AN ADDRESS ON THE THEORIES OF LIFE AND MOTION.

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AT this period of the meeting of the British Association I am quite sure it is unnecessary for me to call to your minds the nature of the business which takes place at our sectional meetings. We there register the progress which science has made during the past year, and we do our best to advance the progress by original communication and free discussion. But when the honourable task of delivering this evening's lecture was imposed upon me, or rather when I undertook to deliver it, it occurred to me that the occasion of an evening lecture might be turned to a different purpose; that we might then, with much propriety and advantage, turn our minds back to the past to consider what had been done by the great men of old, who had gone down into the grave with the weapons of war, but who had fought bravely for the cause of truth while they yet lived—to recognise their merits, and to show ourselves duly grateful for their services. I propose, therefore, to take a retrospect of the condition of that branch of science with which it is my business to be more or less familiar. I shall go no further back than the seventeenth century, and the observations which I shall have to offer you will be confined almost entirely to the biological science of the time between the middle of the seventeenth and the middle of the eighteenth centuries. I propose to show what great ideas in biological science took their origin at that time, in what manner the speculations then originated have been developed, and in what relation they stand to what is now understood to be the body of scientific biological truth. The middle of the sixteenth century, or rather the early part of it, is one of the great epochs of biological science. It was at that time, that an idea which had been dimly advocated previously, took the solid form which can only be given to scientific ideas by the definite observation of fact—I mean the idea that vital phenomena, like all other phenomena of the physical world, are capable of mechanical explanation, that they are reducible to law and order, and that the study of biology, in the long run, is an application of the great sciences of physics and chemistry. The man to whom we are indebted for first bringing that idea into a plain and tangible shape, I am proud to say, was an Englishman, William Harvey. Harvey was the first clearly to explain the mechanism of the circulation of the blood, and by that remarkable discovery of his, and by the clearness and precision with which he reduced that process to its mechanical elements, he laid the foundation of a scientific theory of the larger part of the processes of living beings—those processes, in fact, which we now call processes of sustentation—and by his studies of development he, further, first laid the foundation of a scientific knowledge of reproduction.

But beside these great powers of living beings, there remains another class of functions—those of the nervous system—with which Harvey did not grapple. It was, indeed, left for a contemporary of his, a man who, as he himself tells us, was mainly stimulated in these inquiries by the brilliant researches of Harvey—René Descartes—to play a part in relation to the phenomena of the nervous system, which, in my judgment, is precisely equal in value to that which Harvey played in regard to the circulation. And when we consider who Descartes was, how brief the span of his life, I think it is a truly wonderful circumstance that this man, who died at fifty-four, should be one of the recognised leaders of philosophy—that, as I am informed by competent authority, he was one of the first and most original mathematicians who has ever lived, and at the same time that the fertility of his intellect and the grasp of his genius should have been so great that he could take rank, as I believe he must, beside the immortal Harvey, as a physiologist. And you must recollect that this man Descartes was not merely, as some had been, a happy speculation. He was a working anatomist and physiologist, conversant with all the anatomical and physiological law of his time, and practised in all methods by which anatomical and physiological discoveries were made; and it is related of

him—and a most characteristic anecdote it is, and one which should ever put to silence those shallow talkers who speak of Descartes as a hypothetical and speculative philosopher—that a friend once calling upon him in Holland begged to be shown his library. Descartes led him into a sort of shed, and drawing aside a curtain, displayed a dissecting-room full of the bodies of animals in course of dissection, and said, "There is my library". It would take us a very long time if I were to attempt to pursue the method which would be requisite for the full establishment of all that I am about to say; that is to say, if I were to quote the several passages of Descartes' works which bear out my ascription to him of the several propositions which I am going to bring before you. And I must beg you, therefore, to be so good as to take it on my authority for the present, although for the present time only, that there are to be found clearly expressed in Descartes' works the propositions which I shall proceed to lay before you, and each of which I shall compare as we go on, as briefly as may be, with the existing state of physiological science, in order that you may see in what position with respect to physiology—aye, even to the advanced physiology of the present time—this man stood. And, happily, the matters with which we shall treat are such as to require no extensive knowledge of anatomy—no more, in fact, than such as, I presume, must be familiar to almost every person. I think I need only premise that what we call the nervous system in one of the higher animals consists of a central apparatus, composed of the brain, which is lodged in the skull, and of a cord proceeding from it, which is termed the spinal marrow, and which is lodged in the vertebral column or spine, and that then from these soft white masses—for such they are—there proceed cords which are termed nerves, some of which nerves end in the muscle, while others end in the organs of sensation. That bare and bald statement of the fundamental composition of the nervous system will be enough for our present purpose. The first proposition that you find definitely and clearly stated by Descartes is one which will sound very familiar to you at the present day. It is the view, which he was the first, so far as I know, to state not only definitely but upon sufficient grounds, that the brain is the organ of sensation, of thought, and of emotion—using the word "organ" in this sense, that certain changes which take place in the matter of the brain are the essential antecedents of those states of consciousness which we term sensation, thought, and emotion. Now-a-days that is part of popular and familiar knowledge. If your friend disagrees with your opinion, runs amuck against any of your pet prejudices, you say, "Ah! poor fellow, he is a little touched here"; by which you mean that his brain is not doing its business properly, that he is not thinking properly, thereby implying that his brain is some way affected. But in Descartes' time, and I may say for a hundred and fifty years afterwards, the best physiologist had not reached that point. It remained down to the time of Bichat a question whether the passions were or were not located in the abdominal viscera. There is a great deal to be said for it, but it is a notion which will not bear scientific investigation for a moment. This, therefore, was a very great step. It is a statement which Descartes makes from the beginning, and from which he never swerves.

In the second place, Descartes lays down the proposition that all the movements of the animal bodies are affected by the change of form of a certain part of the matter of their bodies, to which he applies the general term of muscle. You must be aware of this in reading Descartes; you must use the terms in the sense in which he used them, or you will not understand him. That is a proposition which is now placed beyond all doubt whatever. If I move my arm, that movement is due to the change of this mass of flesh in front called the biceps muscle: it is shortened till it becomes thicker. If I move any of my limbs, the reason is the same. As I now speak to you, the different tones of my voice are due to the exquisitely accurate adjustments and adjusted contractions of a multitude of such particles of flesh; and there is no considerable and visible movement of the animal body which is not, as Descartes says, resolvable into these changes in the form of matter termed muscle. But Descartes went further, and he stated that in the normal and ordinary condition of things these changes in the form of muscle in the living body only occur under certain conditions; and the essential condition of the change was, says Descartes, the motion of the matter contained within the nerves which go from the central apparatus to the muscle. Descartes gave this moving material a particular name—the animal spirits. Now-a-days we should not say that the animal spirits existed, but we should say that a molecular change takes place in the nerve, and that that molecular change is propagated at a certain velocity which has been measured from the central apparatus to the muscle. Nevertheless, the modification of the idea is not greater than that which has taken place in our view of electricity, in our change of conception of it as a fluid to our conception of it as a simple condition of propagated molecular

change. Modern physiology has measured the rate of the change to which I have referred; it has thrown marvellous light upon its nature; it has increased our knowledge of its characters, but the fundamental conception remains exactly what it was in the time of Descartes.

Next, Descartes says that, under ordinary circumstances, this change in the contents of a nerve, which gives rise to the contraction of a muscle, is produced by a change in the central nervous apparatus, as, for example, the brain. We say at the present time exactly the same thing. Descartes said that the animal spirits were stored up in the brain, and flowed out from the motor nerve. We say that a molecular change takes place in the brain that is propagated along the motor nerve. The evidence of that is abundantly supplied by experimental research.

Further, Descartes stated that the sensory organs of those apparatus which give rise to our feelings when acted upon by the influences which produce sensation, gave rise to a change in the sensory nerves, to a flow of animal spirits along those nerves, which flow was propagated to the brain. If I look at this candle which I hold before me, the light falling on the retina of my eye gives rise to an affection of the optic nerve, which affection Descartes described as a flow of the animal spirits to the brain. We should now speak of it as a molecular change propagated along the optic nerve to the brain; but the fundamental idea is the same.

In all our notions of the operations of nerve, we are building upon Descartes' foundation. Not only so, but Descartes lays down over and over again, in the most distinct manner, a proposition which is of paramount importance not only for physiology, but for psychology. He says that when a body which is competent to produce a sensation touches the sensory organs, what happens is the production of a mode of motion of the sensory nerves. That mode of motion is propagated to the brain. That which takes place in the brain is still nothing but a mode of motion. But in addition to this mode of motion there is, as everybody can find by experiment for himself, something else which can in no way be compared to motion, which is utterly unlike it, and which is that state of consciousness which we call a sensation. Descartes insists over and over again upon this total disparity between the agent which excites this state of consciousness and the state of consciousness itself. He tells us that our sensations are not pictures of external things, but that they are symbols or signs of them; and in doing that he made one of the greatest possible revolutions, not only in physiology but in philosophy. Till his time, it was the notion that visible bodies, for example, gave for themselves a kind of film which entered the eye and so went to the brain, *species intentionales* as they were called, and thus the mind received an actual copy or picture of things which were given off from it. It is to Descartes we owe that complete revolution in our ideas, which has led us to see that we have really no knowledge whatever of external things, and that the only thing which is certain is that they cannot be like what we imagine them to be, that the only certain knowledge we have of that efficient cause, is that it is in no sense like the picture we present to our consciousness. In laying down that proposition upon what I imagine to be a perfectly irrefragable basis, Descartes laid the foundation of that form of philosophy which is termed idealism, which was subsequently expanded to its uttermost by Berkeley, and has taken all sorts of shapes since. But Descartes noticed not only that under certain conditions an impulse made by the sensory organs may give rise to a sensation, but that under certain other conditions it may give rise to motion, and that this motion may be effected without sensation, and not only without volition, but even contrary to it. I trouble you with as little reading as I can, because it occupies so long; but I must ask your patience for one very remarkable passage—I could have found half-a-dozen such, but I will read you that which is contained in the *Response au quatrième objection*—the answer that Descartes gave to the objections raised to the imputation by the famous Port Royalist, Arnauld, to his Fourth Meditation. Descartes says:—

"It appears to me to be a very remarkable circumstance that no movement can take place either in the bodies of beasts or even in our own, if these bodies have not in themselves all the organs and instruments by means of which the very same movement would be accomplished in a machine, so that even in us the spirit or the soul does not directly move the limb, but only determines the course of that very subtle liquid which is called the animal spirits, which, running continually from the heart by the brain into the muscles, is the cause of all the movements of our limbs, and often may cause many different motions, one as easily as the other. And it does not even always exert this determination, for among the movements which take place in us there are many which do not depend upon the mind at all, such as the beating of the heart, the digestion of food, the nutrition, the respiration of those who sleep, and even in those who are awake, walking, singing, and other similar actions when they are performed without the mind thinking

about them. And when one who falls from a height throws his hands forward to save his head, it is in virtue of no ratiocination that he performs this action; it does not depend upon his mind, but takes place merely because his senses, being affected by the present danger, cause some change in his brain, which determines the animal spirits to pass thence into the nerve in such a manner as is required to produce this motion, in the same way as a machine, and without the mind being able to hinder it."

I know in no modern treatise a more clear and precise statement than this, or a more perfect illustration than this of what we understand by the automatic action of the brain. And what is very remarkable, in speaking of these movements which arise by a sensation being as it were reflected from the central apparatus into a limb, as, for example, when one's finger is pricked and the arm is suddenly drawn up, the motion of the sensory nerve travels to the spine and is again reflected down to the muscles of the arm. Descartes uses the very phrase that we at this present time employ—he speaks of the *esprit réfléchi*, the reflected spirit; and that this was no mere happy guess lost upon his contemporaries will be shown to you if you consult the famous work of Willis, the Oxford professor, *De Anima Brutorum*, which was published about 1672, in which, in giving an account of Descartes' motion he borrows this very phrase from him, and speaks of this reflection of sensation or of a sensory movement into a motor motion *sicut undulatione reflexâ*, as if it were a wave thrown back: so that we have not only the thing reflex action described, but we have the phrase "reflex" recognised in its full significance.

And the last great service to physiology of the nervous system which I have to mention as rendered by Descartes was this, that he first, so far as I know, sketched out the physical theory of memory. What he tells you in substance is this, that when a sensation takes place, the animal spirits travel up the sensory nerve, pass to the appropriate part of the brain, and there, as it were, find their way through the pores of the substance of the brain. And he says that, when this has once taken place, when the particles of the brain have themselves been, as it were, shoved aside a little by the single passage of the animal spirits, the passage is made easier in the same direction for any subsequent flow of animal spirits, and that the repetition of this action makes it easier still, until at length it becomes very easy for the animal spirits to move these particular particles of the brain, the motion of which gives rise to the appropriate sensation, until at length the passage is so easy that almost anything, especially an associated flow which may be set going, allows the animal spirits to flow into these already open pores more easily than they would flow in any other direction; and, in this way a flow of the animal spirits recalls the image, the impression made by a former sensory act. That again is essentially in substance at one with our present physical theories of memory. That memory is a physical process stands beyond question. The results of the study of disease, the results of the action of poisonous substances, all conclusively point to the fact that memory is inseparably connected with the integrity of certain material parts of the brain dependent upon them, and I know no hypothesis by which this is accounted for except by some idea which is essentially similar to the notion of Descartes, a notion that the impression once made makes subsequent impressions easier, and therefore allows almost any indirect disturbance of the brain to call up this particular image. So far the ideas that were started by Descartes have simply been expanded, enlarged, and defined by modern research; they are the keystone of the modern physiology of the nervous system. But in one respect Descartes proceeded further than any of his contemporaries, and has been followed by very few of his successors in later days, although his ideas were for the best part of a century largely dominant over the intellectual mind of Europe. Descartes reasoned thus:—"I can account for many such actions, many reflex actions taking place without the intervention of consciousness, and even in opposition to the will." So far as these occur, as for example, when a man in falling mechanically puts out his hands to save himself, or when a person, to use another of Descartes' illustrations, strikes at his friend's eye, and although the friend knows he does not mean to hit him, he nevertheless cannot prevent the muscles of his eye from winking. "In these cases," Descartes said, "I have clear evidence that the nervous system acts mechanically without the intervention of consciousness, and without the intervention of the will, it may be in opposition to it. Why, then, may I not extend this idea further? As actions of a certain amount of complexity are brought about in this way, why may not actions of still greater complexity be so produced? Why, in fact, may it not be that the whole of man's physical actions are mechanical, his mind living apart like one of the gods of Epicurus, but unlike them occasionally interfering by means of his volition?" And it so happened that Descartes was led by some of his speculations to believe that beasts had no soul, and consequently according to his notion could have no

true mental operation and no consciousness; and thus, his two ideas harmonising together, he developed that famous hypothesis of the automatism of brutes, which is the main subject of my present discourse. What Descartes meant by this was that animals are absolute machines, as if they were mills or barrel organs; that they have no feelings; that a dog does not see, and does not hear, and does not smell, but that the impression which thus gave rise to those states of consciousness in the dog gave rise, by a mechanical reflex process, to actions which correspond to those which we perform when we do smell, and do taste, and do see. On the face of it that appears to be a most paradoxical hypothesis, and I do not wonder that it was the stumbling-block it was in the minds of even such acute and subtle men as Henry More, who was one of Descartes' correspondents; and yet it is a very singular thing that this, the boldest and most paradoxical notion which Descartes broached, has received as much and as strong support from modern physiological research as any other of his notions. I will endeavour to explain to you in as few words as possible what is the nature of that support, and why it is that Descartes' hypothesis, although I am bound to say I do not agree with it, nevertheless, remains at this present time not only quite as defensible as it was in his own, but I should say, upon the whole, a little more defensible."

If it should happen to a man that by accident his spinal cord is broken across, he becomes paralysed below the point of injury—in such case his limbs would be absolutely paralysed; he would have no control over them, and they would be entirely insensible. You might prick his feet, or burn them, or do anything else you liked with them, and they would be absolutely insensible. Consciousness, therefore, so far as we can have any knowledge of it, is entirely abolished in that part of the central nervous apparatus which lies below the injury. But, although the man under these circumstances is paralysed in the sense of not being able to move his own limbs, he is not paralysed in the sense of their being deprived of motion, for if you tickle the soles of his feet with a feather, the limbs will be drawn up just as vigorously as when he was in full possession of the consciousness of what happened to him—perhaps a little more vigorously. Now, that is what is called a reflex action. The impression is transmitted from the skin to the spinal cord, and is reflected from the spinal cord, and passes down into the muscles of the limbs, and they are dragged up in this manner—dragged away from the sources of irritation, though the action, you will observe, is a purely automatic or mechanical action. Suppose we deal with a frog in the same way and cut across the spinal cord. The frog falls precisely into the same condition. So far as the frog is concerned his limbs are useless; but you have merely to apply the slightest irritation to them, and they are instantly drawn away. Now, if we have any ground for argument at all, we have a right to assume that, under these circumstances, the lower half of the frog's body is as devoid of consciousness as is the lower half of the man's body. I say, if we have any ground for reasoning on these matters at all (and I shall assume that we have such ground), the body of the frog below the skin is in this case absolutely devoid of consciousness, is a mere machine, like a musical box, or a barrel-organ, or a watch. Now comes the remarkable circumstance; in the first place, that the movement of the limbs is purposive—that is to say, that when you irritate the skin of the foot, the foot is drawn away from the danger, just as it would be if the frog were conscious and rational, and could act in accordance with rational consciousness.

But you may say, it is easy enough to understand how so simple an action might take place mechanically. Let us take another experiment. Take this creature, which certainly cannot feel, and touch the skin on the side of the body with a little acetic acid, a little vinegar, which, in a frog that could feel, gives rise to great pain. In this case there can be no pain, because the application is made below the point of section; nevertheless, the frog lifts up the limb of the same side, and applies the foot to rubbing off the acetic acid; and what is still more remarkable is this, that if you hold down the limb so that the frog cannot use it, he will, by-and-bye, take the limb of the other side and turn it across the body, and use it for the same rubbing process. It is impossible that the frog, if it were in its entirety and were reasoning, could perform actions more purposive than these; and yet we have most complete assurance that, in this case, the frog is not acting from purpose, has no consciousness, is a mere automatic machine. But now, suppose that, instead of making your section of the cord in the middle of the body, you had made it in such a manner as to divide the hindmost part of the brain from the foremost part of the brain, and suppose the foremost two-thirds of the brain entirely taken away, the frog is then absolutely devoid of any spontaneity; it will remain for ever where you leave it; it will not stir unless it is touched; it sits upright in the condition in which a frog habitually does sit; but it differs from the frog which I have just described in this, that if you

throw it into the water it begins to swim—swim just as well as the perfect frog does. Now, swimming, you know, requires the combination—and a very careful and delicate combination—of a great number of muscular actions, and the only way we can account for this is, that the impression made upon the sensory nerves of the skin of the frog by the contact with the water, conveys to the central nervous apparatus a stimulus which sets going a certain machinery, by which all the muscles of swimming are brought into play, and the remarkable operation is performed. Moreover, if the frog be stimulated, he touched by some irritating body, although we are quite certain it cannot feel, it jumps or walks as well as the complete frog can do. But it cannot do more than this.

Suppose yet one other experiment. Suppose that all that is taken away of the brain is what we call the hemisphere, the most anterior part of the brain. If that operation be properly performed, very quickly and very skilfully, the frog may be kept in a state of full bodily vigour for months, or it may be for years; but it will sit for ever in the same spot. It sees nothing; it hears nothing. It will starve sooner than feed itself; although, if food be put into its mouth, it swallows it. On irritation, it jumps or walks; if thrown into the water, it swims. But the most remarkable thing that it does is this; you put it in the flat of your hand, it sits there, crouched, perfectly quiet, and would sit there for ever. Then, if you incline your hand, doing it very gently and slowly, so that the frog would naturally tend to slip off, you feel the creature's fore paws getting a little slowly on to the edge of your hand until he can just hold himself there, so that he does not fall; then, if you turn your hand, he mounts up with great care and deliberation, putting one leg in front and then another, until he balances himself with perfect precision upon the edge of your hand; then, if you turn your hand over, he goes through the opposite set of operations until he comes to sit in perfect security upon the back of your hand. The doing of all this requires a delicacy of co-ordination, and an adjustment of the muscular apparatus of the body, which is only comparable to that of a rope-dancer among ourselves; in truth, a frog is an animal very poorly constructed for rope dancing, and, on the whole, we may give him rather more credit than we should to a human dancer. These movements are performed with the utmost steadiness and precision, and you may vary the position of your hand, and the frog, so long as you are reasonably slow in your movements, will work backwards and forwards like a clock. And what is still more remarkable is this, that if you put him on a table, and put a book between him and the light, and give him a little jog behind, he will jump—take a long jump, very possibly—but he will not jump against the book; he will jump to the right or to the left, but he will get out of the way, showing that, although he is absolutely insensible to ordinary impressions of light, there is still a something which passes through the sensory nerve, acts upon the machinery and his nervous system, and causes it to adapt itself to its proper action.

Can we go further than this? I need not say that since those days of commencing anatomical science when criminals were handed over to the doctors, we cannot make experiments on human beings, but sometimes they are made for us, and made in a very remarkable manner. That operation called war is a great series of physiological experiments, and sometimes it happens that these physiological experiments bear very remarkable fruit. I am indebted to my friend General Strachey, for bringing to my notice the other day an account of a case which appeared within the last four or five days in the scientific article of the *Journal des Débats*. A French soldier, a sergeant, was wounded at the battle of Bazeilles, one, as you recollect, of the most fiercely contested battles of the late war. The man was shot in what we call the left parietal bone. The bullet, I presume, glanced off, but it fractured the bone. He had enough vigour left to send his bayonet through the Prussian who shot him. Then he wandered a few hundred yards out of the village, where he was picked up and taken to the hospital, where he remained some time. When he came to himself, as usual in such cases of injury, he was paralysed on the opposite side of the body, that is to say, the right arm and the right leg were completely paralysed. That state of things lasted, I think, the better part of two years, but sooner or later he recovered from it, and now he is able to walk about with activity, and only by careful measurement can any difference between the two sides of his body be ascertained. The inquiry, the main results of which I shall give you, is conducted by exceedingly competent persons, and they report that at present this man lives two lives, normal life and an abnormal life. In his normal life he is perfectly well, cheerful, and a capital hospital attendant, does all his work well, and is a respectable well-conducted man. That normal life lasts for about seven-and-twenty days, or thereabouts, out of every month; but for a day or two in each month—generally at intervals of about that time—he passes into another life, suddenly and without any

warning or intimation. In this life he is still active, goes about just as usual, and is to all appearance just the same way as before, goes to bed and undresses himself, gets up, makes his cigarette and smokes it, and eats and drinks. But in this condition he neither sees, nor hears, nor tastes, nor smells, nor is he conscious of anything whatever, and has only one sense-organ in a state of activity, viz., that of touch, which is exceedingly delicate. If you put an obstacle in his way, he knocks against it, feels it, and goes to the one side; if you push him in any direction he goes straight on, illustrating, as well as he can, the first law of motion. You see I have said he makes his cigarettes, but you may make his tobacco of shavings or of anything else you like, and still he will go on making his cigarettes as usual. His action is purely mechanical. As I said, he feeds voraciously, but whether you give him aloes or assafoetida, or the nicest thing possible, it is all the same to him. He is just like my frog, he goes on feeding. The man is in a condition absolutely parallel to that of the frog I have just described, and no doubt, when he is in this condition, the functions of his cerebral hemisphere are at any rate largely annihilated. He is very nearly—I do not say wholly, but very nearly—in the condition of an animal in which the cerebral hemispheres are not entirely extirpated, but very largely damaged. And his state is wonderfully interesting to me, for it bears on the phenomena of mesmerism, of which I saw a good deal when I was a young man. In this state he is capable of performing all sorts of actions on mere suggestions; as, for example, he dropped his cane, and a person near him put it into his hand, and the feeling of the end of the cane evidently produced in him those molecular changes of the brain which, had he possessed consciousness, would have given rise to the idea of his rifle; for he threw himself on his face, began feeling about for his cartouche, went through the motions of touching his gun, and shouted out to an imaginary comrade, "Here they are, a score of them; but we will give a good account of them." This paper to which I refer is one of the most remarkable examples of this kind, and what is the most remarkable fact of all is the modifications which this injury has made in the man's moral nature. In his normal life he is one of the most upright and honest of men. In his abnormal state, however, he is an inveterate thief. He will steal everything he can lay his hands upon; and if he cannot steal anything else, he will steal his own things and hide them away.

Now, if Descartes had had this fact before him, need I tell you that his theory of animal automatism would have been enormously strengthened? He would have said, "Here I show you a case of a man performing actions evidently more complicated, and mostly more rational, than any of the ordinary operations of animals, and yet you have positive proof that these actions are purely mechanical. What, then, have you to urge against my doctrine that the whole animal world is in that condition, and that, to use the very correct words of Father Malebranche, 'Thus in dogs, cats, and other animals there is neither intelligence nor spiritual soul, as we understand the matter commonly; they eat without pleasure, they cry out without pain, they grow without knowing it, they desire nothing, they know nothing; and if they act with dexterity, and in a manner which indicates intelligence, it is because God, having made them with the intention of preserving them, has constructed their bodies in such a manner that they escape organically, without knowing it, everything which could injure them, and which they seem to fear?'" Descartes put forward this theory, and I really do not know that we are in the slightest degree competent to give a distinct and definite refutation of that hypothesis at the present day. You can have no direct observation of consciousness in any creature but yourself, for beasts cannot tell you anything of it, and I am afraid that the matter is one wholly incapable of demonstrative proof. But I must say for myself—looking at the matter on the ground of analogy—taking into account that great doctrine of continuity which forbids one to suppose that any natural phenomena can come into existence suddenly and without some precedent, gradual modification tending towards it—taking that great doctrine into account (and everything we know of science tends to confirm it), and taking into account, on the other hand, the incontrovertible fact that the lower animals, which possess brains at all, possess, at any rate, a rudimentary part of the brain, which we have every reason to believe is the organ of consciousness in ourselves, then it seems vastly more probable that the lower animals, although they may not possess that sort of consciousness which we have ourselves, yet have it in a form proportional to the comparative development of the organ of that consciousness, and foreshadow more or less dimly those feelings which we possess ourselves. I think that is probably the most rational conclusion that can be come to. It has this advantage, though this is a consideration which could not be urged in dealing with questions that are susceptible of demonstration, but which is well worthy of consideration in a case like the present, that it relieves us of the very terrible consequences of making any mis-

take on this subject. I must confess that, looking at that terrible struggle for existence which is everywhere going on in the animal world, and considering the frightful quantity of pain which must be given and received in every part of the animal world, I say that is a consideration which would induce me wholly to adopt the view of Descartes; but, on the other hand, considering that if we regard animals as mere machines, we might indulge in cruelties and unnecessary and careless treatment of them, I must confess I think it, on the whole, much better to err on the right side, and not to concur with Descartes on this point.

But let me point out to you that although we may come to the conclusion that Descartes was wrong in supposing that animals are insensible machines, it does not in the slightest degree follow that they are not sensitive and conscious automata; in fact, that is the view which is more or less clearly in the minds of every one of us. When we talk of the lower animals being provided with instinct, and not with reason, what we really mean is, that although they are sensitive and although they are conscious, yet they do act mechanically, and that their different states of consciousness, their sensations, their thoughts (if they have them), their volitions (if they have them), are the products and consequences of their mechanical arrangements. I must confess that this popular view is to my mind the only one which can be scientifically adopted. We are bound by everything we know of the operations of the nervous system to believe that when a certain molecular change is brought about in the central part of the nervous system, that that change, in some way utterly unknown to us, causes that state of consciousness that we term a sensation. It is not to be doubted that the impression excited by those motions which give rise to sensation leaves in the brain molecular changes which answer to what Haller called *vestigia rerum*, and which that great thinker David Hartley termed "Vibratiuncles", which we might term sensigenous molecular, and which constitute the physical foundation of memory. Those same changes gave rise naturally to conditions of pleasure and pain, and to those emotions which in ourselves we call volition. I have no doubt that is the relation between the physical processes of the animal and his mental processes. In each case it follows inevitably that these states of consciousness can have no sort of relation of causation to the motions of the muscles of the body. The volition of animals will be simply states of emotion which precede their actions. To make clear what I mean, suppose I had a frog placed in my hand, and that I could make it by turning my hand perform this balancing movement. If a frog were a philosopher, he might reason thus:—"I feel myself uncomfortable and slipping; and, feeling myself uncomfortable, I put my legs out to save myself. Knowing that I shall tumble if I do not put them further, I put them further still, and my body will bring about all this beautiful adjustment which results in my sitting safely." But if the frog had so reasoned, he would be entirely mistaken; for the frog just does the thing as well when he has no reason, no sensation, no possibility of thought of any kind.

The only conclusion, then, at which there seems any good ground for arriving is, that animals are machines, but that they are conscious machines. I might, with propriety, consider what I have now said as the conclusion of the observations which I have to offer concerning animal automatism. So far as I know, the problem which we have hitherto been discussing is an entirely open one. I do not know that there is any reason on the part of any person, whatever his opinions may be, that can prevent him, if he be so inclined, from accepting the doctrine which I have just now put before you clearly. So far as we know, animals are conscious automata. That doctrine is perfectly consistent with any view that we may choose to take on a very curious subject of speculation—Whether animals possess souls or not, and whether, if they possess souls, these souls are immortal or not. The doctrine to which I have referred is not inconsistent with the perfectly strict and literal adherence to the Scripture text concerning the beast that perisheth; nor, on the other hand, so far as I know, does it prevent anyone from entertaining the amiable convictions ascribed by Pope to his untutored savage, that when he passed to the realms of the blessed his faithful dog should bear him company. In fact, all these accessory questions to which I have referred, involve problems which cannot be discussed by physical science as such, as they lie not within the scope of physical science, but come within the scope of that great mother of all science, philosophy. Before any direct answer can be given upon any of these questions, we must hear what philosophy has to say for and against the views that may be held. I need hardly say—especially having detained you so long as I find I have—that I do not propose to enter into that region of discussion, and I might, properly enough, finish what I have to say upon the subject—especially as I have reached its natural limits—if it were not that an experience, now extending, I am sorry to say, over a good many years, leads me to anticipate that what I have brought

before you to-night is not likely to escape the fate which, upon many occasions within my recollection, has attended the statements of scientific doctrine and of scientific tendency, which have been made in a spirit intended at any rate to be as calm and as judicial as that in which I have now laid these facts before you. I do not doubt that that fate will befall me which has befallen better men, and that I shall have to bear in patience the reiterated assertion that doctrines such as I have put before you have very evil tendencies. I should not wonder if you were to be told by persons speaking with authority—not, perhaps, with that authority which is based upon knowledge and wisdom, but still with authority—I should not wonder if you were told that my intention in bringing this subject before you is to lead you to apply the doctrine I have stated to man as well as to brutes, and it will then certainly be further stated that the logical tendency of such a doctrine is Fatalism, Materialism, and Atheism.

Now, let me ask you to listen to another product of that long experience to which I referred. The logical consequences are very important; but, in the course of my experience, I have found that they were the scarecrows of fools and the beacons of wise men. Logical consequences can take care of themselves. The only question for any man to ask is this: "Is this doctrine true, or is it false?" No other question can possibly be taken into consideration until that one is settled. And, as I have said, the logical consequences of doctrines can only serve as a warning to wise men to ponder well whether the doctrine be true or not, and to test it in every possible direction. Undoubtedly, I do hold that the view I have taken of the relations between the physical and mental faculties of brutes applies in its fullness and entirety to man; and if it were true that the logical consequences of that belief must land me in all these terrible things, I should not hesitate in allowing myself to be so landed. I should conceive that if I refused, I should have done the greatest and most abominable violence to everything which is deepest in my moral nature. But now I beg leave to say that, in my conviction, there is no such logical connection, as is pretended, between the doctrine I accept and the consequences which people profess to draw from it. Many years ago, I had occasion, in dealing with the philosophy of Descartes, and some other matters, to state my conviction pretty fully on those subjects; and, although I know by experience how futile it is to endeavour to escape from those nicknames which many people mistake for argument, yet, if those who care to investigate these matters in a spirit of candour and justice will look into those writings of mine, they will see my reasons for not imagining that such conclusions can be drawn from such premisses. To those who do not look into these matters with candour and a desire to know the truth, I have nothing whatever to say, except to warn them, on their own behalf, what they do; for assuredly if, for preaching such doctrine as I have preached to you to night, I am cited before the bar of public opinion, I shall not stand there alone. On my one hand I shall have, among theologians, St. Augustine, John Calvin, and a man whose name should be well known to the Presbyterians of Ulster, Jonathan Edwards, unless, indeed, it be the fashion to neglect the study of the great masters of divinity, as many other great studies are neglected nowadays; and I should have upon my other hand, among the philosophers, Leibnitz; I should have Père Malebranche, who saw all things in God; I should have David Hartley, the theologian as well as philosopher; I should have Charles Bonnet, the eminent naturalist, and one of the most zealous defenders Christianity has ever had. I think I should have, within easy reach at any rate, John Locke. Certainly, the school of Descartes would be there, if not their master; and I am inclined to think, in due justice, a citation would have to be served upon Emmanuel Kant himself. In such society it may be better to be a prisoner than a judge; but I would ask those who are likely to be influenced by the din and clamour which are raised about these questions, whether they are more likely to be right in assuming that those great men I have mentioned—the fathers of the Church and the fathers of philosophy—knew what they were about, or that the pigmies who raise this din know better than they did what they meant? It is not necessary for any man to occupy himself with problems of this kind unless he so choose. Life is full enough, filled amply to the brim, by the performance of its ordinary duties; but let me warn you, let me beg you, to believe that if a man elect to give a judgment upon these great questions—still more, if he assume to himself the responsibility of attaching praise or blame to his fellow-men for the judgments which they may venture to express—I say that, unless he would commit a sin more grievous than most of the breaches of the Decalogue, let him avoid a lazy reliance upon the information which is gathered by prejudice and filtered through passion. Let him go to these great sources that are open to him as to every one, and to no man more open than to an Englishman; let him go back to the facts of nature, and to the thoughts of those wise men who, for generations past, have been the interpreters of nature.

AN ADDRESS

ON

RECENT ADVANCES IN ANATOMY AND PHYSIOLOGY.

Delivered in the Section of Biology at the Annual Meeting of the British Association for the Advancement of Science, 1874.

By PETER REDFERN, M.D.,

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GENTLEMEN,—It has occurred to me that, in attempting to give a stronger impulse and a more systematic direction to scientific inquiry, the time ordinarily devoted to an Introductory Address could not be more profitably occupied than by bringing into as great prominence as possible some of the great revolutions in our knowledge of anatomy and physiology which have taken place in my own time, and under my own immediate observation. I remember, as if it were yesterday, the elucidation in the Museum of the Royal College of Surgeons of Edinburgh of the newly discovered cell-theory, by the late distinguished professor of anatomy, John Goodsir; his account of the production of ulceration by cell-growth, of the character of the corpuscles of bone, of the structure of lymphatic glands, and of the germinal centres of basement membranes, as they were then understood.

This was the time when the teaching of histology was first established in Great Britain. Two students, of whom I was one, formed the first class, under the most enthusiastic of teachers, my old friend Dr. Hughes Bennett. The University of Edinburgh had just passed through what was probably the most brilliant period in its history. The race of the last of the Monroes was well-nigh run. The great discoverer of the difference in the motor and sensory nerves, Sir Charles Bell, was still living. The aristocracy of Scotland had only just ceased to crowd the class-room and witness the brilliant and successful experiments of Dr. Hope. The day of Cullen, and Home, and Duncan, and Macintosh was over; but there still remained in the university the most loved and revered of teachers, the benevolent Dr. Alison, Sir Robert Christison, Sir George Ballingall, Mr. Syme, and Dr. Abercrombie, still practising in the city.

At this period, the great discoveries of Schleiden and Schwann seemed likely to upset all that had previously constituted physiology. The idea that all tissues were either composed of cells or had been formed of cells, that nucleated cells elaborated all the secretions, that their energy lay at the root of the foundation, the reproduction, and the function of every tissue and organ, was a revelation of such astounding simplicity as will upset men's minds, and prevent their seeing beyond. No one who did not live through that time will, I believe, ever realise the eagerness and anxiety with which every new statement of the action of cells was received and added to the previous knowledge of their amazing power; or, on the other hand, be able to judge of the feeling, half akin to disappointment, which was experienced as each attack was made on this charming thing, showing it to be really human—very human indeed. Cells were then understood to constitute the mass of all organs, the liver, spleen, kidney, and brain, and to be the main agents in the discharge of their functions: to exist and grow upon the definite membranous walls of the glandular vesicles and ducts; to be fed by blood brought to the attached surface of membranes, which seemed almost everywhere to form an absolute separation of the cellular part, the potential gland, from the non-essential blood and lymph-vessels, the nerves and framework of the organ.

It seemed almost a pity that the little microscopic deities should be hampered by the necessities of their own existence; that they should need such base things as blood-vessels, nerves, and packing materials. Now, how strangely are matters changed! What if it should turn out that these apparently independent little beings are not independent at all; that they are only the dilated endings of nerves? To this subject, I shall refer again by and by.

This great cell-theory has now given place to what, I think, is certain knowledge: that living matter may more than perform all the functions of assimilation and intrusion, and reproduce its like, without having any of the essential characters of a cell. A living mass of protoplasm may change its shape, alter its position, feed and nourish itself, and form other matter having the same properties as it has, and yet be perfectly devoid of any structure recognisable by the highest powers of the microscope.