IVAN PETROVICH PAVLOV (1849–1936)

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ONE hundred years ago on September 14 (according to the Julian calendar; September 27, modern reckoning) Ivan Petrovich Pavlov was born, the son of a priest of one of the humble parishes in a provincial town of Ryazan in Russia. His high-school training was received in an ecclesiastical seminary in Ryazan. He graduated afterwards from the Natural Science Faculty of the University of St. Petersburg, and in 1879 obtained his M.D. degree from the Medico-Chirurgical Academy in that city. During 1879–90 he was director of research in the laboratory of the famous clinician S. P. Botkin; in 1885–86 he studied under Carl Ludwig in Leipzig and R. Heidenhain in Breslau; he was appointed in 1890 professor of pharmacology and in 1895 professor of physiology in the Military–Medical Academy in St. Petersburg. Almost simultaneously, namely, in 1891, he became director of the Department of Physiology in the Institute of Experimental Medicine, a position which he held until the day of his death. He was a member of many learned societies in Russia and abroad and held honorary degrees from several universities. He was married and had three sons and one daughter. He died in St. Petersburg on February 27, 1936.

This life, so simple externally, was extremely rich and varied in a spiritual sense. Pavlov was a pathfinder, who always looked for unexplored fields. With a genius for experimentation, a systematic and searching mind, and an uncompromising devotion to science and a firm belief in it, he became one of the most renowned physiologists of his time.

Roughly, the physiological work of Pavlov may be divided into three periods. The following fields were investigated by him: (1) circulation; (2) functions of the alimentary canal; (3) central nervous system.

All the work of Pavlov was permeated by the idea of 'nervism', as he called it, which postulated that most of the bodily functions are regulated by the nervous system. He certainly did not deny the humoral or hormonal transmission of impulses, especially when the functions of the endocrine glands became better known. But his chief interest always was the organism as a whole, and the interrelation of the organs, and its reaction to the outside world through the nervous system.

Work on Circulation. The principal work of Pavlov in this field was on the innervation of the heart. Simultaneously and independently of W. H. Gaskell, Pavlov discovered in 1882–83 the augmentor effect of the sympathetic nerve stimulation on the heart. According to him, the heart of a warm-blooded animal is supplied by two pairs of nerves. They derive from the sympathetic and the vagus nerves respectively: 'rhythmic' nerves (accelerator and inhibitor) and 'dynamic' nerves (augmentor and 'abator' nerves).

Modern physiology prefers to speak about rhythmic and dynamic *influence* of the nerves on the heart and does not ascribe these effects to four kinds of special nerve fibres. However, the fundamental fact of the dynamic function of the sympathetic nerve discovered by Pavlov remains unshaken.

In 1885, with one of his co-workers, Pavlov worked out a method of isolation of the heart in the dog *in situ*. This method was improved and modified much later by E. H. Starling and is known under the name of the "heart–lung preparation".

Gastro-intestinal Tract. During fifteen years, from the end of the 'eighties of the last century to the beginning of the present, Pavlov studied almost exclusively the physiology of the digestive glands, and to a much lesser degree the motility of the alimentary canal. This work was epoch-making. The results Pavlov presented in the form of a book of lectures in Russian (in 1897) under the title "The Work of the Digestive Glands", which was translated into German (1898), French (1901) and English (two editions, 1902 and 1910). Without exaggeration, the facts discovered by Pavlov, and his ideas, became the foundation of modern gastro-enterology, theoretical and clinical. Everything was new here: a new and unprecedented development of physiological surgery; new and brilliant experimental methods; the discovery of an extraordinarily large number of facts concerning the innervation of different glands, the enzymatic composition of the secretions, the interrelation between the different parts of the alimentary canal, and so on. For the first time, an exact picture was given of the work of the alimentary canal, based on experimental material.

The theoretical foundation on which this magnificent structure was built was: (1) the specific excitability of the gastro-intestinal tract; and (2) the exclusively nervous control of the activity of the digestive glands. The theory of the specific excitability of the mucose of the alimentary canal, first formulated vaguely by N. Blondlot (1843) and fully developed by Pavlov, replaced the crude idea of general excitability, and is retained in somewhat modified form by modern physiology and gastro-enterology. Pavlov's theory of the exclusively nervous control of the functions of the alimentary canal had to be modified after the discovery of pancreatic secretin by W. M. Bayliss and E. H. Starling in 1902.

Pavlov's achievements in the physiology of the gastro-intestinal tract were crowned in 1904 with the award of the Nobel Prize. He was the first physiologist who received this great honour.

Conditioned Reflexes. The last thirty-five years of his life Pavlov devoted to the study of the functions of the cerebral cortex, or, as he called it, more correctly, "higher nervous activity". He attached a far greater importance to this than to his previous work.

Pavlov was led to the studies of the functions of the central nervous system by observation of 'psychic' salivary and gastric secretion which he had the opportunity to see so often. The questions which he asked himself were: (1) Is the cerebral cortex subjected to the same law of reflex action as the rest of the nervous system, notwithstanding its supposed relation to the conscious processes in the animal? and (2) Can the 'psychic' reaction be investigated by purely physiological methods?

Pavlov answered both questions positively. He discriminated between the *unconditioned*, innate reflexes, regulated by the lower parts of the central nervous system, and *conditioned*, acquired reflexes, for the formation of which the presence of the cerebral cortex is of paramount importance. Through the combination of any indifferent stimulus and an unconditioned reflex, a corresponding conditioned reflex is formed. Pavlov certainly did not look on such a highly organised animal as the dog, for example, as a reflex machine; but he was firmly convinced that a conditioned reflex forms the basis of any 'psychic' reaction of the animal. Looking on his study of conditioned reflexes as strictly physiological, he excluded from it any considerations of the psychic states of his experimental animals. However, he spoke repeatedly about the time, far away as it may be, when the coalescence of physiology and psychology will become possible.

The experimental material collected by Pavlov and his co-workers is enormous[1]. Thousands of experiments proved that a conditioned reflex is indeed a reflex, and established multiple rules for its behaviour. Moreover, with the help of conditioned reflexes, such pathological phenomena as neuroses were produced in dogs, and the mechanism of their origin was disclosed. Thus, for the first time in the history of physiology, its methods were applied to the study of the functions of the cerebral cortex, intimately related to the psychic states of an animal, and the activity of the cortex was discussed from a physiological point of view. Pavlov's elaborated theory of conditioned reflexes was purely provisional, and so considered by himself. Its formulation was necessitated by the quickly accumulating facts which had to be brought into relationship.

Although Pavlov had predecessors—the outstanding Russian physiologist, I. M. Sechenov, and the famous English neurologist, J. Hughlings Jackson—they only prepared the way for Pavlov's daring attempt to study the functions of the *whole* central nervous system from a physiological point of view[2].

Contrary to the swift universal recognition of Pavlov's work in the field of gastro-enterology, the idea of the conditioned reflexes did not find full approval. It was looked on with greater favour by psychologists, especially the representatives of the objective psychology in the United States, than by physiologists and neurologists. Of course, Pavlov's facts could not be disputed, and the criticism was directed towards the theoretical part of his teaching.

It would not be a mistake to say that the conception of conditioned reflexes was much in advance of its time and was not quite understood by many. But the day will come when the achievements of Pavlov in neurology, normal and pathological, will be fully recognized and appreciated.

If we look in retrospect on what Pavlov achieved during the span of one human life, we may say without reservation that this remarkable man did the life-work of two great men. His name would never be forgotten if he had left us only the legacy of his gastro-enterological work. But he added to this another achievement more imposing than the first, that of the physiology of the "higher nervous activity".

[1] Only a part of Pavlov's work is available to English-speaking readers. It is contained in his "Conditioned Reflexes" (Oxford University Press, 1927); "Lectures on Conditioned Reflexes" (International Publishers, New York, 1928) and "Conditioned Reflexes and Psychiatry" (International Publishers, New York, 1941).

[2] See Babkin, B. P., "Origin of the Theory of Conditioned Reflexes", *Arch. Neurol. and Psychiat.*, **60**, 520 (1948). A full discussion of Pavlov's scientific achievements will be found in my "Pavlov: a Biography" (University of Chicago Press, in the press).

THE IONOSPHERE AND THE PROPAGATION OF RADIO WAVES

DURING July 14–16 the Physical Society held its summer meeting at the Cavendish Laboratory, Cambridge, on the subject of "The Ionosphere and the Propagation of Radio Waves". The purpose of the conference was to survey research work in progress and particularly to relate the knowledge acquired by the academic workers to that obtained by the practical users. There were five sessions devoted to different aspects of the subject.

The first session dealt with the regular behaviour of long and very-long waves returned from the ionosphere. Mr. R. N. Bracewell and Mr. J. A. Ratcliffe outlined some of the results obtained by the Cavendish Laboratory Radio Group since 1935 on frequencies of 16–127 kc./s. One point of major interest concerns the amplitude of the downcoming wave on a summer day. Near vertical incidence the amplitude is quite large on 16 kc./s. (reflexion coefficient is 0·15), but is unmeasurable on 30 kc./s., and it remains unmeasurable as the frequency is increased up to about 2 Mc./s. The low-frequency limit of the range of small amplitudes appears to change with season, time of day, and obliquity of the reflexion, and it appears probable that there is a fundamental change in the mechanism of reflexion at this frequency. Experiments with waves of frequency 16 kc./s. have indicated a change in the conditions of propagation as the obliquity of reflexion is increased through an angle of incidence of about 70°; for more oblique incidence the reflexion coefficient is greater and the polarization is different. An account was given of the diurnal variation of the amplitude, and the change of reflexion height, of waves of frequency 16 kc./s. and 100 kc./s. incident nearly vertically, and it was emphasized that on 100 kc./s. there is an asymmetry in the curve showing the diurnal change of height, which might be explained if it is assumed that the region responsible for reflecting these frequencies is separated into more than one layer.

Mr. K. W. Tremellen discussed operational results obtained by the Marconi Co. on very long waves in the 1920's. He emphasized that many of the recent experimental results apply only to propagation over short distances, up to about 500 km., and that the older operational experience leads us to expect radical changes at greater distances. In particular, operational experience indicates that on 16 kc./s. propagational phenomena depend markedly on geographical direction. Mr. W. T. Sanderson described observations made during the operation of the Decca Radio Navigational System, working on frequencies near 100 kc./s. From the 'phase' errors obtained at different distances, it is possible to deduce that the reflexion coefficient is greater for distances greater than about 250 km. The overall errors of the system, including their dependence on atmospheric noise, are approximately proportional to the secant of the zenith angle of the sun. Mr. Caradoc Williams described experiments made at the Royal Aircraft Establishment on the navigational systems known as Decca, P.O.P.I. and Consol, all working on frequencies near 100 kc./s. He deduced that the error of the system increases with the length of the base line. A measurement of the daytime interference pattern formed between the ground wave and the