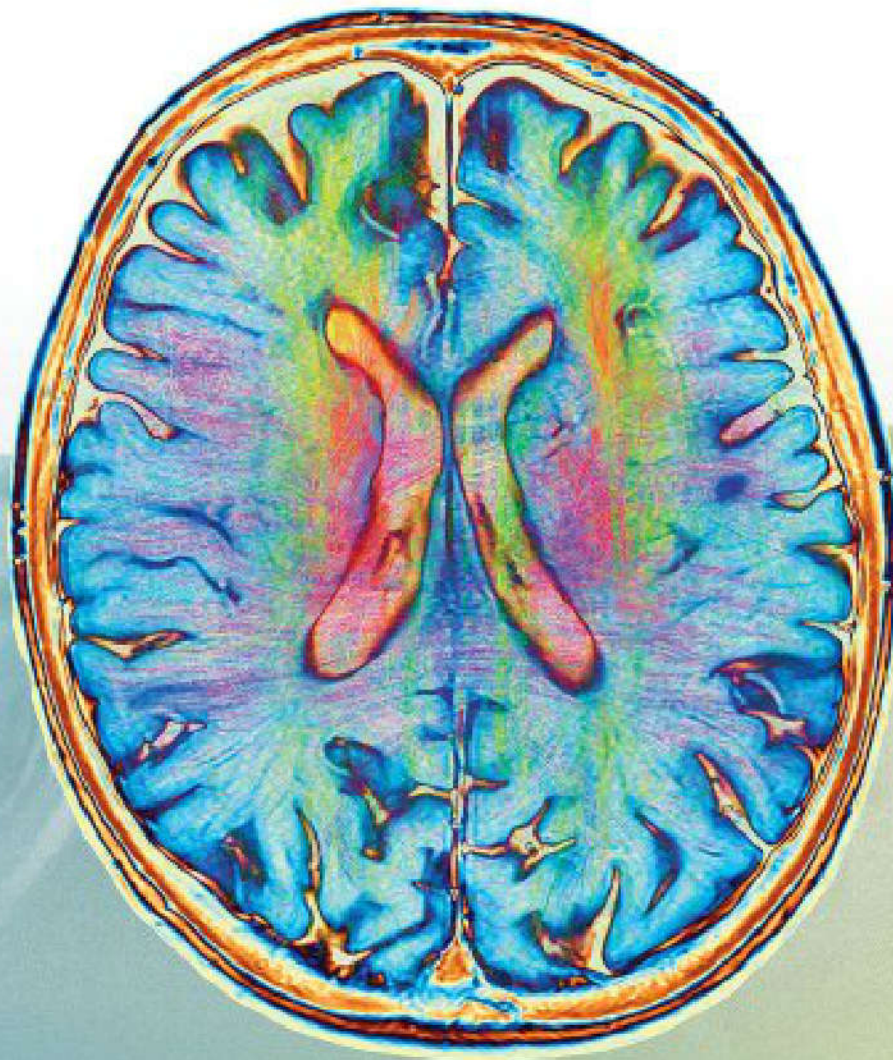


SNELL'S CLINICAL NEUROANATOMY

EIGHTH EDITION



RYAN SPLITTGERBER

SNELL'S CLINICAL NEUROANATOMY

EIGHTH EDITION

IN MEMORIAM

Richard S. Snell, MRCS, LRCP, MB, MD, PhD

1925–2015

Clinical Anatomy by Regions

Clinical Anatomy by Systems

Clinical Neuroanatomy

SNELL'S CLINICAL NEUROANATOMY

EIGHTH EDITION

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The trip has been long and the cost has been high . . . but no great thing was attained easily. A long tale, like a tall Tower, must be built a stone at a time.

—Stephen King

To my wife, Brienne

For providing more love and support than I deserve.

To my boys, Carter and Caden

For providing inspiration and humor . . . a lot of humor.

To my students

May you find your Tower.



Preface

This 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, authorship has transitioned from the late Dr. Richard Snell, who, with brilliance and dedication, fathered the previous seven editions and provided the framework for the eighth. The content of each chapter has been reviewed and edited to be more straightforward and concise. The traditional artwork has been recolored and updated to enhance the clarity and to provide additional information to each image. High-quality magnetic resonance images and histologic photomicrographs have been updated to provide greater visual details.

Each chapter introduces the relevance of neuroanatomy through a short case report.

- **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 MR images.

- **Clinical Notes.** This section provides the practical application of neuroanatomical facts that are essential in clinical practice. It emphasizes the structures that the clinician 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.
- **NEW! Key Concepts.** These quick, bulleted reviews of key topics and information are provided at the end of each chapter.
- **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.

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.

R.S.
R.S.S.



Acknowledgments

Starting with the first edition of *Clinical Neuroanatomy* published in 1980, many people have provided their expertise and should be recognized for their contributions. First and foremost, thanks to Richard S. Snell whose shoulders we stand upon to advance our own intellectual progress.

Throughout this text and in previous editions, the following individuals provided valuable contributions and are gratefully acknowledged: N. Cauna, L. Clerk, D. O. Davis, H. Dey, M. Feldman, T. M. J. Fitzgerald, I. Grunther, J. M. Kerns, T. McCarthy, A. Peters, G. Sze, and L. Wener.

EIGHTH EDITION

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Vosburgh, development editor, and John Larkin, editorial coordinator. Thanks also to freelance development editor Kelly Horvath, who provided invaluable direction and patience with me throughout the entire process.

SPi Global is gratefully acknowledged for their brilliant art recoloring and enhancing the personality of this textbook.

My special thanks to Stephanie Vas, Program Director of the Magnetic Resonance Imaging Program at the University of Nebraska Medical Center, who produced exceptional MR images for this edition.

I would like to extend my gratitude to my students, colleagues, and mentors for their encouragement and wisdom—especially, Sabra Peetz, Art Dalley, Cathy Pettepher, Lillian Nanney, and Kyle Meyer.

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Contents

Preface	vii
Acknowledgments	ix
Color Atlas of Brain.....	xix

CHAPTER 1 Introduction and Organization of the Nervous System 1

Central and Peripheral Nervous Systems	1
Major Divisions of the Central Nervous System	2
Major Divisions of the Peripheral Nervous System	12
Early Development of the Nervous System	14
Clinical Notes	16
Clinical Problem Solving	27
Answers and Explanations to Clinical Problem Solving	28
Review Questions	29
Answers and Explanations to Review Questions	31

CHAPTER 2 Neurons and Neuroglia 33

Neurons	33
Neuroglia	54
Extracellular Space	60
Clinical Notes	62
Clinical Problem Solving	65
Answers and Explanations to Clinical Problem Solving	66
Review Questions	67
Answers and Explanations to Review Questions	69

CHAPTER 3 Nerve Fibers and Peripheral Innervation 71

Nerve Fibers	71
Peripheral Nerves	80
Receptor Endings	84
Effector Endings	93
Segmental Innervation of Skin	98
Segmental Innervation of Muscles	100
Muscle Tone and Muscle Action	101
Motor Unit Summation	102
Muscle Fatigue	102
Posture	102
Clinical Notes	105
Clinical Problem Solving	119
Answers and Explanations to Clinical Problem Solving	122
Review Questions	125
Answers and Explanations to Review Questions	128

CHAPTER 4 Spinal Cord and Ascending, Descending, and Intersegmental Tracts 131

Brief Review of the Vertebral Column 131
Spinal Cord 136
Ascending Tracts 142
Descending Tracts 152
Intersegmental Tracts 160
Renshaw Cells and Lower Motor Neuron Inhibition 162
Clinical Notes 163
Clinical Problem Solving 175
Answers and Explanations to Clinical Problem Solving 177
Review Questions 180
Answers and Explanations to Review Questions 182

CHAPTER 5 Brainstem 185

Skull Anatomy 185
Cranial Cavity 191
Introduction to the Brainstem 195
Medulla Oblongata 196
Pons 204
Midbrain 209
Clinical Notes 215
Clinical Problem Solving 219
Answers and Explanations to Clinical Problem Solving 220
Review Questions 222
Answers and Explanations to Review Questions 226

CHAPTER 6 Cerebellum and Its Connections 229

Gross Appearance 229
Structures 231
Cerebellar Cortical Mechanisms 234
Cerebellar Afferent Fibers 236
Cerebellar Efferent Fibers 239
Functions of the Cerebellum 240
Clinical Notes 241
Clinical Problem Solving 244
Answers and Explanations to Clinical Problem Solving 244
Review Questions 245
Answers and Explanations to Review Questions 247

CHAPTER 7 Cerebrum 249

Subdivisions 249
Diencephalon 249
General Appearance of the Cerebral Hemispheres 255
Main Sulci 256
Cerebral Hemisphere Lobes 258
Internal Structure of the Cerebral Hemispheres (Atlas Plates 4 and 5) 260
Clinical Notes 267
Clinical Problem Solving 273
Answers and Explanations to Clinical Problem Solving 274
Review Questions 275
Answers and Explanations to Review Questions 277

CHAPTER 8 The Structure and Functional Localization of the Cerebral Cortex 279

Structure	279
Cortical Mechanisms	283
Cortical Areas	283
Cerebral Dominance	289
Clinical Notes	290
Clinical Problem Solving	293
Answers and Explanations to Clinical Problem Solving	294
Review Questions	295
Answers and Explanations to Review Questions	297

CHAPTER 9 Reticular Formation and Limbic System 299

Reticular Formation	299
Limbic System	301
Clinical Notes	306
Clinical Problem Solving	307
Answers and Explanations to Clinical Problem Solving	307
Review Questions	307
Answers and Explanations to Review Questions	308

CHAPTER 10 Basal Nuclei (Basal Ganglia) 310

Terminology	310
Corpus Striatum	310
Amygdaloid Nucleus	311
Substantia Nigra and Subthalamic Nuclei	312
Clastrum	312
Connections of the Corpus Striatum and Globus Pallidus	312
Basal Nuclei Functions	314
Clinical Notes	315
Clinical Problem Solving	319
Answers and Explanations to Clinical Problem Solving	319
Review Questions	320
Answers and Explanations to Review Questions	321

CHAPTER 11 Cranial Nerve Nuclei 323

Cranial Nerves	323
Cranial Nerve Organization	323
Olfactory Nerves (Cranial Nerve I)	326
Optic Nerve (Cranial Nerve II)	327
Oculomotor Nerve (Cranial Nerve III)	331
Trochlear Nerve (Cranial Nerve IV)	331
Trigeminal Nerve (Cranial Nerve V)	332
Abducens Nerve (Cranial Nerve VI)	335
Facial Nerve (Cranial Nerve VII)	337
Vestibulocochlear Nerve (Cranial Nerve VIII)	339
Glossopharyngeal Nerve (Cranial Nerve IX)	341
Vagus Nerve (Cranial Nerve X)	343
Accessory Nerve (Cranial Nerve XI)	345
Hypoglossal Nerve (Cranial Nerve XII)	347
Clinical Notes	348
Clinical Problem Solving	356
Answers and Explanations to Clinical Problem Solving	357
Review Questions	358
Answers and Explanations to Review Questions	361

CHAPTER 12 Thalamus 363

- General Appearance 363
- Subdivisions 363
- Connections 366
- Function 367
- Clinical Notes 369
- Clinical Problem Solving 370
- Answers and Explanations to Clinical Problem Solving 370
- Review Questions 370
- Answers and Explanations to Review Questions 372

CHAPTER 13 Hypothalamus 373

- Hypothalamus 373
- Hypothalamic Nuclei 375
- Hypothalamic Lines of Communication 376
- Functions 380
- Clinical Notes 382
- Clinical Problem Solving 383
- Answers and Explanations to Clinical Problem Solving 384
- Review Questions 384
- Answers and Explanations to Review Questions 385

CHAPTER 14 Autonomic Nervous System 387

- Organization 387
- Large Autonomic Plexuses 390
- Autonomic Ganglia 390
- Preganglionic Transmitters 392
- Fast, Slow, and Inhibitory Synaptic Potentials 392
- Ganglion-Stimulating Agents 392
- Ganglion-Blocking Agents 392
- Postganglionic Nerve Endings 393
- Postganglionic Transmitters 393
- Other Postganglionic Transmitters 394
- Cholinergic Receptor Blockade 394
- Adrenergic Receptor Blockade 394
- Higher Control 394
- Enteric Nervous System 394
- Functions 395
- Differences Between Sympathetic and Parasympathetic Systems 395
- Autonomic Innervations 396
- Autonomic Physiologic Reflexes 406
- Clinical Notes 406
- Clinical Problem Solving 411
- Answers and Explanations to Clinical Problem Solving 412
- Review Questions 413
- Answers and Explanations to Review Questions 416

CHAPTER 15 Meninges 418

- Brain Meninges 418
- Spinal Cord Meninges 425
- Clinical Notes 428
- Clinical Problem Solving 432
- Answers and Explanations to Clinical Problem Solving 433
- Review Questions 434
- Answers and Explanations to Review Questions 435

CHAPTER 16	Ventricular System and Cerebrospinal Fluid	436
	Ventricular System	436
	Subarachnoid Space	447
	Cerebrospinal Fluid	448
	Blood–Brain and Blood–Cerebrospinal Fluid Barriers	452
	Clinical Notes	455
	Clinical Problem Solving	458
	Answers and Explanations to Clinical Problem Solving	459
	Review Questions	460
	Answers and Explanations to Review Questions	462
CHAPTER 17	Blood Supply of the Brain and Spinal Cord	464
	Arteries of the Brain	464
	Veins of the Brain	469
	Brain Capillaries	470
	Cerebral Circulation	470
	Spinal Cord Arteries	471
	Spinal Cord Veins	472
	Clinical Notes	472
	Clinical Problem Solving	480
	Answers and Explanations to Clinical Problem Solving	482
	Review Questions	484
	Answers and Explanations to Review Questions	486
CHAPTER 18	Nervous System Development	488
	Spinal Cord	488
	Brain	490
	Clinical Notes	498
	Clinical Problem Solving	502
	Answers and Explanations to Clinical Problem Solving	503
	Review Questions	503
	Answers and Explanations to Review Questions	504
APPENDIX	Neuroanatomical Data of Clinical Significance and Clinical Neuroanatomy Techniques	507
	Index	513

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Color Atlas of Brain

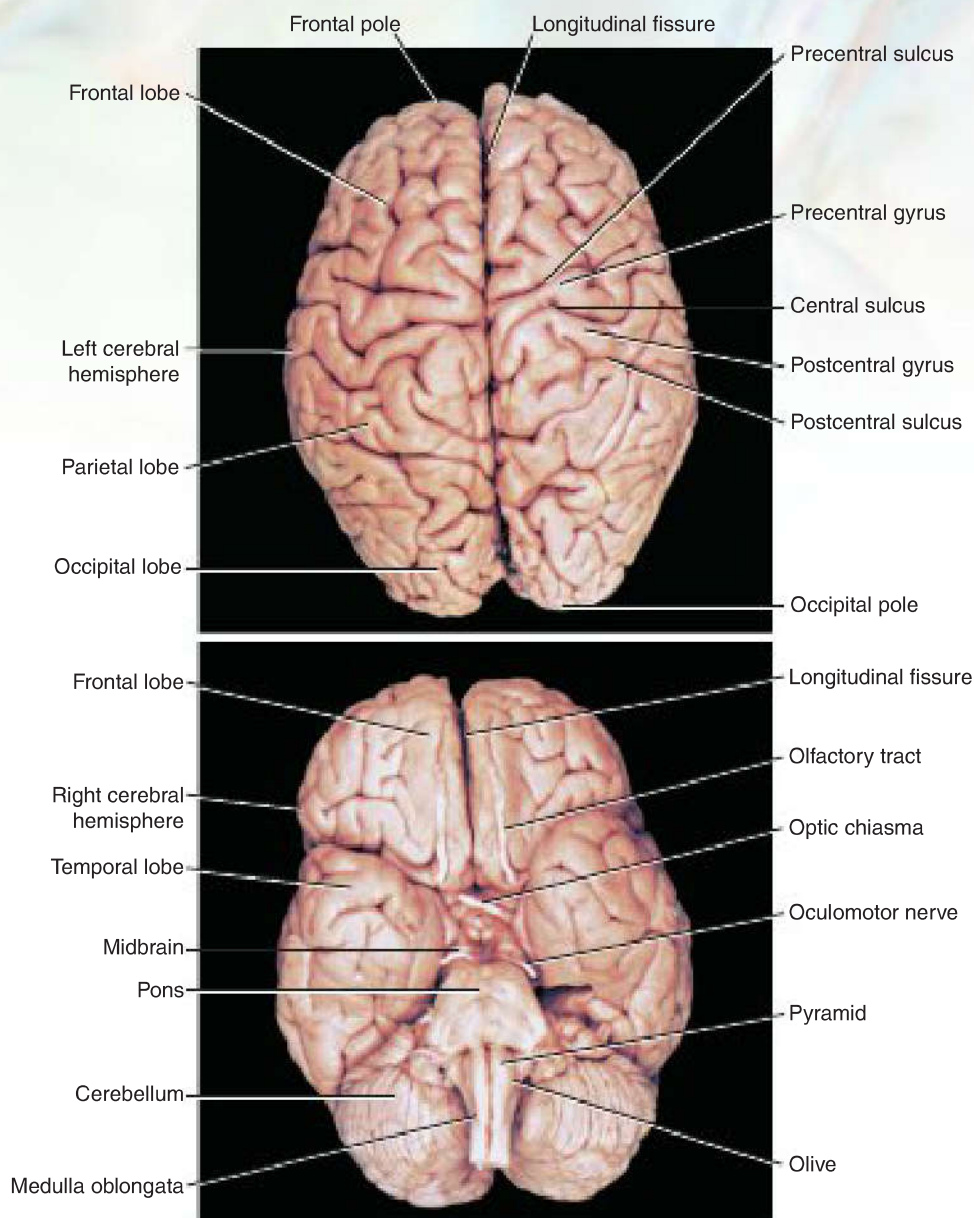


Figure CA-1 Top: Superior view of the brain. Bottom: Inferior view of the brain.

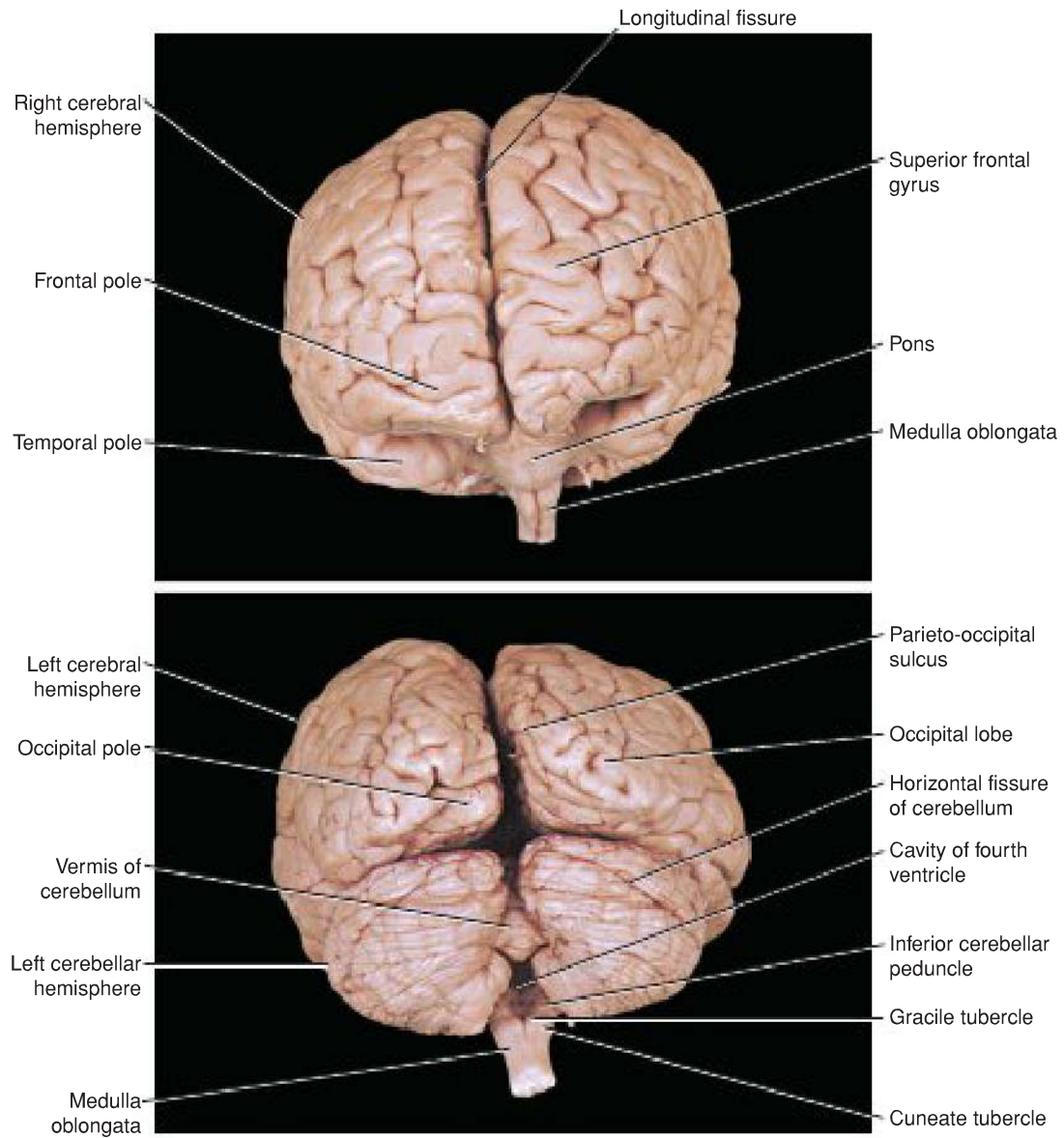


Figure CA-2 Top: Anterior view of the brain. Bottom: Posterior view of the brain.

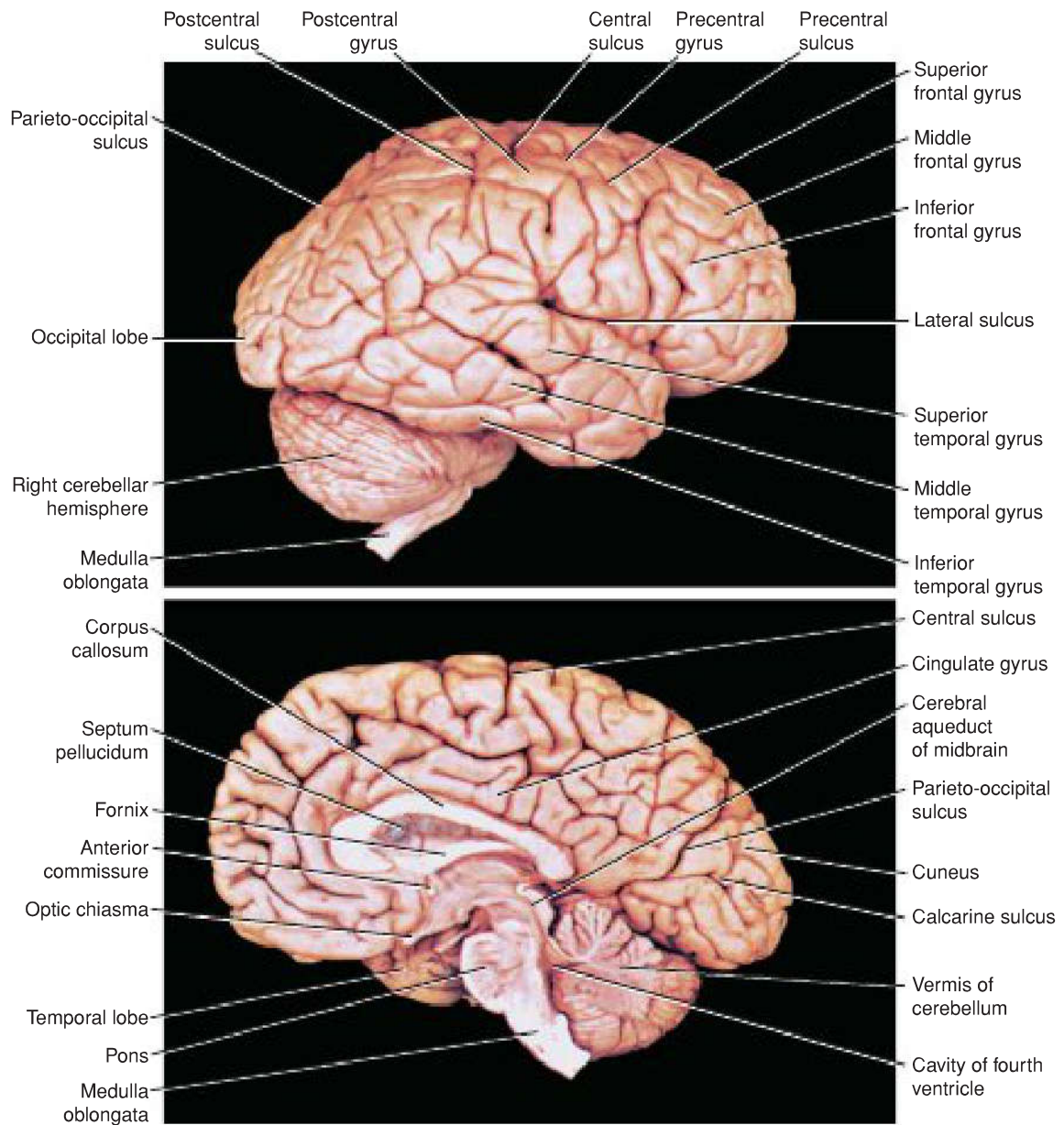


Figure CA-3 Top: Right lateral view of the brain. Bottom: Medial view of the right side of the brain following median sagittal section.

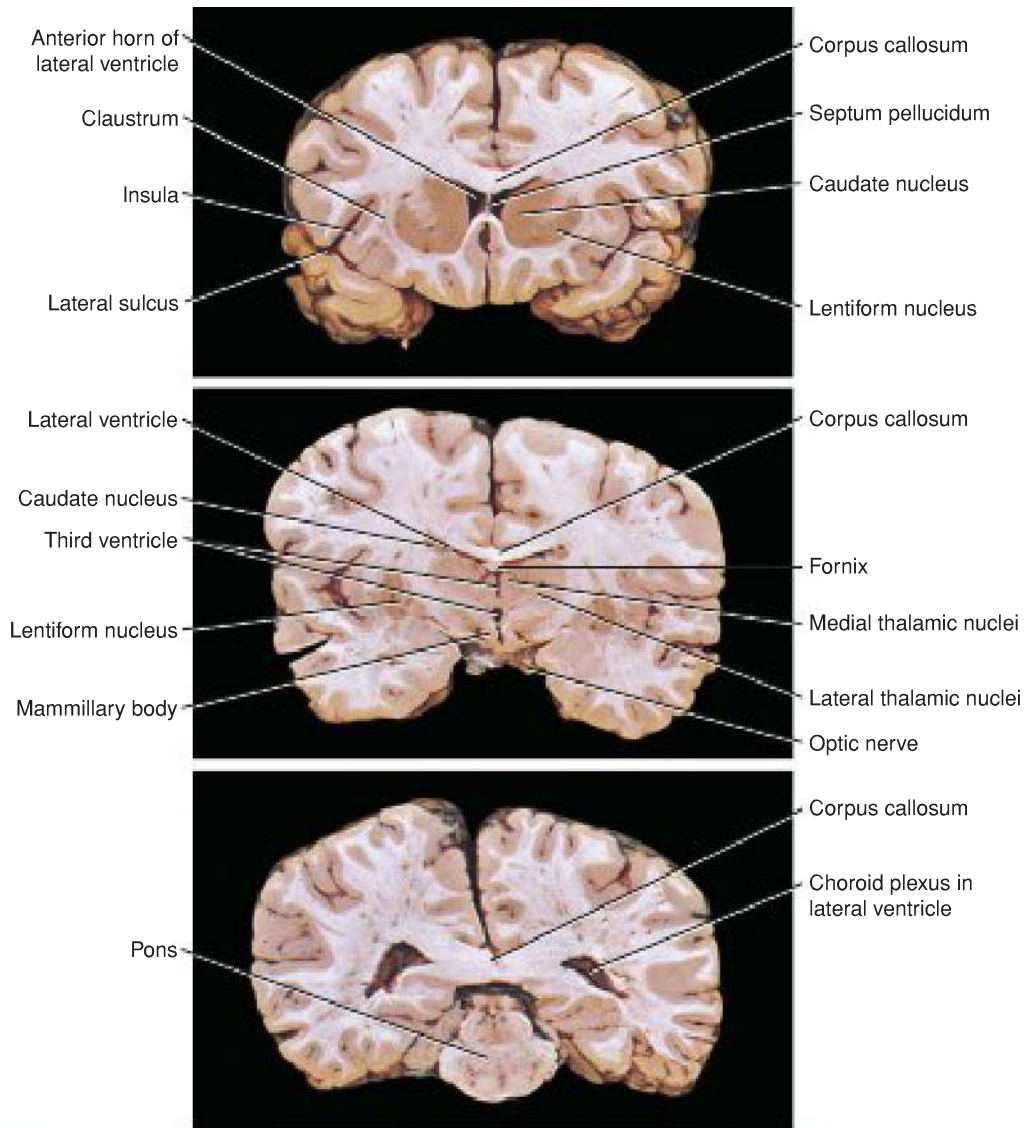


Figure CA-4 Coronal sections of the brain passing through the anterior horn of the lateral ventricle (**top**), the mammillary bodies (**middle**), and the pons (**bottom**).

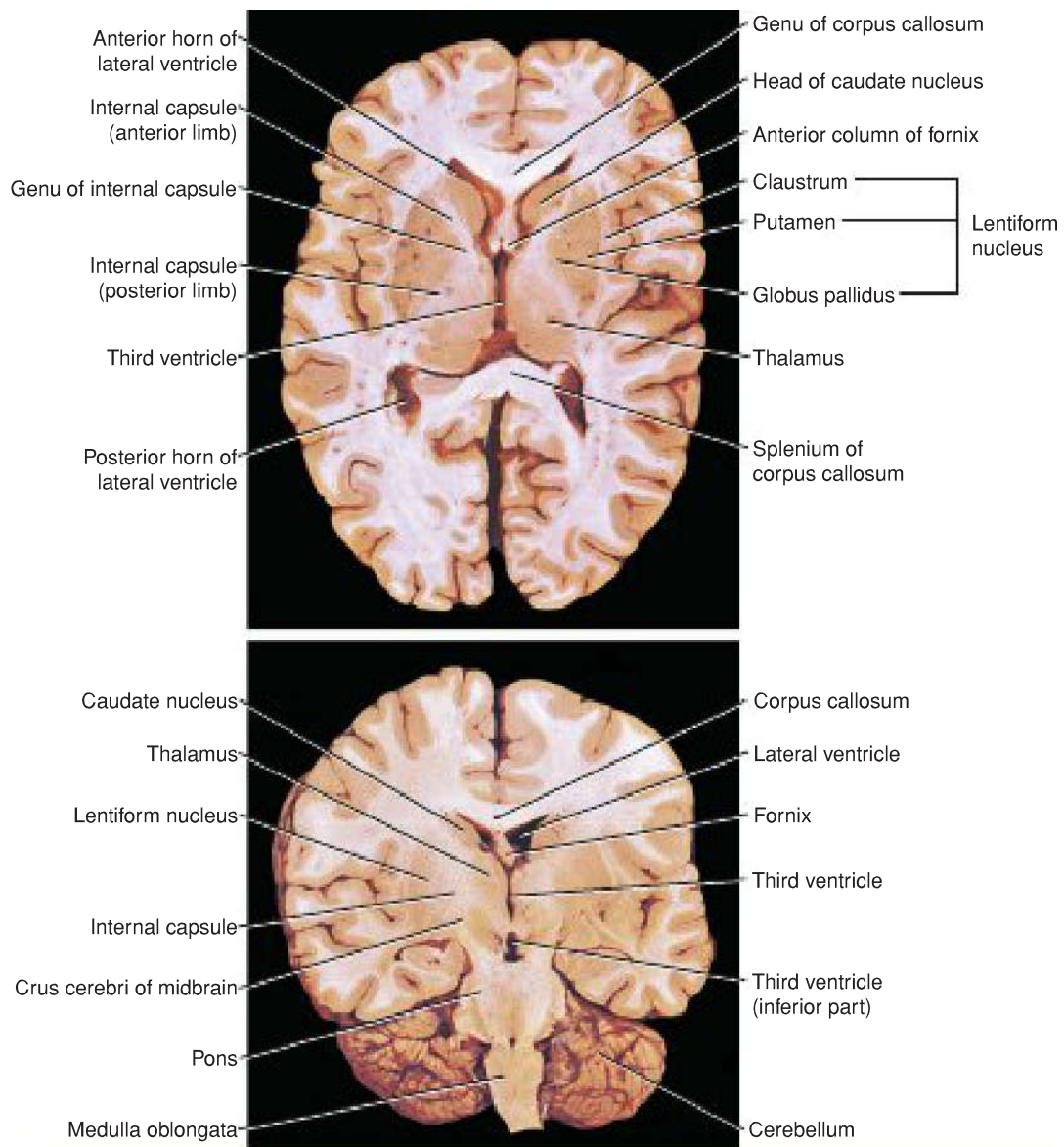


Figure CA-5 **Top:** Horizontal section of the cerebrum showing the lentiform nucleus, the caudate nucleus, the thalamus, and the internal capsule. **Bottom:** Oblique coronal section of the brain.

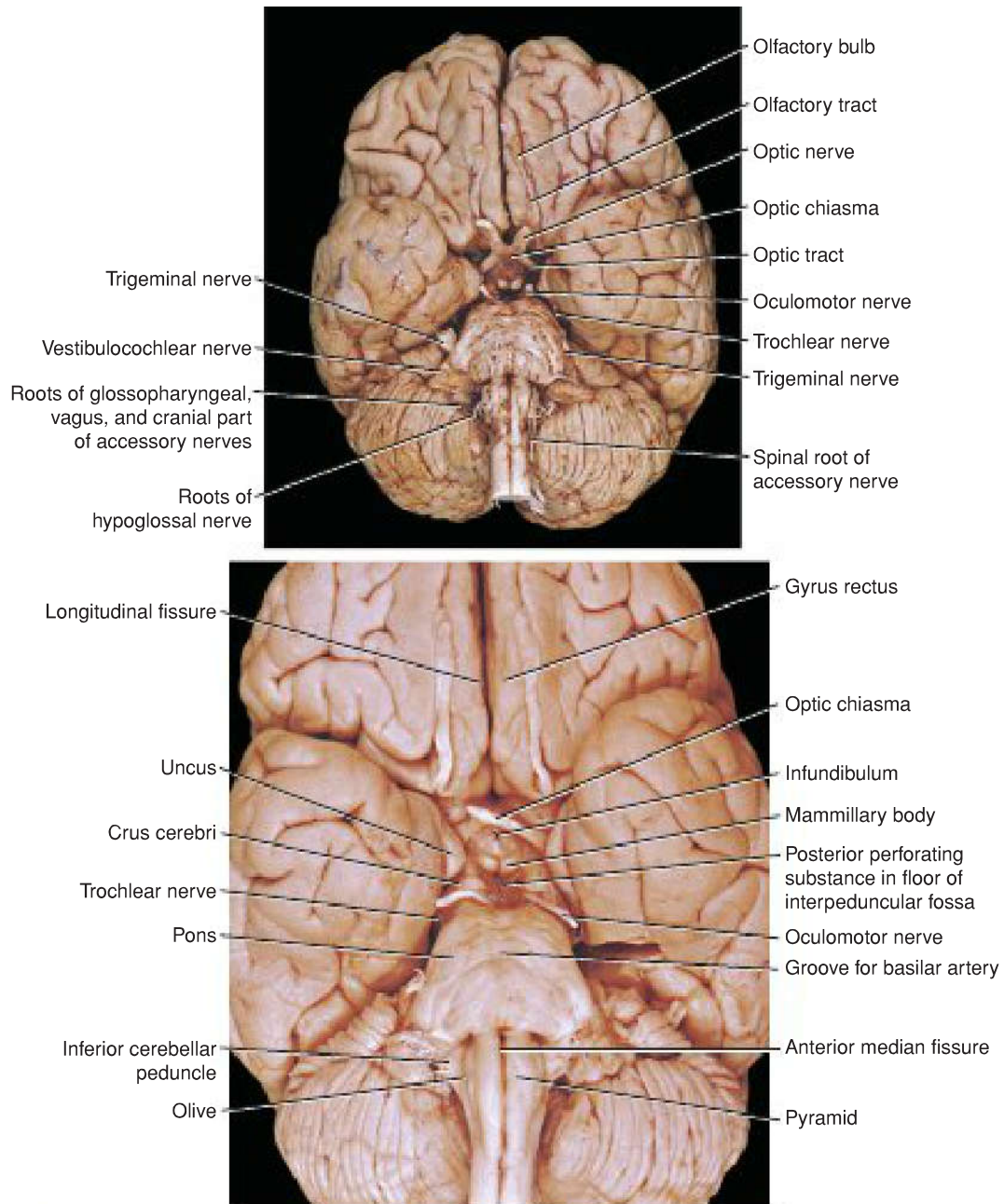


Figure CA-6 **Top:** Inferior view of the brain showing cranial nerves. The abducens and facial nerves cannot be seen. **Bottom:** Enlarged inferior view of the central part of the brain.

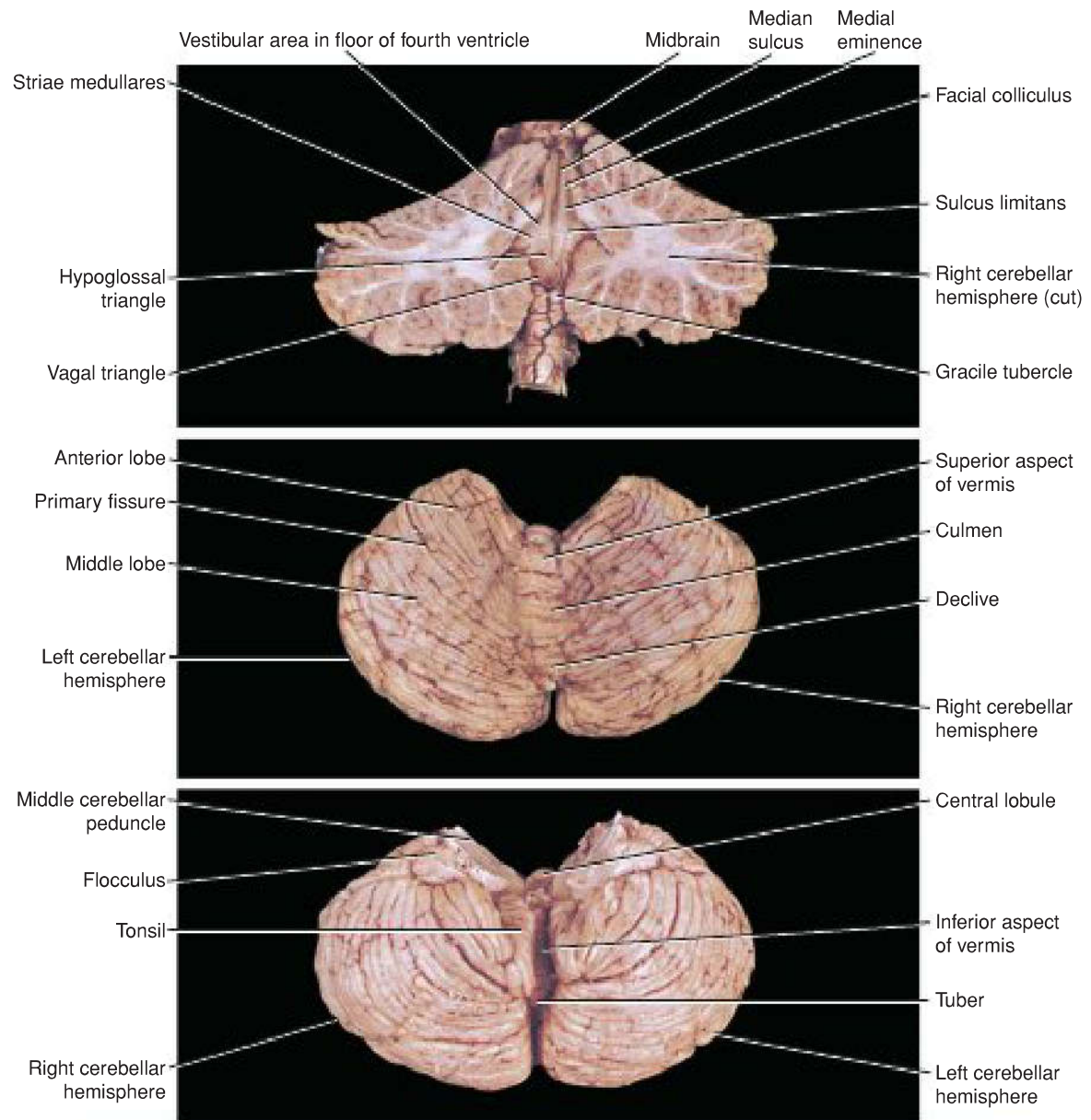


Figure CA-7 **Top:** Posterior view of the brainstem. The greater part of the cerebellum had been removed to expose the floor of the fourth ventricle. **Middle:** Superior view of the cerebellum showing the vermis and right and left cerebellar hemispheres. **Bottom:** Inferior view of the cerebellum showing the vermis and right and left cerebellar hemispheres.

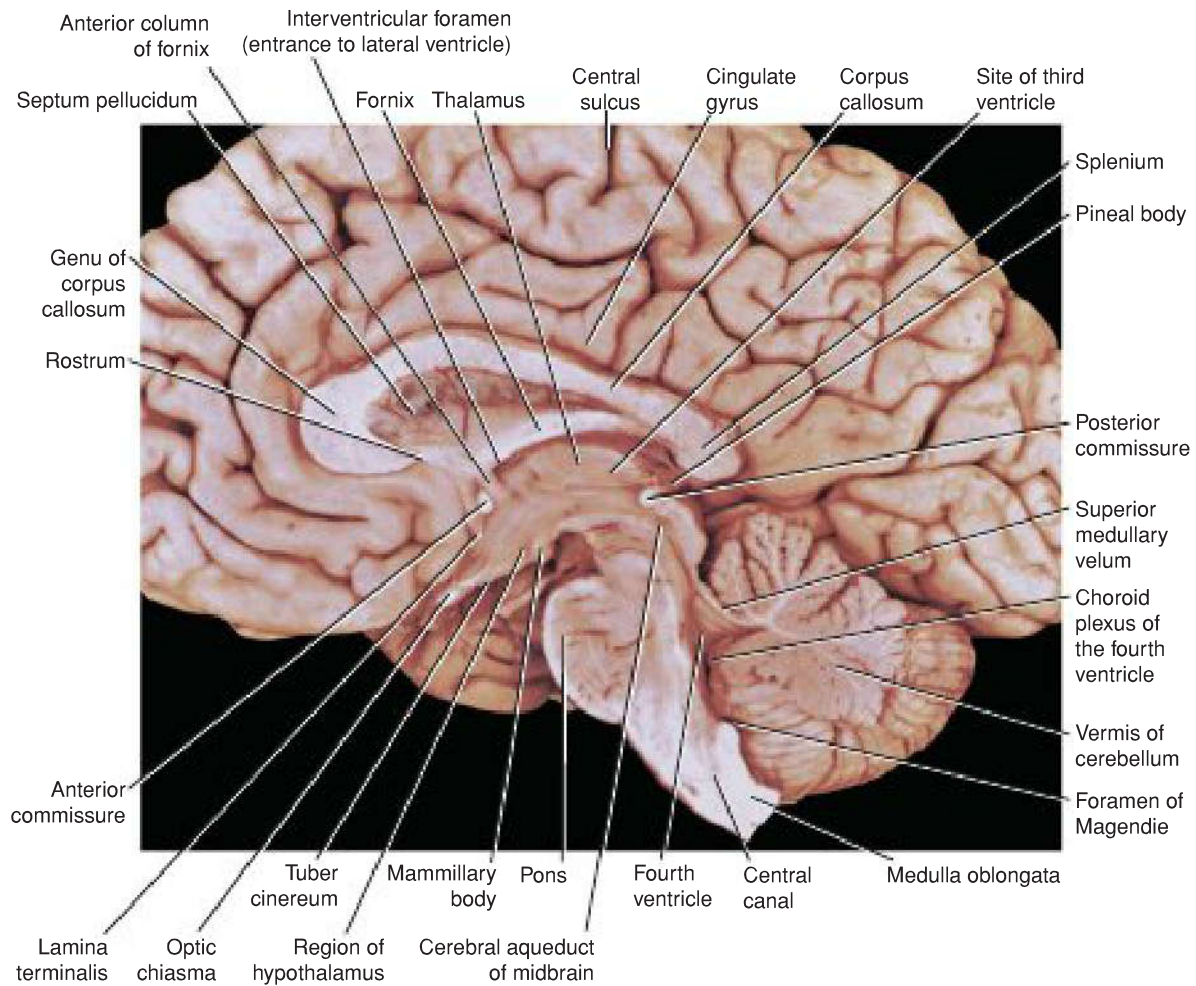


Figure CA-8 Enlarged medial view of the right side of the brain following median sagittal section, showing the continuity of the central canal, fourth ventricle, cerebral aqueduct, and the third ventricle and entrance into the lateral ventricle through the interventricular foramen.

1

Introduction and Organization of the Nervous System

CHAPTER OBJECTIVES

- To understand the basic organization of the main structures that form the nervous system
- To gain a three-dimensional appreciation of the parts of the brain and their relative positions to one another

A 23-year-old student is driving home from a party and crashes his car head-on into a tree. On examination in the emergency department of the local hospital, he has a fracture dislocation of the 7th thoracic vertebra, with signs and symptoms of severe damage to the spinal cord. Later, he is found to have paralysis of the left leg. Testing of cutaneous sensibility reveals a band of cutaneous hyperesthesia (increased sensitivity) extending around the abdominal wall on the left side at the level of the umbilicus. Just below this, he has a narrow band of anesthesia and analgesia. On the right side, he has total analgesia, thermoanesthesia, and partial loss of touch sensation of the skin of the abdominal wall below the level of the umbilicus and involving the whole of the right leg.

With knowledge of anatomy, a clinician knows that a fracture dislocation of the 7th thoracic vertebra can result in severe damage to the 10th thoracic segment of the spinal cord. Because of the small size of the vertebral foramen in the thoracic region, such an injury inevitably results in damage to the spinal cord. Knowledge of the vertebral levels of the various segments of the spinal cord enables the clinician to determine the likely neurologic deficits. The unequal sensory and motor losses on the two sides indicate a left hemisection of the cord. The band of anesthesia and analgesia was caused by the destruction of the cord on the left side at the level of the 10th thoracic

segment; all afferent nerve fibers entering the cord at that point were interrupted. The loss of pain and thermal sensibilities and the loss of light touch below the level of the umbilicus on the right side were caused by the interruption of the lateral and anterior spinothalamic tracts on the left side of the cord.

To comprehend what has happened to this patient, the relationship between the spinal cord and its surrounding vertebral column must be understood. The various neurologic deficits will be easier to understand after the reader has learned how the nervous pathways pass up and down the spinal cord. This information will be discussed in Chapter 4.

The nervous system and the endocrine system control the functions of the body. The nervous system is composed basically of specialized cells, whose function is to receive sensory stimuli and to transmit them to effector organs, whether muscular or glandular. The sensory stimuli that arise either outside or inside the body are correlated within the nervous system, and the efferent impulses are coordinated so that the effector organs work harmoniously together for the well-being of the individual. In addition, the nervous system of higher species has the ability to store sensory information received during past experiences. This information, when appropriate, is integrated with other nervous impulses and channeled into the common efferent pathway.

CENTRAL AND PERIPHERAL NERVOUS SYSTEMS

As shown in Figure 1-1, the nervous system is divided into two main parts, for purposes of description: the **central nervous system (CNS)**, which consists of the brain and spinal cord, and the **peripheral nervous system (PNS)**, which consists of the cranial and spinal nerves and their associated ganglia.

In the CNS, the brain and spinal cord are the main centers where correlation and integration of nervous information occur. Both the brain and spinal cord are covered with a system of membranes (**meninges**) and are suspended in **cerebrospinal fluid (CSF)**. Meninges are further protected by the bones of the skull and the vertebral column (Fig. 1-2).

The CNS is composed of large numbers of **neurons**, which are excitable nerve cells, and their processes,

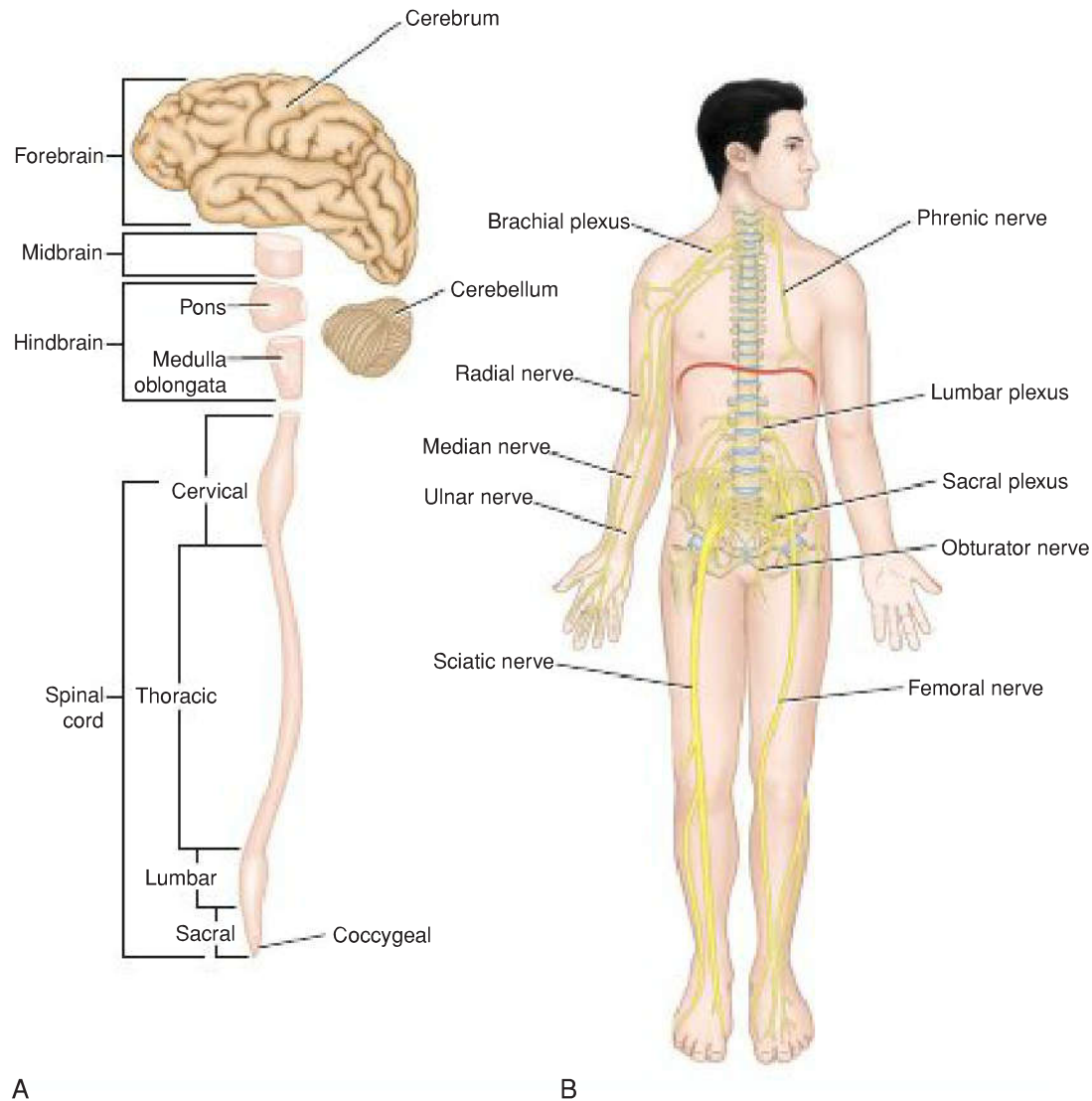


Figure 1-1 **A:** The main divisions of the central nervous system. **B:** The parts of the peripheral nervous system (the cranial nerves have been omitted).

known as **axons** or **nerve fibers**. Neurons are supported by specialized tissue called **neuroglia** (Fig. 1-3).

The CNS interior is organized into gray and white matter. **Gray matter**, which is gray in color, consists of nerve cells embedded in neuroglia. **White matter** consists of nerve fibers embedded in neuroglia and is white in color because of the presence of lipid material in nerve fiber myelin sheaths.

In the PNS, the cranial and spinal nerves, which consist of bundles of nerve fibers (or axons), conduct information to and from the CNS. Although the nerves are surrounded by fibrous sheaths as they run to different parts of the body, they are relatively unprotected and are commonly damaged by trauma.

Autonomic Nervous System

The autonomic nervous system (ANS) is the part of the nervous system that innervates the body's

involuntary structures, such as the heart, smooth muscle, and glands. It is distributed throughout the CNS and PNS and is divided into two parts, the **sympathetic** and the **parasympathetic**, both containing afferent and efferent nerve fibers. The activities of the sympathetic part of the ANS prepare the body for an emergency, whereas those of the parasympathetic part are aimed at conserving and restoring energy.

MAJOR DIVISIONS OF THE CENTRAL NERVOUS SYSTEM

Before proceeding to a detailed description of the spinal cord and brain, understanding the main features of these structures and their general relationship to one another is essential (Table 1-1).

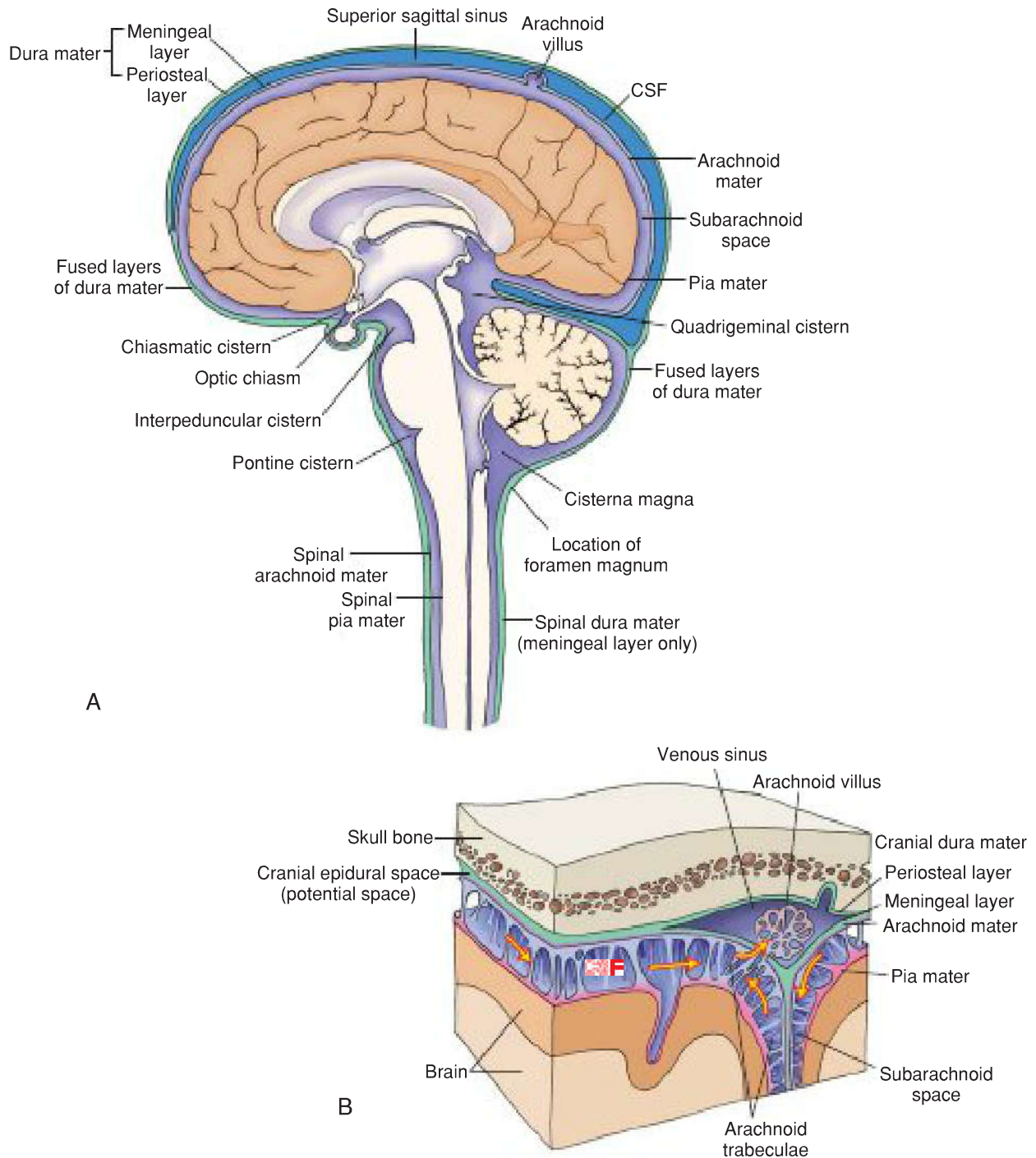


Figure 1-2 **A:** The protective covering of the spinal cord, the meninges, is formed by dura, arachnoid, and pia mater. The space between the arachnoid and pial membranes is called the subarachnoid space and contains cerebrospinal fluid (CSF). The subarachnoid space is enlarged at the cisterna magna and chiasmatic cistern. **B:** In the cranium, the dura consists of fused periosteal and meningeal layers that separate to form dural sinuses. Arachnoid mater projects into the dural venous sinuses to drain CSF from the subarachnoid space. (From Siegel, A., & Sapru, H. N. [2015]. *Essential neuroscience* [3rd ed.]. Baltimore, MD: Wolters Kluwer.)

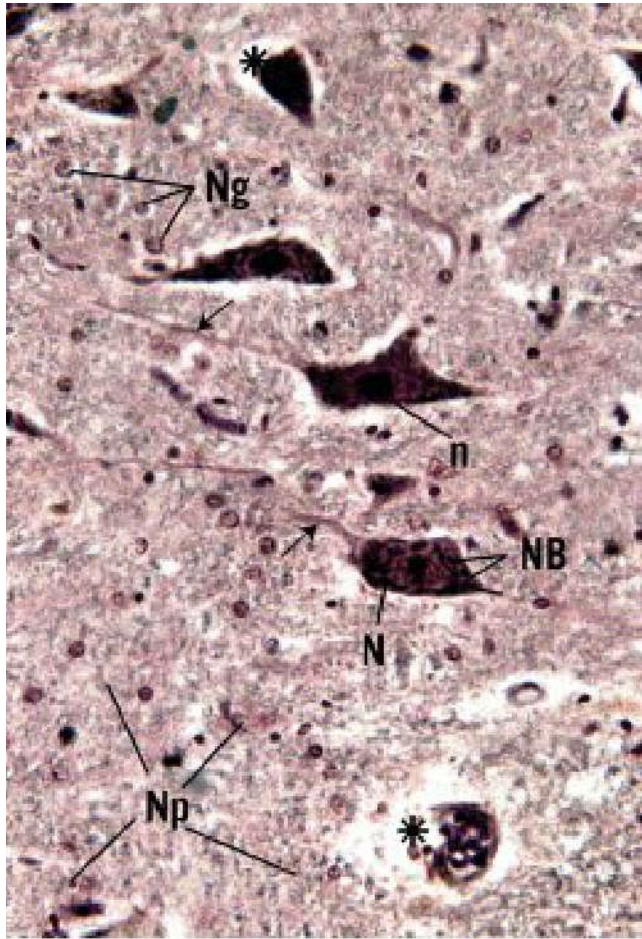


Figure 1-3 Photomicrograph of several large nerve cells with surrounding neuroglia. N, Neuron; n, nucleus; Ng, neuroglia; Np, neuropili; arrows, neurites. (From Gartner, L. P. [2017]. *Color atlas and text of histology* [7th ed.]. Baltimore, MD: Wolters Kluwer.)

Spinal Cord

The spinal cord is situated within the **vertebral canal** of the vertebral column and is surrounded by three meninges (Figs. 1-4 and 1-5): the **dura mater**, the **arachnoid mater**, and the **pia mater**. Further protection is provided by the **CSF**, which surrounds the spinal cord in the **subarachnoid space**.

The spinal cord is roughly cylindrical and begins superiorly at the foramen magnum in the skull, where it is continuous with the **medulla oblongata** of the brain. It terminates inferiorly in the lumbar region. Below, the spinal cord tapers off into the **conus medullaris**, from the apex of which the **filum terminale** (a prolongation of the pia mater) descends to attach to the back of the coccyx (see Fig. 1-4B).

Along the entire length of the spinal cord, 31 pairs of spinal nerves are attached by the **anterior** or **motor roots** and the **posterior** or **sensory roots** (Fig. 1-6; also see Fig. 1-5). Each root is attached to the cord by a series of rootlets, which extend the whole length of the corresponding segment of the cord. Each posterior

Central Nervous System

- Brain
 - Forebrain
 - Cerebrum
 - Diencephalon (between brain)
 - Midbrain
 - Hindbrain
 - Medulla oblongata
 - Pons
 - Cerebellum
- Spinal cord
 - Cervical segments
 - Thoracic segments
 - Lumbar segments
 - Sacral segments
 - Coccygeal segments

Peripheral Nervous System

- Cranial nerves and their ganglia—12 pairs that exit the skull through the foramina
- Spinal nerves and their ganglia—31 pairs that exit the vertebral column through the intervertebral foramina
 - 8 Cervical
 - 12 Thoracic
 - 5 Lumbar
 - 5 Sacral
 - 1 Coccygeal

nerve root possesses a **posterior root ganglion**, the cells of which give rise to peripheral and central nerve fibers.

Spinal Cord Structure

The spinal cord is composed of an inner core of **gray matter**, which is surrounded by an outer covering of **white matter**. The gray matter is seen on cross section as an H-shaped pillar with **anterior** and **posterior gray columns**, or **horns**, united by a thin **gray commissure** containing the small **central canal**. The white matter, for purposes of description, is divided into **anterior**, **lateral**, and **posterior white columns** (see Fig. 1-6).

Brain

The brain (Fig. 1-7) lies in the cranial cavity and is continuous with the spinal cord through the foramen magnum (see Fig. 1-5A). As shown in Figure 1-2, it is surrounded by the **dura mater**, the **arachnoid mater**, and the **pia mater**. These three meninges are continuous with the corresponding meninges of the spinal cord. The CSF surrounds the brain in the subarachnoid space.

The brain is conventionally divided into three major divisions: the **hindbrain**, the **midbrain**, and the **forebrain** in ascending order from the spinal cord (see Fig. 1-1A). The **brainstem** (a collective term for the

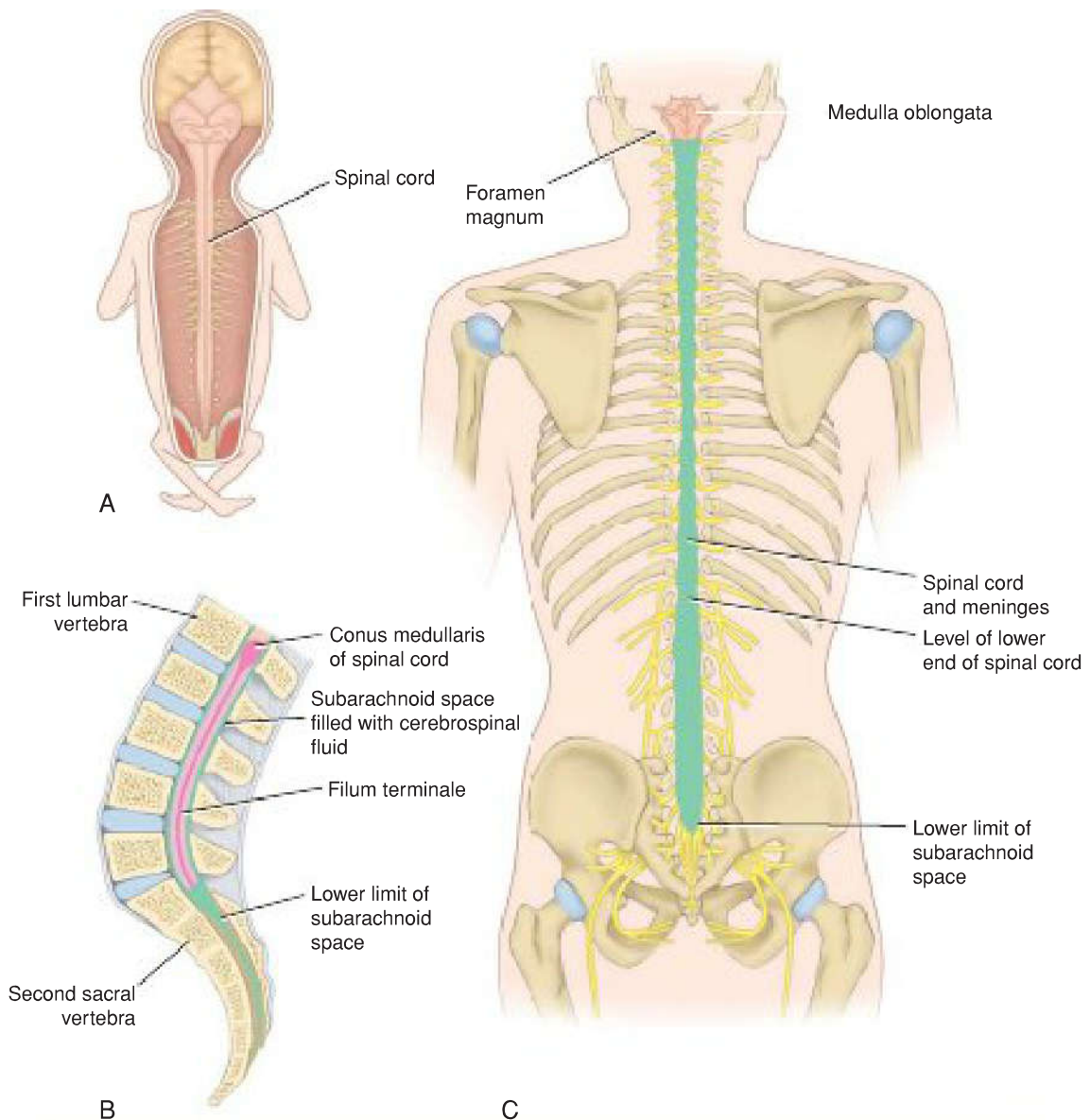


Figure 1-4 **A:** Fetus with the brain and spinal cord exposed on the posterior surface. Note that the spinal cord extends the full length of the vertebral column. **B:** Sagittal section of the vertebral column in an adult showing the spinal cord terminating inferiorly at the level of the lower border of the 1st lumbar vertebra. **C:** Adult spinal cord and covering meninges showing the relationship to surrounding structures.

medulla oblongata, pons, and midbrain) is what remains after the cerebral hemispheres and cerebellum (see below) are removed.

Hindbrain

The hindbrain comprises the **medulla oblongata**, the **pons**, and the **cerebellum**.

Medulla Oblongata

The medulla oblongata is conical in shape and connects the pons superiorly to the spinal cord inferiorly (Fig. 1-8). It contains many collections of neurons, called **nuclei**,

and serves as a conduit for ascending and descending nerve fibers.

Pons

The pons is situated on the anterior surface of the cerebellum, inferior to the midbrain and superior to the medulla oblongata (Fig. 1-9; also see Fig. 1-8). The pons, or bridge, derives its name from the large number of transverse fibers on its anterior aspect connecting the two cerebellar hemispheres. It also contains many nuclei and ascending and descending nerve fibers.

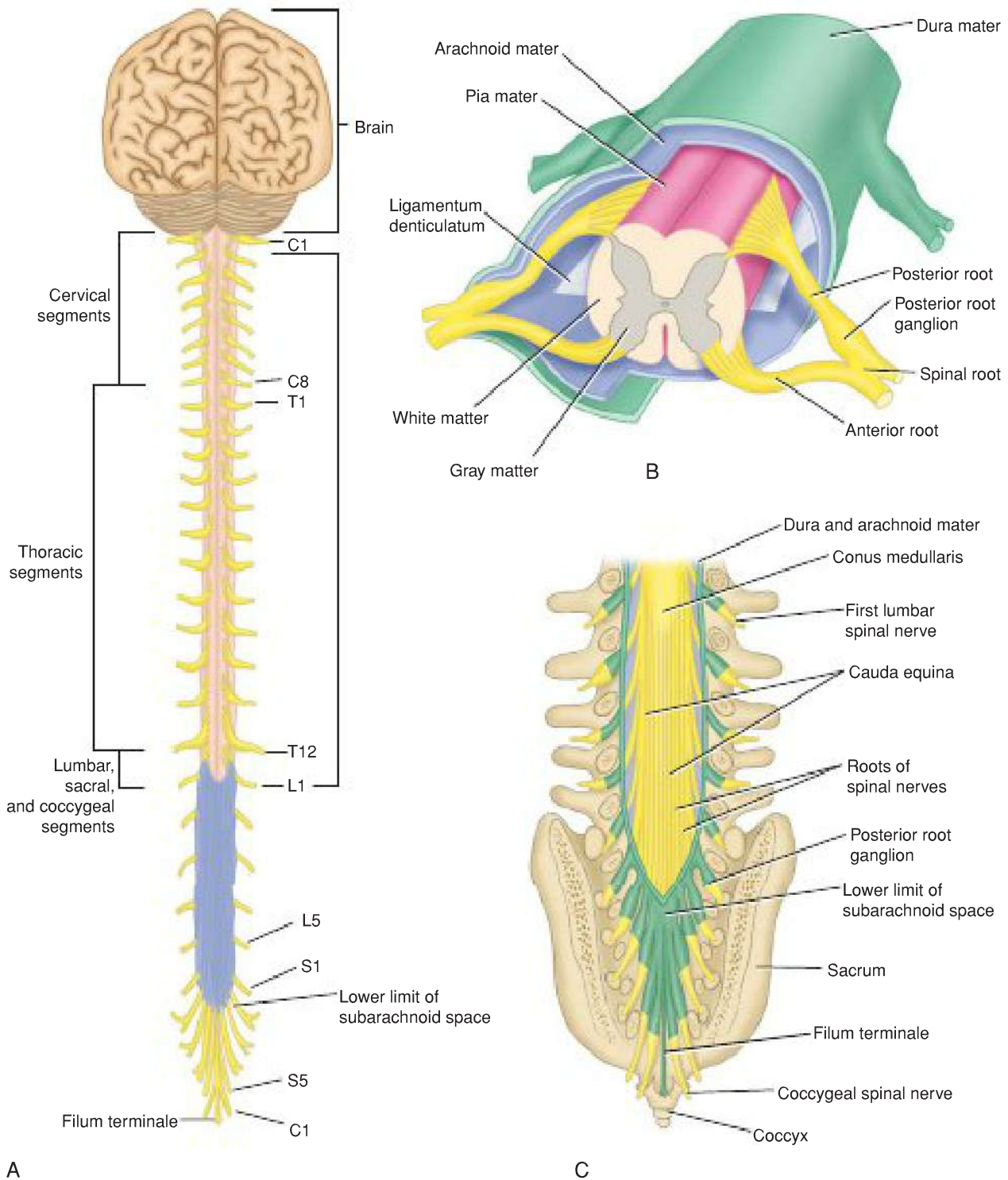


Figure 1-5 **A:** Brain, spinal cord, spinal nerve roots, and spinal nerves as seen on their posterior aspect. **B:** Transverse section through the thoracic region of the spinal cord showing the anterior and posterior roots of a spinal nerve and the meninges. **C:** Posterior view of the lower end of the spinal cord and cauda equina showing their relationship with the lumbar vertebrae, sacrum, and coccyx.

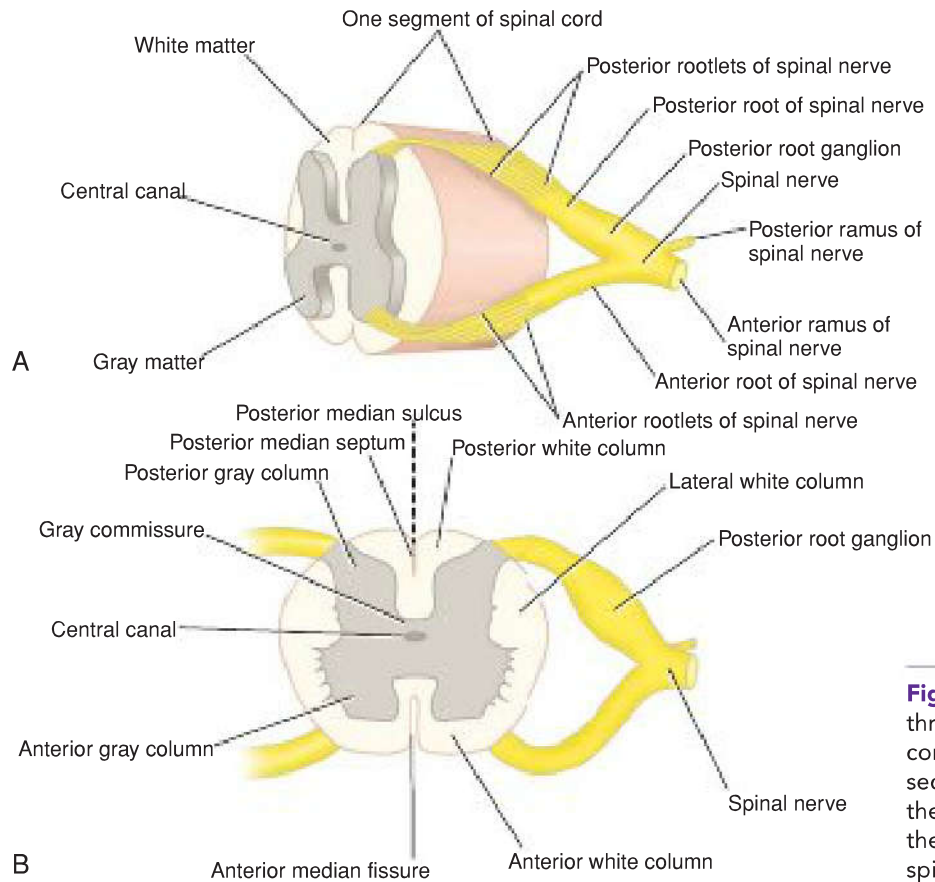


Figure 1-6 **A:** Transverse section through the lumbar part of the spinal cord, oblique view. **B:** Transverse section through the lumbar part of the spinal cord, face view, showing the anterior and posterior roots of a spinal nerve.

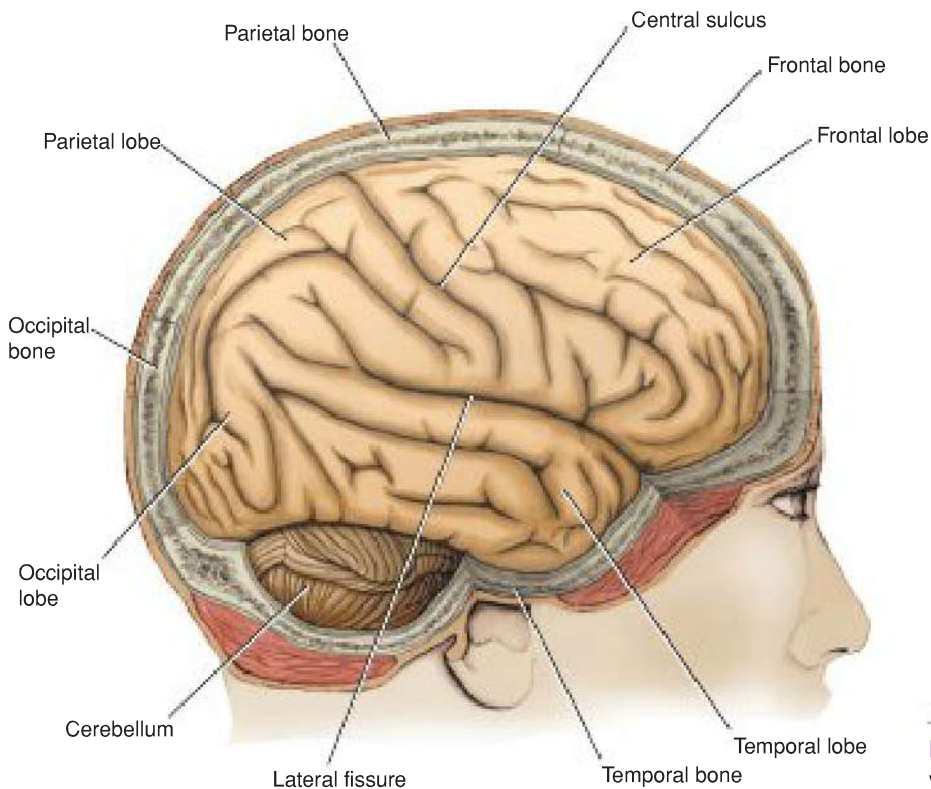


Figure 1-7 Lateral view of the brain within the skull.