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*"To the solid ground*
*Of Nature trusts the mind which builds for aye."*—WORDSWORTH.

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## Scientific Worthies.

### XLIII.—IVAN PETROVITCH PAVLOV.

THE eminent physiologist, whose portrait is published to-day in continuation of the NATURE series of Scientific Worthies, was born on September 14, 1849, in the district of Rjäsan in Russia. He was the son of the village priest. After receiving some education at a theological seminary, he determined to devote himself to science and entered the University of St. Petersburg. On the completion of his course in general science, he took the medical course at the Military Medical Academy, receiving his qualification to practise in 1879. At that time Botkin, the clinician, maintained several younger men as scientific assistants to carry on research in connexion with his wards, and Pavlov, after qualification, became his assistant, with special charge of the work involving animal experimentation. In 1883 he obtained the M.D. of St. Petersburg, and in 1884 was appointed privat-dozent in physiology. Immediately afterwards, he went for two years to Germany to work under Ludwig and under Heidenhain. In 1890 the Institute of Experimental Medicine was built at the cost of Prince Oldenburg, von Anrep being appointed its first director, and in 1891 Pavlov became director of the physiological department of the Institute. In 1897 he was called to the professorship of physiology in the Military Medical Academy, without, however, giving up his post in the Institute of Experimental Medicine, and in 1907 he became one of the four scientific members of the St. Petersburg Academy and obtained in this way another laboratory under his charge. His work from this time forward, therefore, was carried on in three laboratories, his own personal experiments, however, being confined to the Institute of Experimental Medicine, the other two laboratories being in charge of assistants, though the work at all three places was inspired directly by Pavlov and subject to his continual oversight and criticism.

Pavlov married quite young, his wife being a teacher in a school and herself the daughter of a village priest. He has had four children, one of whom is a well-known physicist who has worked in Cambridge under Sir Joseph Thomson and is now professor of physics in Leningrad.

Pavlov's scientific work falls easily into three well-defined chapters, though there is a certain leading idea which has guided him throughout and characterises all the researches for which he has been responsible. He set himself from the beginning to elaborate the analytic method of research. Each function of the body has to be studied in relation to other functions as well as to external conditions, and the exact part played by each condition determined by artificial removal or arousal of the condition *while keeping the other conditions constant.* Up to Pavlov's time the necessity for this last precaution had not been properly appreciated or systematically carried out. Physiologists had been content to study functions in isolated organs or in animals in a profoundly abnormal condition, either through the action of anæsthetics or under the effects of discomfort or pain. Pavlov realised that these disturbing factors, namely, anæsthetics, pain and discomfort, must be eliminated before the part played by excitation of a nerve, for example, under normal conditions could be appreciated, or proper value given to the results of operative procedure.

We see the beginning of these ideas in the first chapter of Pavlov's scientific activities, those connected with the physiology of the circulation. The first papers published by him in German appeared in 1878–1879 and dealt with the normal regulation of the blood pressure in the dog. In these experiments, Pavlov trained a dog to allow the insertion of a cannula in a small superficial artery on the inner side of the knee-joint and to remain quiet while the blood pressure was recorded. In such an animal he was able to study the effects of digestion as well as of drinking large quantities of fluid in the form of broth. He found that neither of these procedures produced any change in blood pressure amounting to more than about 10 mm. of mercury. In 1887 he published two papers on the efferent nerves of the heart, the first based on work carried out in St. Petersburg, while in the second paper he described the results of testing his previous findings with the use of Stolnikow's apparatus for measuring the output of the isolated heart. This research was carried out while he was studying in Ludwig's laboratory.

The work, however, for which Pavlov is best known is that connected with the physiology of digestion. Here the introduction of new methods devised to fulfil the conditions laid down by him at the beginning of his career enabled him to rewrite this chapter in physiology. At the present time our whole idea of the course of digestion is based upon Pavlov's discoveries. This work would have been impossible but for Pavlov's marvellous skill as an operator. Already in 1879 he had published three papers on the pancreatic secretion, and one of these described a new method which he had elaborated for making a pancreatic fistula, but from 1888 to 1900 all his activities were devoted to the problems of digestion. In 1888 he showed that the vagus nerve was the secretory nerve to the pancreas, and also was able to explain why previous observers had failed to obtain any results from stimulating this nerve. In 1889 one of his pupils published a preliminary note in the *Centralblatt für Physiologie* on the secretion of the gastric juice.

It is in this note that we first find a description of Pavlov's method for obtaining pure gastric juice. The animal was provided with fistulous openings into the stomach and also into the œsophagus. Such an animal had to be kept alive and in good condition by the introduction of food through the lower end of the œsophagus or directly into the stomach. It was essential, according to the rules laid down by Pavlov, that the animal should be kept in good condition, free from pain or even from discomfort. After such an operation these objects can only be attained by devoting extreme care to feeding the animals. At that time there were no proper facilities for the care of animals, and this work could not be entrusted to an ordinary laboratory attendant. Pavlov, therefore, after operating on his dogs, took them home, and here in his small flat they were looked after by his wife, with the children.

The success of Pavlov's experiments was entirely due to the devoted care which was given to the animals. In a dog provided with an œsophageal and a gastric fistula Pavlov found that, within a few minutes of giving the animal food, there was a copious flow of juice through the gastric fistula. This was known as "sham feeding," and the secretion was proved by him to be due to the effect of appetite and was therefore named by him "psychical secretion." It could be aroused not only by eating but also by the mere sight of food, though it ceased as soon as the animal realised that the food was not going to be given to it. Pavlov proved also that the efferent channel for the psychical reflex was by the vagus nerves and that the secretion was stopped by section of the vagus nerves and was aroused by artificial stimulation of the peripheral end of a cut vagus nerve.

From 1892 to 1897 a whole array of papers on the physiology of digestion appeared in the *Archives des Sciences Biologiques,* so that Pavlov's discoveries became known to his colleagues in other countries. In 1897 a collected account of his work was brought out in German

and in French under the title "Die Arbeit der Verdauungsdrüsen." A little time later an English translation appeared from the German edition by Prof. W. H. Thompson. In 1904 Pavlov was awarded the Nobel Prize for medicine for his work on the physiology of digestion. By this time, however, Pavlov's methods had become widely known through the agency of his pupils, many of whom had acquired sufficient operative skill to carry out the difficult operations which had previously depended on Pavlov himself, so that the work could be continued on the lines laid down in Pavlov's laboratory. At the date of the award of the Nobel Prize, Pavlov had practically given up a direct personal interest in the subject of digestion and had taken up another subject.

Hitherto, our methods of investigating the functions of the cerebral hemispheres have been extremely unsatisfactory. We may study the effects of removal or excitation of definite areas in the cortex, but the results of such experiments have given rise to conflicting opinions as to their significance. We know, for example, that in most mammals all the apparatus necessary for immediate motor reactions is contained in the parts below the hemispheres, and it is difficult to judge from the presence or absence of a response to some sensory stimulation after removal of portions of the cortex whether the cortical deficiency is really responsible for the effects, if any, observed. More stress has been laid, therefore, on observations on man, where lesions have been produced in the cortex by disease or injury. Here, however, there is a tendency to abandon the pure physiological method, and in our arguments we are apt to jump continually from the objective to the subjective method and vice versa.

Physiology is the objective examination and analysis of the behaviour of an animal under all manner of conditions. Up to the time when Pavlov began his researches, we lacked such objective physiological methods as would do for the analysis of the functions of the cortex the same services that had been rendered by physiological method in the hands of Sherrington for the analysis of the spinal reflex functions, or which have recently been used by Magnus and others in the investigation of the manner in which equilibrium is maintained or restored. We know that the cerebral cortex is what has been called the educatable part of the central nervous system: it is responsible for reactions which have been learnt in the course of the individual's existence. In the higher animals, especially in man, these learnt reactions overlie and take precedence of most of the immediate reflexes carried out by the spinal cord and brain stem, so that almost the whole of a man's behaviour throughout his adult life is carried out by a series of reactions to the environment for which the cortex is primarily responsible. An analysis of the manner in which this complex never-ending series of reactions is built up so as to form an individual with his peculiar reactions, must begin with the simplest.

Pavlov conceived the ingenious idea of using the appetite reactions, with which his previous twenty years' work had made him so familiar, as an objective sign of cortical reactions. It is well known that introducing acid or other gustatory substances into the mouth of a dog evokes a flow of saliva, and the intensity of the reaction can be measured by providing the animal with a salivary fistula and counting the drops or measuring the amount of saliva which is secreted in response to a given stimulus. Such a reaction is called by Pavlov an *unconditioned reflex*. If, however, some other kind of stimulus, for example, ringing a bell, be associated for some time—weeks or even days—with the presentation of food or the introduction of acid into the mouth, the associated stimulus after a time is sufficient to evoke a flow of saliva without the presentation of food. This reaction was called by Pavlov a *conditioned reflex*. It is dependent on the laying down—the "education"—of new paths in the cortex. This method of establishing new reflexes has been used by him for investigating the higher functions of the cortex, the conditioned salivary reflex being employed as the unit sign of cerebral activity, just as the movements of flexion or extension of a limb have been used as a test for spinal function. Instead of studying the physiology of the eye, the ear, and other superficial organs, in its purely subjective aspect, we can use any of these sense organs for the establishment of a conditioned reflex or reflexes. We can proceed, untrammelled by psychological preconceptions, to study the behaviour of animals in its highest aspect by purely objective methods.

A preliminary account of his researches was given by Prof. Pavlov in the Huxley Lecture which he delivered at Charing Cross Hospital on October 1, 1906. Since that time a very large number of researches carried out by this method have been published by Pavlov and his pupils, but almost entirely in Russian, so that they are very little known, except in broadest outline, in Great Britain and other countries. It is satisfactory to learn that he is now engaged in writing a collected account of these researches which, when translated, will make them available for the instruction of physiologists, as well as psychologists, throughout the world, and will enable us to attack by this new method and with a greater hope of success the function of the cerebral hemispheres, which is indeed the capital question in the physiology of man.

Pavlov was elected a foreign member of the Royal Society in 1907 and was awarded the Copley Medal in 1915.

E. H. STARLING.