CLINICAL NEUROANATOMY

SEVENTH EDITION

Richard S. Snell, M.R.C.S., L.R.C.P., MB, BS, MD, PhD
Emeritus Professor of Anatomy
George Washington University
School of Medicine and Health Sciences
Washington, DC
Formerly Associate Professor of Anatomy and Medicine, Yale University Medical School; Lecturer in Anatomy King's College University of London; and Visiting Professor of Anatomy, Harvard Medical School.
his book contains the basic neuroanatomical facts necessary for the practice of medicine. It is suitable for medical students, dental students, nurses, and allied health students. Residents find this book useful during their rotations.

The functional organization of the nervous system has been emphasized and indicates how injury and disease can result in neurologic deficits. The amount of factual information has been strictly limited to that which is clinically important.

In this edition, the content of each chapter has been reviewed, obsolete material has been discarded, and new material added.

Each chapter is divided into the following categories:

- **Clinical Example.** A short case report that serves to dramatize the relevance of neuroanatomy introduces each chapter.
- **Chapter Objectives.** This section details the material that is most important to learn and understand in each chapter.
- **Basic Neuroanatomy.** This section provides basic information on neuroanatomical structures that are of clinical importance. Numerous examples of normal radiographs, CT scans, MRIs, and PET scans are also provided. Many cross-sectional diagrams have been included to stimulate students to think in terms of three-dimensional anatomy, which is so important in the interpretation of CT scans and MRI images.
- **Clinical Notes.** This section provides the practical application of neuroanatomical facts that are essential in clinical practice. It emphasizes the structures that the physician will encounter when making a diagnosis and treating a patient. It also provides the information necessary to understand many procedures and techniques and notes the anatomical “pitfalls” commonly encountered.
- **Clinical Problem Solving.** This section provides the student with many examples of clinical situations in which a knowledge of neuroanatomy is necessary to solve clinical problems and to institute treatment; solutions to the problems are provided at the end of the chapter.
- **Review Questions.** The purpose of the questions is threefold: to focus attention on areas of importance, to enable students to assess their areas of weakness, and to provide a form of self-evaluation when questions are answered under examination conditions. Some of the questions are centered around a clinical problem that requires a neuroanatomical answer. Solutions to the problem are provided at the end of each chapter.

In addition to the full text from the book, an interactive Review Test, including over 450 questions, is provided online.

The book is extensively illustrated. The majority of the figures have been kept simple and are in color. As in the previous edition, a concise Color Atlas of the dissected brain is included prior to the text. This small but important group of colored plates enables the reader to quickly relate a particular part of the brain to the whole organ.

References to neuroanatomical literature are included should readers wish to acquire a deeper knowledge of an area of interest.

R.S.S.
I am greatly indebted to the following colleagues who provided me with photographic examples of neuroanatomical material: Dr. N. Cauna, Emeritus Professor of Anatomy, University of Pittsburgh School of Medicine; Dr. F. M. J. Fitzgerald, Professor of Anatomy, University College, Galway, Ireland; and Dr. A. Peters, Professor of Anatomy, Boston University School of Medicine.

My special thanks are owed to Larry Clerk, who, as a senior technician in the Department of Anatomy at the George Washington University School of Medicine and Health Sciences, greatly assisted me in the preparation of neuroanatomical specimens for photography.

I am also grateful to members of the Department of Radiology for the loan of radiographs and CT scans that have been reproduced in different sections of this book. I am most grateful to Dr. G. Size of the Department of Radiology at Yale University Medical Center for examples of CT scans and MRI images of the brain. I also thank Dr. H. Dey, Director of the PET Scan Unit of the Department of Radiology, Veterans Affairs Medical Center, West Haven, Connecticut, for several examples of PET scans of the brain. I thank the medical photographers of the Department of Radiology at Yale for their excellent work in reproducing the radiographs.

As in the past, I express my sincere thanks to Myra Feldman and Ira Grunther, AMI, for the preparation of the very fine artwork.

Finally, to the staff of Lippincott Williams & Wilkins, I again express my great appreciation for their continued enthusiasm and support throughout the preparation of this book.

To My Students—Past, Present, and Future

This book is designed so that the information is presented without masses of confusing detail involving complicated neural connections. The arrangement permits the students and future health providers to quickly recall the essential features necessary for the diagnosis and treatment of patients.
CONTENTS

Preface ......................................................... iii
Acknowledgments ................................................. iv
Color Atlas of Brain ............................................. xi

CHAPTER 1  Introduction and Organization of the Nervous System 1
  Chapter Objectives 2
  Central and Peripheral Nervous Systems 2
  Major Divisions of the Central Nervous System 2
  Major Divisions of the Peripheral Nervous System 10
  Early Development of the Nervous System 14
  Clinical Notes 17
  Clinical Problem Solving 28
  Answers and Explanations to Clinical Problem Solving 29
  Review Questions 30
  Answers and Explanations to Review Questions 31
  Additional Reading 32

CHAPTER 2  The Neurobiology of the Neuron and the Neuroglia 33
  Chapter Objectives 34
  Definition of a Neuron 34
  Varieties of Neurons 34
  Structure of the Neuron 34
  Definition of Neuroglia 53
  Astrocytes 53
  Oligodendrocytes 54
  Microglia 57
  Ependyma 58
  Extracellular Space 59
  Clinical Notes 61
  Clinical Problem Solving 63
  Answers and Explanations to Clinical Problem Solving 64
  Review Questions 65
  Answers and Explanations to Review Questions 67
  Additional Reading 69

CHAPTER 3  Nerve Fibers, Peripheral Nerves, Receptor and Effector Endings, Dermatomes, and Muscle Activity 70
  Chapter Objectives 71
  Nerve Fibers 71
  Peripheral Nerves 80
  Conduction in Peripheral Nerves 84
  Receptor Endings 86
### Chapter 6: The Cerebellum and Its Connections

- **Chapter Objective** 230
- **Gross Appearance of the Cerebellum** 231
- **Structure of the Cerebellum** 231
- **Cerebellar Cortical Mechanisms** 236
- **Cerebellar Afferent Fibers** 237
- **Cerebellar Efferent Fibers** 240
- **Functions of the Cerebellum** 242
- **Clinical Notes** 243
- **Clinical Problem Solving** 245
- **Answers and Explanations to Clinical Problem Solving** 246
- **Review Questions** 247
- **Answers and Explanations to Review Questions** 249
- **Additional Reading** 250

### Chapter 7: The Cerebrum

- **Chapter Objectives** 252
- **Subdivisions of the Cerebrum** 252
- **Diencephalon** 252
- **General Appearance of the Cerebral Hemispheres** 257
- **Main Sulci** 258
- **Lobes of the Cerebral Hemisphere** 260
- **Internal Structure of the Cerebral Hemispheres** 262
- **Clinical Notes** 271
- **Clinical Problem Solving** 277
- **Answers and Explanations to Clinical Problem Solving** 278
- **Review Questions** 279
- **Answers and Explanations to Review Questions** 281
- **Additional Reading** 283

### Chapter 8: The Structure and Functional Localization of the Cerebral Cortex

- **Chapter Objective** 285
- **Structure of the Cerebral Cortex** 285
- **Mechanisms of the Cerebral Cortex** 287
- **Cortical Areas** 288
- **Cerebral Dominance** 295
- **Clinical Notes** 296
- **Clinical Problem Solving** 298
- **Answers and Explanations to Clinical Problem Solving** 299
- **Review Questions** 300
- **Answers and Explanations to Review Questions** 302
- **Additional Reading** 303

### Chapter 9: The Reticular Formation and the Limbic System

- **Chapter Objective** 305
- **Reticular Formation** 305
- **Limbic System** 307
- **Clinical Notes** 312
- **Clinical Problem Solving** 312
- **Answers and Explanations to Clinical Problem Solving** 313
- **Review Questions** 313
- **Answers and Explanations to Review Questions** 314
- **Additional Reading** 315

### Chapter 10: The Basal Nuclei (Basal Ganglia) and Their Connections

- **Chapter Objective** 317
- **Terminology** 317
Corpus Striatum 317
Amygdaloid Nucleus 319
Substantia Nigra and Subthalamic Nuclei 319
Claustrum 319
Connections of the Corpus Striatum and Globus Pallidus 319
Connections of the Corpus Striatum 319
Connections of the Globus Pallidus 319
Functions of the Basal Nuclei 320
Clinical Notes 322
Clinical Problem Solving 327
Answers and Explanations to Clinical Problem Solving 327
Review Questions 327
Answers and Explanations to Review Questions 329
Additional Reading 329

CHAPTER 11  The Cranial Nerve Nuclei and Their Central Connections and Distribution 331
Chapter Objective 332
The 12 Cranial Nerves 332
Organization of the Cranial Nerves 332
Olfactory Nerves (Cranial Nerve I) 335
Optic Nerve (Cranial Nerve II) 336
Oculomotor Nerve (Cranial Nerve III) 340
Trochlear Nerve (Cranial Nerve IV) 340
Trigeminal Nerve (Cranial Nerve V) 341
Abducent Nerve (Cranial Nerve VI) 344
Facial Nerve (Cranial Nerve VII) 346
Vestibulocochlear Nerve (Cranial Nerve VIII) 348
Glossopharyngeal Nerve (Cranial Nerve IX) 350
Vagus Nerve (Cranial Nerve X) 352
Accessory Nerve (Cranial Nerve XI) 354
Hypoglossal Nerve (Cranial Nerve XII) 356
Clinical Notes 358
Clinical Problem Solving 363
Answers and Explanations to Clinical Problem Solving 364
Review Questions 365
Answers and Explanations to Review Questions 368
Additional Reading 369

CHAPTER 12  The Thalamus and Its Connections 371
Chapter Objective 372
General Appearances of the Thalamus 372
Subdivisions of the Thalamus 372
Connections of the Thalamus 375
Function of the Thalamus 375
Clinical Notes 378
Clinical Problem Solving 378
Answers and Explanations to Clinical Problem Solving 378
Review Questions 379
Answers and Explanations to Review Questions 380
Additional Reading 381

CHAPTER 13  The Hypothalamus and Its Connections 382
Chapter Objectives 383
The Hypothalamus 383
Hypothalamic Nuclei 383
Afferent Nervous Connections of the Hypothalamus 385
Figure CA-1  Top: Superior view of the brain. Bottom: Inferior view of the brain.
Figure CA-2  Top: Anterior view of the brain. Bottom: Posterior view of the brain.
Figure CA-3 Top: Right lateral view of the brain. Bottom: Medial view of the right side of the brain following median sagittal section.
Figure CA-4  Coronal sections of the brain passing through the anterior horn of the lateral ventricle (top), the mammillary bodies (middle), and the pons (bottom).
**Figure CA-5**  Top: Horizontal section of the cerebrum showing the lentiform nucleus, the caudate nucleus, the thalamus, and the internal capsule. **Bottom:** Oblique coronal section of the brain.
Figure CA-6  Top: Inferior view of the brain showing cranial nerves. The abducent and facial nerves cannot be seen. Bottom: Enlarged inferior view of the central part of the brain.
Figure CA-7  Top: Posterior view of the brainstem. The greater part of the cerebellum had been removed to expose the floor of the fourth ventricle. **Middle**: Superior view of the cerebellum showing the vermis and right and left cerebellar hemispheres. **Bottom**: Inferior view of the cerebellum showing the vermis and right and left cerebellar hemispheres.
Figure CA-8 Enlarged medial view of the right side of the brain following median sagittal section, showing the continuity of the central canal, fourth ventricle, cerebral aqueduct, and the third ventricle and entrance into the lateral ventricle through the interventricular foramen.