THE AUTONOMIC NERVOUS SYSTEM

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PREFACE TO THE FOURTH EDITION

THE regulation of the visceral functions of the body and its adjustments to its internal environment are mediated in part through the autonomic nerves and in part through hormonal mechanisms. The autonomic nerves, in conjunction with the hormonal mechanisms, also play the major role in maintaining the internal environment in a steady state. An attempt is made in the present volume to give a simple but adequate account of the anatomy, the physiology, the pathology and the clinical relationships of the peripheral autonomic nerves and the centers in the central nervous system to which they are functionally related.

The data incorporated in this book are derived from a very extensive literature, including contributions of the author and his collaborators during more than three decades. Since the preparation of the third edition, significant anatomical, physiological, experimental and clinical data have been published by many investigators. Knowledge has been advanced in all aspects of the anatomical, the physiological and the clinical relationships of the autonomic nerves, and particularly with reference to their functional relationships to centers in the brain stem and the cerebral cortex. Significant new data relative to the histochemistry and the histopathology of the autonomic ganglia and nerves have been reported, but the data available do not afford an adequate basis for the complete interpretation in terms of modified functions of all the observed variations.

Adequate consideration, within the limits of a single volume, of all the anatomical, the physiological, the histopathological and the clinical data bearing directly or indirectly on the autonomic nervous system would be impossible. It is extremely difficult, furthermore, to present all the significant findings in their true historical setting. The temptation to give the most recent and the most adequately illustrated contributions undue weight is ever present. This tends to create the impression that the latest and the most detailed work is the most significant, whereas in reality the later findings have been made possible in a large measure by the original discoveries of earlier investigators. The author desires to give due credit to the pioneer investigators, but the limitations of space do not permit a complete account of the historical background of our present knowledge regarding many phases of this important subject. Some significant data have been omitted and some have been treated inadequately. An attempt has been made to maintain a proper balance between the various phases of the subject and to correlate the data selected, including the essential findings reported in the recent literature, so that clear concepts may be gained of the regulatory control of visceral functions that is exercised through the autonomic nerves, the importance of such regulatory control under normal physiological conditions and the effects of autonomic dysfunction.

The number of original papers, reports and reviews that make up the literature relative to all aspects of knowledge of the autonomic nervous

system has become so great that it would be impractical to attempt to refer specifically to every important contribution. Listing of all the significant contributions in the bibliography would also be impractical since this part of the volume would be disproportionately large and the cost of publication would be correspondingly increased. In view of these considerations, many findings that have been generally accepted have been set forth without specific documentation. Direct authorship references have been limited chiefly to data that are of fundamental importance, data and points of view that have not been generally accepted and data that may be regarded as controversial. Only those contributions to which direct reference is made in the text are included in the bibliography.

In order to give the reader access to both the older and the current literature, it may be pointed out that most of the significant contributions published prior to 1945 are listed in the bibliography of the third edition of this book. Beginning with 1945 the author has every year prepared a review of the current publications relative to the anatomy, the physiology and the clinical aspects of the autonomic nervous system. These reviews, with complete lists of the publications reviewed, are published in "Progress in Neurology and Psychiatry," Volumes I to VII.

In the preparation of the fourth edition, the entire text has been revised and in part rewritten. New data bearing on certain phases of the anatomical relationships and the functional activity of the autonomic nerves have called for a critical reëxamination of some of the generally accepted concepts which, in some instances, has resulted in a new point of view. Recent clinical and experimental data also afford more adequate criteria for the evaluation of surgical procedures that involve the autonomic nerves in the treatment of patients in various categories. Some of the illustrations have been replaced by new ones in the interest of greater accuracy and clearness, and additional illustrations have been introduced.

The author wishes gratefully to acknowledge his indebtedness to Professors Kermit Christensen and C. A. Richins for valuable advice and assistance, to Dr. N. M. Sulkin for assistance in preparing the account of the histochemistry of the autonomic ganglia and that of variations in the ganglia that may be related to ageing, to Mr. P. A. Conrath for the preparation of illustrations and to the Publishers for their continued interest and courtesy.

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CONTENTS

CHAPTER IV

General Physiology

CHAPTER V

General Physiology (*Continued*)

CHAPTER VI

Development

CHAPTER VII

Innervation of the Heart

CHAPTER VIII

Innervation of the Blood Vessels

CHAPTER IX

Innervation of the Respiratory System

CHAPTER X

Innervation of the Digestive Tube

CHAPTER XI

Innervation of the Biliary System

CHAPTER XII

Innervation of the Pancreas, Spleen, Thyroid, Adrenals and Bone Marrow

CHAPTER XIII

Innervation of the Urinary Organs

CHAPTER XIV

Innervation of the Sex Organs

CHAPTER XV

Innervation of the Skin and Its Appendages

CHAPTER XVI

Innervation of Cephalic Autonomic Effectors

CHAPTER XVII

Sympathetic Nerves in Relation to Skeletal Muscles

CHAPTER XVIII

Histopathology

CHAPTER XIX

Visceral Sensitivity and Referred Pain

CHAPTER XX

Autonomic Imbalance

CHAPTER XXI

The Autonomic Nervous System in Disease

CHAPTER XXII

Autonomic Neurosurgery—Anatomical and Physiological Considerations

CHAPTER XXIII

Autonomic Neurosurgery (*Continued*)—Peripheral Vascular and Cardiac Diseases

CHAPTER XXIV

Autonomic Neurosurgery (*Continued*)—Other Diseases With Autonomic Factors, Visceral Pain and Pain in Extremities

The Autonomic Nervous System

HISTORICAL INTRODUCTION

THE vital physiological functions of the body, in all the higher animals, including man, are subject to nervous regulation in some degree. This involves reflex and coördinating reactions of varying degrees of complexity that are carried out through afferent and efferent conduction systems and reflex and coördinating centers. Peripheral reflex mechanisms have been demonstrated, but the chief reflex and coördinating centers involved in the regulatory control of the visceral functions are located in the central nervous system. The functional activities of these neural mechanisms are essentially involuntary, but they are not independent of regulatory influences emanating from the cerebral cortex. All the neurons located outside the central nervous system that are concerned with the innervation of the viscera, except those which are afferent components of the cerebrospinal nerves, are included in the so-called autonomic nervous system. This system also includes the neurons located within the spinal cord and the brain stem through which the outlying efferent neurons are functionally connected with the central nervous system.

The earliest anatomical description of any part of the autonomic nervous system probably is Galen's account of a nerve trunk lying along the necks of the ribs which receives fibers from the thoracic and the lumbar portions of the spinal cord and gives off branches to the viscera. Galen regarded this nerve as a branch of the vagus and advanced the hypothesis that through it the viscera receive sensitivity from the brain and motor power from the spinal cord. He obviously did not differentiate the cervical portion of the sympathetic trunk from the vagus. He observed three enlargements, or ganglia, along the course of the nerve, the first just above the larynx, the second at the entrance of the nerve into the thorax and the third at its entrance into the abdomen. The upper enlargement described by Galen undoubtedly includes the nodose and the superior cervical sympathetic ganglia. The one at the upper border of the thorax obviously is the inferior cervical or the cervicothoracic ganglion. The description of the one at the entrance of the nerve into the abdomen probably refers to the semilunar ganglion of the celiac plexus.

Galen also advanced the first widely accepted theory of "sympathy" or "consent" between different parts of the body. He rejected the teaching of Aristotle that the brain serves to cool the blood and attributed to it the function of generating "animal" spirits from the "vital" spirits in the blood. The peripheral nerves were regarded as tubular structures through which the animal spirits are distributed. It was further assumed that wherever peripheral nerves join one another communications are effected through which animal spirits may flow freely from one part of the body to

another and thus bring about "sympathy" between various parts of the body.

Galen's description of the vagi, which he regarded as the sixth pair of cranial nerves, was scrupulously followed by all the early anatomists including Vesalius; consequently, the ganglionated sympathetic trunk and the vagus nerve were regarded as a unit both anatomically and physiologically. The sympathetic trunk probably was first differentiated from the vagus nerve anatomically by Etienne (1545). Eustachio (1563) also recognized the sympathetic trunk as anatomically distinct from the vagus nerve. He illustrated it as arising within the cranium from the abducens nerve, thus emphasizing its supposedly cerebral origin. This error was not corrected until the publication of du Petit's work in 1727.

Willis (1664) called the ganglionated sympathetic trunk the "intercostal" nerve, a name which persisted until the time of Winslow. He also introduced the physiological concept of involuntary as distinct from voluntary movements, but he erroneously attributed the initiation of involuntary movements to the cerebellum. His account of a branch of the vagus nerve given off to the arch of the aorta undoubtedly is the earliest reference to the depressor nerve. He advanced the hypothesis that the nerve reacts to changes in the pulse. He recognized the vagus innervation of the heart as an important factor in its functional regulation, but discovered no specific reaction to vagus stimulation. Lower's (1669) observations on the effects of vagus section and vagus stimulation on the heart beat, which were later amplified by Ens (1745), prepared the way for the final demonstration of the inhibitory action of the vagus nerve on the heart beat by the experimental studies of Weber and Weber (1846).

The physiological concept of involuntary and voluntary movements introduced by Willis was greatly extended by Whytt (1751). His interpretation of involuntary movements on the basis of local stimulation marks the beginning of a new era in physiological thought and investigation, since it afforded a secure basis for the theory of reflex action. He envisioned reactions like the peristaltic movements of the gastro-intestinal tract and contractions of the urinary bladder as responses of the musculature to nerve stimulation due to local irritation of the mucous membrane or stretching of the muscle fibers due to distention of the organs. The idea of reflex action was thus introduced in the absence of any knowledge of reflex conduction pathways. Whytt's application of this principle to explain the responses of the pupil to light constitutes the earliest known record of light, accommodation and consensual reflexes. He later (1765) advanced the opinion that all "sympathy" or "consent" presupposes feeling and, consequently, must be mediated through the nerves, but, since in many instances the sympathy occurs between parts of the body whose nerves make no connections with one another, its mediation cannot involve the flow of any substance through anastomosing channels. Sympathy, therefore, must be referred to the brain and the spinal cord which are the source of all nerves. Although he probably had no adequate conception of nerve conduction, he drew attention to nerve fibers as functional units in contradistinction to the older concepts of anastomosing channels.