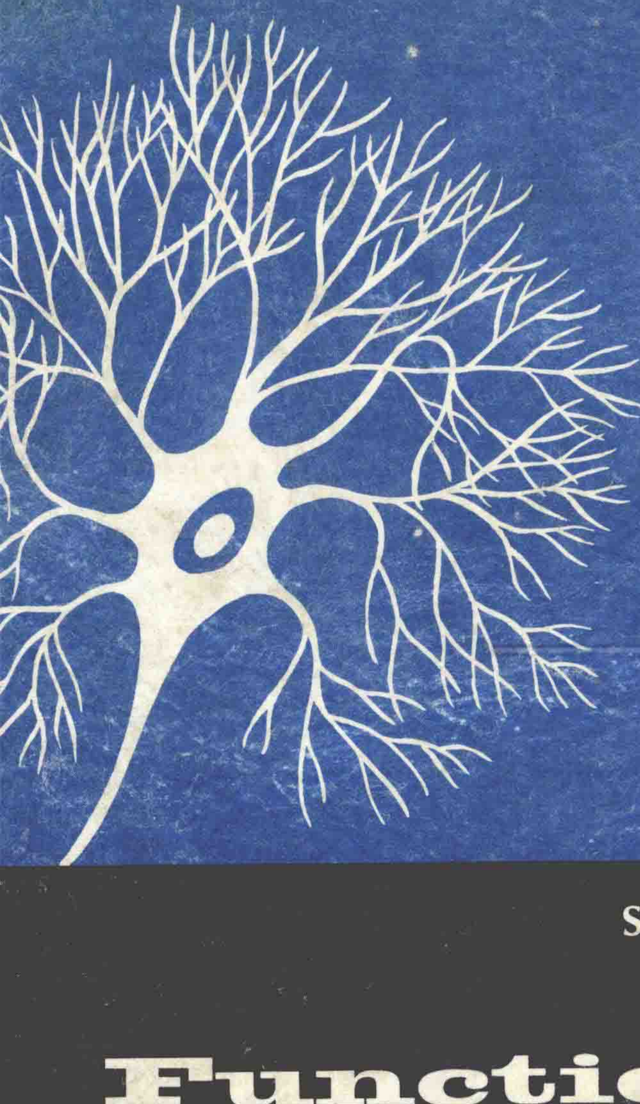

SIXTH EDITION

Functional NEUROANATOMY

N. B. EVERETT

FUNCTIONAL NEUROANATOMY

Including an atlas of the brain stem, and of the whole brain in coronal and horizontal sections.

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FUNCTIONAL NEUROANATOMY

Preface

In this thoroughly revised edition of *Functional Neuroanatomy* an effort has been made, as previously, to present the material necessary for understanding the structure and function of the nervous system in the minimal number of pages. This approach has been extended by eliminating specific references in the body of the text, by combining material of certain chapters, and by deleting unnecessary details. An appropriate list of references, however, is given at the end of each chapter to serve as a guide to further reading. Recent, as well as earlier and more traditional, references are included.

Chapter 3, Histology and Cytology of Neurons and Neurolgia, is a new chapter that includes an appropriate account of the fine structure of nerve cells and of glial elements.

Thirty-nine new figures have been added to this edition and many of the previous illustrations have been improved. Where necessary, changes in labeling of structures have been made to coincide with the Paris Nomina Anatomica (PNA).

Several new and well-labeled photographs of the gross brain and of horizontal and coronal sections of the brain are included. In addition, a new atlas section has been added that includes photographs of three series of sections: (1) Weil-stained transverse sections of the brain stem; (2) a series of coronal sections of the brain stained by the ferric ferrocyanide method of Tompsett; and (3) a series of horizontal sections of the brain, alternately stained for cells and fibers.

The author has been fortunate in having the assistance of Doctors John W. Sundsten and Raymond D. Lund throughout all phases of the revision. Special recognition is accorded Dr. Sundsten for the reorganization and rewriting of Chapters 21 and 24, The Diencephalon and The Rhinencephalon; and to Dr. Lund for contributing Chapter 3, Histology and Cytology of Neurons and Neuroglia.

It is a privilege to acknowledge the contributions of Mr. Thomas Stebbins, Director of the Division of Health Sciences Illustration, and his staff to this revision, and again to Mr. George W. Reis for many of the photographs. Mrs. Doris E. Ringer, Publications Editor within the department and personal secretary to the author, is accorded a sincere and special note of appreciation for her valuable contributions throughout all aspects of this revision.

Acknowledgment is made to many teachers and students of neuroanatomy, who have used the previous edition, for their suggestions, many of which have been incorporated in this revision.

It is again a pleasure to acknowledge the support, patience, and cooperation of the publishers, Lea & Febiger, in making this revision.

N. B. EVERETT

Seattle, Washington

Preface to Fifth Edition

The four previous editions of *Functional Neuroanatomy* were prepared by Dr. A. R. Buchanan, Professor of Anatomy at the University of Colorado School of Medicine. Dr. Buchanan having recently retired from teaching has turned over the book to me. It is indeed a pleasure to revise this book in its fifth edition.

In this edition I have continued the policy of presenting the material necessary for understanding the structure and function of the nervous system in the least number of pages. Additionally, as in previous editions the longitudinal approach has been used in the presentation. For example, ascending and descending tracts are traced from origin to termination at the time they are first mentioned in the text. This approach, in my experience, has made the subject of neuroanatomy more stimulating and comprehensible to the student. A particular advantage of treatment in this way is to provide for an effective correlation with the study of neurophysiology which students often study concurrently with neuroanatomy. The practice of many schools, as has been the case here for many years, is for the anatomist and physiologist, with some support from the clinical neurologist, to join forces in offering a conjoint course in neuroanatomy and neurophysiology for medical and graduate students. Within this framework the longitudinal approach is particularly valuable to students and faculty in making the appropriate structural and functional correlations. The importance of regional considerations of the central nervous system is recognized, however, and in this edition a number of photographs of the various levels of the brain stem and spinal cord are interspersed throughout the text along with diagrams of the corresponding levels to provide more adequately for regional study. These photographs of sections, primarily of Weil-stained preparations, are well labeled and may be used in conjunction with the accompanying diagrams of sections. This combination allows for considerable flexibility in using the text in accord with varying needs for detailed study of the nuclei and fiber tracts of the brain stem and spinal cord. In addition to these photographs a number of new and improved drawings and diagrams have been added. These include several new half-tone and pen and ink drawings, line diagrams and 21 new color illustrations.

Major changes have been made in much of the text material. The chapter on development has been completely rewritten and a new chapter has been added on the genesis and histology of the neural elements which includes a consideration of nerve degeneration and regeneration. Treatment of tactile, pain, thermal, visceral, afferent and proprioceptive pathways has been combined into one chapter. The chapters on the motor systems have been rewritten and rearranged, bringing together the considerations of the extrapyramidal system and basal ganglia. The chapter on the cerebellum has been thoroughly revised, as well as the chapter on the diencephalon which includes a more complete treatise of the thalamus and hypothalamus. Another major change concerns a revision and expansion of the chapter on the rhinencephalon.

I gratefully acknowledge the contributions of three departmental associates to this edition. Chapter 2, "Development of the Nervous System," and Chapter 3, "Genesis and Histology of Neural Elements: Degeneration and Regeneration of Nerves" are the contributions of Dr. Bodemer. The rewriting and reorganization of the material incorporated in Chapter 5, "Somatic Tactile, Proprioceptive, Pain and Thermal Pathways: Visceral Afferent Pathways" are the contributions of Dr. Rieke. In addition, both Drs. Bodemer and Rieke have given general assistance throughout all phases of this revision. Dr. John W. Sundsten contributed significantly to Chapter 20, "The Diencephalon," particularly the section on the hypothalamus. He also made important suggestions for Chapter 23, "The Rhinencephalon."

I am grateful for the contributions made by the medical artists to this revision, particularly those of Miss Jessie Phillips, Director of Health Sciences Illustration and of Marjorie L. Domenowske who made many of the new drawings. The careful and efficient preparation of the manuscript and the valuable contribution to proofreading made by my secretary, Mrs. Doris E. Ringer, are deeply appreciated. Acknowledgment is made to Mr. George W. Reis for the newly added photographs of the brain stem and spinal cord sections.

Finally, I acknowledge the full cooperation of the publishers throughout the course of this revision.

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Seattle, Washington

Contents

Chapter 1

Introduction to the Central and Peripheral Nervous Systems

The nervous system is responsible for maintaining contact between the individual and his external and internal environments and for the individual's proper adjustment to these environments. Contact with the external environment is maintained through receptors at the surface of the body and with the internal environment through receptors in muscles, joints, ligaments, and the visceral organs of the thorax and abdomen. Adjustments to the environment are facilitated by reflex arcs consisting of afferent neurons, centers within the spinal cord or brain, and efferent neurons. The efferent neurons carry motor impulses from the central nervous system to effector mechanisms including smooth and striated muscle (cardiac and skeletal) and glandular structures.

The adult nervous system may be divided into *central* and *peripheral divisions.* The **central nervous system** includes the spinal cord and brain (Figs. 1, 2, 3, 4). The main subdivisions of the brain are *cerebrum, cerebellum,* and *brain stem.* The brain stem consists of the *diencephalon, mesencephalon, pons,* and *medulla oblongata.*

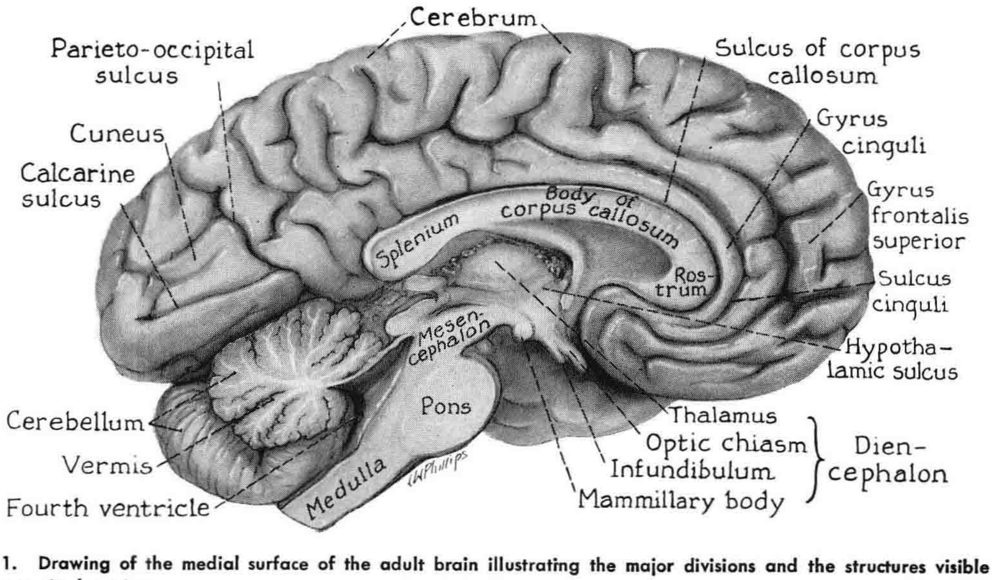

FIG. 1. Drawing of the medial surface of the adult brain illustrating the major divisions and the structures visible in a sagittal section.

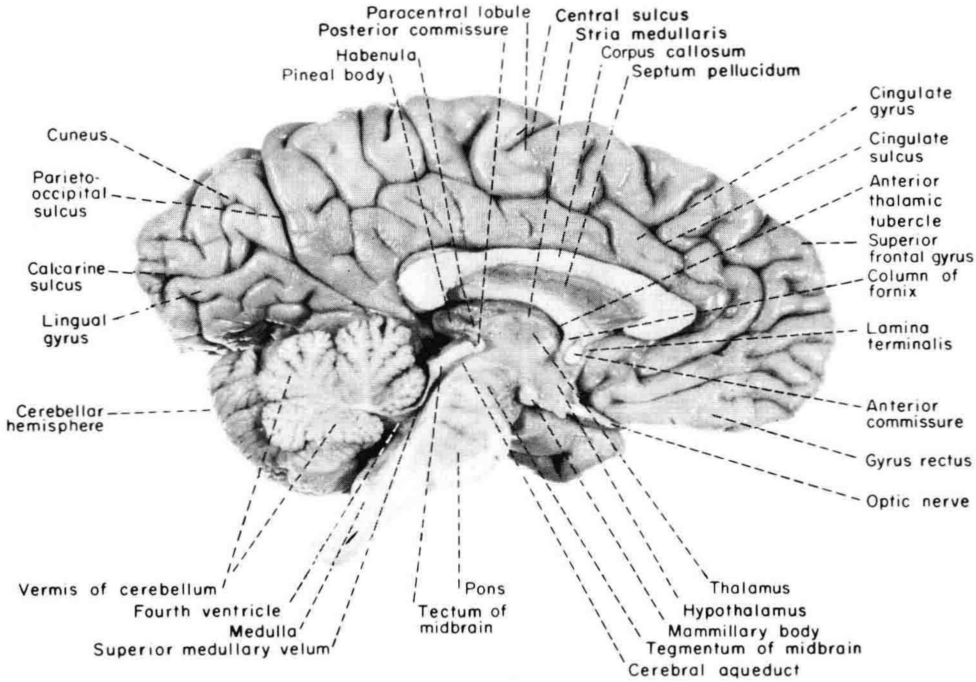

FIG. 2. Photograph of the medial surface of the adult brain cut in sagittal section.

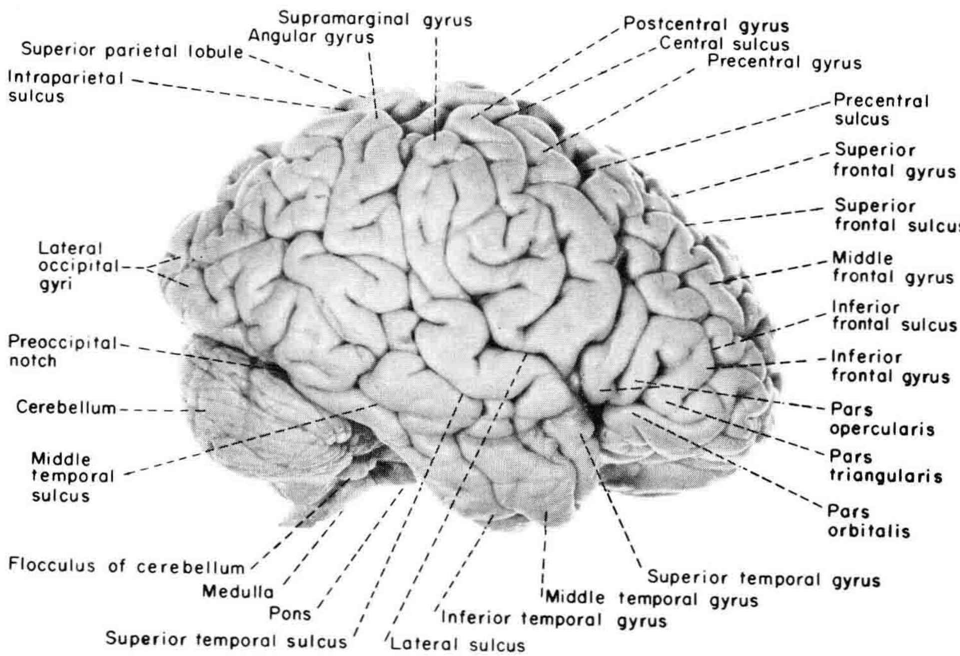

FIG. 3. Photograph of the lateral surface of the adult brain.

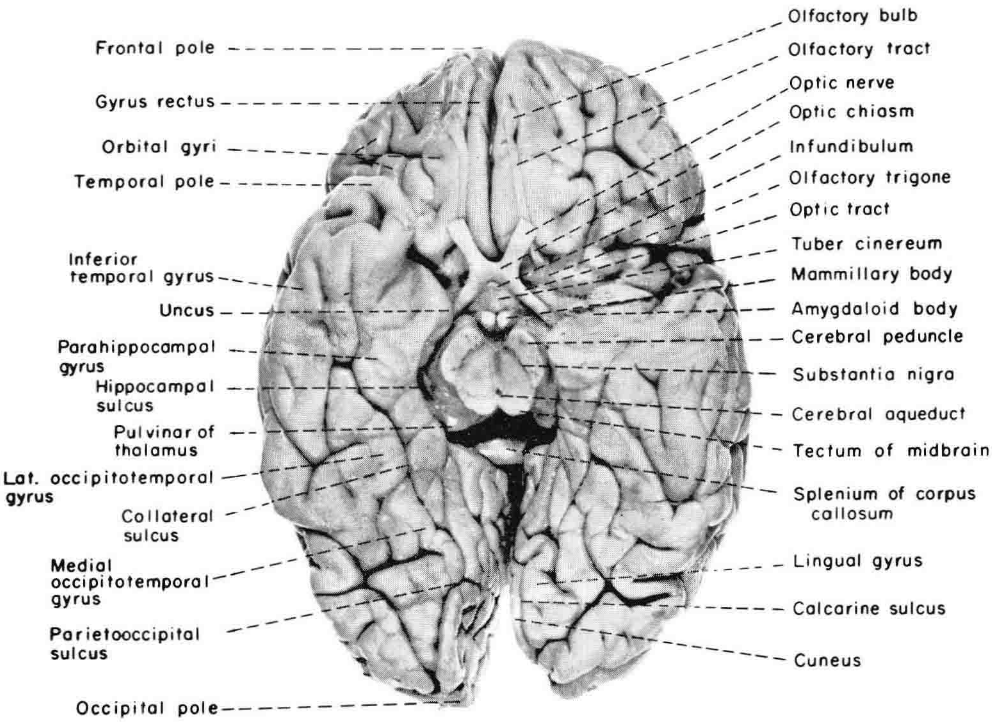

FIG. 4. Photograph of the inferior surface of the adult brain. (The rostral portion of the left temporal lobe and the brain stem caudal to the midbrain have been removed.)

The **peripheral nervous system** includes the spinal and cranial nerves and the numerous ganglia and plexuses concerned with visceral innervation. Each **spinal nerve** is attached to the spinal cord by two roots—a ventral, or anterior, and a dorsal, or posterior; these roots unite to form the spinal nerve which then divides into ventral and dorsal rami (Fig. 5). The anterior or ventral rami of the spinal nerves form the cervical, brachial, lumbar, sacral, and coccygeal plexuses and, in the thoracic region, the intercostal and subcostal nerves. The posterior or dorsal rami are distributed to the skin on the dorsal aspects of head, neck, and trunk and to the erector spinae group of muscles.

The *ventral roots* of all spinal nerves contain somatic efferent (motor) fibers which innervate skeletal muscles (Fig. 5). Those of the thoracic, upper lumbar, and middle sacral nerves also contain general visceral efferent fibers which end in relation to ganglionic cells of the autonomic system and innervate visceral organs. The somatic efferent fibers arise from cells in the anterior (ventral) gray columns of the cord, and the general visceral efferent fibers arise from the lateral gray columns.

The *dorsal roots* contain general somatic afferent (sensory) and general visceral afferent fibers which originate in dorsal root ganglia cells. The single processes of these cells divide into peripheral and central divisions. The peripheral divisions of the processes of general somatic afferent neurons are distributed to somatic receptors by way of the spinal nerves; those of general visceral afferent neurons to visceral receptors by way of the spinal nerves and the various plexuses of the visceral nervous system. The central divisions of the processes of both somatic and visceral afferent neurons enter the spinal cord through the dorsal roots (Fig. 5).

The **cranial nerves** (Fig. 6) are less

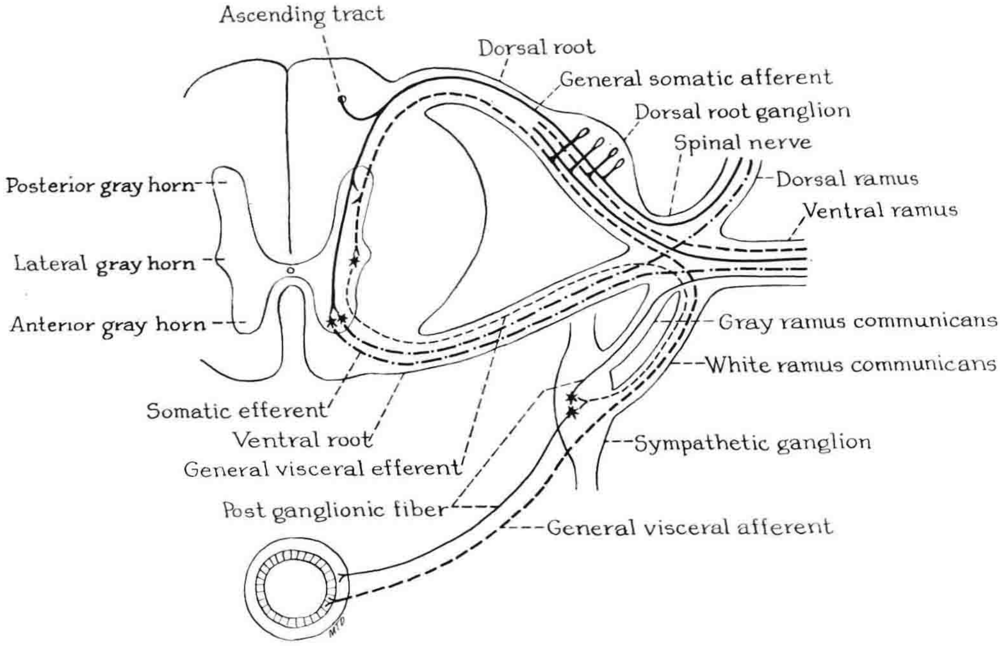

FIG. 5. Cross-section diagram of the thoracic spinal cord with a spinal nerve attached. The component fibers of the nerve are shown.

regular in their arrangement than the spinal nerves. Some have motor and sensory roots; some are entirely sensory in function; and at least one—the hypoglossal—is purely motor. Sensory ganglia, structurally and functionally analogous to the dorsal root ganglia of the spinal nerves, are associated with the sensory roots of cranial nerves. Sensory fibers terminate in and motor fibers originate from gray areas in the brain stem which are functional analogues of the gray columns in the spinal cord.

The *cranial* (or cerebral) and *spinal nerves* contain seven functional types of fibers: general somatic afferent, special somatic afferent, general visceral afferent, special visceral afferent, somatic efferent, general visceral efferent, and special visceral efferent. There are no special somatic efferent fibers and, as will be noted below, no given nerve contains all seven types of fibers.

General somatic afferent fibers are present in all the spinal nerves (except C1 which usually has no sensory root) and in a number of cranial nerves. Their cell bodies are in sensory ganglia, and they conduct impulses to the central nervous system from receptors in skin, muscle, and connective tissues.

Special somatic afferent fibers are found only in the optic and vestibulocochlear nerves. The fibers in the optic nerve conduct visual impulses from the retina to the brain and arise from cell bodies within the retina (Chap. 9). The vestibulocochlear nerve is composed of the axons of neurons whose cell bodies are in the spiral and vestibular ganglia (Chap. 9). The dendrites of these neurons are distributed to special receptors in the internal ear.

General visceral afferent fibers are present in the spinal nerves and in some of the cranial nerves. They are distributed to receptors in the visceral structures of the neck, thorax, abdomen, and pelvis, and to blood vessels and glandular structures everywhere. Their cells of origin are in the sensory ganglia of spinal nerves (Fig. 5, dorsal root ganglia) and in the ganglia

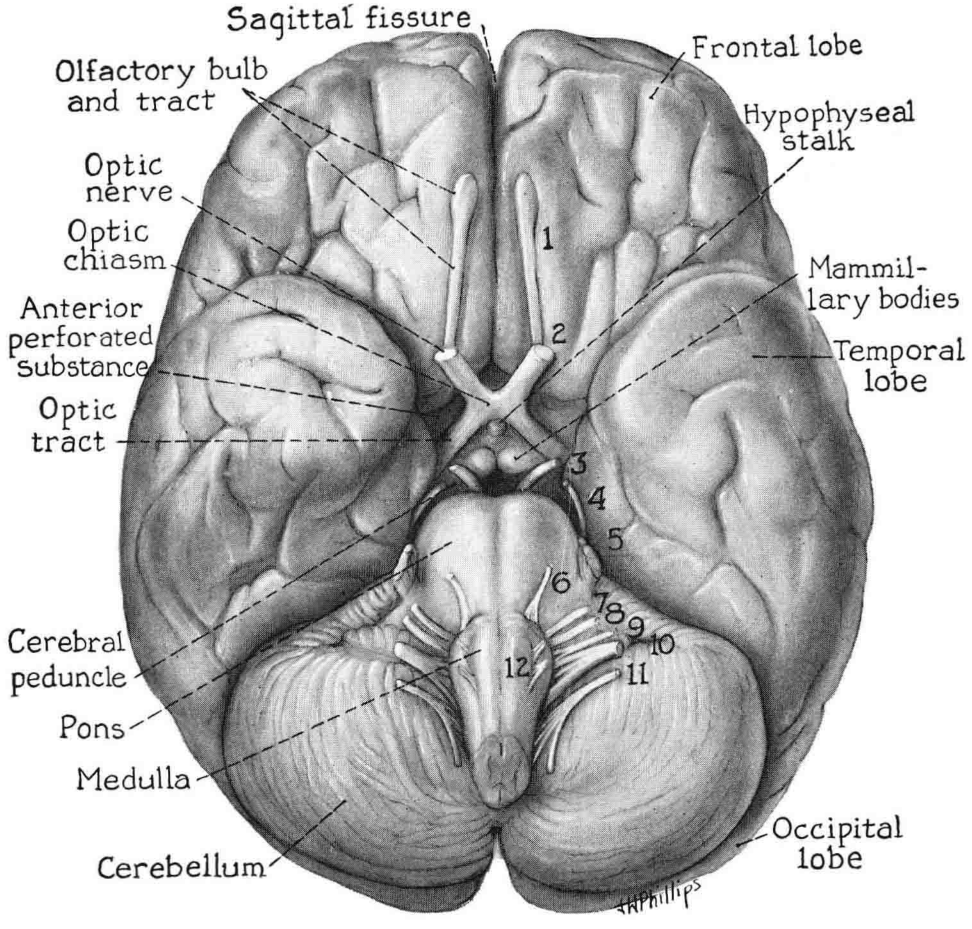

FIG. 6. Drawing of the inferior surface of the brain.

of certain cranial nerves. General visceral afferent neurons function as afferent limbs of visceral reflex arcs and conduct impulses (particularly pain impulses) to the conscious level.

Special visceral afferent fibers are concerned only with the special senses of smell and taste; we therefore find them in the olfactory, glossopharyngeal, vagus, and facial nerves (nervus intermedius). The cell bodies of the olfactory nerves are in the olfactory mucous membrane, those of the facial nerves in the geniculate ganglia, and those of the glossopharyngeal and vagus nerves in the inferior ganglia of these nerves. The *inferior ganglion* of the glossopharyngeal nerve is located in a groove on the posterior aspect of the petrosa of the temporal bone at the upper limit of the jugular foramen. The *inferior ganglion* (nodose) of the vagus is manifested by an ovoid enlargement on the nerve immediately inferior to its emergence from the jugular foramen. The geniculate ganglion is in the facial canal within the petrosa of the temporal bone (Chap. 8) and is so designated because of its association with the external genu of the facial nerve.

Somatic efferent fibers arise from motor nerve cells in the spinal cord and brain stem. They are distributed to striated muscles of mesodermal somite origin and are found in all spinal nerves and in the oculomotor, trochlear, abducens, and hypoglossal nerves. Their occurrence in these four cranial nerves is due to the presence of head and occipital somites in the embryo.

General visceral efferent fibers are present in the oculomotor, facial, glossopharyngeal, and vagus nerves, in all the thoracic nerves, in the upper two or three lumbar nerves, and in the middle three sacral nerves. They arise from cell bodies in certain nuclei of the brain stem and in the lateral gray columns of the spinal cord; they are distributed to the peripheral ganglia of the autonomic system (Fig. 5). The axons of the ganglion cells, on which they synapse, are then distributed to smooth muscle, cardiac muscle, and glands throughout the body.

The term *"special visceral efferent"* is unfortunate in that these fibers are distributed to striated or voluntary muscles, but only to those which originate from the mesoderm of the branchial or *visceral* arches. A more appropriate characterization would be *"branchial motor fibers."* The muscles supplied by these fibers include those of the larynx, pharynx, and soft palate, the muscles of mastication, and the muscles of expression. Special visceral efferent fibers are, therefore, found in the vagus, spinal accessory, glossopharyngeal, trigeminal, and facial nerves. The spinal accessory also supplies the trapezius and sternocleidomastoid muscles which are believed to be at least partly of branchial arch origin.

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Chapter 2

Development of the Nervous System

The human nervous system begins to develop during the third week of embryogenesis as an induced hyperplasia in the superficial ectoderm in the midline cephalic to Hensen's node (Fig. 7). This structure, the *neural plate,* gives rise to all divisions of the adult nervous system. Soon after its formation the neural plate is converted into a trough, the *neural groove;* the neural groove is bounded by prominent *neural folds,* which are most clearly defined in the extreme cranial end of the neural plate. During the first month of development, the neural folds grow from their dorsal borders, and continued overgrowth results in the approximation of the free edges of the folds. An apparent selective affinity of the constituent epithelial cells produces a fusion of the two neural folds with the consequent formation of a *neural tube.* The *neural crest* is a differentiation of cells at the lateral edge of each neural fold in a zone intermediate between the neural plate and skin ectoderm, which separates from the latter at the time the neural folds fuse. Closure of the neural groove does not occur simultaneously along the length of the embryo, but begins in the future thoracic region, progressing cranially and caudally. The ends of the neural tube remain open for some time at the *anterior* and *posterior neuropores.* The anterior neuropore finally closes at the 20-somite stage of development; the caudal end of the tube is completely closed with obliteration of the posterior neuropore at the 25-somite stage. With completion of the neural tube, the neural epithelium is completely dissociated from the superficial ectoderm, and the tube lies bounded dorsally by the epidermis, ventrally by the notochord, and laterally by the mesodermal somites (Fig. 7). The neural crest cells form ear-like clusters at the dorsolateral borders of the neural tube, occupying the angle formed by the neural tube, superficial ectoderm, and mesoderm (Figs. 7, 8).

From the outset of development the cranial portion of the neural tube expands faster than the more caudal portions, and consequently, the prospective brain is clearly visible even before closure of the neuropores. Soon after the neural tube has closed, the brain is divisible into three prominent hollow swellings. These initial cavities are designated the *primary brain vesicles* (Fig. 9). The most cephalic vesicle is the *prosencephalon,* the middle vesicle is the *mesencephalon,* and the large caudal chamber is the *rhombencephalon.* The latter vesicle continues insensibly into the *myelon,* or future spinal cord. The three primary brain vesicles soon divide further into five *secondary brain vesicles* (Fig. 10). Thus, the prosencephalon is subdivided into the *telencephalon* and *diencephalon;* the rhombencephalon constricts to form the *metencephalon* and

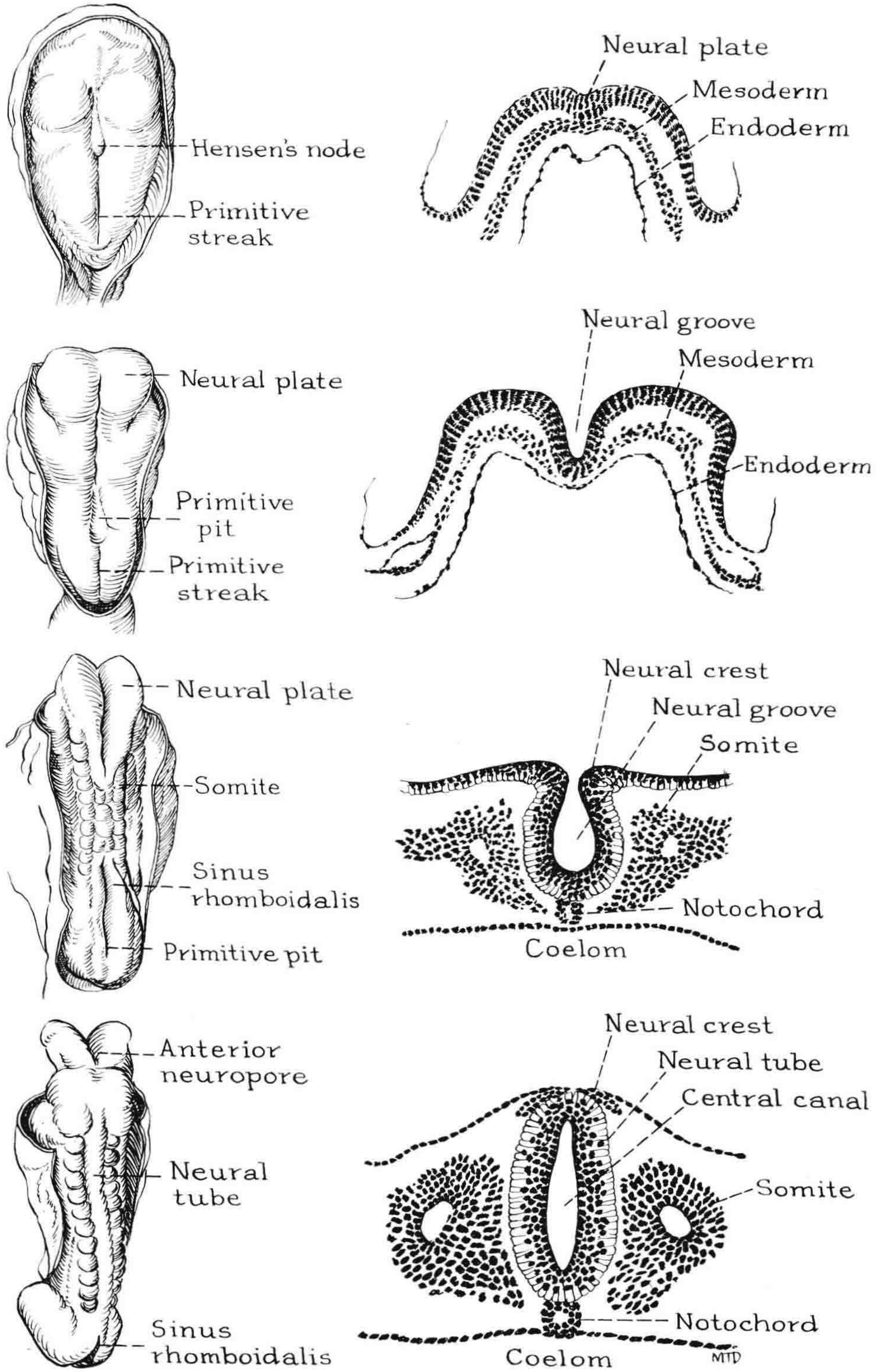

FIG. 7. Stages in the early development of the human nervous system from the presomite stage to closure of the neural tube, except at the anterior and posterior neuropores (after Streeter). At left, the embryo is illustrated in external view; at right, the same stage is shown in transverse section.