THE CEREBRAL CORTEX AND THE INTERNAL ORGANS

by

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TRANSLATOR'S FOREWORD

My interest in undertaking the translation of this—the fourth book I have translated from the Russian—goes back 35 years when I first met Konstantin Mikhailovich Bykov in the laboratory of Pavlov at the Institute of Experimental Medicine in Petrograd, in 1922. At that time he showed me his experiments on the secretion of the kidney in adaptation to the experience of the individual, viz., the renal conditional reflex. During the years that I have known him I have held him in esteem as a scientist of outstanding ability, whose work is characterized by imagination, by extreme thoroughness, and by patient and systematic planning. No pupil of Pavlov's has advanced the work further in many fields than Professor Bykov.

The first edition of this book was sent to me by Bykov about 15 years ago. A few years later I received a translation made in Russia. The translation that I now present is a result of my retranslating a large part of the edition published in Moscow in 1954 and, for the rest, comparing the original Russian translation with the Russian text for accuracy. Owing to the fact that the translation has not been done in its entirety by me, it lacks in some portions consistency in English style that I would have liked to give to it, had I been less involved with the other duties of an active investigator.

I have spent many an exciting hour with Bykov's opus magnum—from Baltimore to Puerto Rico, Virginia and Maine—during the past decade in an effort to render accurately these important researches in the field of our mutual interests.

This tome deals with the physiological principles concerning the adaptation of the individual to his environment, internal and external, as expressed chiefly in the functions of the viscera, of the endocrine glands, and of the general metabolism integrated through the suprasegmental nervous system. The story unfolds with the ex-

citement of a great drama, a romance of the unknown nether world, whose characters are the unseen and normally unfelt organs lying between the hypophysis and the perineum, whose plot is based on the laws of biology which govern our everyday life in health and in sickness, whose denouement rests on the adaptive responses mediated by the higher nervous system which Pavlov called the conditional reflex.

This is the continuation of a story begun 50 years ago by Pavlov, developed through the latter half of his life, till within a week of his death. I have listened to it as enraptured as I was when as a child I listened to the story of Aladdin and his wonderful lamp.

In the past decade our country and the U.S.S.R. have passed through many stages of relationships: from comrades-in-arms, through doubt and suspicion, to "cold war" to what now seems to be an era of recognition of the vital necessity of living together in our rapidly contracting universe. My position in this world of changing opinion has been and remains one of facing what I consider realities, the observance of mutual rules of conduct of living and let-live with noninterference of the desires of peoples to regulate their internal affairs, and the assertion in science of the principle averred by Pavlov that science should be international:

> We (scientists) are all bound together by a feeling of comradeship—in many cases, indeed, by ties of personal friendship. We are working, assuredly, for the rational and final unity of mankind. (*Lectures on Conditioned Reflexes and Psychiatry*, New York, 1941, p. 32.)

Because of the confusion and suspicion that has existed in the past in connection with those having any knowledge extending beyond national borders, the above statement often needs repeating.

May this publication of a series of brilliant scientific experiments performed over a third of a century not only provide American readers with important knowledge, but be a link in a chain of friendship and good will beginning with the scientists and extending to the peoples of the U.S.A. and the U.S.S.R.

It is a pleasure and a duty to recognize the unselfish help of Mrs. Harvey Kushner and Mrs. Rebecca E. Bromiley with details of the manuscript, and to express gratitude to Dr. Irene E. Berck of the Chemical Publishing Company for her unusually careful and helpful editorial corrections.

W. Horsley Gantt

PREFACE TO THE FIRST EDITION

Since the late 19th century the necessity for revising the traditional outlook on psychic phenomena has become more and more imperative. To this end, the outstanding representatives of physiology, zoology, and psychology in different European and American countries have undertaken numerous investigations giving a materialistic interpretation to the complex reactions of animals. The demand for a new method of studying the psychic activity of animals and man became so great that the more objective investigators were no longer satisfied with the older methods of experimental psychology for learning about the complex reactions of an animal organism. The "soaring mental heights" (Pavlov) reached by the Father of Russian physiology, I. M. Sechenov, enabled him, as early as 1863, to represent our subjective world in terms of physiology, but only the great physiologist of our day, I. P. Pavlov, has succeeded in enriching science with a new method of studying the so called "psychic activity," remaining within the field of concepts and terms proper to the physiology of the nervous system in systematizing and interpreting the experimental material obtained. Pavlov established the general biological principle of temporary connections which found its concrete manifestation in the principle of forming the conditional reflex.

The study of the new class of phenomena, i.e., the elaboration and dynamics of conditional reflexes developed through the operation of the cerebral cortex, has grown both in our country and in Western Europe and America.

This new objective method of studying the most complex reactions of the animal organism made it possible to undertake and solve a number of physiological problems which had been inaccessible before.

Our work was first begun, in the laboratory of my teacher Ivan Petrovich Pavlov, by the study of renal activity. All the data obtained in Pavlov's laboratories on the physiology of the cerebral cortex were mainly and purposely focused on an effector apparatus i.e., the salivary gland. There was reason to assume *a priori* that the elaboration of temporary connections either to salivation or to the activity of any other organ should be identical in principle.

Yet logical considerations alone are insufficient for the study of physiological functions, and extensive experimental work was necessary in order to verify the correctness of our hypothesis. The very first of our investigations, carried out with Alexeev-Berkman, showed that environmental agents (sounds, light, smells) could influence an organ concealed in the depth of the body. We were also able to establish the nature of this dependence, i.e., the formation of temporary connections, or, which is actually the same thing, the elaboration of a new conditional reflex to the activity of the kidneys. This essential fact was the starting point for the further study of the dependence between the work of the viscera and the numberless agents of the outer world having no relation to the given organ, which agents, however, may come to act as stimuli to this organ due to the formation of temporary connections.

The experiments on the kidney opened vast possibilities for the experimental study of various other functions. The endeavor to develop the study of the work of the cerebral cortex was necessarily connected with the solution of the following two problems:

1. What is the role of the cerebral cortex in the coordination and regulation of the complex processes occurring in connection with the special functional acts of the viscera?

2. Of what importance are the impulses arising in the viscera to the cerebral cortex? Is the principle of temporary connections applicable in analyzing the interrelations between the receptor field of a viscus and the cerebral cortex? In other words, what is the role of the complex "milieu interieur" of an animal and the physiological acts of its behavior? At the very beginning of our investigations we attempted to understand how the so-called vegetative processes became merged with the world of consciousness.

The study of so vast a problem opening new vistas for the progress not merely of physiological science, but also for theoretical and practical biology, medicine, pedagogics, and psychology could not possibly be accomplished by a single investigator. It was necessary to have a group of workers endowed with creative scientific insight

and capable of persistently following a common line of experimental work.

Gradually a group of workers, including a number of younger scientists, was formed. The generous help we received from the State enabled us to overcome the obstacles that were in our way and to follow the path which led us to the successful completion of the task we had set. The material on which this book is based consists of data obtained in the laboratories of the Institute for Experimental Medicine, of the Naval Medical Academy, and of the Leningrad State University.

To my dear friends and close collaborators of many years, E. S. Airapetiantz, G. E. Vladimirov, V. E. Delov, G. P. Konradi, R. P. Olinyanskaya, A. V. Rikkl, A. A. Rogov, A. D. Slonim, and V. N. Chernigovsky, who have done so much work for our common cause, I feel particularly indebted for helping me collect successfully the necessary material. I should also like to welcome and thank the other collaborators who have worked in our laboratory.

I am sincerely grateful to G. P. Konradi and A. V. Rikkl for assisting me in giving the final form to this book.

The references (appended to the Russian edition) are limited to the investigations which have been made in our laboratories. Some investigations made in other laboratories which have a bearing on our problem have been mentioned in the corresponding chapters but we have had no intention of giving all the available material connected with the subjects discussed.

Repetitions have proved unavoidable, as each chapter had to be short and yet independent of the others, in spite of their all being joined by a common point of view, i.e., the regulation of the "milieu interieur" by the higher nervous apparatus.

I am well aware of the imperfections which have occurred in realizing the plan we had set before us. The tempestuous period of great historical events interfered with the normal development of creative work. I hope that the ideas sown on our native ground by the founders of Russian physiology—Sechenov, Pavlov, Vvedensky, Mislavsky—will find their development in the works of numerous Soviet scientists and yield a rich crop in the near future.

K. M. Bykov

PREFACE TO THE THIRD EDITION

A decade has elapsed since the publication of the first edition of this book by the Military Naval Medical Academy, during which time our factual material has grown considerably. The request of the publishers to bring out the second volume of my collected works coincided with my desire to help the younger investigators to erect a new science appropriate to the important era in which we live and work.

To present the results of our more than 25 years of work would require a new book. To include the material and new concepts which we have accumulated since 1942 would be impossible, for this would destroy the form and arrangement of the previous book, which it seems to me is unnecessary. In this new edition my purpose is chiefly to show the existence and the characteristics of the mechanism of the dual connections of the brain with the various organs and tissues. A new exposition of the subject should describe the normal course of the different physiological functions as they appear in the healthy and in the pathological organism, with the continually existing and continually shifting connections which are established, thanks to the cerebral cortex, between all the processes in the organism and the variegated elements of the environment.

The task of writing such a new book is a very difficult one on which I hope to concentrate my strength in the next years.

The necessity of writing such a book does not alter the plan to bring out this revised edition. The facts and concepts presented in the 1942 book remain the basis for our further research into the cortical regulation of the physiological functions. To the great satisfaction of my collaborators and me, our facts have been confirmed and expanded in many of our laboratories, as well as in several others.

The experiments of this book support the development of Pavlov's reflex theory. Sechenov long ago modified the concept of the reflex theory, and Pavlov with his enormous experimental material discovered a new path to the understanding of the dynamics of the cortical processes, as a result of which there has been a new light thrown on all physiology. This new view represented an integrated and total organism in its connections with surrounding nature—and for the human, with society. Before us and our future generations are the colossal problems and ideas of our great predecessors. The Pavlovian path, assuredly reveals to us the influence of the highest creation of Nature—the cortex of the cerebral hemispheres—on the inner world of the human being, and this path can lead to his successful dealing with his surroundings. A close scrutiny and study of the dynamics of the brain has an influence on all natural history. Following the path blazed by its discoverer leading to new goals in science, based on materialistic concepts in the most complicated processes of the organism, i.e., the psychical, we have continued with energy and enthusiasm to add facts and to uncover the laws which govern these processes.

Our physiology, using its soundest concepts, proceeds along a materialistic path, and Pavlov's teaching concerning the activity of the higher nervous apparatus gives the basis for our philosophy. Thanks to the conditions which can be maintained especially in our country, we have an unusual approach to the development of physiology as well as of other branches of natural history. This furnishes the structure on which to plan the practical work in medicine, pedagogy, physical culture, as well as of other human sciences.

Mistakes are unavoidable in every great scientific movement. We have, indeed, made mistakes, e.g., erroneous ideas concerning the "third signalling system." Serious mistakes were made by those who sought to abandon Pavlovian methods.

Physiology is closely connected with medicine. The study of the human organism with the light thrown on the subject by Pavlov makes possible the formulation of a new and wide view of medicine in all its branches, as well as in veterinary medicine and in psychology. Enormous problems loom in front of us awaiting their solution.

For the last decade we have done our best to complete as much research as we could, conscious of being in debt to people who love science, who give us the means to work, and who await the results of our creative strength.

I should like, in the shortest possible time, to outline the results of our new work in the greatest task of our era, but this cannot be accomplished in a year. To do this will be our most complete gratification and our supreme happiness.

K. M. Bykov

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chapter 1

THE SUBJECT AND METHOD OF INVESTIGATION

Modern physiology, having accumulated vast material on the activity of the separate organs and tissues, is approaching closer and closer to the solution of the two central problems: the physiology of the individual cells and the physiology of the whole organism.

The importance of these problems is clear because we cannot successfully influence the work of any organism without knowing the conditions under which the activity of its cells takes place; we cannot control the state of a human organism if we do not know the conditions which determine its activity as an integrated system. These two requirements are intimately connected, but however complete the knowledge resulting from either of them, if taken separately, neither of them will ever suffice to give an understanding of the *normal physiology of man*. While the necessity of studying in detail the phenomena occurring in separate cells was obvious to every physiologist 100 years ago, the importance of studying the organism as a whole has been given attention only within the past few decades. It was believed possible to build up the physiology of the entire organism, as a sum of different organs and systems, from the data obtained in studying individual organs and separate systems. The purely analytical investigation which led from the simpler to the more complex was believed by many to be entirely or almost entirely adequate.

A study of the material accumulated by modern physiology with regard to different organs justifies the affirmation that at present we are fairly well aware of the work done by different organs, of their innervation, of the way they are affected by various chemical substances, etc. The greater part of the material thus acquired was, however, obtained under intentionally simplified conditions, by means of an abstraction from the integrity of the interrelations

which actually exist in the entire organism. For instance, we are well acquainted with the effect produced by epinephrine on blood pressure, heart rate, the sugar content of blood, the development of fatigue in an isolated muscle, the movements of an isolated intestine, etc. These data were obtained either by injecting epinephrine into the blood, or by studying its effect on isolated organs. Yet, we know little about the role of its secretion by the suprarenal gland in the life of the intact organism. The views held on the subject are most contradictory, beginning with an almost complete denial of any role of epinephrine in normal physiology (Gley, Stuart, Rogov) and ending with its being considered a factor which almost entirely determines the behavior of man (Cannon). Such is the case with epinephrine and yet, of all the hormones, epinephrine has been most studied both biochemically and physiologically.

Still more striking examples can be found in the physiology of the central nervous system. Thus, we are familiar with the activity of the spinal cord after the extirpation of all the higher nervous centers (medulla oblongata, cerebellum, cerebral hemispheres). The functions which can be fulfilled by the spinal cord under these conditions are known from the classical investigations of Goltz, Freisberg, Philipson, Sherrington, Magnus, and many others. Yet, we are ignorant of the processes which occur in the spinal cord under the normal conditions of its activity, when the effective impulses undoubtedly arise in the higher parts of the brain; we are ignorant of the interaction of the spinal mechanisms with the effects originating at the higher levels.

We have given these examples in order to point to the problems which face an investigator as soon as any given physiological function is studied not as an artifically isolated phenomenon, but as one of the elements of highly complex interactions developing in the organism as a whole. The analytical path of investigation, the study of a given phenomenon first in its simplest form and only gradually adding complexities, was and is, of course, a necessary step in the understanding of the most complex relationships. But this method fails to give a complete solution of the problem. The investigations of physiological processes should be directed toward gaining a knowledge of these processes under conditions of normal life, in their usual physiological environment. An artificial simplification and isolation of a function is a necessary means of investigation, but only a means, not an end. At the same time, it is necessary to investigate the same phenomenon as it usually occurs, under optimally *physiological* conditions.

In order to proceed along the path of investigating the intact organism, physiology has, naturally, had to do a tremendous amount of work in the study of isolated, separate functions. Only a few investigators, working in different branches of physiology, have attempted to conduct experiments, under optimally physiological conditions, of the normal activity of an entire organism. Yet, it should always be borne in mind that the action of the different factors in nature is invariably complex. Among this complex effect of different factors, however, there may be one whose action is predominant. Just as every organ is a unique and integrated system possessing a functional architecture peculiar to it, so the effect of a complex of factors is expressed not by their sum but by their integral.

These principles demand that in studying the behavior of an entire organism, the investigator should, in making his observations, take into account, as far as he can, the entire complex and, at the same time, evaluate every component so that he may determine the synchronous and dynamic complex of factors.

Before proceeding with the argument as to the correctness of the method of investigation we have chosen, it is necessary to recall the long road which physiology has traveled in attempting to gain a knowledge of the phenomena occurring in the whole organism. In the study of the reactions of an animal, physiology has already accepted as its starting point the reflex theory. Descartes was the first to conceive of activity as reflex and since then, for several centuries, the concept of the reflex has played a dominant role in physiology. Since the first applications of the experimental method to the study of nervous processes, i.e., since the days of Magendie, Bichat, Bell, J. Müller, Hall, and other famous representatives of physiology, the reflex has been considered as a reflection of a sensation in action. The problem of the interrelation of sensations and voluntary movements occupied physiologists for a long time, even after the reflex theory had evolved and finally become dominant, until the time of Sechenov and Pavlov.

Up to the thirties and forties of the past century, the reflex theory did not exist in its present form, although the term *reflex,* in the sense it was used before Pavlov, was introduced by Prokhaska in 1788. The physiologists of the first half of the nineteenth century did not regard the reflex as the result of activity in the nerve centers but as a consequence of anastomoses between the sensory and the motor systems. Though a few investigators (Whytt, Hales) published the data obtained in their experiments which pointed to the im-

portant role of the spinal cord in the reflex, these data failed to give sufficient ground for proving that reflex activity was essentially due to the role of the central nervous system.

The majority of investigators connected the notion of nervous activity with subjective ideas of sensations and consciousness. Observations at that time were limited to recording the presence or absence of muscular contraction, sometimes a subjective estimation of its force, and, earlier still, merely to an attempt at determining precisely which muscles were contracting. The graphic method was first developed about 1850. The recording of sensory excitations was either limited to self-observation, or, in experimenting on animals, to noting the phenomena of pain (whining, howling, convulsions). The idea of the role played by the central nervous system was crude. Even so brilliant a scientist as Flourens attributed specific functions to definite parts of the brain in a way which seems naive from the modern point of view. The idea of the nervous system being split up into functional and anatomical parts was more definitely expressed by Flourens than by other investigators (Magendie, Bell, Müller, Longet, etc.). Yet, this firmly established concept left a lasting impression on physiology, forcing investigators to seek for an explanation of nervous activity mainly in morphological structure. With great assurance Flourens said:

> . . . in experimenting on every part of the nervous system, I isolated the function of each of these parts; I determined in succession the role of the nerves, of the spinal cord, of the cerebellum, of the corpora quadrigemina and of the cerebral hemispheres. Now that this role has been acknowledged and established, anyone can see the possibility of deducing a change of the parts from a change of their properties and, contrariwise, a modification of properties from a lesion of the parts. Such is the ultimate object and aim of all physiology and all pathology.

Some of Flourens' contemporaries, as well as later physiologists, attempted to follow another path, i.e., to carry their investigations along the line of seeking to explain the regularities of reflex acts by the functional manifestations of the reflex arc itself (Pflüger and others). They were, however, dominated by the accepted interpretation of physiological phenomena from the anatomical point of view, as well as from a subjective estimation of the phenomenon observed. Thus, the main procedure was that of dividing the nervous system. Of course, the initiators of the physiology of the nervous system could not have thought differently. For a long time, there