PHYSIOLOGY IN RELATION TO PSYCHOLOGICAL MEDICINE.*

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An invitation to address a gathering of medical psychologists is, to the physiologist, a great temptation, and on such occasions he is apt to leap into the whirlpools of psychology in an attempt to explain the workings of the brain by hypotheses based, alas, on insufficient evidence. The paucity of information on cerebral function in physiological text-books has an explanation. Our lack of knowledge is due to the absence of available methods for investigating the normal activity of the higher nerve centres. Explanations are too often advanced without a due appreciation of the function of the lower nervous system in bringing about the exquisite co-ordination and relationship that exists between the different areas and organs of the body. This function is well exemplified in the reciprocal innervation of which we have evidence with every normal voluntary contraction. The difficulties of investigation have their root in the complexity of the reactions of an animal endowed with a well-developed cerebral cortex, compared with those seen in the lower types of life, or in the spinal animal. It must be clear that if our knowledge of the physiological factors controlling mental activity is to advance, the physiologist must continue to make measurements, accurate, quantitative measurements, if possible, on structures which he can control, and on preparations in which he is able to isolate the disturbing factors, and from these results and conclusions to construct by slow degrees a knowledge and understanding of the nervous system.

It may appear that the physiologist is not adding much to the subject of psychological medicine, or that his investigations savour too much of physical and chemical methods; yet if we review the progress of the last fifty to sixty years, we become duly aware of the advances which have taken place. I am sure that at no time has activity been greater in this particular field of research than at present; witness the number of articles, papers and books

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published yearly, describing the results of experimental investigations on the nervous system. This progress becomes clear when we realize that Broca first described the speech area as recently as 1861, and it was only in 1864 that Fritz and Hitzig demonstrated the excitability of the grey matter of the cerebral cortex, and by these experiments opened the door to the localization of cerebral function. The further advances in this field were due to men like Ferrier, Horsley, Bolton, Sherrington and Schäfer, to name a few, and we realize how recent this work is when we remember the present-day activities of your President, of Sherrington and of Schäfer.

These advances have been made from small beginnings, and I do not think I can exemplify this better than by referring to the work of Keith Lucas. As far back as 1872, Grünhagen had made what has been called the "gas chamber" experiment on nerve. He took a nerve-muscle preparation and passed a portion of the nerve through a glass chamber, so that this portion could be exposed to the action of carbon dioxide while the parts above and below were in the air. He tested the strength of stimulus which would cause a contraction of muscle when applied either outside or inside the gas chamber. It was later shown that the impulse would fall off less rapidly under a weak anæsthetic than under a strong one, and the explanation was advanced that the effect was due to the decrement of the impulse during its passage through the nerve. This state Lucas likened to the condition which exists in the synaptic junctions of the central nervous system.

In further experiments, using the same preparation, Lucas and Adrian were able to demonstrate the all-or-none law of the nerve-fibre. The experiments established the fact that an impulse which has been reduced in its power of conduction by passage through a region of decrement, recovers in full when it emerges into a tract of normal nerve. On this hypothesis the discharge of impulse from a nerve-cell will reach the tissue with the same maximal intensity whether the pathway through the brain has been simple or complex.

These experiments lead us to a consideration of the grading of impulses in either the efferent or the afferent systems. According to the all-or-none law, the grading effect cannot be explained on the view that the intensity of the impulse varies with the strength of the stimulus which sets it up. Again, a grading effect which depends on the number of nerve-fibres conducting seems inadequate if we consider the function of the various sense-organs. Forbes suggested that reflex response and analysis of sensation by the cerebral cortex may be graded, first by the number of sensory nerves

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conducting the impulses, and, second, by the number of impulses set up by each stimulus. Adrian has recently been able to put this view to the test; using an extremely delicate recording apparatus, he has succeeded in recording the impulses conducted in the sensory nerves on stimulation of an end-organ. The experiment is made by placing a pair of electrodes on the sensory nerves and amplifying the electrical changes, which are recorded by a capillary electrometer.

Adrian has shown that on stimulation of a single isolated end-organ in a tissue, varying frequencies of impulses are set up and conducted by the nerve according to the strength of the stimulus. More recent experiments, using the retina as an end-organ, have provided further evidence that the grading effect of the sensory system is due to alteration in the frequency of impulses set up at the periphery.

These considerations naturally lead to the questions of excitation and of inhibition, which have been so carefully studied by Sherrington in his work on the reflex arc. It was Sherrington who clearly demonstrated the chief differences between conduction in nerve-trunks and in reflex arcs. The influence of the synaptic junction was shown by the fatigability of reflex action in contrast with the comparative non-fatigability of nerve-trunks, and by the presence in reflex arcs of the refractory period, *bahnung* or facilitation, inhibition and shock in degrees unknown for nerve-trunks.

Sherrington, also, has investigated the mechanism and functional significance of muscular tonus, with particular reference to the influence of the proprioceptive arc on the stretching and shortening reactions of skeletal muscle. There is no doubt that the presence of the proprioceptive nerves brings about a delicate balance between excitatory and inhibitory activity, and is an important factor in controlling the gradual character of the response. It is obvious that the ataxic condition which is at once so striking and so pathetic a feature of tabes dorsalis, results from the absence of proper control in both the excitatory and inhibitory phases of movement.

Magnus and his co-workers have investigated the proprioceptive system from another angle. They have demonstrated the maintenance of body-posture through the static and stato-kinetic reflexes, the postural reactions of the body when at rest and in movement. The static reflexes are regulated by the stretching of the neck muscles in moving the head, by the movement of the endolymph in the internal ear, and by the tension of the eye muscles. The stato-kinetic reflexes depend on a similar mechanism for the control of posture during movement. These studies have shown, to use

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Magnus's own words, "that many different sense-organs are involved, that very different centres integrate their stimuli, that the muscles are concerned in many different combinations in the production of the reactions, and that a whole series of diverse reflex groups are balanced together."

During the nineteenth century the attention of neurological physiologists was mainly directed to the study of the functions of the lower parts of the nervous system. As a result of the work of Sherrington and others on the reflex arc, and of Magnus and his school on postural reactions, the functions of the spinal cord, medulla and brain-stem became gradually pieced together and were welded into an understandable chapter of physiology.

It is clear that such an advance was made possible by study of the problems under properly controlled conditions. The symptoms resulting from extirpation of parts of the nervous system, as, for example, the cerebellum, were no longer accepted as illustrating the function of that region. The co-ordination and integrative action which existed were recognized and the interdependence of the different areas was established.

The higher functions of the cerebral cortex were not, however, receiving attention. The physiologist had not discovered methods which could be applied to the investigation of the cerebrum. The field had been prepared for him by the anatomists and histologists, but little use had been made of these discoveries. True, electrical stimulation had aided in the mapping-out of the excitable areas of the cortex, but these methods gave us little information of the actual working of the brain. In the spinal animal, the nature of the response to stimulation may be predicted, but in the normal animal it is impossible to say what type of effect will be produced. Often the animal exhibits actions which have, seemingly, no connection with the stimulation of the end-organ. Pavlov and his pupils have, however, devised a method which is based on sound physiological principles and is purely objective. From these studies it would seem that the complexity of the cerebral function is more apparent than real, and that it is of a true reflex type, subject, however, to inhibitions of great variety.

The reflexes investigated by Pavlov are termed by him "conditioned reflexes"; they are essentially individual, and are not necessarily found in the nervous system of any other individual of the species. A dog secretes saliva when food is placed in its mouth, but it may also secrete saliva on the appearance of the person who feeds it, or as the result of some sound or signal. These reflexes are essentially acquired, and they may be of a simple type or may become combined to form a complex pattern. For the establishment

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of a conditioned reflex, Pavlov advances the law that "stimulation of any receptor organ occurring simultaneously with a reflex excitation of an effector organ leads to a formation of a new reflex." Conditioned reflexes may be established by the use of any of the cerebral analysers. By this method it has been shown that the dog hears sound up to 120,000 vibrations per second, which is much higher than the limit of audibility for any human ear. By the use of the visual analyser, letters, rotation of objects, special rates of movement, etc., can all be made stimuli. Conditioned reflexes established by cutaneous stimuli are well differentiated, and the animal can distinguish between temperatures ½ to 1° C. apart. Reflexes have also been demonstrated with painful stimuli, olfactory stimuli, etc.

If the nervous system is affected by another stimulus before or during the experiment, the normal response will be diminished—a condition of external inhibition. For this reason the experiments must be carried out in special laboratories free from any extraneous noises. Besides external inhibition, conditions of the animal may lead to diminution of the reaction. It is presumed that in these states there is a condition of internal inhibition. Developed inactivity may be produced in the animal experimentally, and does not differ in any respect from the ordinary conditioned reflex. These negative reflexes undergo summation, and they may be experimentally extinguished. By these methods the cerebral cortex may be examined from the points of view of both positive reactions and negative effects. In other words, it is possible to produce states of excitation and inhibition in the cerebrum. Experimental evidence shows that the seat of inhibition cannot be within the lower central nervous system, but must be situated in the cortex.

The older experiments on extirpation of the cortex demonstrated the gross alteration in function resulting from the lesion, but the method of conditioned reflexes allows exact physiological examination to be made. It has been shown that after removal of the cortex all power of forming conditioned reflexes is lost, the lower functions still remaining. Localized damage to cortical areas has only a temporary effect, inhibitory processes being affected to a much greater extent than the excitatory. After a few months the animal returns to its normal condition. Experiments on the cortex agree with the older observations on the localization of particular functions, except in the case of the area of smell. It is interesting to note that no single place in the cortex could be found, removal of which would lead to the disappearance of all conditioned reflexes. From these results it would appear that there is no single association area controlling all association processes.

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In certain circumstances conditioned reflexes may have an injurious effect which may induce a pathological state of the brain. If the animal is made to discriminate between a perfect circle and a very oblong oval, the reaction is perfect. In further experiments the oval is made broader and discrimination is soon established. The oval is gradually made to approximate to the circle, and when the animal is finally unable to discriminate, the inhibitory stimuli become positive. The animal becomes excitable and has the appearance of a neurotic patient. After an interval of a few months it becomes normal and the conditioned reflexes for the old discrimination recover. It would appear that lack of adequate inhibition for a particular stimulus leads to a state of general inhibition.

By such experiments it is possible for the physiologist to make observations on the function of the cerebral cortex, and thus to add his quota to the subject of psychological medicine. From the investigation of the conditions of excitation and inhibition in the isolated nerve and reflex arc the study advances now to the conditions in the cerebral cortex. We must realize, however, that the terms "excitation" and "inhibition" cover more than one type of phenomenon, as, for example, one should not include the inhibition of tonic contraction observed in isolated smooth muscle with the inhibitory state which can be produced in the spinal cord. Again, the presence of inhibitory and excitatory nerves requires explanation. The problems are still plentiful, but the march of investigation continues, and with it the march of progress.

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