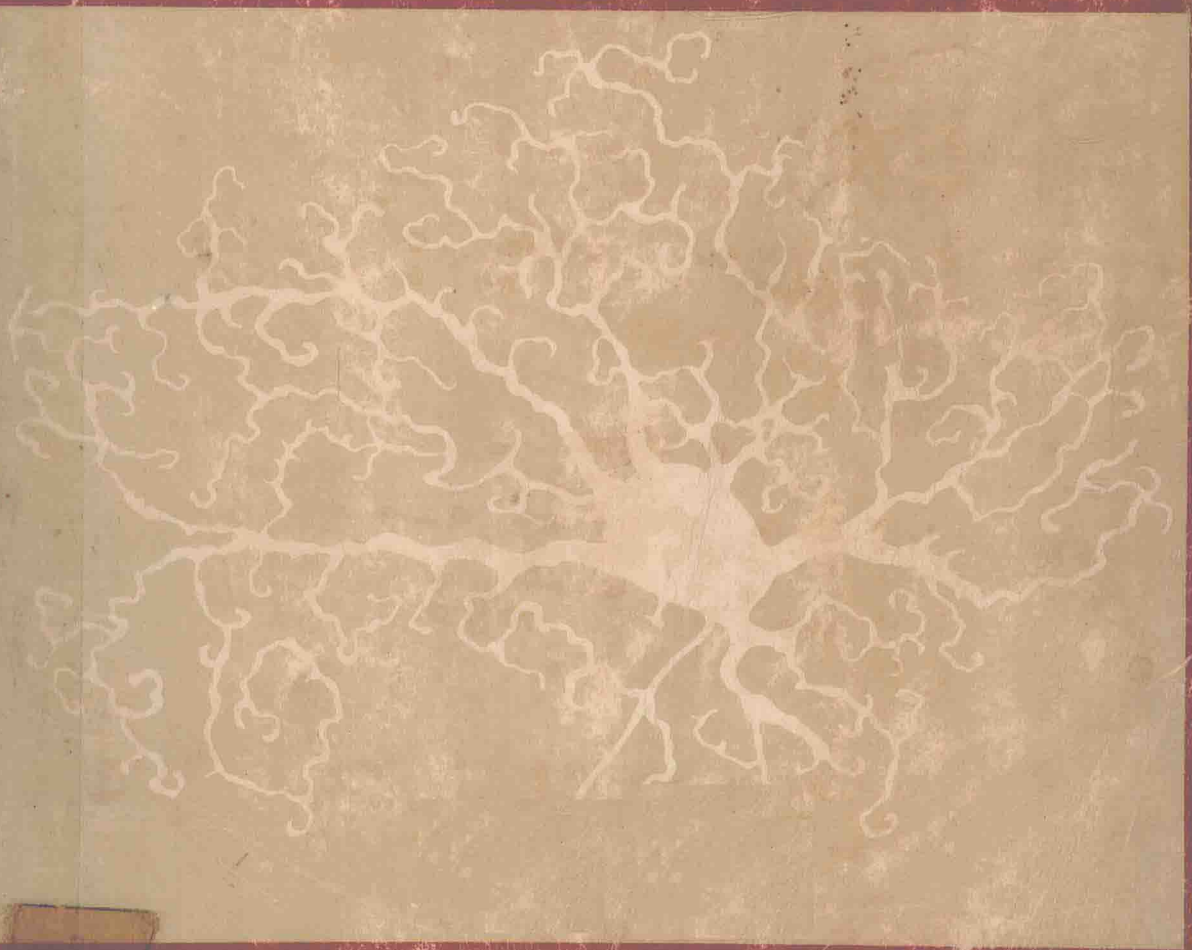
CORE TEXT OF NEUROANATOMY

2ND EDITION

MALCOLM B. CARPENTER



# of Neuroanatomy
2nd edition

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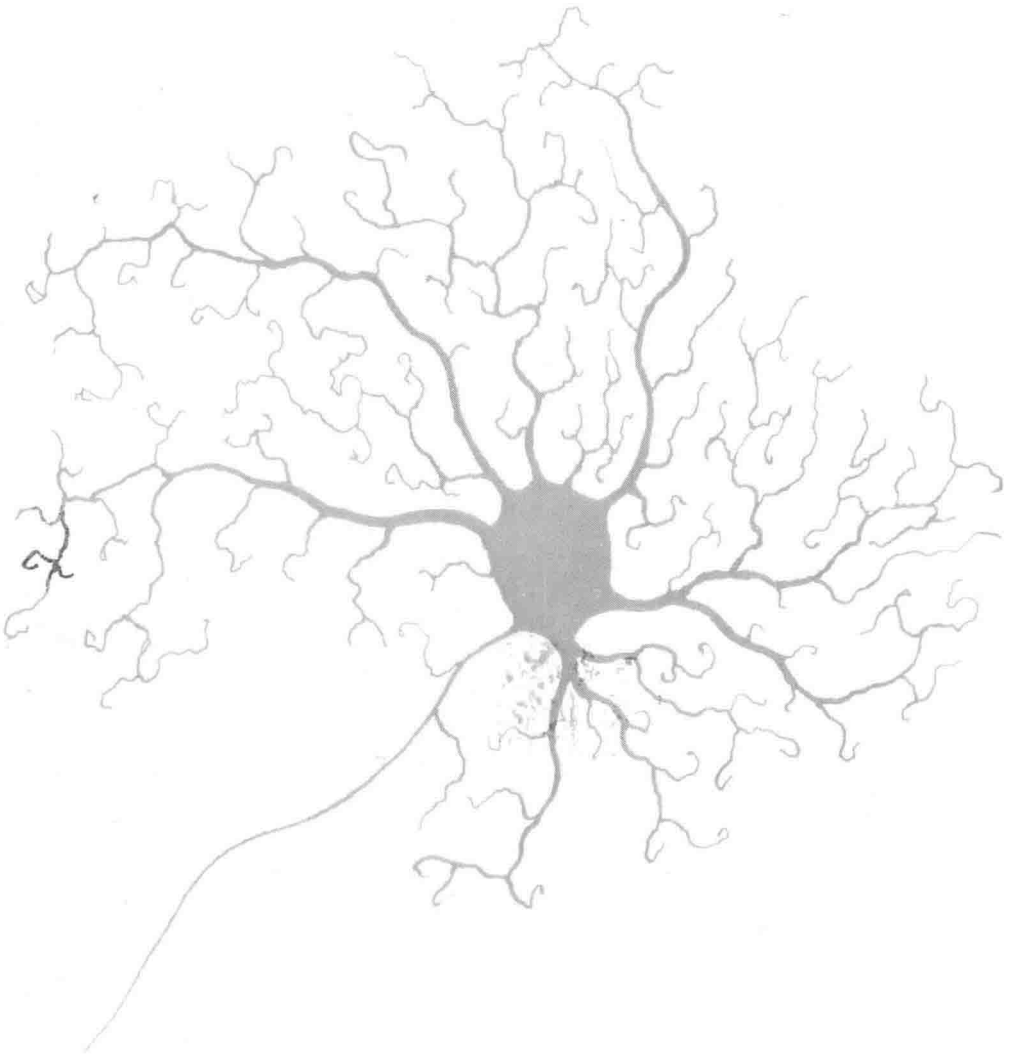

Preface to the Second Edition

Both the neurosciences and the medical school curriculum continue to undergo important changes. The introduction of sophisticated research methods in the neurosciences has produced an enormous increase in the basic literature and many new concepts of neural function and organization. Although neuroscience programs in American medical schools have been expanded in time and scope, it remains a challenge to present a synthesis of basic concepts in the allotted time. The object of this text has been to present the essential neuroanatomy without unnecessary duplication in a form that is lucid, meaningful and useful to the student.

This second edition of the *Core Text of Neuroanatomy* is based upon material drawn from the author's *Human Neuroanatomy* (7th edition) and its uses the same format and many of the same illustrations. The text deals primarily with the central nervous system and no attempt has been made to consider in detail those subjects which ordinarily form important parts of gross anatomy, histology and embryology. There have been numerous suggestions that the text be expanded in a variety of directions but these have been resisted because in its current form the text seemed to satisfy the needs of so many students. This edition contains more references than the first edition, which largely reflects documentation of recent advances. The Paris Nomina Anatomica in its amended form has been used throughout. The material concerning the spinal cord has been divided into two chapters of moderate length which the student should find more convenient. Ninety-one new or revised illustrations have been added, including many teaching diagrams in color. Each chapter dealing with the central nervous system has a section entitled "Functional Considerations" in which attempts are made to correlate structure and function and to demonstrate clinical application by example.

The author is grateful to many colleagues for their criticism, constructive comments and the generous use of materials. Particular thanks must be extended to my mentor, Professor Fred A. Mettler of the College of Physicians and Surgeons, Columbia University, for support over many years and permission to use superb illustrations from his *Neuroantomy* (1948). These illustrations were drawn by the late Ivan Summers and are reproduced by the courtesy of The C. V. Mosby Company of St. Louis. Drs. Louis Sokoloff and Charles Kennedy of the National Institute of Mental Health have been most generous in permitting reproduction of illustrations from their investigative work. To Drs. Stephen T. Kitai and Clement A. Fox of Wayne State University School of Medicine and Drs. Richard M. Bergland and Robert B. Page of the Hershey Medical Center, Pennsylvania State University the author is indebted for the use of several excellent figures. The author is particularly pleased to acknowledge the contributions of Robert J. Demarest of the College of Physicians and Surgeons, Columbia University whose skill, talent and insight into the preparation of medical illustrations have added so much to the usefulness of this book. The secretarial and editorial assistance of Miss Anke Nolting and Mrs. Doris Lineweaver is acknowledged with sincere thanks.

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.

MALCOLM B. CARPENTER

Contents

Chapter 1

Meninges and Cerebrospinal Fluid

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 (Fig. 1-1). 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 dura 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 in relationship 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. 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 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

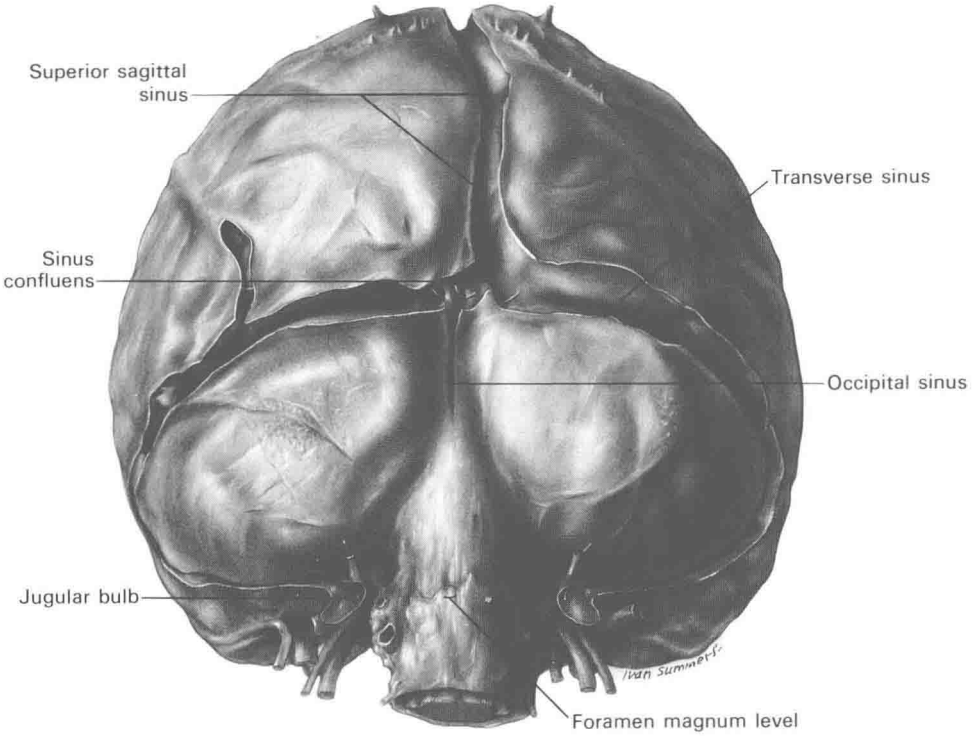

FIG. 1-1. Posterior view of the dura surrounding the brain. Prominent dural sinuses have been opened. The periosteal layer of the dura has been cut at the margins of the foramen magnum. (From Mettler's *Neuroanatomy*. 1948; courtesy of The C. V. Mosby Company.)

layer of flat cells, and the dense membrane is separated from the periosteum by a narrow *epidural space*. The epidural space contains areolar tissue and the internal vertebral venous plexuses.

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 nervous 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. 1-10). 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 ligament is attached medially to the lateral surface of the spinal cord

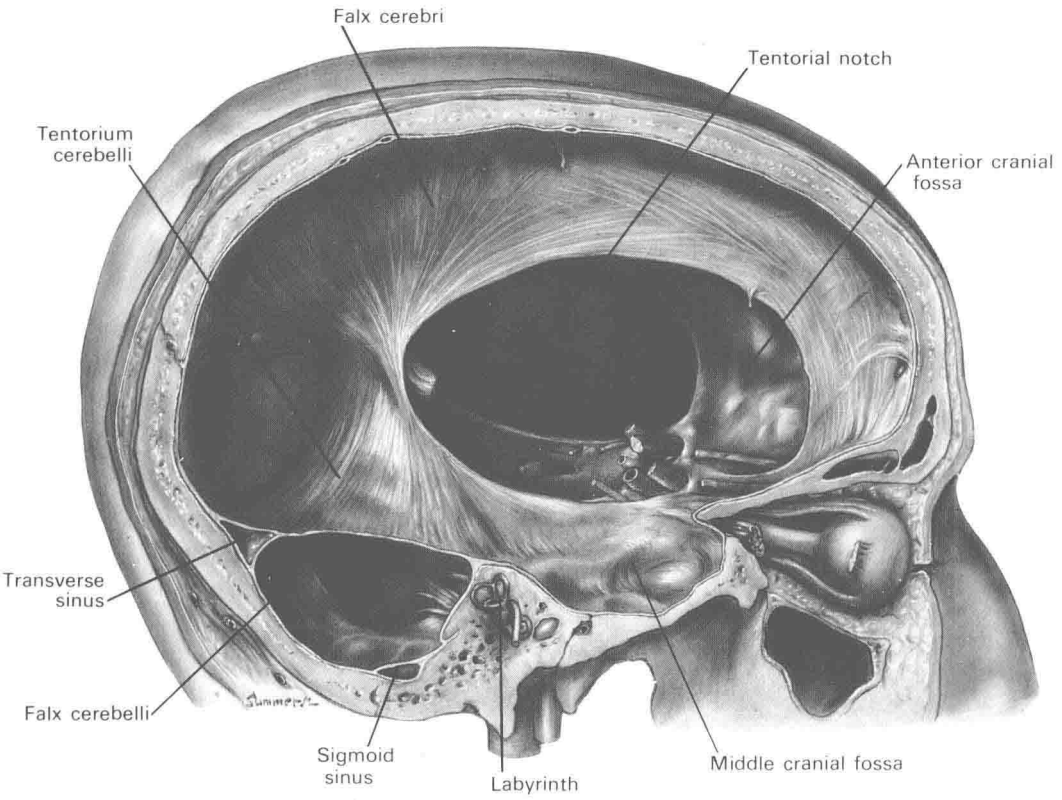

FIG. 1-2. Parasagittal section of the head showing the falx cerebri, the tentorium cerebelli and the falx cerebelli. (From Mettler's *Neuroanatomy*, 1948; courtesy of The C. V. Mosby Company.)

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 arachnoid to the pia. The space between the arachnoid and the pia mater, filled with cerebrospinal fluid, is called the *subarachnoid space*. The extent of the subarachnoid space surrounding the brain shows local variations. Over the convexity of the cerebral hemisphere this space is narrow, except in the depths of the sulci. At the base of the brain and around the brain stem the pia and the arachnoid often are widely separated, creating what are called *subarachnoid cisterna* (Figs. 1-8 and 1-9). One of the largest cisterns is found between the medulla and the cerebellum. This is the *cerebellomedullary cistern* (cisterna magna) into which the foramina of the fourth ventricle open (Fig. 1-9). Cerebrospinal fluid from the fourth

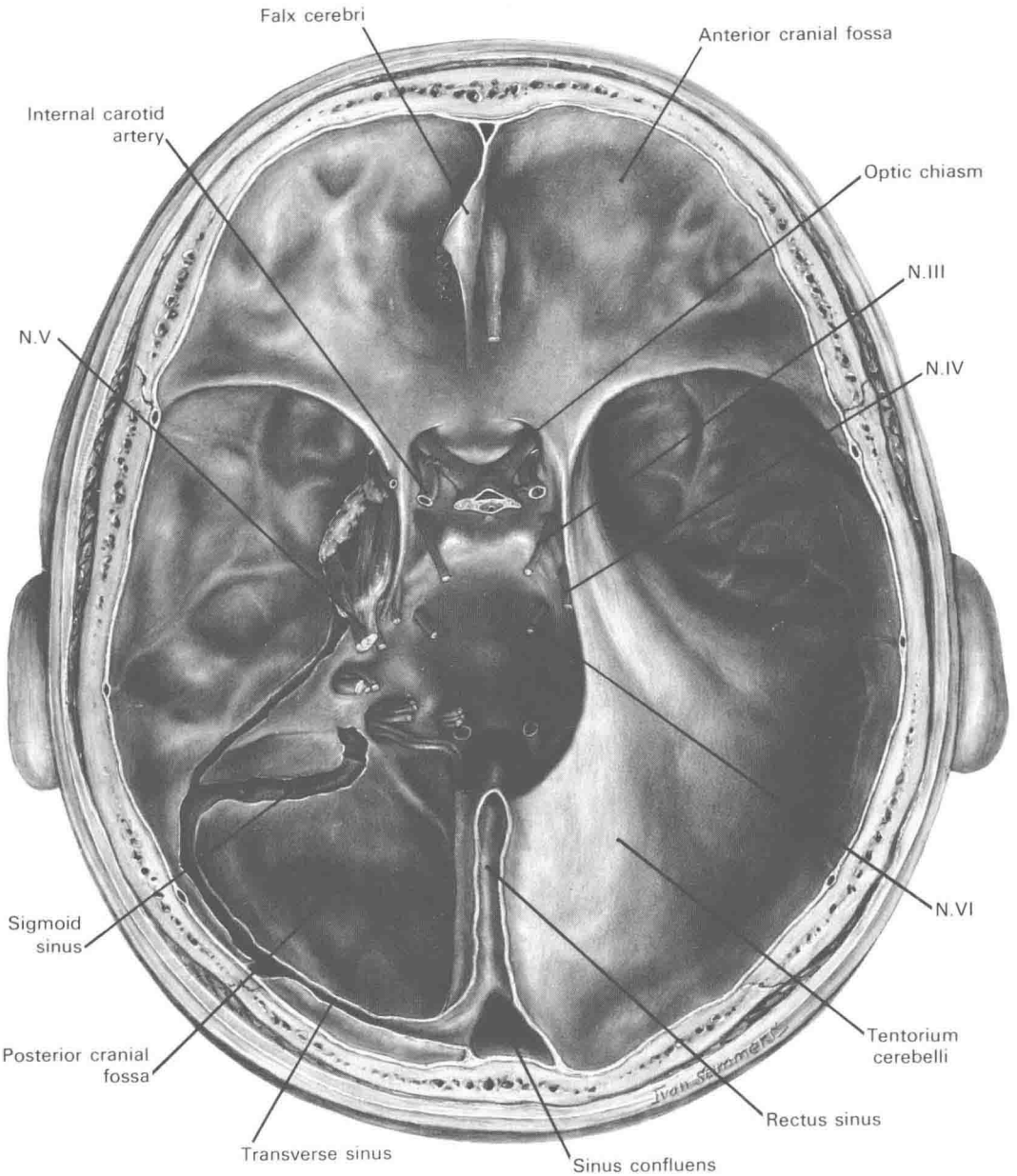

FIG. 1-3. View of the base of the skull with dura mater. The falx cerebri has been removed and the tentorium cerebelli has been cut away on the left to expose the posterior fossa. (From Mettler's *Neuroanatomy*. 1948; courtesy of The C. V. Mosby Company.)

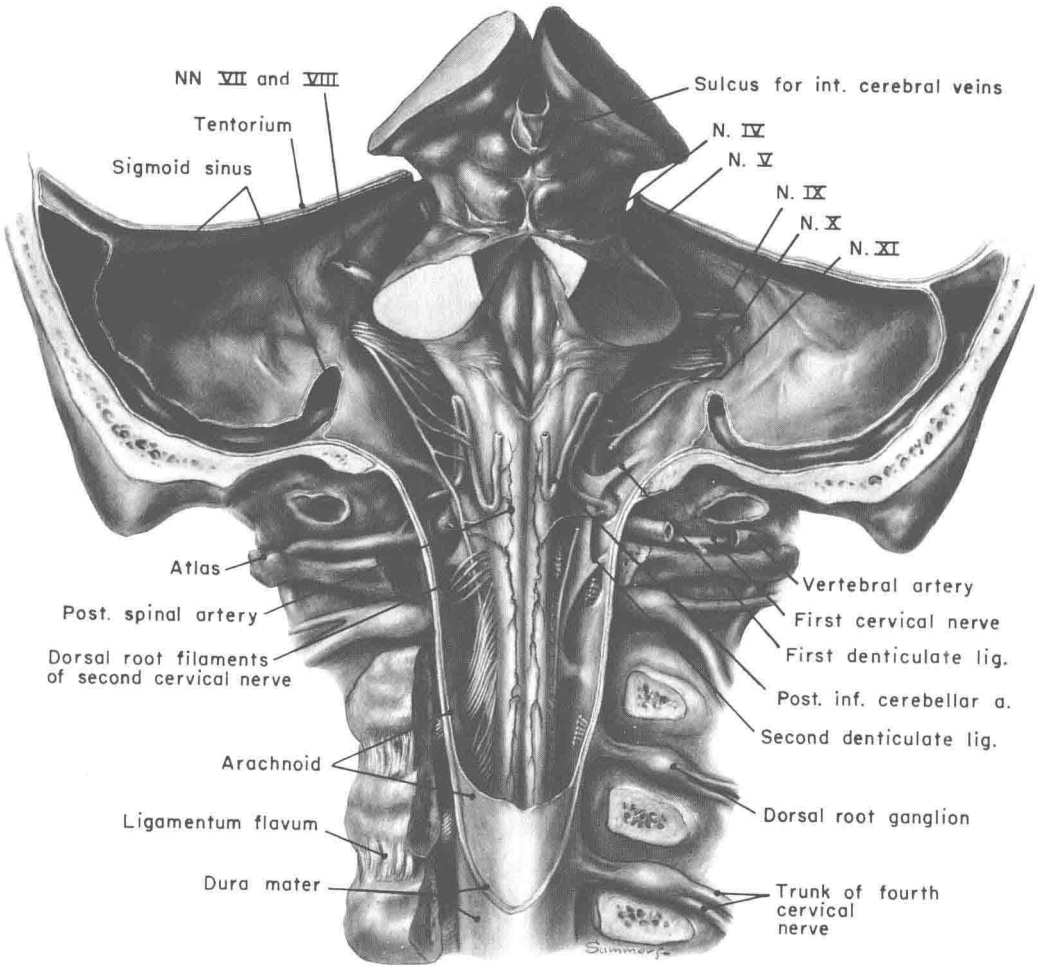

FIG. 1-4. Posterior view of the brain stem, upper cervical spinal cord and meninges. (From Mettler's *Neuroanatomy*, 1948; courtesy of The C. V. Mosby Company.)