THE BASIS
of
CLINICAL NEUROLOGY

The Anatomy and Physiology of the Nervous System in Their Application to Clinical Neurology

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FOREWORD

Now, as in the past, the principles underlying clinical neurology must be drawn from neuroanatomy and neurophysiology. To greater or lesser extent, these principles extend to all fields of clinical medicine, since the rôle played by the nervous system as an integrator and controller of body functions is more and more carrying its implications into all fields of disease. Teachers and investigators of clinical subjects realize the need of a thorough knowledge of the fundamental sciences, and furthermore, searching and detailed studies of disease cannot fail to shed important light upon physiological processes and their underlying structures. This reciprocal relationship continues to invite the attention of those devoted to crystallizing the decisive facts for the use of students.

Dr. Brock, in this new treatise, shows his scholarly sympathies both for the needs of the student and the general content of the subject. In such a presentation it is not sufficient to be a mere tabulator of physical signs or an interpreter of pathological processes. Both of these features of disease must be seen simultaneously in the light of an understanding which can give full value to symptoms and the structural disturbances underlying them.

It is unquestionably true that few students of neurology have been more ardent in their devotion to this part of the medical calling. Dr. Brock's long and extensive experience as a clinician, his keen appreciation of clinical phenomena, combined with his protracted opportunity for studying the morphology, physiology, and pathology of the nervous system, have made him an invaluable guide as a sound and practical interpreter of nervous diseases.

Laboratory neurology in the narrower sense of the term still continues to make its valuable contributions to this field of science. On the other hand, it should not be forgotten that the clinic, ward, and sickroom have in a very true sense the essential potentialities of a laboratory set-up. Many of the most penetrating observations in the past have come from these sources. The idea that research has acquired a sanctity which associates it inseparably with the laboratory has become far too prevailing. It is a matter of fact, in so far as neurology is concerned, that the court of last appeal is not to be found in the laboratory where experimental data are gathered from the observations of subhuman mammals or other vertebrates. The conclusions drawn from such sources can only in the most guarded way and with much hesitation be applied directly to the activities and disturbances of the nervous system in man.

FOREWORD

Dr. Brock, with great wisdom, has balanced the experience derived from the laboratory against that gained in the clinic. He has not been unmindful of the highly important leads and suggestions which animal experimentation provide. He has utilized these facts skillfully and well, but throughout his entire presentation he has maintained that conservative attitude which demands that the physiology and pathology of the human nervous system fill the supreme position and have no wholly satisfactory substitute in the organization of lower animals. It is this feature of Dr. Brock's which gives his book its greatest value to the student, to the teacher, and to the practicing clinician.

FREDERICK TILNEY, M.D.

New York City

PREFACE TO FIRST EDITION

A successful approach to the understanding of disease of the nervous system requires a thorough knowledge of neuroanatomy and neurophysiology. The application of these basic sciences in the study of human illness is often difficult. This volume is intended to present neuroanatomy and especially neurophysiology mainly from the standpoint of clinical usefulness. It will be noted however that some of the context is of purely "laboratory" interest. I have included this aspect of neuroanatomy and neurophysiology because of the firm belief that the clinician will devise new methods of examination and arrive at a better understanding of nervous mechanisms by using the fundamental sciences. The past teaches us that the abstract neurophysiology of to-day becomes an instrument of clinical neurology to-morrow.

I have referred to the following excellent text-books and herewith make grateful acknowledgment to the authors:

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SAMUEL BROCK.

New York

PREFACE TO THE THIRD EDITION

Since the last appearance of this book eight years ago, neurology has continued to make great advances, thanks to the brilliant work of investigators in the clinic, in the neurophysiologic and anatomic laboratories and in the neurosurgical operating room. It is hoped that the numerous revisions in the following pages adequately reflect this progress. One of the most heartening signs of our deepening knowledge is the fact that neurology and psychiatry are drawing nearer to one another. Psychic phenomena are being re-interpreted and newly defined in terms of a richer "neuropsychology". Even though one can only see the dawn, there can be no doubt of the coming day when neurology and psychiatry will not only be quite inseparable, but will speak the same language.

The author is indebted to a number of colleagues for contributions of a distinguished order. Thanks are due to Dr. Paul F. A. Hoefer for revising his section on electroencephalography and for the new chapter on electromyography; to Dr. Joseph Moldaver for revising his section on electrodiagnostic methods; to Dr. Max Chamlin for his section on the visual pathways and for valuable suggestions in connection with the oculomotor innervations; to Drs. Leo M. Davidoff and Emanuel H. Feiring for their chapter on cerebral angiography; and to Dr. Morris Bender for the section on sensory extinction and double simultaneous stimulation.

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New York

SAMUEL BROCK

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CHAPTER 1

INTRODUCTION

In recent years the study of mammalian and human neurophysiology has proceeded with great intensity along various lines and yet the knowledge gained is still far from complete.

The defect in function resulting from *disease* or *injury* has thrown much light on various problems. But unfortunately, a number of factors tend to nullify the effect of the "experiments of disease." What are these factors? One of the most important is the partial assumption of function by healthy tissue to compensate or make adjustment for the impairment or loss due to disease in another part. This makes it difficult to define the functional quality of a given area of the nervous system. Again, certain parts, as the cerebellar or cerebral cortices, possess such an over-abundance of cells that the loss of many neurones may produce little or no disturbance in function. This is an example of the factor of safety so well known in connection with such viscera as the liver and kidney. Another difficulty lies in the fact that some of the effects noted after destruction of a given area must be attributed to changes in function of other parts due to disruptions in the nervous connections to distant or neighboring areas,—a phenomenon called diaschisis by Von Monakow. Further, in man, the functional capacity of various parts of the cerebral cortex differs greatly from individual to individual so that one must be quite wary in drawing conclusions as to the site of certain disorders. Furthermore, it may be very difficult to define function in physiological or psychological terms merely from a study of the symptoms produced by disease. This is specially true in the intellectual sphere. For example, granted that frontal lobe disease may produce childishness in behavior and a lack of ability to foresee the consequences of an act, just what is the basic function destroyed or impaired?

Because of these stumbling blocks investigators have turned to *animal experimentation* and have studied the defects in function following careful removal of parts of the nervous system, or the results of stimulation. But the above factors still continue to obscure the issue. Moreover, another obstacle is met. Many of the structures in the animal's nervous system have an entirely different functional significance and quality than their counterparts in man. This may be due in part to the brainward shifting of function in the higher anthropoids and man—the so-called encephalization of function which will be discussed in greater detail on p. 249.

Handicapped by such considerations, investigators have turned to a study of the changes in central nervous structure brought about by evolution. This kind of work covers the nervous system of invertebrates and vertebrates and also infant and child in different stages of development. Since form and function are so closely linked, it must follow that changes in morphology are closely associated with alterations in function. In this study of comparative neurology, many brilliant deductions concerning function have been made.

The *actions of various drugs* have been analyzed in intact animals and in those with experimental lesions of the central nervous system. So pharmacology has also helped to throw light on the functional nature of parts of the nervous system. But in this field investigators have encountered difficulties,—the main one being that the effects of drugs are often quite different in various species of animals and sometimes in the same animal under different conditions.

In recent years *physico-chemical studies* of nervous (especially cerebral) tissue have thrown a new light on nervous function. Of outstanding significance are the results of electroencephalography and the analysis of a variety of neuronal activities through analysis of accompanying electrical phenomena (page 314). At present the progress of *bio-chemical investigation*—such as studies in cerebral cell metabolism—is too limited to have any clinical application.

Recent engineering advances in the *science of communication* also have stimulated comparison between it and nervous function. Thus, the various signal devices, the return of certain messages back to the mechanical control center to modify or influence the activity of the center (by so-called feed back circuits) and the incorporation of purposeful mechanisms ("servo-mechanisms") may have their counterparts in the human nervous system (W. S. McCulloch). This introduction of "Cybernetics, or Control and Communication in the Animal and Machine" by N. Wiener (Technology Press, John Wiley & Sons Inc., New York, 1948) has given a dynamic interpretation to cerebral cortical function which is as highly speculative as it is attractive. Cobb has recently summarized the subject in an excellent essay (On the Nature and Locus of Mind, Arch. Neur. & Psych. 67, 172, 1952).

A very important advance in modern neurophysiology has been made by the introduction of concepts which explain the functions of the nervous system, more especially the cerebral cortex, not in terms of a time-fixed, static perceiving and discharging apparatus, but as a dynamic mechanism capable of memory, "choice between incompatibles", and recognition of universal characteristics as well as "particulars".

Pitts and McCulloch (1947) postulated the existence of neuronal nets operating as "scanning circuits", by which sensory impulses carrying "particular impulses" may not only evoke the immediate specific reflex effect, but a *universal* response as well. As Brazier (1952) says, "the sight of a bird, whatever its shape, size, color, or orientation, the written or spoken word for it in any of the languages known to us, the sound of its song, the feel of its wings in the dark, and sometimes even its smell, will inform us of the same universal".

Even a rat's brain is capable of simple "universalizing" by virtue of memory mechanisms. A rat may be trained to differentiate a square from a triangle, no matter what the size of the immediate stimulus square. The neuronal basis for the development of these faculties seems to lie in the existence of "a self-reexciting loop of neurones, sharing neurones with other loops", in which reverberation aroused by sensory impulses of different kinds "preserves the association between different particular events and allows the recognition of a universal to be sparked by the receipt of a particular stimulus" (Brazier).

In man, the ability to symbolize fragments of his past experience and use the latter in service of symbolic formulation and expression is the highest and most intricate neurophysiological manifestation of cortical brain activity. In such highly speculative formulations, the idea of feedback circuits introduces a possible neural mechanism by which "signals from the goal can alter the final behavior of the individual", whether by inhibiting, facilitating or otherwise altering the patterned response. This is a far cry from regarding behavior as a mere addition of many reflexes, however complicated they may be. Brazier states the issue very lucidly when she says, "In the old concept the nervous system was bound in space by the paths of neurones, in direction by the Bell-Magendie law, and bound in time by the conduction rate of nerve fibers and the delay time of synapses. No persistence in time was possible, and the dimensions of its activity were rigorously imposed by the all-or-nothing law. It was temporally and spatially fettered. The new neurophysiology has broken the fetters of this concept. Temporal summation, spatial summation, inhibition, all release the synapse from rigidity of response. After-potentials, after-discharge, and reverberating circuits release the nervous system from the fetters of time. No longer is the nervous system seen as responding only when it is stimulated. It can seize and retain stimuli and respond to them at a later time. One no longer seeks merely an individual response to the individual stimulus; it can respond to the category. And now it has been emancipated in space by the discovery of moving fields of direct current potentials, making possible the use of other parts of the brain than those directly served by the specific incoming nerve pathway. An object seen with one eye is recognized with the other. A system learned through one sensory system is recognized by another. The tune that is read from the score can be recognized by the ear".

The functional part of the nervous system is composed of countless nerve cells and their fibers. The *anatomical unit* of nervous activity, the neurone, is the nerve cell and its processes. Neurones receive stimuli by way of antennae-like processes called dendrites; in the cell body the impulse undergoes certain changes and leaves the cell by way of another fiber, the axone. Then the impulse reaches the terminal branches of the axone to make contact with the arborization of the dendrites of the next neurone in the chain. At these points of contact, called *synapses*, the efferent fibers of one cell are contiguous to but not continuous with the afferent fibers of the next neurone.

It is essential that the student of the nervous system understand basic laws pertaining to it before he attempts to master the many details underlying specific nervous functions. The mammalian central and peripheral nervous mechanism has been compared to a great telephone system with a mammoth central office or switchboard, composed of a great many receiving and emitting units (centers) connected by countless intrinsic cables. These central units make contact with the outside world by way of many "wires" (peripheral nervous system) which enter and leave the central "office". The incoming messages (afferent impulses) arise in special receivers at the periphery (receptors); the outgoing messages (efferent or executant impulses) are sent to various effector organs such as muscles and glands. This is but another way of illustrating the make-up of the reflex arc with its (a) receptor, (b) afferent limb, (c) center, (d) efferent limb, and (e) effector organ, activity of which determines the form of the final response. However diverse its connections may become, the reflex arc in one form or another is the *physiological unit* which forms the basis of most subcortical nervous activity. Probably every nerve cell and its processes operate in the interest of some form of reflex activity. *Reflex activity* at infracerebral levels of the nervous system is characterized by *immediacy, inevitability* and *automaticity of response* with a comparatively narrow margin of variation.

But the comparison of the central nervous system with a very complicated central telephonic switchboard or a very intricate computing machine falls far short of the mark. It fails to convey any idea of the remarkable smoothness and complexity of operation of our central nervous apparatus. One of the best illustrations of this perfect integrative arrangement is afforded by a consideration of the evolution of motor functions.

In the evolution of the nervous system new functions and systems were evolved. Each more recent motor acquisition dominated the older mechanism, which became less useful to the animal. This process of subordination of older motor activities to newer ones resulted in an integration of nervous responses operating in the interests of smoother and more complicated motor activity.

At a low level of animal life one may see the very limited movements of a jelly fish brought about by the operation of a simple nervous network without any central reflex mechanism. In man this is represented by the activity of the smooth muscle of the gut under the government of the vegetative nervous net (plexuses of Auerbach) contained in the intestinal wall.

The "nocifensor" system in the skin recently described by Lewis (p. 16) may also represent such a simple type of nervous activity.

As the need for greater range of movement developed, a ventral condensation of cells of the nervous net appeared; these ganglia become prominent features of the nervous system of invertebrates and are grouped in a segmental way. With the appearance of the vertebrates, a true segmental central tube of nervous tissue was evolved and the range of complexity of reflex activity widened. Thus the *spinal cord* appeared. Even in man its segmental structure betrays its phylogenesis. Later in the progress of evolution the motor, sensory and trophic functions of the cord (i.e., its intrinsic or resident functions), became more complicated and its motor, sensory and visceral conducting capacities more elaborate. To permit of better *associated* movements and more complicated coördinated postural reactions, a higher suprasegmental motor organization (the cerebellum—motor basal ganglia) was evolved. The *cerebellum* is a constant feature of the vertebrate brain; it first shows an advance of development in those fishes (the sharks and rays) and birds capable of a wider range of motor response. The cerebellum emerges early in evolution to contribute an extrapyramidal influence concerned with coördination, tone and patterns of tone distribution. Similarly, a type of *motor basal ganglia* (*corpus striatum*) is well developed in birds and reptiles. With further development of the head end, a suprasegmental mechanism came into being. The most caudal part of this suprasegmental component is the *brain stem*. Its intrinsic functions are concerned with the government of such vital processes as breathing and cardiovascular control. The brain stem possesses important reflex postural centers which supersede the simpler, outgrown postural centers resident in the spinal cord. Moreover, the brain stem innervates the structures derived from the branchial clefts and head end. So it is that the tongue, jaw, oro- and nasopharynx, the face, the eye muscles, and the organs of hearing and equilibrium come under its dominion. Like the spinal cord, it permits the passage of various afferent and efferent tracts.

The pyramidal tracts constitute a late motor acquisition. The latest and highest motor organization lies in the prepyramidal cortical areas of the frontal lobes. In kinesthetic motor-pattern centers arise impulses which make possible man's most *dissociated* and skilful movements. These suprapyramidal impulses activate the pyramidal cells whence the pyramidal tracts convey the motor impulses to the brain stem and spinal cord.

In health, the various motor organizations coöperate so harmoniously that no lines of cleavage are apparent. A man may run or swim swiftly and so exhibit a primitive form of movement. He may show a higher degree of kinetic and postural activity on the tennis court. Lastly, he may bring into play highly individual movements on a musical instrument, as the piano. How manifold are these activities—though based on the motor capacities of one nervous system.

Higher up in the brain stem the *thalamus* is encountered. This is the great sensory center. In it, certain vital sensations make conscious registration and are compounded, forming the basis of complicated instinctive reflexes. Thalamo-hypothalamic connections permit the evocation of important visceral reflexes which are correlated with instinctive "drives." At the thalamo-hypothalamic level, complicated emotional behavioral reactions take place.

The thalamus also plays an important part in the innervatory control of the motor *basal ganglia*,—the striopallidum. As will be seen, this interesting extrapyramidal motor system has important posture-making and tone- and tremor- and movement-inhibiting functions.

In the adjacent *hypothalamus*, important centers are found which control a large number of vegetative (metabolic) functions.

At the highest level of all in the suprasegmental integration, is the *cerebral cortex*, aptly called the master of destiny (Tilney). Here is a convoluted mantle, containing millions of cells, intricately connected by fibers. Some of these cells send long processes downward as projection paths, viz., the pyramidal tract, others receive ascending afferent fibers. In the cerebral cortex, reflex action may still be simple enough to be analyzed, as in the case of the conditioned reflexes, or be so complicated as to be lost in the maze of human behavior and personality. In the *diffuse* cortical mantle are millions of cells, the activities of which underlie such very complex phenomena as consciousness, intelligence, judgement, memory, speech and other phases of symbolic thinking. Very little is known concerning the ultimate nature of these mental processes. Here one finds that part of the nervous government which is so rich in cells that only a fraction is put to use by the average man. By dint of practice and/or special endowment many other cells, usually quiescent, may reach the threshold of functional activity. The possession of a cerebral cortex permits man alone to make ever-continuing advances along intellectual frontiers. On the other hand, the other localized masses of cell-containing gray matter below the cortex are fixed, unmodifiable organizations, the functions of which may be complicated but incapable of change.

One may approach the study of the nervous system from several angles. Thus, it may be divided into two large parts—the voluntary and involuntary (or autonomic) systems. These two subdivisions function at all levels of the peripheral and central nervous systems. Though separable, the voluntary and involuntary divisions act together in a harmonious manner. Or one may regard the nervous system in terms of its central and peripheral parts. We have been describing the *central* organization in very general terms. *The peripheral nervous network* consists of many fibers or cables, some of which carry sensations and other stimuli (afferent messages) to the central nervous mechanism; other fibers carry efferent, i.e., executant impulses to somatic and visceral end organs. It is not unlikely that some very simple reflexes are carried out in peripheral visceral nerve plexuses.

In the chapters to follow, various anatomic-physiologic levels, or units, beginning with the peripheral nervous system, will be described.