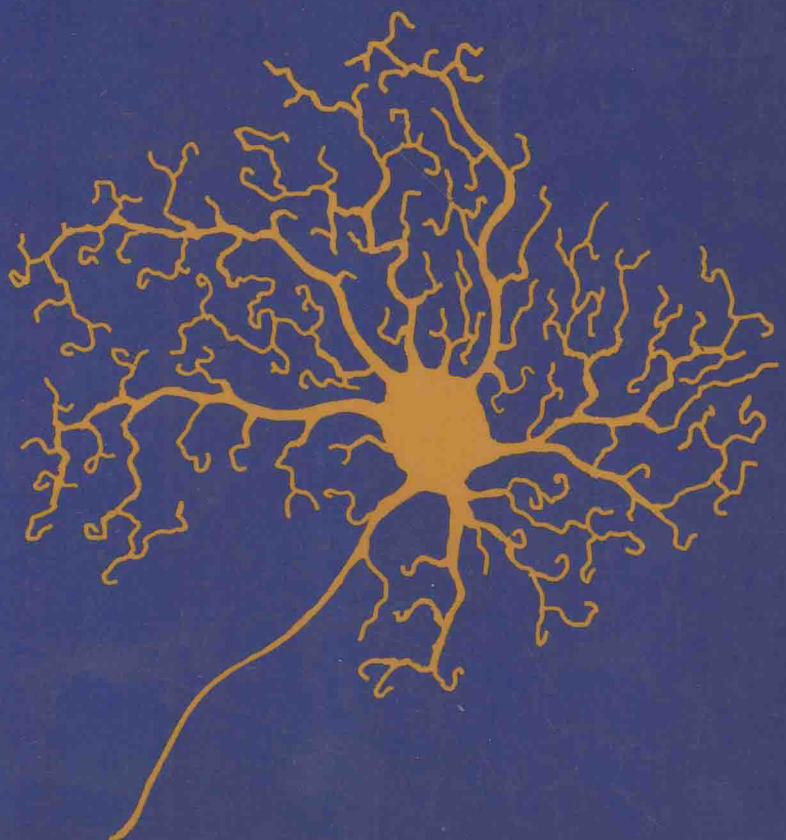
CORE TEXT OF NEUROANATOMY

THIRD EDITION

MALCOLM B. CARPENTER



NEUROANATOMY

THIRD EDITION

MALCOLM B. CARPENTER, A.B., M.D.

Professor of Anatomy
F. Edward Hébert School of Medicine
Uniformed Services University of the Health Sciences
Bethesda, Maryland

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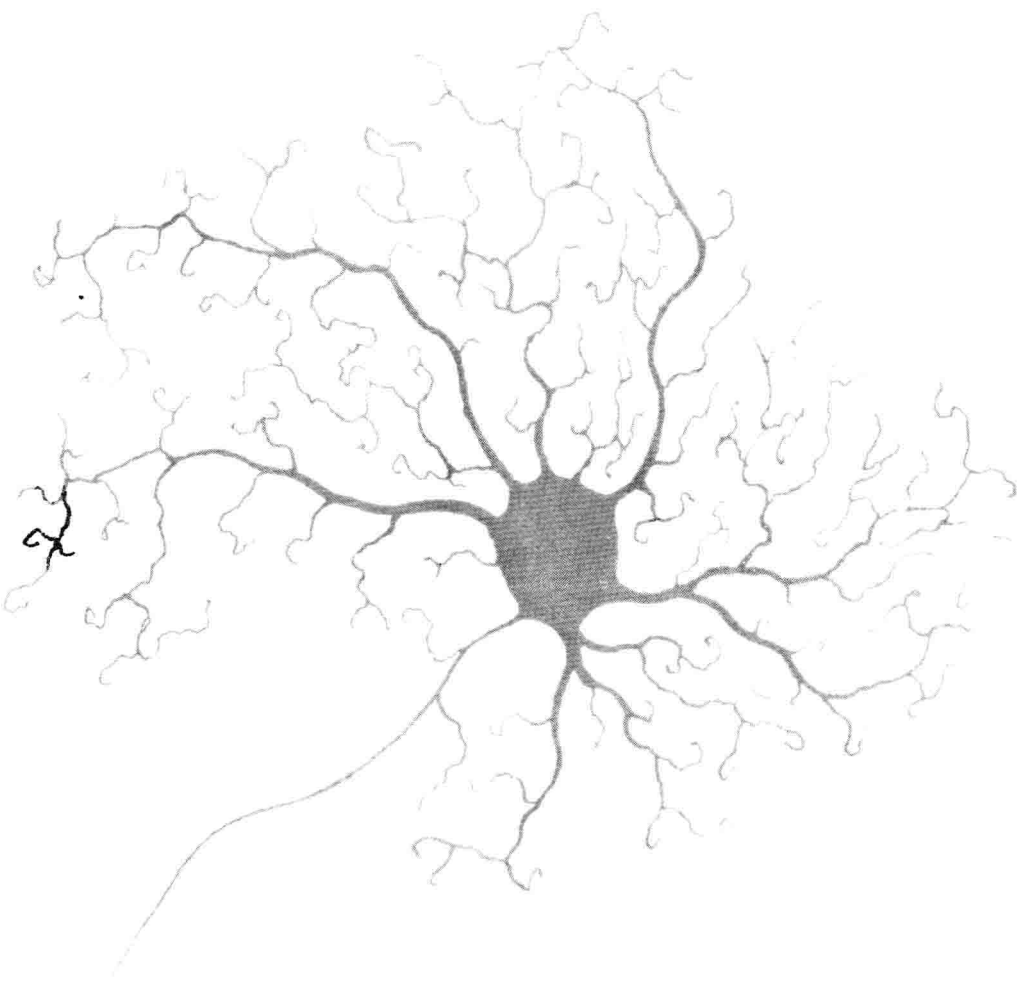

Preface to the Third Edition

The tremendous expansion of knowledge in the neurosciences continues and its ramifications extend broadly into all basic sciences and into a variety of clinical disciplines. The challenge remains the same: to present a synthesis of modern concepts of the structure and function of the central nervous system within the time allotted. The objective of this text from the beginning has been to present and explain the organization of the central nervous system in a lucid, meaningful fashion that will serve the needs of the student now and in the future. The suggestion that the text be expanded to include other pertinent and related subjects has been resisted. Instead a little more depth has been added in those areas where progress has changed or clarified basic concepts. Attempts have been made not to duplicate material considered in other anatomical areas. The text represents a reasonable treatment of the central nervous system and should meet the requirements of a broad spectrum of medical students.

The third edition of the *Core Text of Neuroanatomy*, like previous editions, is based upon part of the material appearing in Carpenter and Sutin's *Human Neuroanatomy* (eighth edition). While the organization of the book follows a format similar to that used in the larger work and shares many of the same illustrations, the text has been rewritten in a more concise fashion. Most chapters have been revised and brought up-to-date; all have benefited by the clarity that characterizes hindsight. Considerable new material has been added to chapters on the mesencephalon, diencephalon, corpus striatum, and cerebral cortex. Attempts have been made to balance factual material and its interpretation. Over 90 new or revised illustrations have been added, many in the form of teaching diagrams which students find especially helpful. Each chapter contains sections entitled "Functional Considerations" which address special problems and attempt to elucidate major relationships and clinical applications.

The author is grateful to colleagues and associates for their constructive criticisms and generous comments relative to the text as a teaching guide. Particular thanks goes to my mentor, the late Professor Fred A. Mettler of the College of Physicians and Surgeons of Columbia University, whose contributions to my understanding of the nervous system spanned a forty-year period. Permission to use the superb illustrations from Mettler's *Neuroanatomy* (1948) have greatly enhanced the quality of this text. The artistic skills of Robert J. Demarest, Director of the Audiovisual Department of the College of Physicians and Surgeons of Columbia University, is evident throughout the text and each of his illustrations displays his rare talent and insight. Martin Nau of the Department of Anatomy, Uniformed Services University, also contributed his artistic skill to many drawings, for which the author is grateful. The author is pleased to acknowledge the continued expert assistance of Antonio B. Periera. The strong support of Dean Jay P. Sanford deserves special thanks for creating the academic environment conducive to scholarly pursuit. My teaching colleagues

at the Uniformed Services University, Drs. Rosemary C. Borke, Rita P. C. Liu, and Donald B. Newman, contributed in many ways during our teaching experience. Mrs. Doris Lineweaver provided superb secretarial and editorial assistance which the author considered invaluable. The author is grateful to the Publishers, especially Toni M. Tracy, Vice President and Editor-in-Chief, for numerous courtesies and helpful suggestions which made this endeavor a pleasure.

MALCOLM B. CARPENTER

Preface to the First Edition

At a time when many American medical schools have shifted to the new core curriculum, or are considering doing so, it is apparent that few of the standard textbooks are entirely appropriate. If the basic medical sciences are to be presented in one academic year, more or less, it is necessary to winnow that which is not essential, to reduce duplications and to present the basic concepts and facts so lucidly that their importance is obvious and their assimilation is possible. With these principles in mind, an attempt has been made to present a *Core Text of Neuroanatomy.*

This text is patterned after part of the material appearing in Truex and Carpenter's *Human Neuroanatomy* (6th edition) and utilizes a similar format and many of the same illustrations. Material which properly falls within the provinces of gross anatomy, histology and embryology has been left to those disciplines except where it is germane to the subject under discussion. The text deals primarily with organization of the central nervous system. References have been kept to a minimum. While the labors of my scientific colleagues, past and present, are not always cited, they are acknowledged fully in the text of *Human Neuroanatomy,* and the interested student will have little difficulty in finding the authors who made the original contributions. The Paris Nomina Anatomica (PNA) in its amended form (1965) has been used throughout.

The author is grateful to Professor Raymond C. Truex, of Temple University School of Medicine, for his permission to use materials from Truex and Carpenter's *Human Neuroanatomy* (6th edition) and for his valued advice and encouragement. Professor Fred A. Mettler, at the College of Physicians and Surgeons, Columbia University, generously permitted the use of many superb illustrations from his *Neuroanatomy* (1948), which were made by Ivan Summers. I am indebted to both Dr. Mettler and The C. V. Mosby Company of St. Louis for permission to publish these illustrations. New illustrations were prepared by Mr. Robert J. Demarest, of the Department of Anatomy, College of Physicians and Surgeons, Columbia University. His skill and talent are acknowledged with deep appreciation. Special acknowledgment must go to Mrs. Ruth Gutmann for her excellent secretarial and editorial assistance in preparing the manuscript.

The author is especially grateful to the Publishers for their continued confidence, encouragement and numerous courtesies which have made the preparation of this book a satisfying experience.

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CHAPTER 1

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Cerebrospinal Fluid
Brain Barriers
  Blood-Brain Barrier
  Blood-Cerebrospinal Fluid Barrier
  Circumventricular Organs

The brain and spinal cord are delicate semisolid structures requiring protection and support. The brain is invested by three membranes, floated in a clear fluid, and encased in a bony vault. Three membranes surround the brain. The most external membrane is a dense connective tissue envelope known as the *dura mater* or *pachymeninx*. The innermost connective tissue membrane is the *pia mater*, a thin, translucent membrane, adherent to the surface of the brain and spinal cord, which accurately follows every contour. Between these membranes is a delicate layer of reticular fibers forming a weblike membrane, the *arachnoid*. The pia mater and arachnoid have a similar structure and collectively are called the *leptomeninges*.

DURA MATER

The cranial dura consists of: (1) an outer *periosteal layer* adherent to the inner surface of the cranium which is rich in blood vessels and nerves and (2) an inner *meningeal layer* lined with flat cells. At certain sites these layers are separated and form large venous sinuses (Figs. 1-1, 1-2, and 1-3). The meningeal layer gives rise to several septa which divide the cranial cavity into compartments. The largest of these is the sickle-shaped *falx cerebri* which extends in the midline from the crista galli to the internal occipital protuberance (Fig. 1-2). Posteriorly this septum is continuous with other transverse dural septa arising from the superior crest of the petrous portion of the temporal bone. These septa form the *tentorium cerebelli* which roofs over the posterior fossa. The free borders of the tentorium form the *tentorial incisure* (Figs. 1-2 and 1-3). Thus these dural reflections divide the cranial cavity into paired lateral compartments for the cerebral hemispheres, and a single posterior compartment for the cerebellum and lower brain stem. The tentorial incisure (notch) forms the only opening between these compartments. The brain stem passes through the tentorial notch (Fig. 1-4). The occipital lobes lie on the superior surface of the tentorium. A small midsagittal septum below the tentorium forms the *falx cerebelli* (Fig. 1-2) which partially separates the cerebellar hemispheres. The *diaphragma sellae* roofs over the pituitary fossa and is perforated by the infundibulum. The dural sinuses are discussed with the cerebral veins in Chapter 14.

The major blood supply for the dura is provided by the middle meningeal artery, a branch of the maxillary artery, which enters the skull via the foramen spinosum (Fig. 1-3). The ophthalmic artery gives rise to anterior meningeal branches and the occipital and vertebral arteries provide posterior meningeal branches. Skull fractures lacerating these meningeal arteries produce

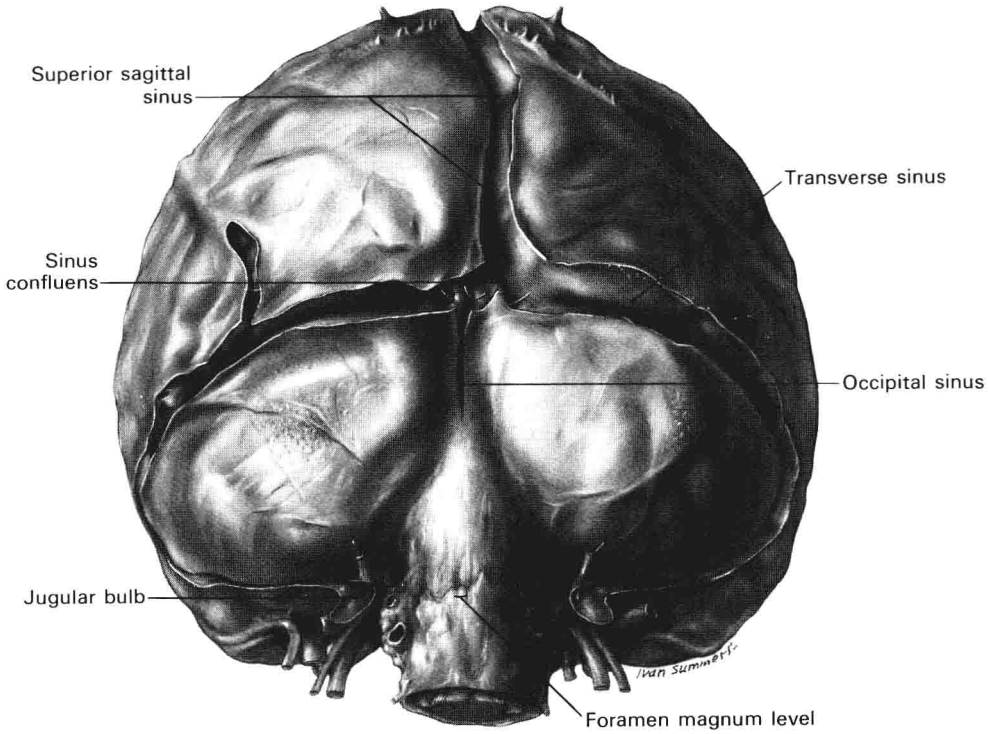

Figure 1-1. Posterior view of the dura surrounding the brain. Prominent dural sinuses have been opened. The periosteal layer of the dura has been cut at the margins of the foramen magnum. (From Mettler's *Neuroanatomy*, 1948; courtesy of The C. V. Mosby Company.)

space occupying epidural hemorrhages between the skull and the dura that require prompt surgical intervention.

The supratentorial dura is innervated by branches of the trigeminal nerve, while the infratentorial dura is supplied by branches of the upper cervical spinal nerves and the vagus nerve.

The *spinal dura* is a continuation of the meningeal layer of the cranial dura (Figs. 1-4, 1-5, and 1-6). The periosteum of the vertebrae corresponds to the outer layer of the cranial dura. Inner and outer surfaces of the spinal dura are covered by a single layer of flat cells, and the dense membrane is separated from the periosteum by the *epidural space*. The spinal epidural space, containing areolar tissue and the internal vertebral venous plexus (Fig. 14-3), is largest at the level of the second lumbar vertebra. This space is used to inject local anesthetics to produce an extensive paravertebral nerve block, known as *epidural anesthesia*. *Caudal anesthesia*, used in obstetrics, is a form of epidural anesthesia in which the anesthetic agent is injected into the epidural space via the sacral canal.

The spinal dura extends as a closed tube from the margins of the foramen magnum to the level of the second sacral vertebra (Fig. 1-7). The caudal termination of the dural sac invests the filum terminale to form a thin fibrous cord, the *coccygeal ligament* (Fig. 1-7). This ligament extends caudally to the coccyx where it becomes continuous with the periosteum. The spinal cord ends at the lower border of the first lumbar vertebra. Extensions of the dura passing laterally around the spinal nerve roots form dural root sleeves (Figs. 1-5 and 1-6).

PIA MATER

This vascular membrane is composed of: (1) an inner membraneous layer, the *intima pia*, and (2) a more superficial *epipial layer*. The intima pia, adherent to underlying ner-

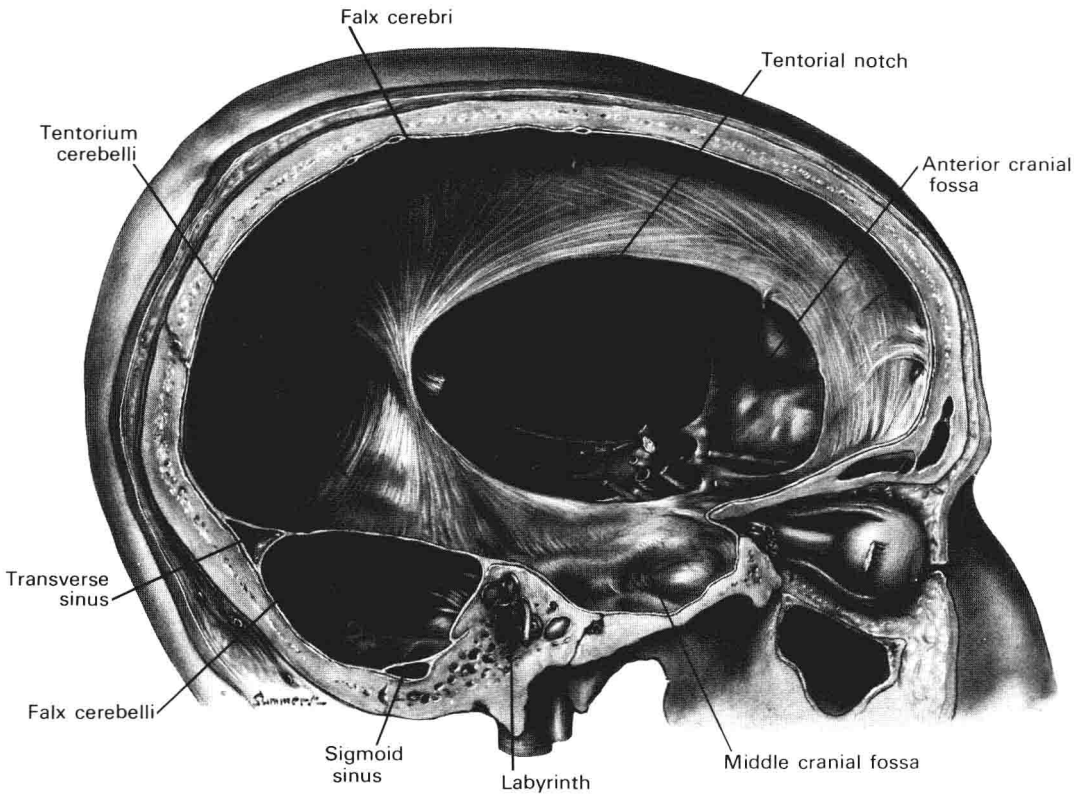

Figure 1-2. Sagittal section of the head showing the falx cerebri, the tentorium cerebelli and the falx cerebelli. (From Mettler's *Neuroanatomy*, 1948; courtesy of The C. V. Mosby Company.)

vous tissue, follows its contours closely and is composed of the fine reticular and elastic fibers. Where blood vessels enter and leave the central nervous system, the intima pia is invaginated forming a perivascular space (Fig. 1-12). The intima pia is avascular and derives its nutrients from the cerebrospinal fluid and underlying neural tissue. The epipial layer is formed by a meshwork of collagenous fiber bundles continuous with the arachnoid trabeculae. The blood vessels of the spinal cord lie within the epipial layer. Cerebral vessels lie on the surface of the intima pia within the subarachnoid space (Fig. 1-8).

The spinal cord is attached to the dura mater by a series of lateral flattened bands of epipial tissue known as the *denticulate ligaments* (Figs. 1-4 and 1-5). Each triangular-shaped dendiculate ligament is attached medially to the lateral surface of the spinal cord midway between the dorsal and ventral roots. The bases of these ligaments arise in the pia mater, and apices are firmly attached to the arachnoid and the inner surface of the dura. The denticulate ligaments anchor the spinal cord to the dura and are present throughout the length of the spinal cord. In the region of the conus medullaris epipial tissue forms a covering of the filum terminale (Fig. 1-7).

The more fibrous intima pia is firmly attached to the surface of the spinal cord by the superficial glial membrane. The latter is composed of fine processes of more deeply located fibrous astrocytes.

ARACHNOID

The arachnoid is a delicate nonvascular membrane between the dura and the pia mater which passes over the sulci without following their contours (Figs. 1-5 and 1-8). This membrane also extends along the roots of the cranial and spinal nerves. Arachnoid trabeculae extend from the