BASIC HUMAN NEUROPHYSIOLOGY

THIRD EDITION

ARTHUR C. GUYTON, M.D.

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PREFACE

In this third edition of this book, *Basic Human Neurophysiology*, several very important changes have been made. Foremost of these has been the addition of four new chapters on the somatic control functions of the nervous system, such as nervous control of the circulation, of the heart, of the gastrointestinal system, of the endocrine system, of body temperature, and even of sexual functions. These chapters should be especially valuable to students of physiological psychology, to help in understanding the way that the nervous system interfaces with the total body. To make it easier for the student to understand transmission at synapses, a new introductory chapter has also been added to the text, which discusses basic mechanisms of membrane transport, especially movement of ions through membranes.

Another new feature of this edition is the use of color in the figures and major headings of the text. This new format makes it possible to emphasize important essentials of the different structures and mechanisms. And, because major advances have been made in recent years, especially in the understanding of molecular and chemical bases for nervous function, much new information will be found in almost every chapter.

This text is intended for those persons—medical students, paramedical students, students of psychology, students of basic physiology, and others—who wish to study the general organization and function of the nervous system without the detail often associated with a research-oriented text. Also, neuroanatomy is presented only to the extent that it is important to understanding how the nervous system performs its many tasks; this means mainly emphasis on nerve tracts and on function of the nerve signals when they reach their destination.

I have tried above all to present the beauty and logic intrinsic in the design of the nervous system—the automaticity of such feats as walking, sleeping, waking, and even search for food; the inbred pace-setting effects of emotions; and the almost magic processes for channeling, storing, and deciphering information. The nervous system is an overall controller of our bodily function. It is a computer with capabilities that have never yet been duplicated by the most massive electronic computer. And it is that quality of our being that makes life meaningful, thoughtful, exciting.

At many points in the text, one will find discussion of neurological illnesses as examples of abnormal function of the nervous system. These are presented not with the view that this book is dedicated only to medical students but, instead, because of the enlightening experience that a student can achieve when he correlates basic conceptual knowledge with happenings in the world about him. Indeed, understanding neurological abnormalities adds immeasurably to one's understanding of basic neurophysiological concepts. Therefore, even for the non-medically oriented student, the discussions of abnormal function in the nervous system are meant to give values that are difficult to establish in other ways.

I wish to thank many others who have made this text possible, particularly Mrs. Billie Howard, Mrs. Jane Strickland, Miss Gwendolyn Robbins, and Mrs. Laveda Morgan for their excellent secretarial services, Miss Tomiko Mita for her superb work on the new and colored illustrations, and the staff of the W. B. Saunders Company for its continued excellence in editing and preparing the text for publication.

ARTHUR C. GUYTON

INTRODUCTION

The nervous system is the major controller of man's activities. It is composed principally of *nerve cells,* also called *neurons*. The nerve cell, in turn, has two major parts, the *nerve cell body* itself and long extensions called *nerve fibers.*

In the central nervous system, the neurons form a complex network that functions as a central computer for storing information and for controlling the different functional units of the body.

Leading from the central nervous system to the periphery is a vast array of peripheral nerves containing millions of nerve fibers which are the filamentous extensions of the neurons mentioned above. These provide two-way communication between the brain and the periphery, carrying sensory signals from all parts of the body to the brain and in turn carrying motor control signals back to the separate organs and tissues.

Basically, nerve signals are transmitted by the nerve cell membranes. To achieve this, each membrane has an electrical charge across it between the inside and the outside of the membrane. When this charge is sufficiently disturbed in any part of the neuron, for instance in a peripheral nerve ending or in the central nervous system, electrical currents suddenly begin to flow through the membrane. These currents in turn induce similar discharges in rapid succession all the way along the neuronal membrane, creating a ripple current that spreads over the entire nerve fiber and even over the neuronal cell body itself. This is called the *nerve impulse*; it is by means of many such impulses that signals are transmitted in the nervous system.

Within the central nervous system, and also in a few areas in the periphery, nerve signals are relayed from one neuron to another. This is achieved through special contact points between the successive neurons called *neuronal synapses*. It is mainly the synapses that determine where in the nervous system the signals will be transmitted. Later in this text we shall discuss in detail the mechanisms of nerve signal control, for they are the bases of the different nerve reflexes, of the processes of memory and thinking and generally of all other intellectual processes.

The nerve fibers that provide the communicating linkages between the body periphery and the central nervous system are of two types: *sensory nerve fibers* and *motor nerve fibers*. The sensory fibers all originate at special nerve endings called *nerve receptors*. Examples of these are pain receptors, touch receptors, vision receptors, hearing receptors, and so forth. Each one of these receptors is specifically organized so that it can elicit the needed electrical disturbance in the nerve fiber to generate nerve impulses. The motor nerve fibers, on the other hand, carry nerve signals outward from the central nervous system to the functioning elements of the body, especially to the muscles, the visceral organs, and the glands.

The first requirement in understanding the function of the nervous system is to study the basic means by which the nerve impulses themselves are transmitted along the nerve cell membranes. But, to understand this, it is also necessary to become familiar with the mechanisms for movement of the different ions through

the cell membrane. Therefore, in Chapter 1 we will begin not with a discussion of the neuronal network of the nervous system but instead with the much more fundamental mechanisms that underlie ion transport through the cell membrane. The membrane transport processes are essentially the same for all types of cells whether they be nerve cells or other cells; these processes have special significance for nerve signal transmission, as will become evident as we proceed to the discussion of membrane potentials and nerve impulse transmission in Chapter 2.

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