Clinical Neuroscience for Communication Disorders

NEUROANATOMY AND NEUROPHYSIOLOGY

SECOND EDITION

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Preface: How to Use This Textbook

Thank you for choosing the second edition of *Clinical Neuroscience for Communication Disorders: Neuroanatomy and Neurophysiology*. The intent of this tutorial is to briefly describe and demonstrate the organization of chapters, which follow the format as discussed next with a few exceptions (e.g., the cases chapter [Chapter 16]). Understanding the organization may help both course instructors and students to best utilize the resources.

Initial paragraph ties content to clinical applications. Each chapter begins with an application to everyday clinical practice for speech-language pathologists, audiologists, and related professionals. Clinical applications are intuitive for many of the chapters/topics, but we do our best to connect the dots in those chapters and provide content where the connection might not be as obvious.

Our **customized illustrations** help solidify connections between anatomy and physiology. This is accomplished through

- a variety of views and perspectives (superior/inferior, dorsal/ventral, sections—coronal/transverse/sagittal, frontal/lateral/posterior);
- resections/cutaway illustrations to visualize deep, difficult to see or visualize structures;
- close-up (magnified) pullout illustrations of small sections of a structure along with the broader view of the structure itself for context;
- structures in situ (within the larger structure, which is transparent to allow you to see the deeper structure); and
- schematics, depicting sequences or processes, systems or networks.

In addition, we intentionally use both left and right hemisphere views throughout the book. This is done to implicitly support the message made explicit in Chapter 14 that both hemispheres play critical roles in communication.

We highlighted foundational concepts and terminology by **bolding keywords** throughout as well as including Latin and Greek word origins and meanings. In the second edition, these bolded words are accompanied by a **glossary of terms** found at the end of the book.

Tables. Help sort out complex, multicomponent anatomy, physiology, and networks.

Examples		
Structure		
Blood supply		
Innervation		

Boxes. A place for applying learning.

Applications—These include everyday examples such as hitting your funny bone, which help tie anatomy and physiology with practical experiences.

Key terminology and concepts—Whenever there are numerous key terms necessary to understand broader concepts, a mini-glossary is included to define terms and concepts.

Exercises—Some applications include mini-labs or experiments you can conduct on yourself or a friend. These include things such as mapping your sensory receptor fields.

Clinical cases—Those embedded within each chapter are typically abridged to highlight the concepts of the chapter (e.g., hemorrhagic stroke, consequences of cerebellar damage). Expanded versions of key cases are included in the clinical cases chapter (Chapter 16) to provide more opportunities to interact with foundational concepts. Expanded cases also include guiding questions and an answer key for instructors/students. The broad intent of cases is to solidify understanding of content knowledge and make direct applications to clinical practice. This provides an initial exposure to the process of localization and differential diagnosis, preparing learners for much deeper learning about diagnostics and interventions within their future disorder-based coursework.

The appendix. This provides a review of anatomical foundations typically covered in-depth in courses and texts on anatomy and physiology of the speech and hearing mechanism. This is particularly helpful to use in combination with Chapter 11 to remind students of the head and neck musculature.

The glossary. This provides definitions and etymologies of the bolded words found throughout the text.

The oral mechanism examination. Although not intended to be a replacement for a fully comprehensive and exhaustive oral mechanism exam for all types of clients and situations, this element of Chapter 11 ties anatomy directly to an application for our profession. Ties to clinical assessment of swallowing are also presented briefly here.

The neuroplasticity chapter (Chapter 15). This chapter connects readers to key principles of contemporary neuroscience, particularly extensions to everyday practice and broad support for habilitation and rehabilitation.

The communication and cognition chapter (Chapter 14). This chapter is broader than the typical language application chapter found in neuroscience books for communication disorders. We expanded this to address two areas that typically receive little attention in similar books, namely, right hemisphere contributions to communication and developmental cognitive communication disorders . Motor speech disorders are covered in Chapters 10 and 11.

The cases chapter (Chapter 16). Mentioned previously, this is cross-referenced within and across chapters.

Summary. At the end of each chapter, there is a plain-language summary that highlights key concepts within the chapter. Some learners may wish to begin there by reading the summary and key concepts before delving into the content, and then returning to it at the end of the chapter.

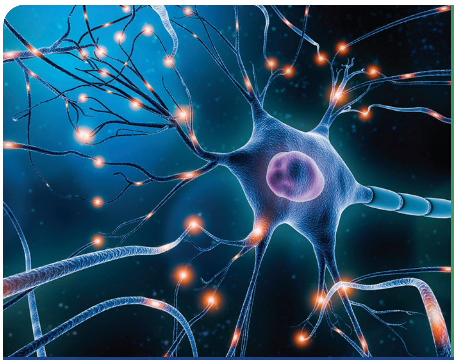
Key concepts.

1. A bulleted list is included at the end of each chapter to highlight key concepts and learning outcomes.
2. For students: at minimum, you should be sure to understand these key concepts. If you do not, we suggest that you return to the chapter resources provided by your instructor (recorded lectures/screencasts, animations, supplementary readings), and ask your peers/instructors to clarify questions.

References and additional resources. In some cases, these items are referenced directly in the text, whereas others are useful resources to augment your learning.

Chapter study guides. Study guides are a new addition to the second edition. They include image labeling and fillable spaces for definitions and descriptions. The chapter study guides can be found on the PluralPlus Companion Website.

Final note. The order of the chapters is based on how we teach neuroanatomy and physiology, but in some cases, the order is a bit arbitrary. Instructors can choose to assign chapters in the order that best fits their conceptualization and teaching style. Each chapter has references to others for more information, so you can easily find background or in-depth information if you teach the chapters in a different order.



1

Overview of the Nervous System

CHAPTER OUTLINE

Learning Objectives

1. Identify and describe the structures of the central versus peripheral nervous systems and their functions.
2. Describe cytoarchitectural and functional organization schemes for the nervous system.
3. Define and use anatomical terminology to refer to structures and locations in the nervous system.
4. Describe the structure and function of neurons.
5. List different types of glial cells and their functions.
6. Identify and describe the location and function of structures and regions in the central nervous system including the cerebral lobes, subcortical structures, cerebellum, brainstem, and spinal cord.

Overview

Welcome to *Clinical Neuroscience for Communication Disorders*. We are excited to share foundations in neuroanatomy, physiology, and contemporary neuroscience, while making connections to the everyday practices of speech-language pathologists and audiologists. Throughout this book, you will find clinical cases and everyday applications that connect neuroanatomy and physiology to development (both typical and disrupted), aging (both typical and disrupted), and acquired neurological disorders.

The nervous system can be divided into structures and regions that are anatomically or functionally distinct. This chapter provides an overview of the major components and their functions as well as common terminology. Everything that is mentioned here is discussed in more detail in later chapters of the book. You can think of this as a quick tour so you know your way around the nervous system to prepare you to dive in deeper.

Major Components

The human nervous system can be broken down into two major components: the central nervous system (CNS) and the peripheral nervous system (PNS). The **central nervous system** includes the brain and spinal cord. The word *brain* is commonly used to refer to a collection of several major structures: the right and left cerebra (cerebrum), otherwise known as the two hemispheres; the brainstem; and the cerebellum. All are encased within the **cranium** (Figure 1–1). At the point where the brainstem exits the skull through the **foramen magnum**, the structure becomes the spinal cord. The spinal cord extends down through the spinal canal, the protective "tunnel" created by the stacked vertebrae.

A slice through the CNS—whether in the brain or spinal cord—will show dark and light areas, referred to as **gray matter** and **white matter**, respectively (Figure 1–2). The gray matter is made up of **cell bodies**. The white matter is made up of extensions from those cell bodies called **axons** (discussed later; see also Chapter 3). The cell bodies generate signals that are sent down the axons to another cell. In the brain, the gray matter makes up the outer, superficial surface called the **cortex** (Latin: "tree bark") as well as several collections of cell bodies (called **nuclei** or ganglia) deep in the brain. In the spinal cord, the arrangement is reversed, so the gray matter is deep (internal) and surrounded by white matter. As a general rule, gray matter processes information, and white matter transmits signals.

The slice through the CNS also will reveal cavities of the ventricular system (see Chapter 2). The ventricles are filled with cerebrospinal fluid (CSF), which provides nutrients as well as protection. Two other structures that

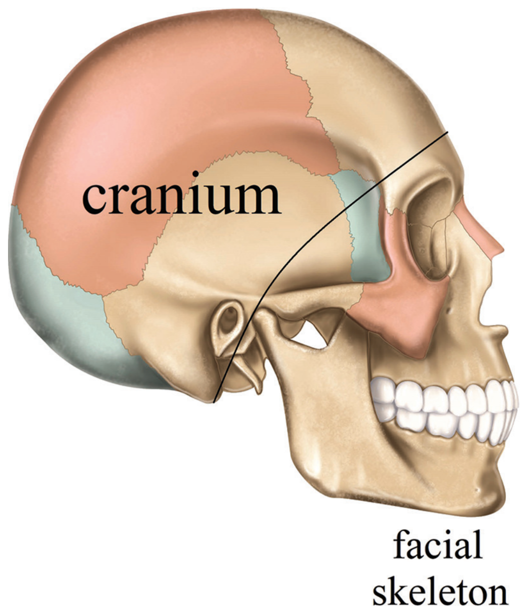


FIGURE 1–1. Cranium and facial skeleton.

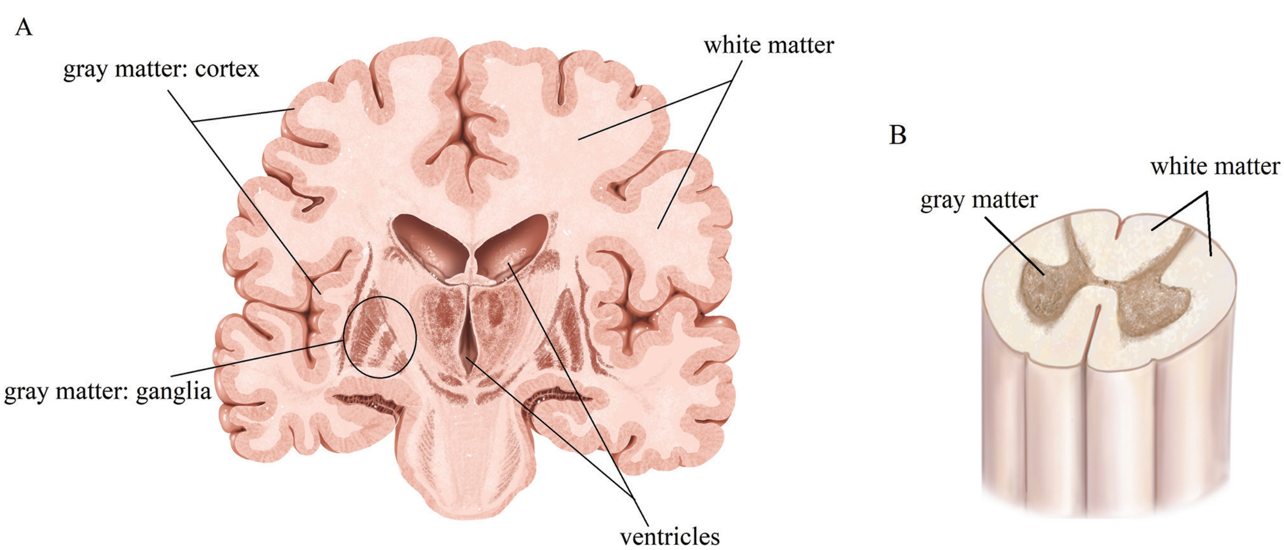


FIGURE 1–2. Gray and white matter in the brain (**A**) and spinal cord (**B**).

provide protection are the meninges and the bony encasing (Figure 1–3). The meninges (see Chapter 2) are a set of three tissue layers that cover the entire brain and spinal cord and provide a space for CSF to surround the CNS structures. The combination of the tissues and the fluid limits the movement of the brain and spinal cord. Superficial to

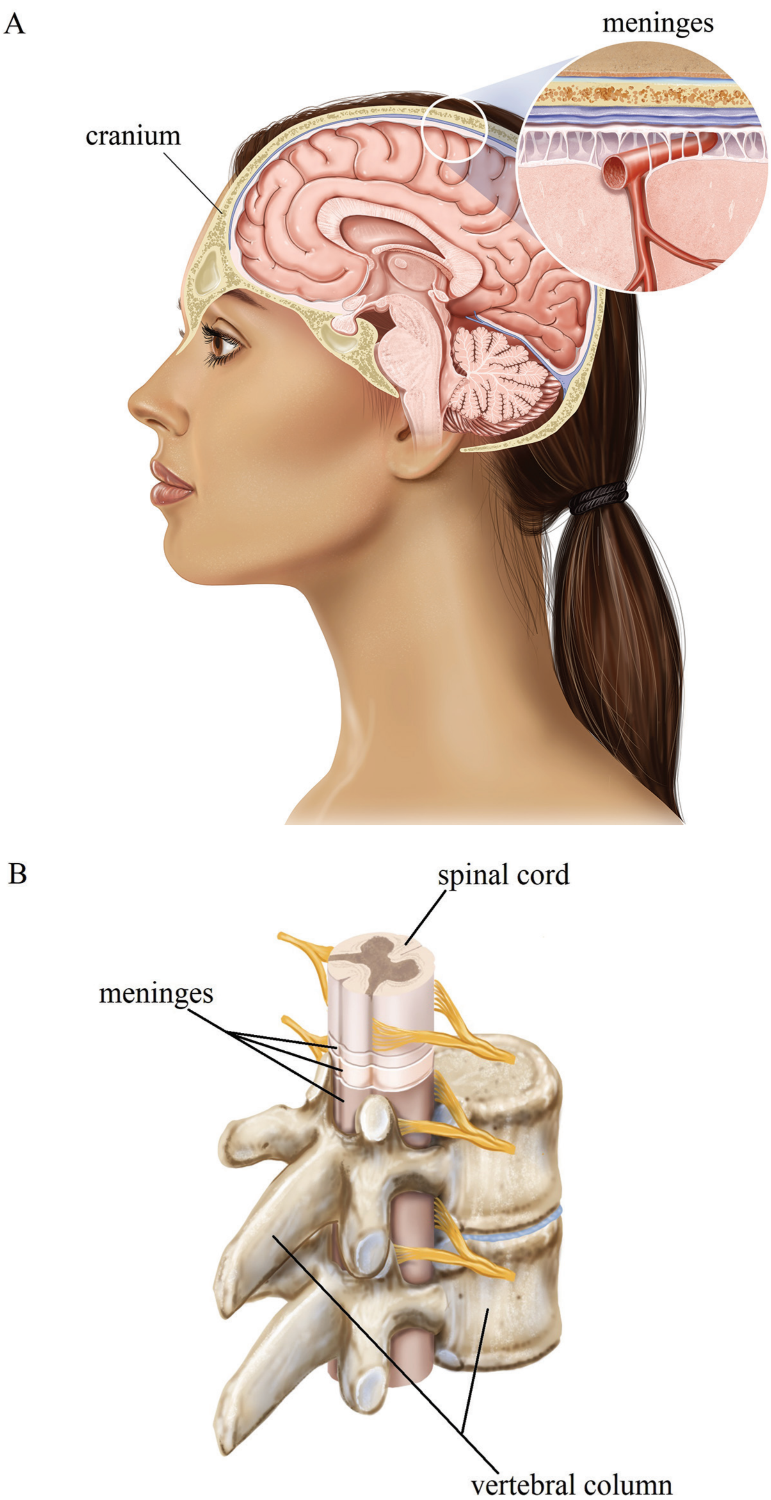


FIGURE 1–3. Meninges and bony casing for brain (**A**) and spinal cord (**B**).

the meninges is the bony structure. The cranium encases the brain, and the vertebral column surrounds and protects the spinal cord.

The PNS consists of all of the nerves that exit from the brainstem and spinal cord. These extend out into the body (the periphery) to innervate muscles, organs, and tissues of the body (Figures 1–4 and 1–5). Twelve pairs of cranial nerves exit from the brainstem and innervate structures of the head and neck. Thirty-one pairs of spinal nerves exit from the spinal cord and innervate the structures below the neck.

The PNS can be further divided into functional subsystems. The somatic (Greek: *soma* = "body") nervous system innervates skeletal muscles and is primarily responsible for conducting signals regarding body sensation and movement. The autonomic (Greek: "having one's own laws; independent") nervous system is responsible for unconscious control of body systems. It can be subdivided into the sympathetic and parasympathetic nervous systems. The sympathetic system prepares the body for "fight, flight, or freeze": When encountered with an emergency or crisis situation, the sympathetic nervous system will divert blood flow from unnecessary regions (e.g., the digestive system) to muscles and to the CNS to heighten perception, speed up response times, and facilitate muscle movements. The parasympathetic system returns the body to homeostasis (Greek: "same, steady") or to baseline levels once the crisis has passed.

Unlike the CNS, the PNS is not protected by either a layer of tissue or a bony structure. The nerves exit from the spinal cord and extend out to the organs, tissues, and muscles of the body.

Box 1–1. That's Not So Funny

When you "hit your funny bone," you actually are hitting a nerve of the PNS. The ulnar nerve extends from the spinal cord and travels along the arm out to the medial portion of the hand, including the pinky and ring fingers. When you hit your elbow just right, you compress the ulnar nerve, resulting in a painful tingling sensation. Because the PNS is not protected by a bony structure, the nerves can be impacted by everyday actions.

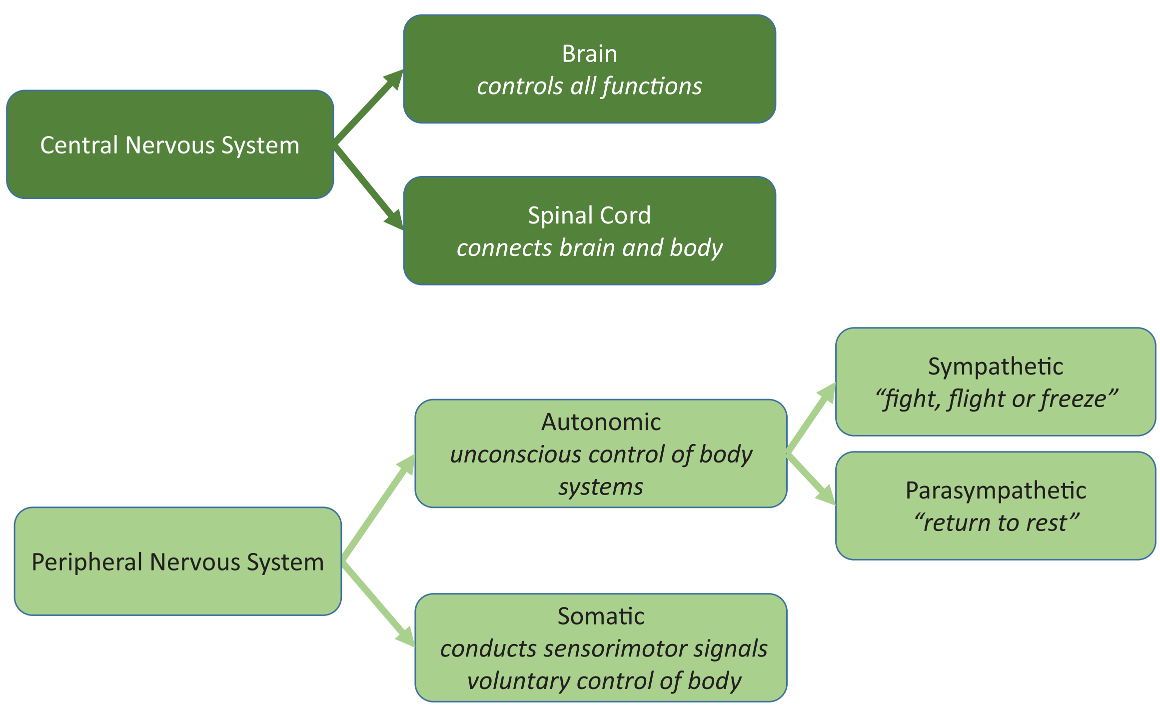


FIGURE 1–4. Schematic of the central and peripheral nervous system components.

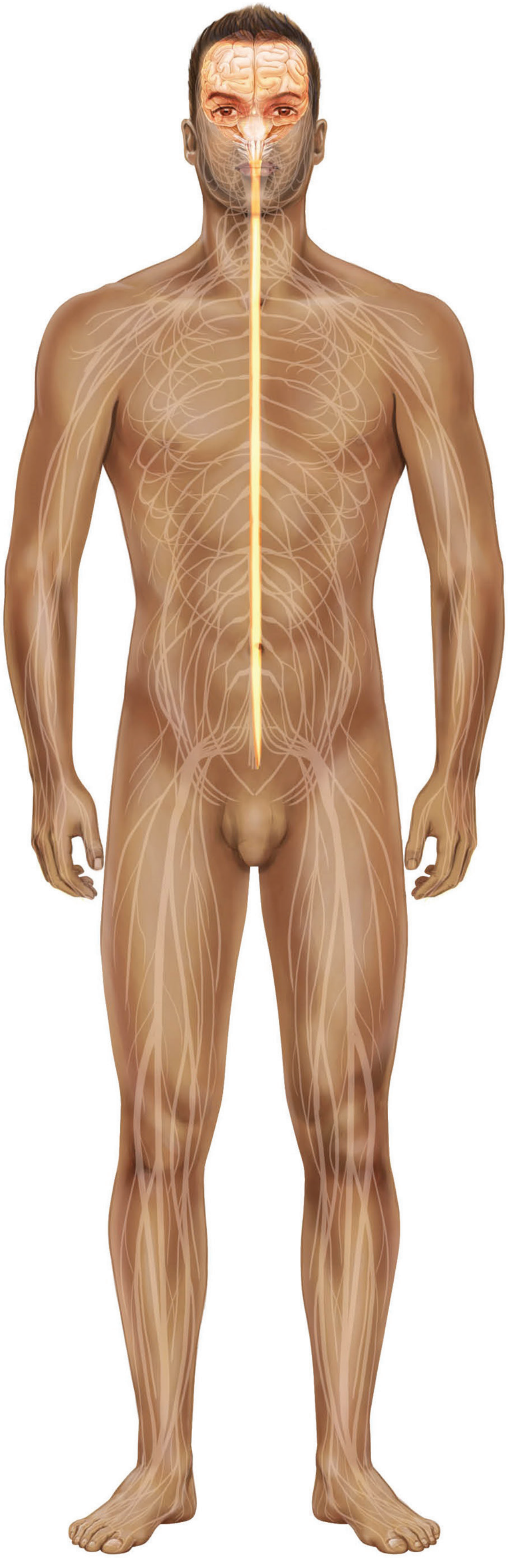


FIGURE 1–5. Peripheral nervous system. The central nervous system (brain and spinal cord) is highlighted. All nerves exiting from the brainstem and spinal cord make up the peripheral nervous system.

Organization of the Nervous System

The nervous system is organized in several different ways. Along the vertical (superior–inferior) axis, there are both structurally and functionally distinct sections. In addition, there are functional differences along the horizontal (right–left) axis.

There is a hierarchy of complexity along the vertical axis. Beginning from the bottom and moving superiorly, the spinal cord primarily serves as a conduit for signals and controls only the most basic sensorimotor functions—reflexes. The brainstem controls autonomic and visceral systems. These are of the utmost importance for keeping your body alive because they regulate heart rate and respiration, but they are not part of the "thinking brain." Integration of signals begins in the brainstem, such as integration of auditory signals from the left and right ear and integration of auditory with visual signals. The diencephalon extends superiorly from the brainstem and is involved in not only relaying signals coming up from the spinal cord but also integration of signals from multiple sources (see Chapter 5). Some cognitive processing occurs in the diencephalon, although this is not well understood. Finally, the **cerebrum** is responsible for complex sensory and motor integration, perception, and cognitive functions such as planning, organization, reasoning, language, and emotions (see Chapter 14).

Organizational Systems

The hemispheres of the brain have been subdivided in multiple ways. Broadly, they are divided into lobes (frontal, parietal, occipital, and temporal; Figure 1–6), each with a variety

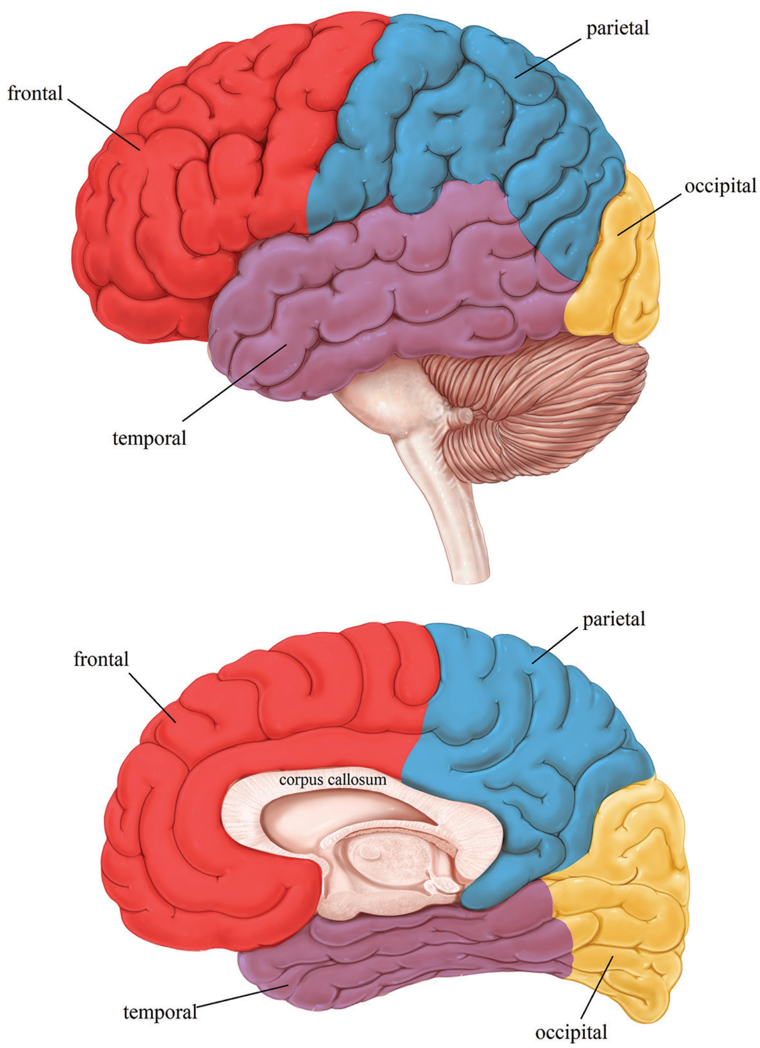


FIGURE 1–6. Lobes of the brain.

of functions, many of which (e.g., reading, social interacting) require input and integration from multiple lobes.

Cytoarchitecture Organization

The cortex (outer layer of gray matter in the hemispheres) is made up of six layers of cells. The thickness of the individual layers varies across regions of the brain. Layers III (cortex-to-cortex connections) and IV (thalamus-to-cortex connections) are particularly important for signaling within the cerebrum (Blumenfeld, 2010; Shipp, 2007; Figure 1–7). In 1909, Korbinian Brodmann published a numbered map of the cortex based on the cellular organization (Figure 1–8). The implication of the map was that cellular organization was linked to function: Each numbered area had a different function. Although the map is not perfect, functional differences are related to cellular structures. Throughout this book, Brodmann areas are noted for areas commonly identified by the numbers.

Organization by Function

Another way to describe organization of the CNS is by function. CNS regions can be subdivided into those that control movement (motor) and body sensation (somatosensory), special senses (visual, auditory, vestibular, taste, smell), language, and higher level cognition. There are several principles that govern functional organization. First, throughout the CNS, motor areas tend to be located more anteriorly, and sensory areas are located more posteriorly (see Chapter 4). Second, sensory and motor functions are controlled contralaterally. This means that the right side of the brain controls the left side of the body and vice versa. Third, the cortex contains **primary**, **secondary** (**association**), and **tertiary** (**heteromodal**) areas. **Primary regions** are the core and initial location of processing. For example, in the auditory system, all input is processed initially in the primary auditory area in the superior temporal lobe. Further processing then occurs in **association areas** where there is integration of multiple aspects of signals (e.g., pitch and intensity and duration) as well as integration across modalities (e.g., linking visual with auditory signals to determine what object is creating a sound). The heteromodal areas are characterized by multimodal inputs and functions. The highest order areas of the brain, such as the prefrontal and limbic cortices, are heteromodal.

Primary processing areas are precisely organized based on a relevant principle. The organizing principle for motor and sensory areas is **somatotopy**. This means that they are arranged in reference to the body (soma). As shown in Figure 1–9, regions of the body are controlled by different areas within the primary motor and sensory areas. The resulting map, shown in Figure 1–10, is called a homunculus (Latin: "little human"). As you can see, the repre-

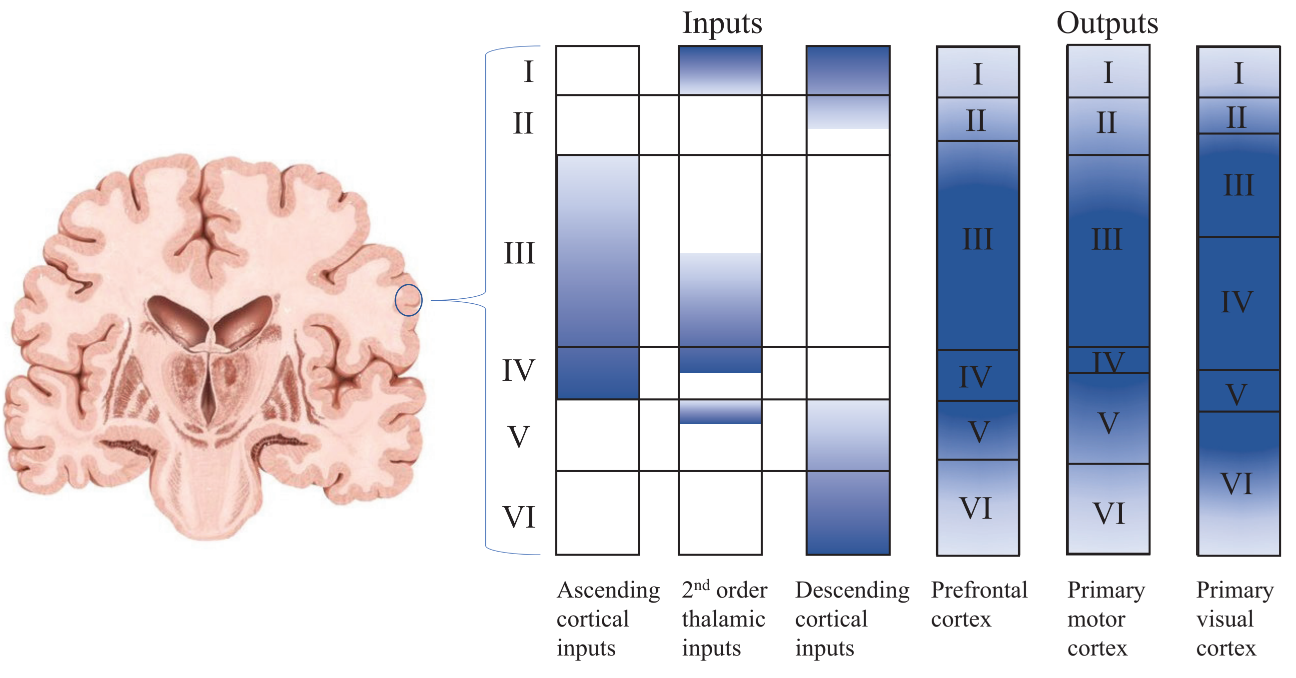


FIGURE 1–7. Cortical layers and connections.