Principles of Neural Science

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A book by a single faculty reflects its university. It is therefore a particular pleasure to express our indebtedness to Dean Donald F. Tapley, and to the College of Physicians & Surgeons of Columbia University. Columbia has provided an intellectual environment that encourages interaction between basic science and clinical departments, an essential condition for writing an interdisciplinary book.

Preface

I

Principles of Neural Science is designed as an introductory text for students of biology, behavior, and medicine. Our overall goal is to convey the interest and excitement surrounding the recent attempts to apply cell-biological techniques to the study of the nervous system, its development, and its control of behavior. The text also places emphasis on those neurological and behavioral disorders that are at once instructive scientifically and important clinically.

A modern discussion of the nervous system can no longer be competently achieved by a single author. We have therefore chosen to write a multiauthored book along the lines of those currently useful in cell biology, pharmacology, and medicine. Each chapter is written by an effective classroom teacher who is also a research person with a sense of direction and taste about his particular discipline that comes only from working within it. To ensure a consistent perspective and to counterbalance the tendency in multiauthored texts for each author to speak a different dialect, we have decided, in this first edition, to limit the authors to a single teaching faculty. For five consecutive years this faculty, which includes neurophysiologists, morphologists, psychologists, biochemists, psychiatrists, and neurologists, has taught a course in the neural sciences based upon earlier versions of this text. The course has been given to graduate students, medical students, dental students, and house officers in neurology, psychiatry, and neurosurgery. A shortened version has also been offered as continuing education for practicing physicians. Numerous discussions among the faculty and comments from students and from other colleagues around the country have helped us to develop a cohesive presentation, to stress the essential concepts, and to explain them clearly.

We have attempted to be selective and to emphasize the major principles that emerge from the study of the nervous system without becoming lost in detail. Toward this end we have divided the book into eight parts:

I. An overall view of the brain
II. The cell biology of nerve cells and the rules that determine their interconnections
III. The cellular basis of perception
IV. The control of movement
V. The brain stem and reticular core
VI. Motivation and homeostasis
VII. The mechanisms of development
VIII. Behavior and its disorders

Within each part we also briefly survey the relevant regional neuroanatomy. At Columbia, and at many other institutions, regional neuroanatomy is taught as a laboratory course, not a lecture course, with a separate laboratory syllabus. If neuroanatomy were to be included here in the descriptive detail it deserves, it could obscure the functional emphasis that we have striven to

achieve. Nonetheless, it is impossible to consider the functions of the brain without describing its structures. Therefore, those aspects of neuroanatomy essential for understanding neuronal function are described. Detailed treatment of this subject has been left to standard textbooks of neuroanatomy.

Our ultimate aim is to integrate information from experimental studies with practical areas of interest. For the general student, it will be important to see how basic information about the nervous system can be applied to psychology. For the student of medicine, integration with clinical fields of neurology and psychiatry is of prime importance. Integration with neurology is relatively easy; neurology and neural science have long been interdependent. The bridge to psychiatry is more difficult. We have therefore made a concerted effort to provide the beginnings of a systematic introduction to the biological basis of behavior. Behavior is one of the last frontiers in biology at which we still stand in relative ignorance. We hope that this text can provide insights and enthusiasm that will encourage the student to view behavior with the same combined social and biological perspective that serves so well in other areas of biology and medicine.

II

There is a sense of excitement and optimism in the brain sciences today, a sense that we may soon have some new insights into several previously intractable problems—into the development of the brain and the mechanisms of perception, motor coordination, and learning. This optimism is not completely new to neural science, but it is probably fair to say that it is more realistic now than ever before.

The modern era in neural science began about 30 years ago. In 1953, Sir John Eccles (who later won the Nobel Prize in Physiology and Medicine with Alan Hodgkin and Andrew Huxley) reviewed results based on the first intracellular recordings from single nerve and muscle cells in a book he modestly entitled *The Neurophysiological Basis of Mind.* At the time this title seemed overly bold because so little was then known about the mechanisms of behavior. What could be learned by sticking cells with microelectrodes which could possibly help understand the mind? As time went on, many of us have returned to this marvelous book, and each time we become more impressed with its author's prophetic insight. Eccles' book pointed the field in the right direction. His major message was that it is essential to study the brain in terms of its elementary units—individual nerve cells. Only by applying analytical techniques that can resolve neural processes at a cellular level can we develop a realistic and synthetic understanding of how the brain works. However, studying nerve cells with analytical techniques is necessary but not sufficient for understanding how the brain works (how people think, behave, feel, act, and relate to one another as human beings). It is also essential to relate cellular function to behavior.

We do not maintain that in the years since *The Neurophysiological Basis of Mind* was published neural science has fulfilled Eccles' prophesy. We hope, however, to show that neural science is beginning to provide insight into some of the most difficult problems of cellular differentiation on the one hand, and some of the most fascinating problems of behavior on the other. For example, considering that the brain is made up of a million million (10^{12}) cells, it is remarkable how much has been learned about the functioning of the nervous system as a whole by looking at nerve cells one at a time. It has become apparent from cellular studies that the building blocks of different regions of the vertebrate nervous system, and indeed of all nervous systems, are everywhere about the same. What distinguishes one brain region from another and one brain from the next are the number of building blocks and the way they are interconnected. Moreover, by applying a cellular approach to different sensory systems of the brain, it is possible to gain insight into how visual and other sensory stimuli are sorted out and transformed at various brain levels and how these regions contribute to perception. These studies show that the brain does not simply replicate the reality of the external world or project it onto a tabula rasa, but begins at the lowest levels of the sensory system to abstract and restructure reality according to its own rules and encode it into informational signals. These developments in neural science press upon the borders of experimental psychology.

The merger of the concepts and techniques of neural science with those of experimental psychology promises further advances in understanding perception and learning. In addition, neural science has recently benefited from vigorous interactions with other disciplines, particularly biochemistry and molecular biology, and these have resulted in fresh approaches to the in-

vestigation of brain function. Indeed, the merger of these disciplines has resulted in an integrated view of the nervous system.

It is our intention that this textbook present the important facts and the fundamental concepts of modern neural science. These not only are interesting and coherent in their own right, but also are necessary for effective work in neurology and psychiatry. The past 30 years have seen splendid progress in the techniques and practice of neurology and psychiatry, but we believe that this book would be inadequate if it merely summarized the information now accumulated that is directly pertinent to clinical practice. We also consider it our responsibility to provide a sense of direction for future developments by introducing students to the most important advances of our times, so that they will be able to evaluate the progress of this field in years to come. For this reason we are not content to consider only those aspects of neural science immediately relevant to neurology and psychiatry, but shall also discuss important scientific developments from current studies of animals that promise to provide a foundation for more effective understanding of normal and abnormal human behavior.

Engraved at the entrance to the Temple of Apollo at Delphi was the famous maxim "Know thyself." Central to enlightened Western culture from ancient times has been the idea that it is wise to understand oneself and one's behavior. Not needed only for clinical application, neural science is required for understanding human behavior, because all behavior is an expression of neural activity. Beyond medicine, in society at large, the problems of crowding, addiction, violence, and war revolve around the nature of human beings. Any intelligent solutions to the enormous problems of human behavior, individual and collective, must benefit from greater knowledge of neural function. Many of these problems are not now in the immediate domain of neural science, but progress is rapid and we can hope that neural scientists will soon be able to contribute directly to understanding them.

Eric R. Kandel
James H. Schwartz

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