reproduced in its proper proportion. Now were the behaviour of the cells determined by anything of the nature of mechanisms within them, we should find that they did their work in the same way as machines do their work—that is to say, blindly. We should,

¹ *Essays in Philosophical Criticism*, p. 54.

in fact, find that, when placed in circumstances not previously met with by them, and therefore not provided for, they would fail to act so as to attain the end which conduces, under these circumstances, to maintaining the organism in action. This, however, is just what these cells do not do; since in whatever way the injury to the limb may be varied, they adapt their behaviour to the circumstances of the case, and attain the end of reproducing the limb. In the process of healing, then, we meet with facts similar to those already discussed in the case of the earthworm.

The two cases which I have taken are of course only isolated examples of phenomena which prevail more or less throughout the whole organic world, and to which phenomena as a whole the above analysis may be made to apply. That analysis enables us to conclude that the purposive behaviour displayed in the attainment by organisms of such ends as the reproduction of a newt's limb, or the stopping up of an earthworm's burrow, cannot be due to the mere action of neuro-muscular or intracellular mechanisms.

This conclusion does not, however, carry with it an assertion of the existence within the organism of phenomena altogether different from those outside of it. It is quite intelligible that a stone falls back again to the earth, in whatever direction it may have been propelled in the air. The attraction of the earth overcomes the force which propels the stone away, in whatever direction that force may be. The propelling force may be varied in direction to any extent, yet the stone reaches the earth with certainty. Now if we do not make the unmeaning assumption that an intelligence which is supernatural influences, nevertheless, the physical world, it is necessary to suppose that, in the case of the class of phenomena which we have been considering, there must be some explanation similar to that of the behaviour of the stone. When an earthworm stops up its hole in spite of such disturbing influences as were introduced by Darwin, its behaviour is analogous to that of a stone in reaching the ground in whatever direction it may have been originally propelled. And in order to render the movements of the worm intelligible we must suppose it to be in some way influenced by a force of attraction. But it is at least clear that no *direct* force of this sort guides the worm in its movements relatively to the burrow and the materials used; and the like is true of other instances of purposive action. This, however, does not exclude the existence of a connecting force which acts in an indirect and

roundabout manner ; and the only escape from the difficulty lies in assuming that there is such a force. Let us consider more particularly how this force must act.

When an earthworm fills up its burrow it is not performing an action unconnected with other events in its life. The filling up of the burrow is determined with reference to further ends, in the same sense as that in which the seizing of the apical portion of one of Darwin's triangles is determined with reference to the end of filling up the burrow. And if this reasoning be followed out, it leads to the conclusion that all the actions of the worm can be regarded as determined more or less directly with reference to one comprehensive end—the end, namely, of so influencing the surroundings as to cause them to direct to the animal a supply of energy sufficient to make up for what has been spent by it.

From this it follows that the force whose existence we found it necessary to assume for the explanation of the movements of the worm in filling up its burrow—that this force is subordinate to a force which connects generally the organism and its surroundings. Since the hypothesis of mechanisms within the organism fails us, it is only by assuming the existence of such a force that we can explain the determination with reference to the one comprehensive end mentioned above of all the actions of the animal. This force must be conceived as acting from the surroundings in all sorts of indirect ways on the parts of the organism, so as to cause them to act in their turn on the surroundings. In the same way a force is thought of as acting from the earth so as to cause a stone thrown into the air sooner or later to act on the earth by striking against it. Not only, however, do surroundings and organism successively act and react on one another ; but the organism, as we have seen, reacts on the surroundings in a certain particular manner—in such a manner, namely, as to bring it about that the surroundings act again on the organism in transferring to it energy contained in food. In other words, the surroundings determine the organism to react upon them in a certain manner, but this manner of reaction is determined with reference to the organism itself. Now what is implied in saying that this manner of reaction is determined with reference to the organism itself, is that in being made to react on the surroundings the organism is determined by its own influence acting through the surroundings. The surroundings in acting on the organism are therefore at the same time acted on by it. The organism is thus no more determined by the sur-

roundings than it at the same time determines them. The two stand to one another, not in the relation of cause and effect, but in that of reciprocity.

What is true of the organism and its surroundings looked at as wholes in relation to one another, applies of course equally when the organism is looked at as made up of a number of separate parts. These parts stand to one another and to the surroundings, not in the relation of cause and effect, but in that of reciprocity. The parts of an organism and its surroundings thus form a system, any one of the parts of which constantly acts on the rest, but only does so, *quod* part of the system, in so far as they at the same time act on it.

This general conception of the nature of life does not in any way postulate the existence of a vital force, the action of which is unknown to physiology. All that is meant is that when the processes which physiology investigates, one by one, are looked at as a whole, in their relation to one another, these processes must be regarded under the general conception, or category, of reciprocity, rather than under that of cause and effect. It is therefore irrelevant to point to isolated physiological phenomena, and say that they, at any rate, are nothing more than series of causes and effects. They participate in the life of an organism; and when they are looked at as doing so they must be brought under the category of reciprocity. To illustrate this point let us take the case of the transmission, from the cells of one of the motor areas of the cerebral cortex, of nervous impulses to a group of muscles, and the consequent movement of the corresponding limb. If the phenomena in question be looked at by themselves, they present nothing more than a series of causes and effects. But when these same phenomena are looked at in relation to the whole life of the animal, it is altogether different. For the movement of the limb has some purpose or other in relation to the nutrition of the animal; and this implies, as we have seen above, the general conception of reciprocity.

It might be said that this conception of reciprocity must, after all, be ultimately subordinated to that of mechanism. For the potential energy contained in the food of an organism has its source in the heat of the sun. And the energy expended by the organisms on its surroundings is all finally dissipated. Life can thus at the most be nothing more than an eddy in a stream of energy passing from the sun to be dissipated in surrounding space.

Now this objection derives its apparent force from a tacit assumption, of the nature of which it is well to be clearly

aware. We have already seen why a living organism and its surroundings must be regarded as a system of parts reciprocally determining one another. But when the sun is treated as a source of energy and as such considered in its relation to life, it is really taken for granted at the outset that life is a mechanical process. For if one phenomenon is brought under a certain category, all other phenomena are potentially brought under the same category. It is not possible without contradiction to regard phenomena under two categories simultaneously.¹ Therefore the form of the above objection precludes the possibility of an answer to it. All that can be said with regard to it is that in relation to the essential characteristics of life, the conception of the sun as a source of energy may be shown to be self-contradictory, in the same way as was done with the conception of the organism as a machine. The range of application of a category cannot be limited in space; so that in bringing the phenomena of life under the category of reciprocity we do not limit the application of this category to a certain portion of space, leaving an outside region in which the category of cause and effect holds undisputed sway. Hence we may regard the sun as participating, inasmuch as it is a part of the surroundings, in the system of life of an organism, but not as acting on that system from without.

It follows from this that the surroundings of an organism are to be looked on, not merely as objects in ambient space which may act on, or else be acted on by, the organism, but as these objects in so far as they participate with other objects in forming with the organism a system whose parts reciprocally determine one another. The mode of life of organisms on the earth, for instance, is suited to the present condition of the solar system, and so indirectly to conditions beyond. But it is not enough simply to say that these conditions modify the life of terrestrial organisms, since that life actively adapts itself to them. The relation is that of reciprocal action: not merely that of cause and effect.

So long as it is allowed to appear that, apart from a consideration of life, the category of cause and effect has an absolute validity of its own, the foregoing reasoning will seem incomplete in some sense. For the world as it is for physical science—the world of causes and effects—seems to have no definite relation to the same world regarded, in relation to life, under the category of reciprocity. The task undertaken in this article is not, however, to inquire how

¹ This point is worked out in *Essays in Philosophical Criticism*, ii.

far a world of causes and effects is real. All that has been undertaken is to show that the ordinary conceptions of physical science are insufficient when applied to the phenomena of life, and that other conceptions must be substituted.

The result of our inquiry up to this point has been to show that biological phenomena are to be interpreted under the category of reciprocity rather than under that of cause and effect. But we shall see that the category of reciprocity has after all only a relative appropriateness, there being essential characteristics of life which it does not express.

In the case of a system whose parts reciprocally determine one another, each part, though determined by and determining the rest of the system, has yet a certain independence of its own. The fact of its taking part in the system is not essential to its own existence, since it has numerous properties which belong to it apart from its relation to the system. Now in the case of the system of life the parts are not thus independent. They are determined, not only as regards their reciprocal action on one another, but also as regards what is inherent in the parts themselves of a system whose parts reciprocally determine one another. Size, shape, consistence, and other properties which we think of as inherent in a thing itself, as well as what relates to its determination of and by other things, are determined, in the case of what is concerned in the life of an organism, with reference to that life as a whole. For instance, it is not enough to say that the action of a limb at the same time determines and is determined by the rest of the organism and by its surroundings. For the size of the limb, its shape, structure, and other properties such as ordinarily appear to us to inhere in a thing itself, apart from its relation to other things, are determined with reference to the function which the limb performs.

Let us consider again the phenomena which may be observed in connexion with the amputation of one of the limbs of a newt. From the previous discussion we gathered that the characteristic behaviour of the cells concerned in the reproduction of the limb must remain unintelligible unless the life of the animal be brought under the general conception of reciprocity. But it is not only the movements of the cells relatively to one another that have to be explained, but also the assumption by them of properties which inhere in themselves, such as certain sizes, shapes, and consistencies. For the cells which take part in the process assume in each case a certain size, consistence, and shape suited to the functions which they severally have to perform. Certain

cells, for instance, assume the form, consistence, size, and colour suited to the function which the contractile pigment-cells beneath the epidermis have to perform, while others assume the properties required for muscle-cells. Now here the conception of reciprocity fails us. For in a system of parts which reciprocally determine one another, each part, as we have seen, is independent as concerns its own individual properties. We regard the planets in the solar system, for example, as reciprocally acting on one another, but yet as each independent of the system so far as concerns such properties as shape and consistence. In the case, however, of life, the fact of the determination in a certain way of the individual properties of the parts has to be explained, as well as the behaviour of the parts relatively to one another.

It is common to account for the fact that the properties of any part of an organism are adapted to the function which they perform, by supposing that they have been made so by forces acting from outside of the life of the organism. These forces are found, either in a God existing independently of the physical universe, or in the environment of organisms. Thus it is argued that the parts of organisms are constantly undergoing slight modifications under the influence of the environment; that some of these modifications give the organism which has undergone them an extra chance of survival; and that, as offspring resembles parent, the advantageous modifications must necessarily tend to be transmitted and preserved in a stock, which will prevail over other stocks. This account of the matter implies, then, that the presence of design is, in ultimate analysis, accidental to the parts, in the same sense as that in which the form of a marble bust is accidental to the marble.

But how can such an explanation be reconciled with the fact, for instance, that the developing cells of the new limb of a newt assume the properties suited to their future function, in whatever way the method of amputation may be varied? It is not only the behaviour, under these circumstances, of the cells relatively to one another that has to be accounted for; but also the fact that as to its individual properties each cell constitutes itself in a certain manner according to its particular future function, and does so, not in a blind mechanical manner, but allowing for complicated disturbing conditions. This latter fact becomes altogether unintelligible if a cell be looked upon as something whose properties have been passively received from without, as the parts of a machine have received their shape, &c. For this reason, among others, Hæckel's ingenious theory of the nature of reproduction seems to me to be quite untenable.

To get over the difficulty we must conclude that the determination of the parts as members of a system extends, not only to their behaviour relatively to one another, but also to properties in them which they seemed to possess independently. For only in this way can we account for the circumstance that the 'design' which is seen in the parts is not accidentally present in them, apart from the fact of their determination as members of the system, but is dependent on this fact. There is, then, not merely a reciprocal determination of one another by the parts as subordinate independent wholes; but this reciprocal determination extends right through the parts. That is to say, what appeared to belong to the parts independently of their relation to the whole, for instance their size, shape, and structure, is really only the manifestation in the parts of the influence of the whole.¹

The nature of this conception of the whole determining the parts through and through, may be made more clear if we consider its application in a much less complicated case. The general contour, at any moment, of that part of the earth's surface which is covered by the sea is due, not merely to the mutual attraction between all parts of the earth, but also, as shown by the tides, to the mutual attraction between the earth and other members of the solar system. We may therefore consider that the contour of the sea is a manifestation in the earth of the influence of the solar system regarded as a whole. There is thus in the case even of the solar system something more than a reciprocal determination by the parts of one another as subordinate independent wholes. For, so far as our illustration is concerned, the influence of the whole manifests itself right through one of these subordinate wholes, and determines its shape, which is one of the properties as to which the parts of a whole of reciprocity are independent. The general conception of reciprocity must here give way to that of the whole determining the parts through and through, so that their essential independence of the whole is lost.

Here again it may be well to state that in the application to biological phenomena of this idea of the whole determining the parts through and through, the existence of no mysterious force is postulated. All that is done is to take a more concrete and comprehensive view of forces with which physiology familiarly deals, the previous view having turned out to be narrow and abstract.

¹ The word 'whole' is used here, not in the sense of a spatial whole, but with a significance which the context sufficiently determines.

In order to get a clearer idea of the conception which we have now reached of the nature of life, we may compare this new conception with that of reciprocity. The parts of a whole of reciprocity are thought of as having a certain independence of their own, manifested in properties which they possess individually, apart from their relation to the whole. And this independence is an essential part of the conception. For it is not merely that the parts seem independent when we leave out of account the whole; but it is of the essence of a whole of reciprocity that its parts are at the same time dependent on it and independent of it. In so far as the parts participate in the system formed by the whole, the influence of the whole in them is not the influence of something foreign to themselves. They are not determined by another, as in causal determination, but by themselves through another. In as far, however, as regards that in the parts with respect to which they are essentially independent, in so far as is the influence of the whole in them a foreign determining influence. It is thus true of a whole of reciprocity that its parts are at the same time free and determined by another. In the case, however, of the conception of a whole which determines the parts through and through it is different. For, so far as concerns what is essential to the conception, there is nothing in the parts that is not a manifestation of the whole. The shape, consistence, size, and other properties in which the independence of the parts previously seemed to show itself, are now only manifestations of the whole. In all that the parts do and all that they are they only show forth the whole. It follows from this that if we speak of them as determined by the whole, we use the word 'determined' in a sense altogether different from its ordinary sense. For, since the parts are what they are, only as taking part in the whole, there can clearly be nothing foreign to them in their determination. In this apparent determination they are only manifesting what they are in themselves.

I shall devote the rest of this article to showing how this conception may be brought to bear on specific biological questions. Some apparent difficulties which suggest themselves in connexion with these questions will at the same time be considered.

In the phenomena of reflex action those who uphold the belief that the organism is at bottom only a complicated piece of mechanism find what appears to afford to that belief a reasonable basis. If the finger be lightly and quickly drawn across the sole of the foot it will be noticed that the

foot gives an involuntary jerk. In cases where from injury or other morbid conditions the physiological communication between the brain and the lower part of the spinal cord is severed, the jerking of the foot can still be elicited, and indeed is now exaggerated. It is therefore clear that the jerking is not brought about through the medium of the higher nerve-centres in the brain, but concerns only those of the spinal cord. As the jerk follows the stimulus to the skin with perfect regularity it is evident that there must be a causal connexion between the two phenomena, and it is not difficult to follow out that connexion through the afferent nerves, certain groups of ganglion-cells in the cord, and the motor nerves, to the muscles which move the foot. So far as these facts go they entirely corroborate the belief that the organism is a machine. And it is a plausible deduction from them that, since the cells of the higher nerve-centres are presumably in all fundamental respects similar to those of the lower centres, the actions in which they are concerned are in reality only very complicated reflex actions, the element of consciousness being sometimes added, but in no way altering the matter from a physical point of view.

Of course it is clear that the deliberately purposive actions in which the higher nerve-centres are concerned are of the same sort as those which we have already considered in the case of the earthworm. The restoration of function which, in greater or less degree, follows cerebral lesions in man is also similar in kind to the reproduction of a limb in the case of the newt. Accordingly the reasoning of the previous part of this article may be applied to show that in the case of the higher nerve-centres in man there is something more than mechanical action. But if the matter is left there, and it be at the same time admitted that reflex action is purely mechanical in itself, the conclusion follows that the ganglion-cells of a lower centre are altogether different from those of a higher one, and manifest in themselves the life of the organism in a far less intimate manner. Such a conclusion, however, strikes one at once as being altogether contrary to biological analogy; and a further consideration of the facts will show that it is unnecessary. The fact that a soldier instinctively performs a certain action on receiving the word of command from his superior officer, does not imply that he is a machine. His obedience may have the appearance of being more or less mechanical, but the fact that he originally learned to obey, and was not made to do so by influences acting on him merely from without, shows that he is not in reality a machine. For in the process of

learning he showed that his actions were really purposive; and therefore it is a warrantable conclusion that his apparently mechanical obedience is at bottom a purposive obedience. Now if, in the case of the ganglion-cells concerned in reflex action, we find similar evidence of their behaviour being originally purposive, we shall similarly be warranted in concluding that reflex action is at bottom purposive and not mechanical. It will be sufficient to compare in respect of their reflex actions a mammal with one of the lower vertebrates, such as a frog; as it may safely be inferred from analogy that reflex action in a frog corresponds roughly with an early stage in the development of reflex action in a mammal.

If the spinal cord of a frog be severed from the brain, and a stimulating substance be applied to the skin of one of the hind limbs, the leg is moved in such a way as to make it evident that an attempt is being made to get rid of the source of irritation. And if the leg be held, the other leg is made use of to remove the irritating substance. The animal is also capable of performing many other actions which appear to be to a certain extent really purposive, and scarcely capable of being explained by the hypothesis of a prearranged mechanism in the cord.

In the case, now, of a mammal whose cord has been similarly severed from the brain, what is observed is different. Complicated and highly co-ordinated reflex actions are, it is true, performed. But there is not the same power of adapting these movement to varied circumstances. In other words, the behaviour of the animal corresponds much more closely to what one would expect if the centres in the cord were only so many mechanisms, each previously arranged so as to act in a certain definite way.

Now if it were true that reflex action, looked on as a purely mechanical phenomenon, is the type of the behaviour of the nervous system generally, one would expect to find this type manifested, not less, but more clearly in the case of the lower animals. But the opposite of this is found to be the case. Therefore the mechanical interpretation given to the facts of reflex action can be only superficially correct. The ganglion-cells of the cord can no more be regarded as mechanisms than can the ganglion-cells of the brain. As regards the doctrine often taught, that reflex action is the fundamental type to which the behaviour of the nervous system generally may be referred, physiologists would seem to have been led astray by an erroneous *a priori* conception.

What is true of the ganglion-cells of the cord is true of the cells in parts of the body other than the nervous system.

A cell may superficially resemble a mechanism in its behaviour. But that it is not really a mechanism may be deduced from a consideration of the behaviour of the cells which morphologically correspond to it in the lower animals. The lower we go in the scale of multicellular animals, the more clear does it become that the cells are fundamentally alike in manifesting purposive behaviour. In the higher animals, however, differentiation of function among the cells has gone so far that they have much more the superficial appearance of being mechanisms, with the prominent exception of the ganglion-cells of the higher nervous centres.

This interpretation of the facts is strengthened by a consideration of what may be observed in connexion with pathological conditions of the human body. When any part of a machine is injured or destroyed, there is no tendency to its spontaneous repair. If the injury is repaired, this is only brought about by interference from without. But in the case of injury of any part of the human body there is a manifest tendency to restoration of the function of the injured part, and this quite apart from interferences from without. Sometimes this restoration of function is brought about by means of the reproduction of tissue that has been destroyed, as, for instance, occurs when the shaft of a long bone that has been destroyed by inflammation is reproduced again entire. More frequently, however, this reproduction is due to neighbouring parts modifying themselves so as to be capable of carrying on the function of the part that is lost. As a good instance of this, may be taken a case of locomotor ataxy recorded by Professor Schultze.¹ In this disease, which is very rarely recovered from and almost always ends fatally sooner or later, there occurs progressive destruction of the fibres of the posterior columns of the spinal cord. The symptoms are very marked, as would be expected from the fact of such an important part of the body being affected. Professor Schultze's patient presented the fully developed symptoms of the disease; but, contrary to the usual rule, recovered, there being hardly a trace of the disease left. He died some years later from the effects of an accident. When the spinal cord was examined *post mortem*, the posterior columns in the lower part of the cord were found to be destroyed in the manner characteristic of the disease. The process of wasting had doubtless stopped at the time when the symptoms of the disease began to disappear; and other parts of the cord had thus been given time to modify themselves in such a way as to reproduce the function of the lost part.

¹ *Archiv für Physiologie*, xii., s. 232.

But it is not necessary to go out of the way to find instances which, it seems reasonable to suppose, are analogous. When, from valvular disease or other causes, increased work is required from the heart, it becomes hypertrophied. Similar hypertrophy in other muscular organs, and in voluntary muscles, occurs under similar circumstances. When one kidney is destroyed the other becomes hypertrophied and does double duty. On the other hand tissues which from any cause have become useless tend to atrophy, as may be seen in the case of muscles which are not used, the collar-bone after amputation of the arm on the same side, or the jaw-bone after the teeth have been lost. The restoration to their ordinary condition of organs whose structure has been profoundly altered by inflammation is almost as remarkable a phenomenon as any of those just mentioned. The more one considers such phenomena as these, even apart from other biological facts, the more does one feel the difficulty, if not impossibility, of putting on them any different interpretation from that which was put on the reproduction of the limb in the newt. But when the behaviour of the tissues generally in the lower animals, and that of the higher nervous centres in man, are also considered, it appears to me that there can scarcely remain any further doubt on the matter.

Clear conceptions as regards this matter would seem to be of great importance in medicine. As has been seen already, the apparent action on an organism of one of its parts is just as much the action of the organism on the part; and part and organism, as regards both what they are in themselves, and their apparent action and reaction on one another, only manifest in themselves the life of the organism regarded as a whole. In like manner a remedy cures diseases only in so far as its physical or physiological action is taken up into the life of the organism, so that that life becomes manifested in it. It is a common source of misconception that in the process of cure the remedy is regarded merely as a cause, producing a certain measurable effect in the diseased organism. To this source may be traced the fact that with the advance of pathological anatomy there grew up so much scepticism as regards therapeutics. For it is clearly impossible to replace artificially the exquisitely delicate tissues which are destroyed or injured by disease. But experience shows that remedies actually do most materially assist in the process of restoration of the function of a part of the body that has been injured or destroyed. For instance, when a valve of the heart has been injured by inflammation, and the circulation thus becomes inefficient, digitalis can be given, not merely in

order to palliate the disease, but with the hope that a relative cure may follow. The digitalis causes the heart to contract powerfully, so as to overcome the obstruction to the circulation and thus keep the patient in health. If this were all, its action would be merely palliative. But while it is being given the heart enlarges, so that after a time it becomes sufficiently powerful to carry on the circulation without the artificial stimulus of the digitalis. Now in this case it is only from an abstract point of view that we can regard the organism as passively undergoing cure through the influence of the digitalis; although death might speedily have resulted had this drug not been given. The rôle of the digitalis in the process of cure is as much passive as active. In this process the organism actively utilises the temporary effect of the digitalis on the heart, just as much as it passively submits to the action of the drug. It is thus proper to speak of the physiological *action* of a drug when its administration is regarded from the abstract point of view of physiology. But it is more correct to speak of its therapeutical *function* than of its therapeutical action, since medicine deals with what is concrete.

As another among countless instances of the application of the same principle, may be taken the operation of sewing together the ends of a nerve that has been accidentally divided. This is done in order that the two ends of the nerve may be kept in apposition with certainty. After the lapse of a sufficient time the function of the nerve is entirely restored. When one considers what is implied in this restoration of function, the process seems scarcely less wonderful than the reproduction of limbs in the lower animals. Let us suppose that there is a bundle consisting of several hundred insulated telegraph-wires, each wire being exactly like its neighbours, but coming from a different place: and that this bundle is cut in two. It will be most difficult to find the corresponding ends; and one can imagine the difficulty and confusion thus arising. But the case of the division of a nerve is in every way analogous to that of the division of the bundle of telegraph-wires. What happens usually, if not always, is that the nerve-fibrils of the peripheral portion of the nerve disintegrate, and are replaced after a time by prolongations of the fibrils of the central end, which grow down the connective tissue of the nerve from the point of section. One must suppose, either that these prolongations find their way, each to exactly the same spot as that to which the fibril of which it is a prolongation originally went; or, what seems more likely, that the exact destination of the new fibrils is more or less indifferent, but that the central nerve-

cells to which they lead adapt themselves to the new destination of their fibrils. In any case, the restoration of the function of the nerve is a very significant process; and it would be a manifest abstraction from the actual facts to regard this process merely as the joint effect of keeping the cut ends in apposition and other local causes. Sewing together the cut ends has a therapeutic *function*, but cannot be regarded merely as a cause acting from without on the organism. Such considerations as these justify the conclusion that the scepticism above mentioned with regard to therapeutics is based on an inadequate conception of the real nature of this art; and that advances in the treatment of disease are likely to be as great as, if not greater than, advances in the 'diagnosis' and 'prognosis'.

Perception, in so far as it is treated of by physiology, is commonly assumed to be essentially nothing more than a mechanical process, in which physical impulses are transmitted from surrounding objects to the nerve-cells of the brain. The impressions thus produced may set a-going nervous processes of various kinds; and these may end in muscular motion, or in other ways. It is unnecessary to consider here the doctrine that changes in the nervous system give rise to, or are accompanied by, consciousness. That doctrine in its various forms has been exhaustively and finally dealt with by Green. I shall only consider the physical, or what is often called the 'objective,' side of perception—that is to say, perception in so far as it is a process which may be investigated by physiological methods. The use of the word 'perception' in this sense is no doubt objectionable; but it is hard to find a more suitable expression.

If it can be shown that in perception the surroundings affect the organism in a purposive manner, it will be possible to draw from this fact the same inferences as were previously drawn from the fact that the organism acts purposively on the surroundings. A condition which is more or less essential to perception is attention on the part of the perceiving organism. Now this of course might be taken to mean that certain causes acting from within the bodily mechanism must co-operate with those acting from without in order that there may be perception. But to say this is only to put aside, and not to solve, what is a real difficulty in the way of a mechanical interpretation. For it may be asked what it is that causes attention to be directed to one object rather than another. The ultimate answer to this question is that those objects are attended to, the perception of which is of advantage to the perceiving organism, or conduces in some way to its life. And as attention is directed in this manner,

even in circumstances which had not previously been experienced by the organism or its ancestors, we may infer that the action is purposive, and that therefore objects perceived are perceived purposively. From this may be drawn conclusions similar to those drawn from the consideration of purposive actions in the case of the earthworm and other cases.¹

Attention conditions not only the fact of perception, but also the nature of that which is perceived. To two men, especially if they are of altogether different tastes, the same phenomenon will seem altogether different, although both of them attend to it most carefully, and form a distinct conception of it. That which a thing perceived is for the perceiving organism, it is as manifesting in itself the life of the organism, just as any one of the organs has its being as a manifestation of this same life. Thus it is that a man's whole self can be truly said to be expressed in his perception or non-perception of a few bars of music, or a few lines of poetry. It is not sufficient to say that his mind reacts on them just as much as they affect him; for this implies that there is something in them that is foreign to him, which is not the case. They have just as little independent significance in their details as they have considered as wholes. In all that they are for him they are determined through and through as taking part in his life; so that in perceiving them he may be truly said to be perceiving nothing but himself. This is of course only in accordance with the conception previously reached of the surroundings of an organism as participating in its life just as really, though not so intimately, as do its own parts. We are thus enabled to see how it is that separation in time and space is only real in a world looked at abstractly under the category of cause and effect, but becomes altogether unreal when we penetrate behind this abstractness. Nothing less than the unreality of such separation is implied in the doctrine that the bodily parts

¹ To attend effectually to an object of perception is often a simple 'voluntary' act. That is to say, any passing interest is sufficient to direct attention on the object. Frequently, however, far more is required than a mere passing interest; so that it may be quite impossible voluntarily to give the necessary attention. For example, some persons who are familiar with the Prelude to 'Lohengrin' profess to see in it little more than "a study of orchestral effects"; and it may be that no amount of voluntary study of the music will enable them to perceive it as it ought to be perceived. Something deeper than a passing interest is necessary. Even in our ordinary perceptions it is only in appearance that a passing interest is sufficient to direct attention, in this wide sense, on the object. This becomes evident if the perceptions of a civilised man be compared with corresponding ones in a savage, or one of the lower animals.

and the surroundings of an organism have their being and motion in a life that is yet one and indivisible. This life, from its nature, cannot be envisaged as a something that is 'here and now'. It can be thought, but cannot be pictured. In this sense it is ideal. But none the less it is far more real than those abstract aspects of it which are commonly taken for reality.

Apart from this general conception, it seems impossible to reconcile the conclusions of philosophy with those of the natural sciences, and especially physiology. For if an organism be looked upon as nothing more in ultimate analysis than a mechanism kept in motion by energy supplied from the surroundings, it is impossible to avoid conceptions which philosophy has shown to be absolutely meaningless—such as that of consciousness being produced by, or accompanying, certain physical states of the brain. Unless we get over in some way such contradictions as this, either our philosophy or our science must prevail at the expense of the other.

A subject in connexion with which difficulties of this sort are peculiarly liable to arise is that of evolution. It is pretty clear that, if life is more than a mechanical process, evolution cannot be regarded merely as brought about by the action and reaction on one another of organisms and their environment. That it is so brought about is, however, commonly believed. It appears to me to be not difficult to show that this belief is not warranted by the facts. I can only, however, discuss the matter here in a very general way.

When it is said that variations in the environment of an organism tend to produce in it corresponding changes, and that these changes are transmitted to its descendants, a covert assumption is made—the assumption, namely, that the word 'produce' correctly renders the actual nature of the facts referred to. The peculiarities in the breed of dray-horses, for instance, have been 'produced' artificially. But these peculiarities occur in parts of a living organism, which parts have all the characteristics of what is living. For instance, the nerves supplying the muscle and other parts which are so largely developed in the dray-horse, would, if divided, doubtless reproduce themselves in the same way as in other parts. And the behaviour of the parts of the central nervous system which are modified to correspond with the increased development of muscles, ligaments, skin, bone, &c., would give evidence of a participation in the one living whole which we saw that an organism is. As, from its nature, that whole cannot be thought of as acted on from without, it is necessary to re-

gard as *function* in that whole what was taken to be *action* on the organism from without. When, therefore, we say that variations in the environment produce changes in the organism, we can mean no more than when we say that a surgical operation produces a reproduction of lost tissue.¹

It is thus an error to treat development as a process in which organisms are *made* what they are, or, which comes to the same thing, a process taking place in space and time. This latter statement may seem specially paradoxical; but becomes perfectly intelligible as soon as it is realised that knowledge is not limited to what can be envisaged in space and time.

The idea that abiogenesis is possible or conceivable depends on the same transcendent use of the categories of physical science that is at the bottom of so many other misconceptions. So long as the organism is looked at from the point of view of physical science, it certainly cannot be supposed that there is any insuperable difficulty as to the origin of life from ordinary physical conditions. The whole question is assumed from the outset; and the only real difficulty that can arise is that of drawing a line between the organic and inorganic. But if the contention of this article as to the nature of life is correct, it follows that it is as unreasonable to consider the possibility of the origin of life out of mechanical conditions, as it would be to consider the possibility of the origin of matter and energy from mere relations of time and space. We may trace the steps in the development of life back to the time when the solar system was in the gaseous state. But in thus retracing our steps we carry with us into phenomena which we had abstractly considered to be purely mechanical, the same conception that we originally started with.

The want of a sufficient philosophical vocabulary in English has been a source of great difficulty in a discussion in which it was specially necessary to be clear as to the meaning of the expressions made use of. I have found it necessary to employ words, the use of which, if taken in their ordinary sense, would seem inconsistent. As it appears to be almost impossible for anyone who writes on philosophy in English to avoid such apparent inconsistencies, I have been forced to leave the context to determine in what sense a word is used at any particular place.

¹ In *Principles of Biology*, pp. 451-457, Mr. Spencer discusses, in relation to the argument of *The Origin of Species*, what is really one aspect of the difficulty of a mechanical interpretation of evolution. I cannot, however, agree with Mr. Spencer's conclusions in the matter.