The Spanish Journal of Psychology
2003, Vol. 6, No. 2, 112-120

1138-7416

The Pavlov Department of Physiology: A Scientific History

Victor M. Klimenko and Juri P. Golikov
Institute for Experimental Medicine

The scientific adventure of the Ivan Pavlov Department of Physiology is traced from Pavlov's and his students pioneer work on "psychic salivation" to the times of the Biological Station at Koltushi. The development of the Department after Pavlov's death is described and the research trends of the three present laboratories (Neurobiology of Integrative Brain Functions, Psychophysiology of Emotions, and Neurodynamic Correction of Psycho Neurological Pathology) are discussed.
Keywords: Pavlov department, physiology, Pavlovian conditioning, neuroscience

Se sigue la aventura científica del Departamento de Fisiología Ivan Pavlov desde los trabajos pioneros de Pavlov y sus discípulos sobre la "salivación psíquica" hasta los tiempos de la Estación Biológica de Koltushi. Se describe el desarrollo del Departamento tras la muerte de Pavlov y se comentan las líneas de investigación de los actuales laboratorios (Neurobiología de las Funciones Integradoras del Cerebro, Psicofisiología de las Emociones y Corrección Neurodinámica de la Patología Psiconeurológica).
Palabras clave: departamento de Pavlov, fisiología, condicionamiento pavloviano, neurociencia

Correspondence concerning this article should be addressed to Victor M. Klimenko, Institute of Experimental Medicine, akad.Pavlov str., 12. 197376 Russia, St.Petersburg. E-mail: klim@iemcns.spb.su

The organization of the brain and the exploration and understanding of its activity is the boldest challenge to human intellect, as the brain is the most complicated and most highly developed structure created by nature. Throughout history, the challenge of understanding the brain has been taken up by many outstanding people of different nations belonging to different time periods. However, no final conclusions have been reached, as the questions were too multiple and the means for their exploration were limited. Although the world of science was accumulating more and more knowledge about the brain during the XIX century, activity of the higher compartments of cortex, psychic activity above all, was still out of reach of natural science. Russian physiologist Setchenov was one of the first to lead the way towards solutions in his work *Reflexes of the Brain*. He was followed by Pavlov and his colleagues who studied the same questions in the Department of Physiology at the Imperial Institute for Experimental Medicine in St. Petersburg (IIEM).

The Institute of Experimental Medicine

In 1890 in St. Petersburg, the official opening of the Imperial Institute of Experimental Medicine took place, the organization of which was initiated by Prince Oldenburgsky. It was the first Russian scientific research institution in the field of biology and medicine. Pavlov was drawn into the development of the Institute, which included Departments of Chemistry, General Bacteriology, Pathologic Anatomy, Epizootology, and Syphilidology. Pavlov was invited to head the Department of Physiology and guide their researchers –a job he successfully performed for 45 years: from 1890 until 1936.

At the same time, in April 1890, Pavlov accepted a position as the Head of the Pharmacology Department at the Military Medical Academy (MMA), which he left in 1895, when he became the Head of the Physiology Department of the MMA. Since the Department did not have sufficient facilities for his studies, students of the Academy practiced at the Department of Physiology headed by Pavlov at the IIEM. At that time, the IIEM constructed a new building, specifically equipped for scientific research. Young students evolved into researchers here, under the guidance of Pavlov. Therefore, we could say that Pavlov's physiological school was actually formed at the Department of Physiology of the IIEM.

With the aid of the permanent fistulae technique, the Department at the IIEM studied the activity of the gastro-intestinal tract, determined the mechanisms of the digestive glands activity, and made the role of the nervous system in regulating these activities more easily understood. The classic operation of oesophogotomy, isolation of the gastric pouch, pancreatic and bile fistulae and a number of other experimental techniques were developed.

The innervations of gastric glands and the physiology of the pancreas were investigated here. In spring of 1895, Pavlov delivered lectures on digestion at the IIEM. During these presentations he reviewed the achievements of the Department in this area of physiology.

Those lectures were an important step in bringing order to the vast field of information on nervous regulation of the digestive glands, on the laws ruling the production of digestive juices, and on the interaction of stomach secretion with the functions of the liver, pancreas, and small intestines, as well as with the functions of other parts of the digestive tract.

Pavlov demonstrated that wide use of experimental surgery in long term experiments on animals gave the opportunity to investigate interactions between the functions of the digestive glands and mechanisms of their functioning. It was a new group of studies in digestion: exploration of physiological mechanisms of the digestive glands under conditions of long term experiments on healthy animals with complete and continuously working digestion systems. Pavlov summarized all his achievements in this field in his book *Lectures on the Work of the Chief Digestive Glands* (1897). In this book he added his eighth lecture, "Physiological Data, Human Instinct and Medical Empiricism." A year later the book was published in German after being translated by his pupil Valter.

By 1904, when Pavlov was awarded with the Nobel Prize, he had been engaged in scientific and pedagogical activities for 25 years. His studies made a large impact on the scientific community—never had physiology helped clinical medicine so significantly. In his lectures, Pavlov regarded the process of digestion as a physiological conveyer which combined separate organs of the digestive tract into a system. Such an approach helped to create a complete picture of the mechanisms of digestion.

At every stage of his research, Pavlov paid great attention to the connection of physiological investigation and clinical medicine. Elaborating on questions regarding physiology of digestion, he systematically studied questions of pathology of digestive organs too. Between 1898 and 1904 studies of the digestive function of the liver and transport of food from the stomach to intestines were carried out under Pavlov's direction. The general co-ordination of all parts of the digestive tract was revealed as well. Special research was devoted to bile, pancreatic, and gastric juice secretion into the stomach. Conditions for such secretion and its relevance to digestion were determined.

Pavlov's research formed the basis for the modern concept of disturbances in functions of the gastro-intestinal tract and facilitated the development of adequate therapeutic methods for their treatment.

The highest form of appreciation during the period of Pavlov's research was the Nobel Prize which was first given to a Russian scientist in 1904 as a token of acknowledgement of his works on physiology of digestion, which reformed and widened the knowledge in this field.

Pavlov's work on the physiology of digestion was a separate and complete set of systemic studies which was internationally acknowledged in 1904. It served as a starting point for a large series of studies, which laid the foundation for a new area of physiology—physiology of higher nervous activity, or the theory of conditioned reflexes.

The phenomena of "psychic secretion" of digestive glands attracted Pavlov's closest attention. Pavlov endeavored to fill in this "white spot" on the map of knowledge and decided to explore the psychic aspect of the digestive glands activity. This decision was followed by 35 years of tenacious work devoted to the exploration of special brain reflexes which Pavlov called "conditioned." As the history of science shows us, his work on conditioned reflexes brought him more success, popularity and fame than his work on the physiology of digestion for which he was awarded the Nobel Prize.

It is necessary to note that it was Bidder and Schmidt from Derpt University, who for the first time in 1852, described gastric secretion from the gastric fistula conditioned by food demonstration. However, at that time the theory of psychic secretion of gastric juice did not attract the serious attention of scientists. The data gained in the Physiology laboratory at the MMA by von Anrep went unnoticed as well, though he was one of the first who, before Pavlov's work, came to understand the role of the nervous system in gastric secretion. Questions were finally answered by Pavlov and Shumova-Simanovskaia and results were published in the article "Gastric Gland Innervation in Dogs."

A study carried out by Glinsky, who was a temporary member of the Department of Physiology at the IIEM, played a crucial role in the exploration of salivary glands and nervous regulation. It also played a basic role in the physiology of conditioned reflexes. He was the first to invent the operation of implanting fistula into the ducts of salivary glands in 1895, and he also performed the first experiments with reflective salivation in dogs. His work was not published because of unknown reasons, but on May 13, 1895, Pavlov presented the results of Glinksy's study at the meeting of the Society of Russian Physicians. Pavlov also wrote in 1902 about the same matter in an article on Dr. Glinksy's technique. From then on, Glinsky's technique was accepted all over the scientific world as the most convenient method of precise and full registration of secreted saliva in long term experiments.

Early in the 20th century, Pavlov's investigations attracted the attention and interest of specialists. In his letter to Prince Oldenburg, curator of the IIEM, Pavlov remarked that the Department of Physiology had become a significant attraction for brilliant and loyal scientists not only from Russia, but from other counties, too. In 1902 Doctors Stensma (Amsterdam), Straub and Fridental (Berlin University), Gross and Professor Konheim (Heidelberg University), and Professor Chermak (University of Halle) worked in the Department under the direction of Pavlov. Translations of Pavlov's *Lectures on the Work of the Chief Digestive Glands* into German and English, and his lecture delivered at the XIII International Congress of Physicians in July, 1900, where he addressed an international audience for the first time, were the reasons for the growing interest in his work. In his report "Experimental Therapy as a New and Fruitful Technique of Physiological Studies" he did not limit himself to the contents of his latest works. He concentrated on the questions related to "experimental therapy" and announced that physiology, with its special resources and its chances for success, being moved by its own initiative and for its own purpose, is aimed at such scientific work which, in its main ideas, completely coincides with modus operandi of medicine in its treatment of sick human beings.

In natural science, one of the obstacles in the way of understanding the activity of the higher compartments of the brain was the initial problem of the relationship between physical and psychic processes in nature. That is (in a philosophical approach) the question of material and spiritual, or objective and subjective. Throughout the history of science we can find evidence of this debate.

The Birth of a New Era: Conditional Reflexes

The theory of psychic excitation of salivary glands was elaborated between 1896 and 1901 by Pavlov in co-operation with Wolfson and Snarsky. In Wolfson's dissertation on salivary glands (1899), which was given at the Department of Physiology at the IIEM, psyche was regarded as a special entity regulating the process of salivation.

In the dissertation given by Snarsky (1901) on salivary glands functioning, (which was also carried out at the Department of Physiology), the facts were explained from the point of view of zoo-psychologists. Discussing the mechanism of "psychic" salivation, the author, for example, compared animals and human beings with their subjective inner world. That approach was not accepted by Pavlov. Snarsky insisted on looking for explanations of the phenomena in the field of the subjective. Pavlov, in his own words, "was astonished by scientific unfruitfulness of such an approach to the problem," and he began to look for another solution. After many hours of speculation and "hard intellectual struggle" he decided to treat psychic excitation as a "pure" physiologist, that is, as an objective external observer and experimenter who deals exclusively with external phenomena and their interactions. This decision was made in 1901.

Pavlov was sure that a physiological approach to psychic phenomena exploration would allow the fruitful development of brain physiology which would explore the role of the brain in organizing the interactions between the organism and its environment.

The moment in which Pavlov stated his "physiological" approach to the phenomenon of "psychic salivation" is regarded as the birth date of a new notion called "conditioned reflex."

The first work on conditioned reflexes was carried out, after Pavlov suggested it, by Tolotchinov (1902) who temporarily formed a part of the Department of Physiology. The results were presented in 1902 at the Congress of Physicians and Natural Scientists of Northern Countries of Europe in Helsingforse (Finland). Tolotchinov described some external conditions under which temporary connections appear in the cortex. He also established the fact of the natural reflex generating the natural reflex, the facts of its dissipation and restoration, and the possibility of external inhibition of a newly elaborated reflex. The experiments registered not only secretion, but also a motor conditioned reaction.

Pavlov, just as many other scientists who were looking for the explanation of the essence of life, was interested in the way in which the brain generated the mind and mentality. All his life he longed to explore the depth of the human psyche. In his first report on the theory of conditioned reflexes, delivered in Madrid at the XIV International Medical Congress in 1903, he said, "Relying on the likeliness and sameness of external phenomena, all objective data obtained in experiments will be used by future science to explain our subjective world. Thus our mysterious nature will be illuminated, and the mechanism of the most interesting human function—of his mind, torments of his mind—will become clear" (p.119).

The varied and in depth methods of exploring conditioned reflexes chosen by Pavlov in 1901 provided natural science with the opportunity to regain its unconstrained development and enabled it to tread into the "last facet of life"—into mechanisms of the brain's higher activities.

The theory of conditioned reflexes developed at the Department of Physiology at the IIEM pre-ordained the field of future scientific activities for Pavlov, his practicians and colleagues.

The formation and development of Pavlov's work on the physiology of higher nervous activity were permanently linked with the Physiological Department at the IIEM. It was there that Pavlov and his disciples carried out research which permitted Pavlov to give the first lecture on the theory of conditioned reflexes at the Medical Congress in Madrid in April 1903. In his lecture, he demonstrated an objective method of study of higher nervous activity in animals and in humans. "Only by the way of objective investigations," Pavlov (1903) stated, "step by step we will reach the complete analysis of that infinite device as a whole, which forms the life on the Earth" (p. 120).

The Congress lasted from March 30th until April 26th and there were 6,961 delegates who participated in its work. The Russian delegation consisted of 297 members. Pavlov and his wife were well acquainted with many European capitals, but in Madrid they were deeply impressed by an exposition of Fancisco Goya's works in The Prado. They spent a lot of time standing in front of the pictures. Pavlov and his wife also visited Escorial, Toledo and some places in Seville.

Beginning in 1904 all efforts of the Department staff were focused on the methodological aspects of exploring the conditioned reflexes. According to Pavlov, high speed accumulation of accurate facts and their easy interpretation presented a drastic contrast with uncertain and questionable results provided by the subjective approach.

It was in 1905 that the method of "artificial" conditioned reflexes was introduced into practice in research. The technique allowed quantitative analysis of the processes of higher nervous activity. As a result, Pavlov formulated the main principle of the conditioned reflex theory according to which the magnitude of the response depends on the intensity of the stimulus.

By 1906, almost all types of cortical inhibition had been discovered: conditioned, differentiating, retarding, external and sequential. Basic ideas of the conditioned reflex were formed and conditioned trace reflexes were discovered. Under Pavlov's guidance, investigations were carried out after removing different areas of cerebral cortex (in dogs) to reveal the link between conditioned salivary reflexes and cerebral cortex.

Pavlov presented his most important findings in his lecture dedicated to Huxley, which he delivered in London in 1906. At the conclusion of his presentation he felt it necessary to stress his strong belief of the inevitable unity between physiology and medicine. "If the doctor in reality and even more so in ideal is a mechanic repairing a human organism, —Pavlov remarked—then any new physiological achievement will sooner or later inevitably expand his power over the mechanism, the power to maintain and repair it" (p.915).

In 1907 Pavlov's disciple Krasnogorsky obtained data on the role of conditioned reflexes in the formation of behavior as he worked with children. In 1908 Nikiforovskiy, took the first steps towards the application of the conditioned reflex technique to pharmacology.

Beginning in 1908, investigations in the field of physiology of higher nervous activity under Pavlov's direction were conducted not only at the Physiological Departments at the IIEM and MMA, but in the Physiological Laboratory at the Academy of Sciences. However, the Physiology Department remained the main center of scientific work and the experimental base for the development of studies at Pavlov's physiological school. From 1891 to 1917 more than 110 persons worked here during different periods of time under the direction of Pavlov.

Dissertations and studies at the Department of Physiology were accomplished by Babkin, Zelioniy, Savich, Orbeli, Krasnogorsky, Zavadsky, Folbort, Tsitovitch, Krestovnikov, Kupalov, Deriabin, Rozhansky and many others.

In connection with the development of research in physiology of higher nervous activity at the IIEM, the problem of establishing a special laboratory equipped with soundproof chambers arose. Since the IIEM did not have sufficient funds, Pavlov turned to the Ledentsov Fund for monetary assistance. In 1910 in Moscow, at the Society

Council Session, Pavlov gave a lecture about tasks and arrangement of a model laboratory for studying higher parts of the central nervous system in higher animals. The Society granted Pavlov 50,000 rubles and in 1913 the "Tower of Silence," a three-story building with three soundproof chambers, was built. Five more chambers were added by 1917.

In 1911 Pavlov started a broad investigation of cortex inhibition and formulated the major laws of the development of neural processes in the brain cortex. He also defined the notion of two main mechanisms operating in the central nervous system: the mechanism of temporary connection and the mechanism of analyzation. Further on in his scientific investigations he returned to these definitions repeatedly.

Ten years after the first presentation on conditioned reflexes, Pavlov delivered a report called "Investigation of HNA" (higher nervous activity) at the final meeting of the IX International Physiological Congress in Groningen (Holland). Such outstanding physiologists as Sherrington, Starling, Gemmeter, and Fisher participated in the work of the Congress. In his report, Pavlov substantiated his idea that analyzers were a special part of the nervous system, and he also presented his research with this perspective based on the idea of unity of the center and periphery. He also mentioned the possibility of conditioned reflexes being hereditary. This idea later transformed into the question of high cerebral functions inheritance.

During World War I, the two revolutions that followed it and during the Civil War, scientific work went on at the IIEM. The period between 1918 and 1920 was especially difficult because the country was in ruins, and as a result of starvation and the cold it was impossible to experiment on dogs.

Pavlov after the Revolution

Between 1921 and 1923 scientific work in the Department of Physiology at the IIEM gradually returned to normal and investigations began again. In Pavlov's report "Normal Activity and General Constitution of Cerebral Cortex" delivered in 1922 at the meeting of the Society of Finnish Physicians in Helsingfors, he distinguished 6 types of events which "embraced the whole HNA without residue." Those 6 events included excitation, inhibition, movement (irradiation and concentration), mutual induction, connecting and disconnecting, and, finally, analysis. It was a report which summarized the most important results of two-decades of his work. In 1923 Pavlov published a new book. It was comprised of his articles, reports, lectures and speeches presented in chronological order, so that it reflected the course of development of the theory of conditioned reflexes. Placing special significance on the sixth edition of this book, the last one published during his lifetime, Pavlov wrote in January of 1936 that the book was enriched abundantly—12 new works had been added to it. According to Pavlov those works clearly demonstrated how immensely the horizon of research had extended. Physiology, pathology with therapy of the cortex of the brain, and psychology with its practical applications, start to join, to merge, so that they become the same field of scientific work, and, judging by the results, to their mutual benefit.

Between 1925 and 1927 much attention was paid to investigating nervous system types and to studying different kinds of internal inhibition and their mutual induction. In 1927 Pavlov published a book on the functions of the hemispheres. In the same year, he suggested that nervous system types be studied on dogs and while researching other questions the type of nervous system should be taken into consideration.

The years between 1922 and 1935 were a time of active development of the Physiological Department at the IIEM and in depth study of the questions of physiology and pathology of higher nervous activity under the supervision of Pavlov. In 1923 Pavlov received land to build a special facility for breeding and keeping experimental animals in the country, in the vicinity of Koltushi, a village near St. Petersburg. A short time later, Pavlov decided to organize a Biological Station for experimental investigations here. The Station was officially opened in 1926 and it became a base for investigation of conditioned reflexes in dogs in connection with in-born peculiarities of their nervous systems. The stone-work laboratory building was completed in 1933. In the same year, the first studies of the higher nervous activity of anthropoids were carried out at the Biological Station under the direction of Pavlov.

Koltushi became known world wide as the "Capital of Conditioned Reflexes" after the XV International Physiological Congress which took place in Leningrad and Moscow in 1935. Several days before the Congress started, Pavlov initiated the building of a monument dedicated to the dog not far from the Physiological Department building on the premises of the IIEM. The statue was created by the sculptor Bespalov.

American physiologist and Harvard University Professor Cannon wrote in memoirs about his meetings with Pavlov: "The last time I saw Pavlov was in Leningrad and Moscow at the conferences of the Physiological Congress in 1935. He was 86 years old then but he looked lively, full of his former energy. I will never forget the day we spent together in the environments of Leningrad, in the huge new buildings of the Institute built by the Soviet Government for Pavlov's experimental works. During our talk Pavlov heaved a sigh and said regretfully that he did not have such huge possibilities 20 years before" (Cannon, 1945, p.229).

In 1918 Pavlov resumed his visits to a mental hospital with the aim of studying physiological mechanisms of the activities of the cerebral hemisphere cortex of man. In those years, Pavlov and his team paid more attention to studies in psychiatric hospitals, which they had started in the middle

of 1890 with the aim of exploring physiological mechanisms of human cerebral cortex activity. In 1923 Pavlov decided to investigate natural psychopathological syndromes and psychic diseases. In 1931 Pavlov initiated the establishment of two clinics: One based on the neuropsychiatry dispensary and another based on a mental hospital, at the Physiology Department. Neurasthenia, hysteria and psychasthenia, narcolepsy, schizophrenia and circular psychosis were investigated in these clinics. The types of higher nervous activity of patients with different sickness dynamics in the cases of neuroses and psychoses were studied. The search for methods of therapy was conducted as well.

It should be noted that investigations in physiology and pathology of higher nervous activity reached their peak in the 1930s. Positive and negative induction phenomena and their temporal and spatial features were discovered with the conditioned reflex method. A concept of sleep as well as sleeping control methods were elaborated there. The possibility of producing conditioned reflexes to complexes of irritants working concurrent or one after another, as well as producing reflexes to time intervals ("time reflex") was discovered.

The research on conditioned reflex activity in the cases of disturbances in normal work of higher parts of brain, and understanding the conditions inducing such disturbances, led Pavlov to the elaboration of the concept of four main types of nervous system, which later formed one of the most important parts of physiology of higher nervous activity. Based on the results of the investigation of behavior of anthropoids, Pavlov proposed the concept of conditioned sensory and signal temporal associations. The latter meant the possibility of forming genetic causative relations between subjects and events in anthropoids. Pavlov stated his belief that it is incorrect to interpret the behavior of highly developed animals relying on the mechanism of conditioned reflex only.

Pavlov and his School

The formation and development of Pavlov's scientific school between 1903 and 1925 was characterized by the dedication of Pavlov and his disciples and, for the most part, on questions related to the physiology of higher nervous activity. Under the guidance of Pavlov, and with his personal participation, the mechanisms of conditioning and the closing function of the brain were studied. The research stated the idea of analyzation and synthesizing activities of the higher brain levels. The role of conditioned stimuli strength was formulated, the main nervous processes (excitation and inhibition) were characterized, the phenomenon of beyond-limits-inhibition and mutual induction was discovered, the theories of dynamic stereotyping, experimental neuroses, and types of higher nervous activity were evolved.

The questions of experimental pathology of the higher nervous activity were worked on at the Department of Physiology, and pharmacological substances restoring nervous activity were studied. Results of the work performed at neurological and mental clinics provided a physiological basis for the mechanisms of a number of nervous and mental diseases in humans.

Under Pavlov's guidance, Anokhin, Biriukov, Bykov, Ivanov-Smolensky, Maiorov, Orbeli, Razenkov and Speransky worked at the Department of Physiology as well as many other scientists and disciples of the Pavlov physiological school.

It was a period when many prominent scientists and representatives of Pavlov's school left the Department of Physiology at the IIEM and began to work independently. Among them were scientists who influenced the development of physiology abroad, e.g., von Anrep. After 1920, von Anrep worked at London and Cambridge Universities, became a Member of Royal Society and for more than 20 years headed the Department of Physiology at the Egyptian University of Cairo. Babkin, who introduced Pavlov's ideas into physiological research in England and Canada, was a Member of Canadian Royal Society. Boldyreff emigrated to Japan in 1918 and in 1922 moved to the USA, where he headed the Pavlov Laboratory at the Sanatorium in the State of Michigan until 1940. In Poland, Konorsky developed neurophysiology as did Ten-Kate who worked in Holland. Gantt, who worked at Pavlov's laboratories from 1925 to1929, played a great role in the subsequent development of Pavlov's ideas in the USA. Within the archives of Gantt there is a rich collection of documents connected with Pavlov. Among other things he organized the Pavlov Scientific Society in the USA.

Besides the wide field of investigations in physiology and pathology of higher nervous activity, Pavlov contributed to the development of new trends of research at the Physiology Department. It was because of physiology and pathology of cortical-visceral relations, first and foremost, that a trend originated at the intersection of physiology of higher nervous activity and physiology of autonomic functions. Investigations in this field began with the work *Development of Urinary Excretion Conditioned Reflexes* carried out in 1926 by Pavlov's disciple Bykov in collaboration with Alekseev-Berkman.

By 1931 significant experimental material on cortical regulation of the activities of the internal organs had been accumulated.

The second trend of research initiated by Pavlov was the first in Russia on the systematic study of the influence of different health factors in animal and human organisms. In 1931, the further development of these two trends was passed on to the Department of Applied Physiology which was newly organized at the IIEM. In 1931 it was called the Department of Common Physiology and headed by Bykov. It is now called the K.M. Bykov Department of Visceral Systems. In 1933 Orbeli, one of Pavlov's oldest disciples and collaborators, organized the third physiological department within the IIEM - the Department of Special

and Evolutionary Physiology. Systematic study of some branches of physiology, which had not been studied yet in the Soviet Union, as well as the theories of the evolution of functions of animal and human organisms were the subject of study in this Department. It is interesting to note that Orbeli became successor to Pavlov as the Head of the Physiology Department at the MMA, when Pavlov left in 1925.

By the end of Pavlov's life, at the IIEM, two physiological departments besides the Physiological Department and the Biological Station had been established and were headed by Pavlov's disciples. Both were geared towards the study of physiology and pathology of higher nervous activity. By that time, Pavlov was an Honorary Member of more than 100 Scientific Societies in many countries of the World, including Cambridge University.

Pavlov died on February 27, 1936. The last time he visited the Department of Physiology at the IIEM, on February, 18th of the same year, is commemorated by a desk calendar on the desk in his office which is now a memorial. The coffin with the body of the Honorary Director of the IIEM and Nobel Laureate, was placed for its last farewell in Tavritchesky Palace, the former sitting place of Duma -Russian Parliament before the Revolution. He was buried in the Academician Yard of the Memorial Cemetery "Litterateurs' Brow."

According to the decision made by the Government, his name was given to the Department of Physiology at the IIEM which was founded by him, to the 1st Leningrad Medical Institute (now the St.Petersburg State Medical University named after Pavlov), to the Physiological Institute of the USSR AS (now called the Institute of Physiology named after Pavlov by the Russian Academy of Sci), and also to many other research and educational medical institutions.

To perpetuate the memory of the organizer and first Head of the Department, Pavlov's office was preserved as a memorial in the Department of Physiology at the IIEM, and Pavlov's museum was opened in his apartment on Vassilievsky Island, which is a part of St. Petersburg.

From Pavlov to the XXI Century

After the death of Pavlov, the Department at the IIEM was headed by Academicians of the USSR AMSci Orbeli (1936 to 1937), then by Kupalov (1937 to 1964), Khananashvili (1965 to 1976) and Vartanian (1978 to 1995). Since 1995 the Department has been headed by Professor Klimenko.

Academician of the USSR AMSci Kupalov was the closest disciple and colleague of Pavlov, about whom Pavlov said, "Kupalov is my alter ego." Under the guidance of Kupalov, new regularities were revealed in brain functions: shortened conditioned reflexes were discovered, the mechanisms of the tonus regulation were found in the brain cortex, properties of long-term neural processes were studied under normal and pathological conditions and properties of cortical representation of the unconditioned reflexes were characterized. Thanks to the technique of situational conditioning suggested by Kupalov, general regularities of higher nervous activity were studied in animals under conditions of unrestrained behavior and some new causes for experimental neuroses and their mechanisms were revealed.

During the same time period another disciple of Pavlov, Correspondent Member of USSR AMSci Abuladze, carried out his investigations. He is the author of original investigations based on outward extension of the tongue's symmetrical areas which was used to study the conditions of joint and separate functioning of the brain hemispheres, and of unilateral conditioned reflexes.

The experiments carried out under the guidance of Academician of the USSR AMSci Khananashvili resulted in formation of the concept of the integrated systems of conditioned reflexes as the functional units of general behavior; it also developed the concept of the informational neuroses in animals and in humans and of the ways of their prophylaxis and treatment. Influence of various forms of animal interspecies communication upon the mechanisms of higher nervous activity was studied under normal and pathological conditions.

In 1976, Khananashvili left the Department of Physiology to accept the position of Director of the Beritoshvily Institute of Physiology in Tbilisi, the capital of Georgia. For two years, the investigations in the Department were continued under the guidance of Professor Silakov. Scientists used microelectrode techniques to reveal the mechanisms of formation of temporal connections. It looked like this was due to the activity of a special group of unspecific neurons called "the learning neurons." Their unique feature involves the ability to establish new functional connections among themselves in the course of conditioning. A concept of microsystems of such learning neurons, as the structural-functional basis, has been advanced.

Later, when the Department was headed by Correspondent Member of the USSR AMSci Vartanian, attention was focused on the question of reinforcement and the role of emotional mechanisms and unconditioned reflex mechanisms in the brain's reinforcement functions. New details were revealed concerning the role environmental agents in neurophysiological and psychophysiological mechanisms emotional behavior. A number of main structural and functional patterns of the brain's emotional mechanisms were described for animals bred under the conditions of communicative deprevation.

Currently, there are three laboratories at the Physiological Department at the IIEM: a) The Laboratory of Neurobiology of Integrative Brain Functions, b) The Laboratory of Psychophysiology of Emotions, and c) The Clinical Laboratory of Neurodynamic Correction of Psycho-Neurological Pathology.

Laboratory of Neurobiology of Integrative Brain Functions, Headed by Klimenko

Main interests of the laboratory include the conditions through which physiological processes in the brain may transform into pathological conditions. We explore central mechanisms of nervous and immune system interaction, first of all by means of afferent signals involving cytokines and transmitted through nervous and humoral pathways from an activated immune system.

Cytokines recognized initially as immunopeptides demonstrate distinctive influence on the brain's functions. They are produced by CNS cells and are ligands of neuron receptors. Moreover, taking into consideration their participation in the signal transferring from the immune system to CNS and their ability to induce the cascade of regulatory processes, one has every reason to consider that cytokines in the brain act as regulatory peptides. These peptides transfer the signal about immune cell activation to the brain, reorganize the perception and behavior of the individual and subordinate the current functions to the strategy of survival in the wild environment. Furthermore, in the central compartment, cytokines play the same role as they do on the periphery, that is—as the mediators of inflammation.

Techniques used in exploring the brain's functions cover the subject from the level of conditioned reflexes and integral behavior to the mRNA level of peptides and receptor expressions and of neuropeptide production in the brain. Our experiments include studies of neuromediators and cytokine system interaction in autoimmune neurodegenerative processes in EAE (experimental autoimmune encephalo-myelitis).

Completely original data has been obtained regarding the role of enhancement of pro-inflammatory cytokine levels in blood circulation and in the brain tissue due to hypoxia, trauma, infection, etc., during critical periods of early postnatal ontogenesis. The increase of cytokine levels correlates with the development of psycho-neurological pathology in these adult animals or during the period of their maturation.

The Laboratory of Psychophysiology of Emotions, Headed by Tsykunov

This laboratory's work is directed towards investigating the mechanisms of emotions, emotional disorders and solving the problems of anxiety and depressive conditions.

Pavlov was one of the first who introduced the concept of reinforcement into scientific literature. Nowadays the phenomenon of reinforcement is the central point in different theories of emotions and behavior. Main principles of forming conditioned reflexes—a specially directed control of emotional state—are employed by staff during investigations of purposeful activity of dolphins in free behavior.

Adequacy and agility of emotions are destroyed in affective disorders, especially in depressions. While working with models of depression in rats (as a result of mental trauma, caused by a threat to life, or zoo-social conflicts) developed by us, it was shown that there were two forms of depressive-like disorders. Those disorders have common depressive symptoms, but they were divided by structure of modified investigation and aggressive behavior as well as by level of anxiety. It was shown that those conditions are characterized by opposite shifts of lipid turnover. A result of mental trauma is a decrease in Alfa-cholesterol. Disclosure of mechanisms of those disorders will raise our understanding about pathogenesis of depression and will give the basis for the development of new drugs.

Clinical Laboratory of Neurodynamic Correction of Psycho-Neurological Pathology, Headed by Jakovlev

The role of generating conditioned reflexes in formation of children's behavior was the subject of exploration by Pavlov's disciple Krasnogorsky. The study was carried out when Pavlov was still alive. On the basis of this research it is possible to conclude that mechanisms of the feedback a person maintains with the environment play an essential role in developing healthy behavior. Conditions of informational deficit from a poor environment often result in brain dysfunctions in children younger than 7-10 years old.

A risk factor of alcohol and drug addiction, which has the widest distribution among teenagers, is attention deficit syndrome and hyperactivity disorders (ADHD). Pathogenesis of ADHD, and of alcohol and drug addiction is based on the deficit of emotional reinforcement which, in turn, results from an imbalance in the systems of neuromediators, peptides and opioids (dopamine-serotonin, GABA-ergic receptors), centered in mesocortical-limbic structures of the brain.

A technique involving outer computerized biofeedback for training ADHD children was elaborated at the Department of Physiology. As a result of training with biofeedback, all patients demonstrated positive dynamics of vegetative, emotional, and motor reactions, and of behavior as a whole.

It has been discovered that the kind of guided parameter (for example, EEG, ECG, breathing and so on) chosen to work out adaptive self-regulation does not matter, a new stereotype of function regulation is formed in the CNS and new functional nervous connections are established.

Concluding the description of the scientific history of Pavlov's Physiological Department at the IIEM in St. Petersburg, the authors would like to once again stress the importance of Pavlov's contribution to world science: he built a new system of knowledge and introduced new notions which have become an inherent part of such disciplines as physiology, medicine, psychiatry, psychology and pedagogy. He also created a vast field of knowledge

available to upcoming generations of scientists. This field of knowledge and guidelines created by him will help these future investigators achieve their goals for many years to come.

References

Cannon, W.B. (1945). *The way of an investigator, a scientist's experiences in medical research*. New York: Norton.

Pavlov, I. (1897). *Lectures on the work of the chief digestive glands*. St. Petersburg: Kushneroff.

Pavlov, I. (1903). Experimental psychology and the psychopathology of animals. *Bulletin of the Imperial Medical Academy, 7*, 109-120.

Pavlov, I. (1906). The scientific investigation of the psychical faculties or processes in the higher animals (The Huxley lecture). *Lancet, I*, 911-915.

Pavlov, I. (1927). *Conditioned reflexes*. London: Humphrey Milford.

Pavlov, I. (1923/1928). *Lectures on conditioned reflexes.Twenty years of objective study of the higher nervous activity (behavior of animals)*. New York: International.

Setchenov, I.M. (1965). *Reflexes of the brain*. Cambridge, MA: MIT Press.

Snarsky, A.T. (1901). *Analysis of normal conditions for the dog's saliva glands functioning*. Unpublished doctoral dissertation. Petrograd.

Tolotchinov, J. (1902). *Contribution à l'étude de la physiologie des glandes salivaires. Comptes rendus du congrès du natural science et medecine du Nord à Helsingfors.*

Wolfson, S. (1899). *Observations upon salivary secretion*. Unpublished doctoral dissertation. Petrograd.

Received August 1, 2003
Revision received September 25, 2003
Accepted October 2, 2003