The Huxley Lecture

ON

RECENT ADVANCES IN SCIENCE AND THEIR BEARING ON MEDICINE AND SURGERY.*

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THE SCIENTIFIC INVESTIGATION OF THE PSYCHICAL FACULTIES OR PROCESSES IN THE HIGHER ANIMALS.

[AFTER some introductory remarks Professor Pawlow proceeded:]

For a consistent investigator there is in the higher animals only one thing to be considered—namely, the response of the animal to external impressions. This response may be extremely complicated in comparison with the reaction of animals of a lower class. Strictly speaking, natural science is under an obligation to determine only the precise connexion which exists between the given natural phenomenon and the responsive faculty of the living organism with respect to this phenomenon—or, in other words, to ascertain completely how the given living object maintains itself in constant relation with its environment. The question is simply whether this law is now applicable to the examination of the higher functions of the higher quadrupeds. I and my colleagues in the laboratory began this work some years ago, and we have recently devoted ourselves to it almost completely. All our experiments were made on dogs. The only response of the animals to external impressions was a physiologically unimportant process—namely, the excretion of saliva. The experimenter always used perfectly normal animals, the meaning of this expression being that the animals were not subjected to any abnormal influence during the experiments. By means of a systematic procedure easy of manipulation it was possible to obtain an exact observation of the work of the salivary glands at any desired time.

It is already well known that there is always a flow of saliva in the dog when something to eat is given to it or when anything is forcibly introduced into its mouth. In these circumstances the escaping saliva varies both in quality and quantity very closely in accordance with the nature of the substances thus brought into the dog's mouth. Here we have before us a well-known physiological process—namely, reflex action. It is the response of the animal to external influences, a response which is accomplished by the aid of the nervous system. The force exerted from without is transformed into a nervous impression, which is transmitted by a circuitous route from the peripheral extremity of the centripetal nerve through the centripetal nerve, the central nervous system, and the centrifugal nerve, ultimately arriving at the particular organ concerned and exciting its activity. This response is specific and permanent. Its specificity is a manifestation of a close and peculiar action of the external phenomena to physiological action, and is founded on the specific sensibility of the peripheral nerve-endings in the given nervous chain. These specific reflex actions are constant under normal vital conditions, or, to speak more properly, during the absence of abnormal vital conditions.

The responses of the salivary glands to external influences are, however, not exhausted by the above-mentioned ordinary reflex actions. We all know that the salivary glands begin to secrete, not only when the stimulus of appropriate substances is impressed on the interior surface of the mouth, but that they also often begin to secrete when other receptive surfaces, including the eye and the ear, are similarly stimulated. The actions last mentioned are, however, generally considered apart from physiology and receive the name of psychical stimuli. We will take another course, and will endeavour to restore to physiology what properly belongs to it. These exceptional manifestations unquestionably have much in common with ordinary reflex action. Every time that there is a flow of saliva attributable to this cause, the occurrence of some special stimulus among the

external influences may be recognized. On very careful exercise of his attention, the observer perceives that the number of spontaneous flows of saliva forms a rapidly diminishing series, and it is in the highest degree probable that those extremely infrequent flows of saliva for which no particular cause is at first sight apparent are in reality the result of some stimulus invisible to the eye of the observer. From this it follows that the centripetal paths are always stimulated primarily and the centrifugal paths secondarily, of course with the interposition of the central nervous system. In the first place, they arise from all the bodily surfaces which are sensitive to stimulation, even from such regions as the eye and the ear, from which an ordinary reflex action affecting the salivary glands is never known to proceed.

It must be observed that ordinary salivary reflexes may originate not only from the cavity of the mouth, but also from the skin and the nasal cavity. In the second place, a conspicuous feature of these reflexes is that they are in the highest degree inconstant. All stimuli introduced into the mouth of the dog unfailingly give a positive result in reference to the secretion of saliva, but the same objects when presented to the eye, the ear, etc., may be sometimes efficient and sometimes not. In consequence of the last-mentioned fact, we have provisionally called the new reflexes "conditioned reflexes," and for the sake of distinction we have called the old ones "unconditioned." Every conditioned stimulus becomes totally ineffective on repetition, the explanation being that the reflex action ceases. The shorter the interval between the separate repetitions of the conditioned reflex the more quickly is this reflex obliterated. The obliteration of one conditioned reflex does not affect the operation of the others. Spontaneous restoration of the obliterated conditioned reflexes does not occur until after the lapse of one, two, or more hours, but there is a way in which our reflex may be restored immediately. All that is necessary is to obtain a repetition of the unconditioned reflex—as, for instance, by pouring vinegar into the dog's mouth and then either showing it to him or letting him smell it. The action of the last-mentioned stimuli, which was previously quite obliterated, is now restored in its full extent. If for a somewhat long time—such as days or weeks continuously—a certain kind of food is shown to the animal without being given to him to eat, it loses its power of imparting a stimulus from a distance—that is, its power of acting on the eye, the nose, etc.

We may, therefore, say that the conditioned reflex is in some way dependent on the unconditioned reflex. At the same time we see also the mechanism which is necessary for the production of our conditioned reflex. When an object is placed in the mouth, some of its properties exercise an action on the simple reflex apparatus of the salivary glands, and for the production of our conditioned reflex that action must synchronize with the action of other properties of the same object when the last-mentioned action, after influencing other superficial parts of the body that are sensitive to such stimuli, arrives in other parts of the central nervous system. Just as the stimulant effects due to certain properties of an object placed in the mouth may be associated as regards time with a number of stimuli arising from other objects, so all these manifold stimuli may by frequent repetition be turned into conditional stimuli for the salivary glands. It must be remembered that in feeding a dog or forcing something into its mouth each separate movement and each variation of a movement may by itself represent a conditioned stimulus. If that is the case, and if our hypothesis as to the origin of the conditional reflex is correct, it follows that any natural phenomenon chosen at will may, if required, be converted into a conditioned stimulus. Any ocular stimulus, any desired sound, any odour that might be selected, and the stimulation of any portion of the skin, either by mechanical means or by the application of heat or cold, have in our hands never failed to stimulate the salivary glands, although they were all of them at one time supposed to be ineffective for such a purpose. This was accomplished by applying these stimuli simultaneously with the action of the salivary glands, this action having been evoked by the giving of certain kinds of food, or by forcing certain substances into the dog's mouth. These artificial conditioned reflexes, the product of our training, showed exactly the same properties as the

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natural conditioned reflexes previously described. As regards their obliteration and restoration, they followed essentially the same laws as the natural conditioned reflexes.

Up to the present time the stimuli with which we had to do were comparatively few in number but were constant in action. Now, however, in another more complicated portion of the nervous system we encounter a new phenomenon—namely, the conditioned reflex. On the one hand, the nervous apparatus is responsive in the highest degree—that is, it is susceptible to the most varied external stimuli, but, on the other hand, these stimuli are not constant in their operation and are not uniformly associated with a definite physiological effect. The introduction of the idea of conditioned reflexes into physiology seems to me to be justified because it corresponds to the facts that have been adduced, since it represents a direct inference from them. It is in agreement with the general mechanical hypotheses of natural science. It is completely covered by the ideas of paths and inhibition, ideas which have been sufficiently worked up in the physiological material of the present day. Finally, in these conditioned stimuli, looked at from the point of view of general biology, there is nothing but a very complete mechanism of accommodation or, which amounts to the same thing, a very delicate apparatus for maintaining the natural equilibrium. There are reasons for considering the process of the conditioned reflex to be an elementary process—namely, a process which really consists in the coincidence of any one of the innumerable vague external stimuli with a stimulated condition of any point in a certain portion of the central nervous system. In this way for the time being a path is made by which the stimulus may reach the given point.

Although there are differences in the time required for the establishing of the conditioned reflexes, some proportionality may be perceived. From our experiments it is very evident that the intensity of the stimulation is of essential importance. In contradistinction to this we must state with regard to acoustic impressions that very powerful stimuli, such as the violent ringing of a bell, were not, in comparison with weaker stimuli, quick to produce conditioned increase of function in the salivary glands. It must be supposed that powerful acoustic stimuli produce in the body some other important reaction which hinders the development of the salivary reaction.

What is it that the nervous system of the dog recognizes as individual phenomena of external origin? or, in other words, What are the elements of a stimulus? If the application of cold to a definite area of the skin acts as a conditioned stimulus of the salivary glands, the application of cold to another portion of the skin causes secretion of saliva on the very first occasion. This shows that the stimulus of cold generalizes itself over a considerable portion of the skin, or perhaps even over the whole of it.

Stimulation by musical sounds or by noise in general is remarkably convenient for determining the discriminating or analytical faculty of the nervous system of the dog. In this respect the precision of our reaction goes a great way. If a certain note of an instrument is employed as a conditioned stimulus, it often happens that not only all the notes adjoining it, but even those differing from it by a quarter of a tone, fail to produce any effect. Musical *timbre* is recognized with similar or even much greater precision.

We have hitherto spoken of the analytical faculty of the nervous system as it presents itself to us in, so to say, the finished condition. We have now accumulated material which contains evidence of a continuous and great increase of this faculty if the experimenter perseveres in subdividing and varying the conditioned stimulus, and thereby makes it coincide with the unconditioned stimulus. Here, again, is a new field of enormous extent. In this material relative to the conditioned stimuli there are not a few cases in which an evident connexion between the effect and the intensity of a stimulus can be seen. As soon as a temperature of 50° C. had begun to induce a flow of saliva it was found that even a temperature of 30° C. had a similar effect but in a much less degree. Trial was then made of combinations consisting of stimuli of the same kind and also of stimuli of different kinds. The simplest example is a combination of different musical

notes, such as a harmonic chord, which consists of three notes. When this is employed as a conditioned stimulus each two notes together and each separate note of the chord produce an effect, but the notes played two and two together accomplish less than the whole, and the notes played separately accomplish less than those played in pairs. The case becomes more complicated when we employ as a conditioned stimulus a combination of stimuli of different kinds, that is, of stimuli acting upon different kinds of susceptible surfaces. Only a few of such combinations have been provisionally experimented with. In these cases for the most part one of the stimuli was a conditioned stimulus. In a combination in which rubbing and cold were employed the former was preponderant as a conditioned stimulus while the application of cold taken by itself produces a hardly perceptible effect. But if an attempt is made to convert the weaker stimulus separately into a conditioned stimulus it soon becomes an energetic conditioned stimulus. If we now apply the two stimuli together we have before us an evident case of them acting in combination. The following problem had for its object to explain what happens to an active-conditioned stimulus when a new stimulus is added to it. In the cases that were examined, the action of the pre-existing conditioned stimulus was hindered when a new stimulus of a like kind was added to it. A new odour of a like kind hindered the operation of another odour which was already acting as a conditioned stimulus; a new musical note similarly hindered the operation of the note previously employed which was a conditioned stimulus. After a conditioned stimulus had been applied, together with another one which inhibited its action, the action of the first one alone was greatly weakened and sometimes even stopped altogether. This is either an after-effect of the inhibiting stimulus which was added or it is the obliteration of the conditioned reflex, because in the experiment of the added stimulus the conditioned reflex is not strengthened by the unconditioned reflex. The inhibition of the conditioned reflex is also observed in the converse case. When you have a combination of stimuli acting as a conditioned stimulus—in which, as has been already stated, one of the stimuli by itself produces almost no effect—frequent repetition of the powerful stimulus by itself without the other one leads to a powerful inhibition of its action, even to the extent of its action being almost destroyed. The relative magnitudes of all these manifestations of stimulation and inhibition have a very close connexion with their dependence on the conditions under which they originate.

Experiments have been made in the production of conditioned reflexes by traces or latent remnants both of a conditioned and of an unconditioned stimulus. The method was that a conditioned stimulus was either allowed to act for one minute immediately in advance of an unconditioned stimulus or it was even applied two minutes earlier. Conversely, also, the conditioned stimulus was not brought into action until the unconditioned reflex was at an end. In all these cases the conditioned reflex developed itself; but in the cases in which the conditioned stimulus was applied three minutes before the unconditioned one, and was separated from the latter by an interval of two minutes, we obtained a condition which was quite unexpected and extremely peculiar, but was always repeated. When scratching was applied to a particular spot—for instance, as a conditioned stimulus—after it began to produce an effect it was found that scratching of any other place also produced an effect, just as in the case of cold or heat applied to the skin, new musical sounds, optical stimuli, and odours. The unusually copious secretion of saliva, and the extremely expressive movements of the animal attracted our attention. It may appear that this manifestation is of a different kind from those with which we have hitherto been occupied. The fact was that in the earlier experiments at least one coincidence of the conditioned stimulus with the unconditioned one was necessary, but on the present occasion manifestations which had never occurred simultaneously with an unconditioned reflex were acting as conditioned stimuli. Here an unquestionable point of difference naturally comes to light, but at the same time there is also to be seen another essential property of these manifestations which they have in common with the former ones—that is, the existence of a very sensitive

point in the central nervous system, and in consequence of its position this point becomes the destination of all the important stimuli coming from the external world to make impressions on the receptive cells of the higher regions of the brain.

Three characteristic features of this subject make a deep impression upon him who works at it. In the first place, these manifestations present great facilities for exact investigation. I am here referring to the ease with which they may be repeated, to their character of uniformity under similar conditions of environment, and to the fact that they are capable of further subdivision experimentally. In the second place, it is inevitable that opinions formed on this subject must be objective only. In the third place, the subject involves an unusual abundance of questions. To what departments of physiology does it correspond? It corresponds partly to what was in former days the physiology of the organs of special sense and partly to the physiology of the central nervous system.

Up to the present time the physiology of the eye, the ear, and other superficial organs which are of importance as recipients of impressions has been regarded almost exclusively in its subjective aspect; this presented some advantages, but at the same time, of course, limited the range of inquiry. In the investigation of the conditioned stimuli in the higher animals, this limitation is got rid of and a number of important questions in this field of research can be at once examined with the aid of all the immense resources which experiments on animals place in the hand of the physiologist. The investigation of the conditioned reflexes is of very great importance for the physiology of the higher parts of the central nervous system. Hitherto this department of physiology has throughout most of its extent availed itself of ideas not its own, ideas borrowed from psychology, but now there is a possibility of it being liberated from such evil influences. The conditioned reflexes lead us to the consideration of the position of animals in nature; this is a subject of immense extent and one that must be treated objectively.

Broadly regarded, physiology and medicine are inseparable. Since the medical man's object is to remedy the various ills to which the human body is liable, every fresh discovery in physiology will sooner or later be serviceable to him in the preservation and repair of that wonderful structure. It is an extreme satisfaction to me that in honouring the memory of a great physiologist and man of science I am able to make use of ideas and facts which from a unique standpoint affording every prospect of success throw light upon the highest and most complicated portion of the animal mechanism.

Introductory Addresses

AT THE

OPENING OF THE MEDICAL SCHOOLS.

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THE PAST, PRESENT, AND FUTURE OF THE MEDICAL SCHOOL OF UNIVERSITY COLLEGE.

[ABSTRACT.]

MR. GODLEE began by explaining the conditions which led to the foundation of University College, or, as it was then called, the University of London, in 1826. He compared the educational difficulties of that period with those of the present day. The impossibility of obtaining a University education at Oxford and Cambridge without subscribing to the articles of the Church of England and taking other oaths prevented Nonconformists and others from entering these seats of learning. The idea of founding a secular University in London suggested itself to the school of Jeremy Bentham, the philosophical Radicals, and the Whigs, and was ultimately brought before the public in a letter from Thomas Campbell, the poet, to Henry Brougham, which was published in the *Times*, February 9th, 1825. Some extracts from the letter were given. The object of the University was said to be "the advancement and promotion of literature and

science by affording to young men residing in, or resorting to, the cities of London and Westminster, the borough of Southwark, and the counties adjoining, adequate opportunities for obtaining literary and scientific education at a moderate expense." The scheme raised great opposition from the Churchmen and Tories, but it rapidly proved to be a great success. The part first opened was the Faculty of Medicine, which immediately attracted large numbers of students. There was no hospital attached to the University, but Charles Bell (afterwards Sir Charles Bell), and Dr. Thomas Watson (afterwards Sir Thomas Watson), who were on the staff of Middlesex Hospital, were professors at the University, and the students of the University were allowed special facilities for obtaining clinical instruction at the Middlesex Hospital. A dispensary was started at No. 4, George Street in 1828. It was called the "University Dispensary," and was under the aegis of the University. The North London Hospital was founded in 1833, and was completed in 1846. In 1836 its name was changed to "University College Hospital," and in 1851 to "North London or University College Hospital," by which it is known at the present day.

The state of medical education at the beginning of last century was then described, and it was shown how imperfect and unscientific was the teaching of that time. The medical profession was usually entered by the portal of apprenticeship, and the qualifying diplomas required only a very insufficient amount of training. A very small proportion of medical men obtained university degrees, and these were mostly sought either on the Continent or at the Scottish universities. The University of London aimed at modifying the course of education by making the attendance at systematic lectures the primary object of the earlier years, and by rendering this part of the instruction thorough and sound. It was hoped also that medical students would take up a course of instruction in arts before starting on their medical career.

In 1836, when the present University of London was founded, the institution in Gower Street was incorporated by Royal Charter under the name of University College, London, resigning at the same time one of its early ambitions—namely, that of being allowed to grant degrees.

Some description was then given of the old hospital, which was defective from a sanitary and hygienic point of view. Projects for rebuilding it were discussed from 1886 to 1896, when Sir John Blundell Maple provided the funds with which the present hospital was built.

A brief account was then given of the steps leading to the modification of the University of London, which rendered it a true teaching university, and of the absorption by it of University College. When this took place it was felt to be impossible, or inadvisable, for the University to undertake the management of the hospital and the teaching of the advanced medical subjects. It thus became necessary that these should be separated from University College and fused in a new corporation. This was accordingly agreed to, on the understanding that the University should undertake to conduct the teaching of the preliminary subjects, including anatomy and physiology, to all comers in the College as before. The school of advanced medical studies is to be accommodated in a building now in course of erection, the cost of which will be defrayed by the gift of £100,000 from Sir Donald Currie.

The advantages and disadvantages of this plan of separating the teaching of the advanced from that of the earlier medical subjects was fully discussed. It is a new one as far as this country is concerned, but there are indications that some other medical schools may be disposed to adopt the same course. The lecturer then described in some detail the precise position of the new corporation, its capacity, equipment, and objects, and stated his views as to what its prospects and functions should be. It was pointed out that in spite of the large sums of money which have been given, it might almost be said in consequence of them, still more was wanted for endowment. This was always urgently required for the hospital, and it was difficult to put any limit to its needs. The requirements of the school were more moderate, and if it proved successful and attracted a sufficient number of students its chief need would be the endowment of the chair of pathology. This in order to make the department