



# HUMAN NEUROANATOMY

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# Preface to the Seventh Edition

This edition, like the last, comes at a time when the curricula of many American medical schools are changing. After a period in which basic science teaching has been shortened, concentrated and fragmented, there appears to be renewed interest in more comprehensive course offerings that recognize the importance of broad integration. While appreciation of the basic sciences usually shows its strongest development after considerable clinical experience, even the beginning student recognizes that they form the foundation of a medical education, that they cannot be adequately taught, or comprehended, in a hurry, and that abbreviations usually are accomplished by serious omissions. In many medical schools new neuroscience programs have been developed and expanded in recognition of the importance of the nervous system in all clinical disciplines. Neuroanatomy is regarded as the most basic of the neurosciences because of the close correlation between structure and function, and its fundamental nature. As in all previous editions of this text attempts have been made to present clearly the structural organization of the nervous system together with interpretations of functional mechanisms and their clinical significance. Since few courses dealing with the structure and function of the nervous system will be identical, there appears to be a need for a reasonably comprehensive stu-

dent textbook. The author has attempted to provide the student with a textbook of neuroanatomy that might meet these requirements.

The seventh edition has undergone extensive revisions and reorganization, which has resulted in consolidation of certain chapters and the addition of others. Material dealing with segmental and peripheral innervation has been combined in a single chapter. The chapter on the autonomic nervous system has been rewritten, and incorporates recent material on transmitter substances. Although the spinal cord is the simplest part of the central nervous system considerable revision of this section seemed necessary. The gross anatomy and internal structure of the spinal cord are presented as a unit, together with the basic principles of spinal reflexes. Spinal tracts and spinal cord syndromes are dealt with separately and new emphasis has been given to the analysis of spinal cord lesions. Experience has shown that a good understanding of the organization and function of spinal cord elements is essential before the student can appreciate the more complex organization of the brain stem. Presentation of the brain stem follows the format used in previous editions, except for rearrangements and additions designed to make reading and comprehension easier. The diencephalon, which represents the most difficult region for most students, has

been divided into two main parts, the thalamus and the hypothalamus. The basal ganglia and related nuclei are discussed together; even though certain information is repeated, this seems to be the best context for understanding these structures. The amygdala has been grouped with the olfactory pathways and hippocampal formation. The cerebral cortex remains formidable, but the principal emphasis is upon clinical and functional concepts, rather than upon anatomical minutia. Each chapter dealing with the central nervous system has a section entitled, "Functional Considerations", in which attempts are made to: (1) relate structure and function, and (2) provide certain insight into clinical problems. Since details concerning regional blood supply have little meaning until the student understands the organization of the central nervous system, this chapter has been moved to the back of the book. This chapter and the atlas section, containing 24 full color plates, should be referred to frequently in the course of reading other chapters. In this revision the total number of chapters has been reduced by two and over one hundred and twenty new or revised illustrations have been added to various chapters, many of them in color. The Paris Nomina Anatomica (PNA) in its amended form as adopted by the International Anatomical Nomenclature Committee has been used.

The author has missed the wise and prudent counsel of his former co-author, Professor Raymond C. Truex of Temple University School of Medicine, who contributed so much to this text. The present author now accepts total responsibility for the contents of this text. Robert J. Demarest of the Department of Anatomy, College of Physicians and Surgeons, Columbia University, has been responsible for all new drawings in this edition. His unusual talents have contributed enormously to the success of this text. Dr. Fred A. Mettler has made available to the author

many superb illustrations from his *Neuroanatomy* (1948) which were drawn by Ivan Summer. I am grateful to Dr. Mettler and the C. V. Mosby Company for permission to publish these illustrations. The excellent technical assistance of Mrs. Greta Katzauer and Mr. Antonio B. Pereira who have worked closely with the author at Columbia for over fifteen years is acknowledged with special gratitude.

Colleagues at many medical schools have offered valuable suggestions, given generously of their time and complied graciously with my requests for illustrations. While the names of all individuals who supplied illustrations are cited in the figure legends, particular gratitude is expressed to the following: Drs. Ray C. Henrikson, Fred A. Mettler, Charles R. Noback, Roberta J. Pierson, Virginia Tennyson and Ernst Wood at Columbia University; Dr. David Bodian at Johns Hopkins University; Drs. Richard and Mary Bunge at Washington University; Dr. Milton W. Brightman at National Institutes of Health; Dr. William Bondareff at Northwestern University; Dr. Marc Colonnier at the University of Ottawa; Dr. David Felten at Indiana University; Dr. Clement A. Fox at Wayne State University; Dr. Torbjörn Malmfors, Karolinska Institutet, Sweden; Drs. Sanford L. Palay and Victoria Chan-Palay, Harvard Medical School; Dr. Alan Peters, Boston University; Dr. Joyce E. Shriver, Mt. Sinai Medical School; Dr. John E. Swett, University of Colorado; Dr. Constantino Sotelo, Laboratoire de Neuro-morphologie, Paris; and Dr. James E. Vaughn, City of Hope National Medical Center. The cooperation of the C. V. Mosby Company, Rockefeller University Press, Oxford University Press, Elsevier Publishing Company and the Wistar Institute of Anatomy and Biology in granting permission to use certain illustrations is acknowledged with thanks.

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*Malcolm B. Carpenter*

# Preface to the First Edition

Neurology, more perhaps than any other branch of medicine, is dependent on an accurate knowledge of anatomy as a basis for the intelligent diagnosis and localization of neural disturbances. This book, the result of many years of neuroanatomical teaching, is intended to supply this basic anatomical need, to give the student and physician a thorough and clear presentation of the structural mechanisms of the human nervous system together with some understanding of their functional and clinical significance. It is an attempt to link structure and function into a dynamic pattern without sacrificing anatomical detail.

The book is a human neuroanatomy sufficiently rich in content to obviate the necessity of constantly consulting larger anatomical texts. It may be conveniently divided into two parts. The first part (Chapters I-VIII) is concerned with the general organization and meaning of the nervous system, its embryology and histological structure, and with some fundamental neurological problems as they apply to man. This is followed by a discussion of the organization and segmental distribution of the peripheral nerve elements, including an analysis of the functional components of the spinal nerves and of the various receptors and effectors. If these earlier chapters are perhaps more extensive than in most other texts, it is due

to the conviction that the book should be complete in itself, and also that a knowledge of these preliminaries is essential for an understanding of the complex machinery of the spinal cord and brain.

The second and larger part (Chapters IX-XX) is devoted to the architectonics of the central nervous system and may be regarded as "applied neuroanatomy." Special features of this part are the many fine photographs, both gross and microscopic, of the human brain and spinal cord, the great wealth of anatomical detail, and the discussion of the structural mechanisms in the light of clinical experience. While the individual portions of the nervous system are treated separately, an attempt has been made to achieve organic structural continuity by judicious repetition and overlapping and by constant reference to related topics already familiar to the student from previous chapters. The plan of exposition is substantially the same for each topic. The gross structure and relationships are concisely but thoroughly reviewed with the aid of clear and graphic illustrations. The internal structure is then presented in detail, usually based on a carefully graded series of fine and clearly labeled microphotographs of human material. At each level the student is familiarized with the exact location, extent and relationships of the various structures seen in the section. Finally the anatomical fea-

tures of each part are reviewed more comprehensively as three-dimensional structural mechanisms, with a full discussion of their connections and clinical significance. We believe that this treatment will make the complicated structural details alive and interesting to the student. The illustrations are not segregated in the back of the book in the form of an atlas but are scattered in the text, in proper relation to the levels studied.

Besides the many original illustrations, a number of others selected from various and duly acknowledged sources have been completely redrawn and relabeled for the sake of clarity and simplicity. All the illustrations, whether original or borrowed, have been executed by Frances H. Elwyn to whose skill and patience the authors are deeply indebted. We are also indebted to

Dr. H. Alsop Riley for the use of several microphotographs; to Drs. R. C. Truex and Benjamin Salzer for the reading of several chapters; and especially to Dr. Otto Marburg for his many stimulating discussions and suggestions and for his critical reading of the chapters on the mesencephalon, diencephalon, and cerebral hemispheres. Thanks are also due to Rosette Spoerri for her competent help in preparing the manuscript and bibliography.

The authors cannot express too strongly their obligation to the publishers for their continuous courtesy and cooperation in all matters, and for their infinite patience in waiting for a manuscript long overdue.

*Adolph Elwyn*  
*Oliver S. Strong*



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## CHAPTER 1

# Meninges and Cerebrospinal Fluid

The brain and spinal cord are delicate semisolid structures requiring protection and support. The brain is invested by various membranes, floated in a clear fluid and encased in a bony vault. Three membranes surround the brain. The most external 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), the only opening between these compartments. 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 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 20.

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 (Figs. 1-3 and 20-3). 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 space occupying epidural hemorrhages between the skull and the dura that require prompt surgical intervention.