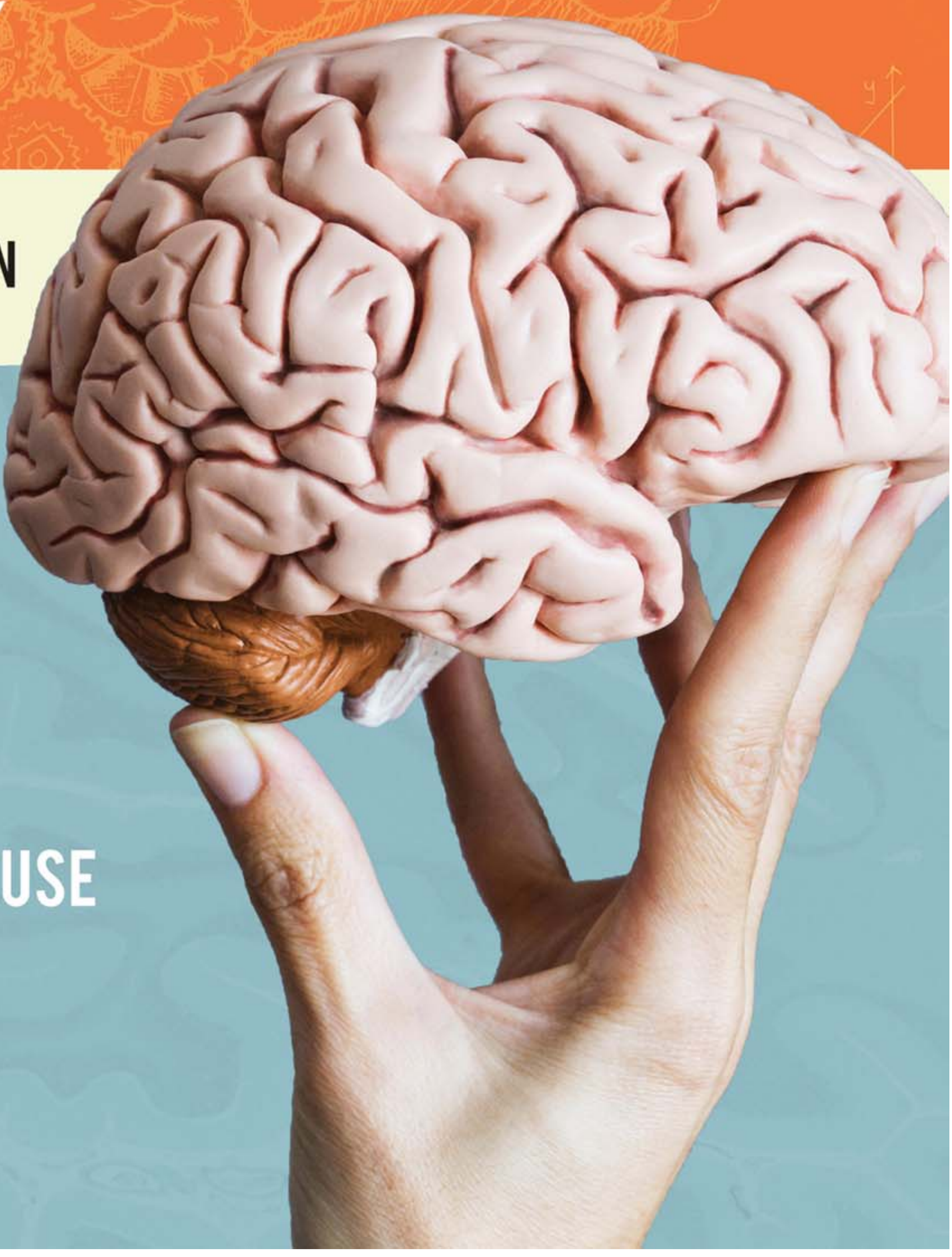
NEUROANATOMY

FOR SPEECH-LANGUAGE PATHOLOGY AND AUDIOLOGY

SECOND EDITION



MATTHEW H. ROUSE

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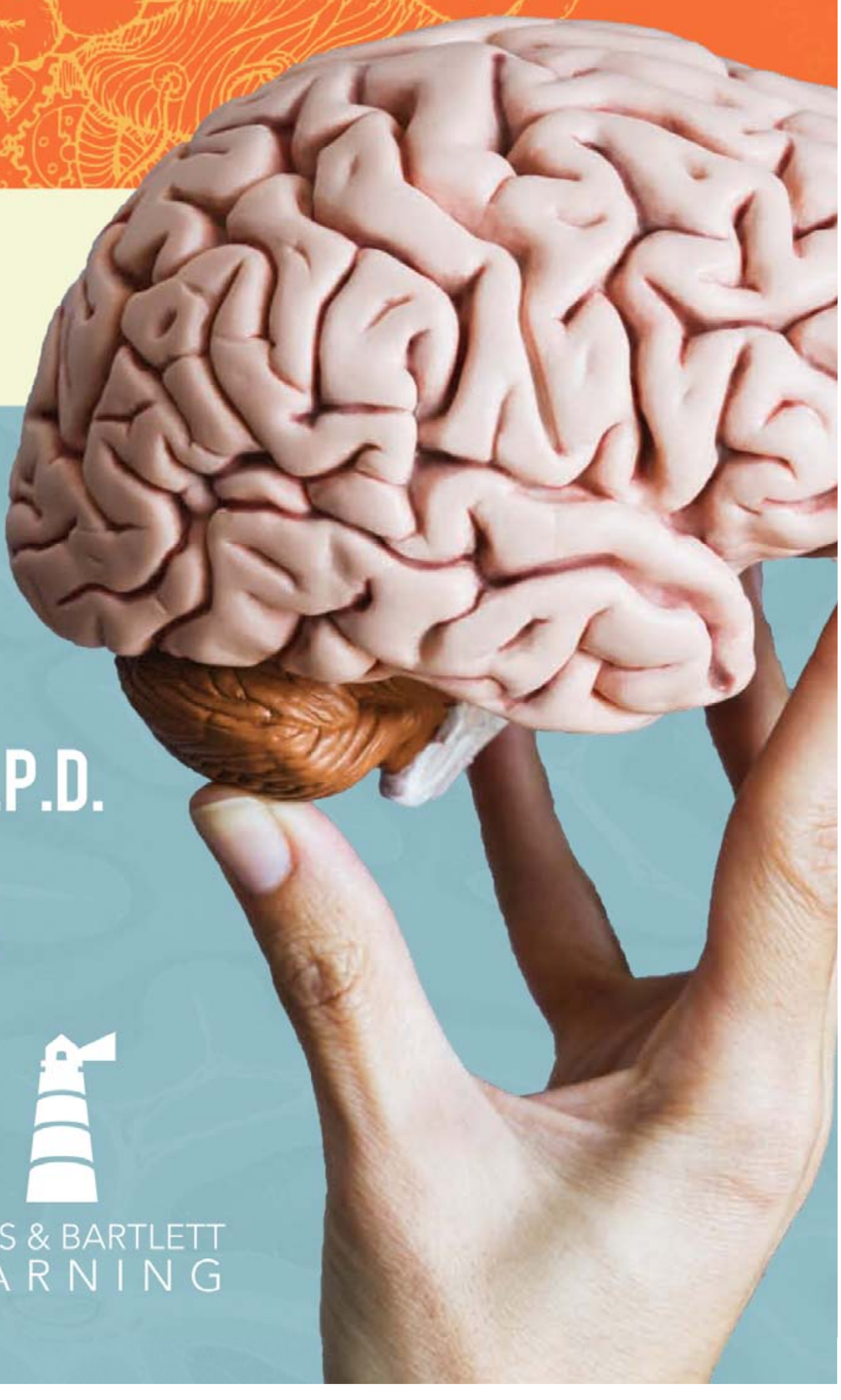

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This book is dedicated to three sets of people:

To my wife, Chrissie, and my daughters, Torie and Lexie… thank you for your gracious gift of time to complete this work.

To my parents… thank you for your years of love, commitment, and encouragement.

To my neuroanatomy students… thank you for your feedback. You have all made this text better.

Brief Contents

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Preface

This text is primarily intended for graduate students studying communication sciences and disorders, but it is also written in an accessible way for junior or senior undergraduates preparing for graduate school. It is more important than ever for communication science and disorders students to understand the neurological underpinnings of communication disorders. As I think back on my own education, I did not have a standalone neuroanatomy class in either my undergraduate or graduate communication sciences and disorders training. At that time, this kind of information was imbedded over the span of a couple of weeks in an undergraduate anatomy of speech and hearing course. After graduate school, I entered the profession as a medical speech-language pathologist at a regional trauma center. It was here that I was challenged to learn about a variety of neurological disorders that I had previously learned little about. It has been over a quarter century since I completed my master's studies, and a lot has changed since that time. Now, nearly all graduate training programs have a full class in neuroscience to help students better understand, assess, and treat people with neurogenic communication disorders.

This text was born after a 15-year search for a neuroscience book focused on communication and communication disorders for my class. I adopted general neuroscience texts written by neurologists and neuroscientists, but I was unhappy with the lack of discussion about communication and communication disorders. I also tried texts written by communication scientists and others in communication disorders, but I found these to resemble the general neuroscience texts with some discussion of communication disorders sprinkled in here and there. Often, robust discussions of language or swallowing were entirely missing. I mentioned this frustrating search to a salesperson from Jones & Bartlett Learning, who asked "Have you ever thought about writing one?" The seed was planted and I realized that it was time to stop complaining and produce something that would at *least* help me in my class. My hope is that this text will be helpful to those of you who also teach this subject matter as well as helpful to your students.

Organization of the Text

Neuroanatomy for Speech-Language Pathology and Audiology is organized into four main sections. The first three chapters, comprising Part I, Introductory Issues, introduce readers to the nervous system. Chapter 1 starts this process by taking the reader into the world of the nervous system. Important terms like *neurology* and *neuropathology* are explored, as well as the classification of neurological disorders and a brief introduction to the history of neuroscience. An introduction to imaging technology is included in this chapter because professionals in communication sciences and disorders are consumers of the reports generated by these studies. Chapter 2 introduces some basic orientation terms that will help in navigating around neurological structures as well as three methods for organizing the nervous system. Chapter 3 surveys the development of the neurological system through the life span, from conception to the last years of life.

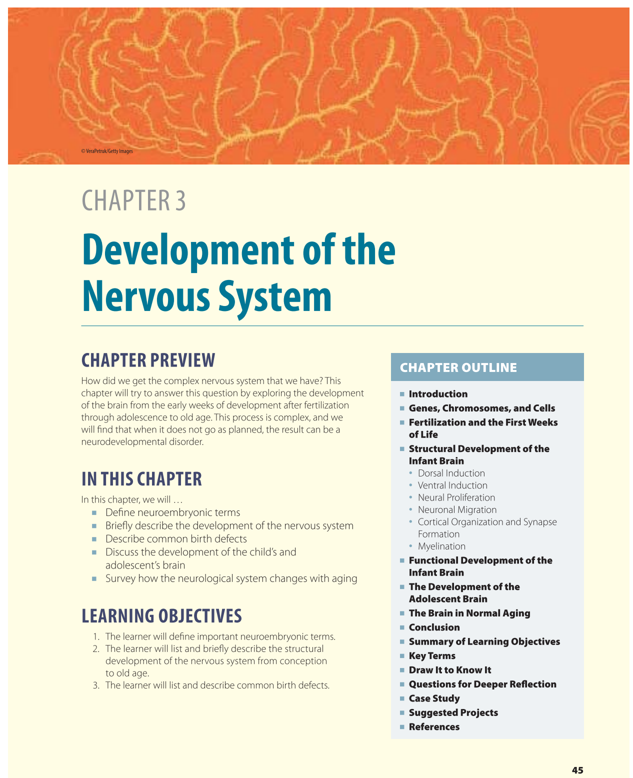
Part II, General Neuroanatomy, includes Chapters 4 through 8. These chapters introduce the reader to the main neurological structures. This journey begins with the cells of the nervous system and ends with a review of the cerebral hemispheres. In Chapter 4, we take a microscopic approach and discuss the cells of the nervous system, both their structure and function. Chapter 5 zooms out to begin a macroscopic journey around the neurological structures (i.e., structures we can see and examine with the naked eye). More specifically, it looks at the spinal cord, brainstem, cranial nerves, and cerebellum. A close inspection of the 12 cranial nerves will occur in this chapter. The journey continues in Chapter 6 by examining structures above the brainstem and inside the brain—namely, the diencephalon and the surrounding thalamic structures and structures in close proximity, such as the brain's ventricles. The focus again moves in the next two chapters to the cerebral hemispheres. Chapter 7 discusses the overall structure of the cerebral hemispheres, such as their sulci, gyri, and blood supply. Chapter 8 then surveys important areas of the cerebral cortex using the Brodmann numbering system. Here we discuss the structure and function of various areas, such as Broca's and Wernicke's, two of several areas crucial in speech production and comprehension.

Part III, Neuroanatomy Applied to Communication and Communication Disorders, includes Chapters 9 through 15. I believe these chapters are unique when compared to other neuroscience texts for speech-language pathologists and audiologists because they specifically focus on the neurology of speech, language, hearing, cognition, emotion, and swallowing. These are the communication processes important to these professionals. Chapter 9 begins this third section by exploring consciousness. We say that speech is a voluntary, conscious activity, but what do we mean by consciousness? What are the disorders of consciousness (e.g., coma) that might affect communication? Chapter 10 is of special interest to audiologists because it explores the neurology of the hearing and balance systems and includes discussion of select disorders of these systems. Chapter 11 turns to the topic of speech. Here we look at neurological structures crucial for speech production and attempt to connect problems with these structures to various speech disorders observed in clinical practice. Language is the focus of Chapter 12. The neurological structures involved in speaking, listening, reading, and writing are explored as well as communication disorders associated with each of these modalities. Chapter 13 moves away from communication to swallowing. The cortical and subcortical controls of swallowing are surveyed as well as neurogenic swallowing problems. In recent years, speech-language pathologists have taken a more active role in what are called cognitive-communicative disorders. Chapter 14 focuses on cognition by looking at three main areas of cognition: attention, memory, and executive functions. Several cognitive-communicative disorders, like right hemisphere disorder, are examined through the lens of attention, memory, and executive functions. The final chapter of this section, Chapter 15, looks at the neurology of emotion. Children with autism have become more prevalent on caseloads, so there has been increased interest in how these children process and produce emotional responses. Chapter 15 discusses what we know about the neurology of emotion and the neurological differences between typical children and those with conditions like autism.

Finally, Part IV, Practicing Neuroanatomy, helps prepare students to apply what they have learned throughout the text. Chapter 16 discusses how a neurologist examines a person with a suspected neurological condition and looks at points of overlap with what a speech-language pathologist or audiologist would do in his or her assessment. A cranial nerve examination form is included in this chapter for students to practice this important exam. Also, major signs and symptoms of neurological conditions are surveyed.

Features and Benefits

Each chapter includes a number of pedagogical features designed to enhance student learning. At the beginning of each chapter, you will find a Chapter Preview that offers a general introduction to the chapter's contents, an In This Chapter feature that lists main points discussed in the chapter, Learning Objectives that present the chapter's desired outcomes, and a Chapter Outline that lists the main headings for quick reference.



CHAPTER 3

Development of the Nervous System

CHAPTER PREVIEW

How did we get the complex nervous system that we have? This chapter will try to answer this question by exploring the development of the brain from the early weeks of development after fertilization through adolescence to old age. This process is complex, and we will find that when it does not go as planned, the result can be a neurodevelopmental disorder.

IN THIS CHAPTER

In this chapter, we will …

- Define neuroembryonic terms
- Briefly describe the development of the nervous system
- Describe common birth defects
- Discuss the development of the child's and adolescent's brain
- Survey how the neurological system changes with aging

LEARNING OBJECTIVES

1. The learner will define important neuroembryonic terms.
2. The learner will list and briefly describe the structural development of the nervous system from conception to old age.
3. The learner will list and describe common birth defects.

CHAPTER OUTLINE

- Introduction
- Genes, Chromosomes, and Cells
- Fertilization and the First Weeks of Life
- Structural Development of the Infant Brain
  - Dorsal Induction
  - Ventral Induction
  - Neural Proliferation
  - Neuronal Migration
  - Cortical Organization and Synapse Formation
  - Myelination
- Functional Development of the Infant Brain
- The Development of the Adolescent Brain
- The Brain in Normal Aging
- Conclusion
- Summary of Learning Objectives
- Key Terms
- Draw It to Know It
- Questions for Deeper Reflection
- Case Study
- Suggested Projects
- References

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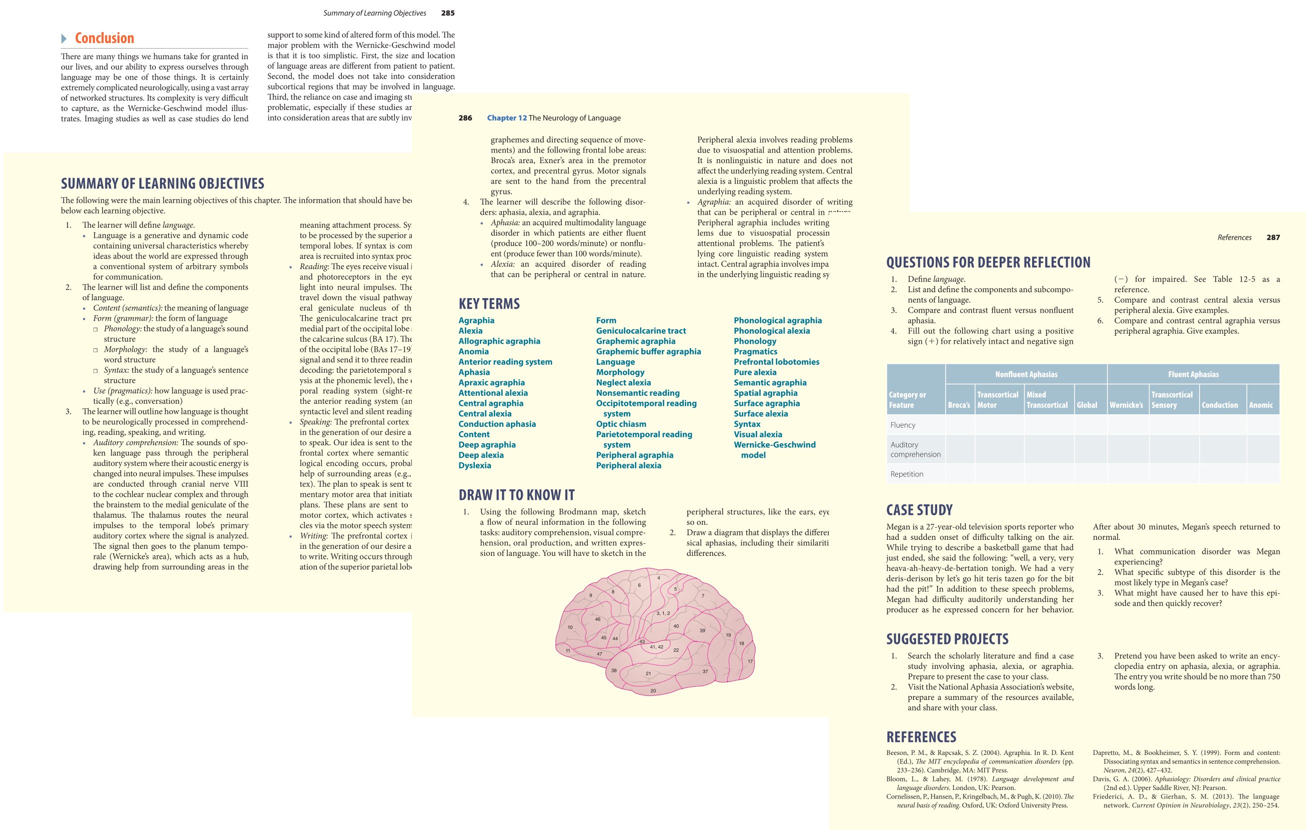
At the end of each chapter, the information related to the chapter's learning objectives is described in the Summary of Learning Objectives feature. Key Terms are also listed, the definitions of which can be found in the Glossary at the end of this text. Suggestions for drawing activities—critical for visual learners—are presented in the Draw It to Know It feature, and Questions for Deeper Reflection and Suggested Projects encourage students to delve deeper into the material.



In addition to these activities, at least one Case Study is included in each chapter that allows students to apply what they are learning. Finally, References are included to credit sources cited in the chapter and to facilitate further study.

Instructor Resources

In addition to the listed features within the text, supplemental learning materials are available for teachers through Jones & Bartlett Learning. They include the following:

- Test Bank, containing more than 250 questions
- Instructor's Manual, including sample answers for the Questions for Deeper Reflection and the Case Studies
- Slides in PowerPoint format, featuring more than 200 slides with select artwork from the text
- Image Bank, supplying key figures from the text
- Sample Syllabus, showing how a course can be structured around this text

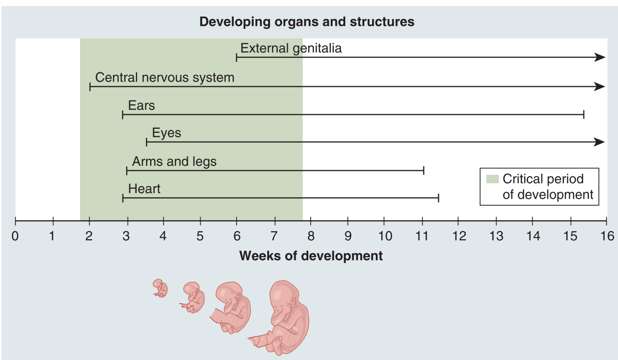
Qualified instructors can gain access to these teaching materials by contacting their Health Professions Account Specialist at go.jblearning.com/findarep.

What's New in This Edition?

The second edition of this text has been thoroughly updated. Some of these changes have come about through my own experience teaching with the text. Other changes have been made because of student feedback. Still other changes have been made due to feedback from colleagues. I highly value feedback from students and colleagues and am grateful for it.

The following is a list of the significant changes made in this edition of the text:

- The content from the previous edition's Chapter 3 has been divided into two chapters. Chapter 2 now covers the navigation and organization of the nervous system, while Chapter 3 more deeply explores nervous system development.
- Chapter 3 now takes a life span perspective, including information about the adolescent and adult brain.
- The content from the previous edition's Chapter 2 relating to the neurological exam has been moved to the end of the text (Chapter 16). This change came about because reviewers of the *First Edition* thought students would be better served to have



all the background information in place before thinking about how to apply it to a patient.

- Information about neuroimaging has been moved to the first chapter to better continue the discussion of neuroscience's history.
- All of the chapters have many additional figures, tables, and boxes to better enhance student learning.
- Some of the figures from the *First Edition* have been updated and changed to better illustrate the text's discussion.
- More information has been added about key neurogenic communication disorders and their connection to the nervous system. For example, Chapter 14, which covers the neurology of cognition, now has a substantial section on right hemisphere disorder as well as dementia.
- Case Studies have been added to encourage problem-solving

Eponymous Terminology

Many of the terms you encounter in this text are eponyms, meaning they are named after a person or place, such as the person who discovered a neurological process or the location in which a disease was first encountered. When named for a person, such terms have traditionally taken the possessive form. For example, you may be used to seeing the term *Alzheimer's disease* as opposed to *Alzheimer disease*, or *Parkinson's disease* instead of *Parkinson disease*. The latter form, which omits the apostrophe and the letter *s*, is increasingly preferred in medical and scientific writings, and as more organizations and publishers adopt this form, it will likely become the more familiar approach even in general contexts. For example, if you do an internet search of the term *Down syndrome*, you will notice that few current sources write this term as *Down's syndrome*, although the possessive spelling was quite common in the not-too-distant past.

In this edition of *Neuroanatomy for Speech-Language Pathology and Audiology*, eponymous terms are generally written in the nonpossessive form (e.g., Parkinson disease). Some terms may look odd to you (e.g., Bell palsy), but in the near future, such spellings may become the norm. That said, a few exceptions to this rule have been made throughout this text to allow for common usage within the field of neuroanatomy. There remains a clear preference to use the possessive form of the terms *Broca's area*, *Wernicke's area*, and *Exner's area*. To maintain a sense of consistency among these terms, the possessive form is used for all eponymous terms relating to Broca and Wernicke (e.g., Broca's aphasia).

About the Author

Matthew H. Rouse earned a BS in Biology from the University of Redlands in 1990 before he transitioned into the field of Communication Sciences and Disorders, earning an MS in Communication Disorders from the University of Redlands in 1992. After graduation, he worked in the hospital system as a medical speech-language pathologist from 1992 to 2000. In 1999, Dr. Rouse accepted a full-time teaching position at Biola University in the Communication Sciences and Disorders program and is currently the chair of the Department of Communication Sciences and Disorders. He earned his doctoral degree in Speech-Language Pathology in 2009 and wrote his dissertation on training students in empathetic counseling skills. His research interests include neuroscience, neurogenic communication disorders, and counseling. Matt lives in La Habra, California, with his wife Chrissie and their two children.

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PART I

Introductory Issues

CHAPTER 1

Introduction to Neurology

CHAPTER PREVIEW

In this chapter we will begin our journey into the world of neuroscience. We will define important terms, like *neurology*, to help us begin to frame this world. We will then make a case on why it is important for a speech-language pathologist and audiologist to have a working knowledge of the nervous system. Lastly, we will examine theoretical perspectives and technologies that speak to the question: How does the brain work?

IN THIS CHAPTER

In this chapter, we will . . .

- Define the term *neurology*
- Discuss why speech-language pathologists and audiologists need to know and understand neurology
- Discuss why the neurological system is a precious resource
- Answer the question: What does neurology mean to me?
- Define the terms *function*, *activity*, and *participation barriers*
- Survey examples of famous people who have suffered neurological conditions
- Examine statistics concerning neurological disorders
- List various categories of neurological disorders
- Discuss basic theoretical perspectives as to how the brain works
- Survey important researchers in the history of neuroscience
- Compare and contrast neuroimaging techniques
- Discuss why these theoretical perspectives matter to fields associated with communication sciences and disorders

CHAPTER OUTLINE

- **Introduction: Defining Neurology**
- **The Need for Neurological Training**
- **A Broad Overview of the Nervous System**
  - The Nervous System Is a Precious Resource
  - What Does Neurology Mean to Me?
  - Famous People With Neurological Conditions
  - Prevalence, Incidence, and Cost of Neurological Disorders
  - Classification of Neurological Disorders
- **A Brief History of Neuroscience**
  - Prehistory
  - Early History
  - Later History
  - Modern History
- **Neuroscience Today**
  - Structural Imaging Techniques
  - Functional Imaging Techniques
  - Combined Structural and Functional Imaging Techniques
  - Which Test When?
  - A Caution Regarding Imaging Techniques
- **Conclusion**
- **Summary of Learning Objectives**
- **Key Terms**
- **Draw It to Know It**
- **Questions for Deeper Reflection**
- **Case Study**
- **Suggested Projects**
- **References**

LEARNING OBJECTIVES

1. The learner will define the following terms: *neurology*, *anatomy*, *physiology*, and *pathology*.
2. The learner will be able to create an argument as to why speech-language pathologists and audiologists need neurological training.
3. The learner will be able to list various categories of neurological disorders and provide one example in each category.
4. The learner will be able to draw and explain the spectrum of belief as to how the brain works.
5. The learner will list and define structural and functional imaging techniques and list at least one reason why communication disorders professionals should know about neuroimaging techniques.

Introduction: Defining Neurology

We begin our journey into the human nervous system with this question from the anthropologist Stephen Juan: "Have you ever wondered about how fantastic the human brain really is? Every thought, every action, every deed relies upon this incredible organ. Although we take the brain for granted, we couldn't wonder without it" (Juan, 1998, p. 1). The brain is the vehicle we use to wonder. It includes not only the brain but also those other parts of the neurological system that pertain to communication. **Neurology** is simply the study of the anatomy, physiology, and pathology of the nervous system. **Anatomy** is the study of structure, **physiology** is the study of function or structures in motion, and **pathology** is the study of disease processes that affect both anatomy and physiology. Put the prefix *neuro-* in front of each of these words and you get distinct yet highly related fields of study. **Neuroanatomy** is the study of the nervous system's structure. A neuroanatomical topic is a neuron (i.e., a nervous system cell) and its structure. When we want to talk about how a neuron functions, we have just entered into the area of **neurophysiology**. The study of nervous system diseases is called **neuropathology**. An example of neuropathology would be amyotrophic lateral sclerosis, or Lou Gehrig disease, which affects both the anatomy and physiology of neurons and leads to serious neurological problems. There are other fields in addition to these, including neurosurgery (removal of structures that impair normal nervous system functioning), neuroradiology (use of radiation therapy for nervous system tumors), and neuroembryology (normal and pathological development of the nervous system).

The **nervous system** is a series of organs that make communication between the brain and body possible in order for us to interact with the world around us. It is through the nervous system's connections to the body (and vice versa) that we think, feel, and act. The most well-known organ of the nervous system is the brain, followed by the spinal cord and then the various nerves (FIGURE 1-1). The purpose of this chapter is to give a broad overview of the nervous system as well as a brief survey of neuroscience's history and the important figures in that history. This chapter also explores modern neuroimaging techniques that have led to a better understanding of the brain and how it works.

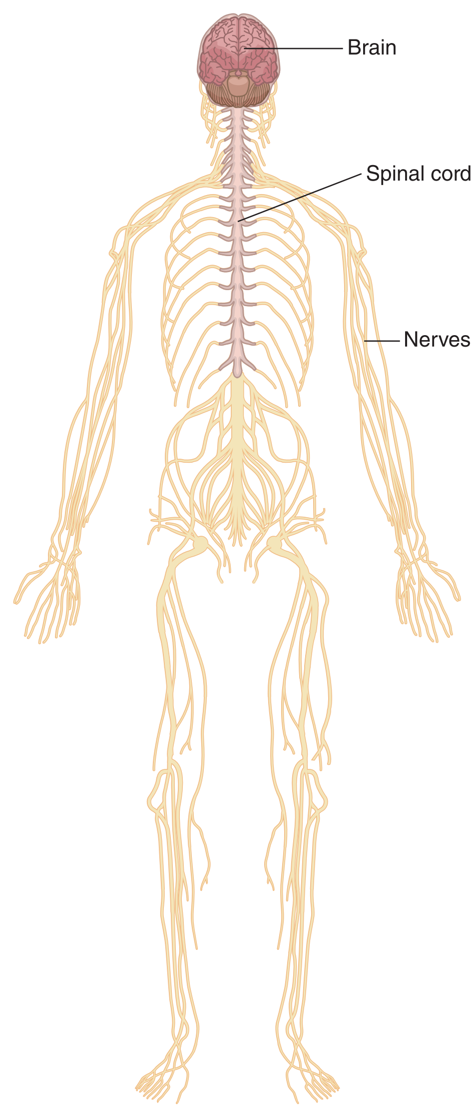

FIGURE 1-1 The brain, spinal cord, and nerves are the major components of the human nervous system.

The Need for Neurological Training

Why should a speech-language pathologist (SLP) or audiologist be concerned about the anatomy, physiology pathology of the nervous system? What difference does this knowledge make to clinical practice?

Rubens (1977), a neurologist, outlined several reasons why SLPs and audiologists should know about neuroscience and neurology. First, he argued that these professionals should know how to speak the language of neurology so that they and neurologists could better communicate. Neurologists have their own language. When communication disorders professionals have knowledge of this language, they can communicate more easily with neurologists. In turn, neurologists may be more willing to learn the language of SLPs and audiologists. An example of this neurological language is the word *dyskinesia*, a general word for a disorder of movement. Neurologists also extensively use abbreviations (e.g., CVA for cerebral vascular accident, or stroke) and use them considerably in their charting. Knowing these terms and abbreviations can obviously help the SLP or audiologist understand the neurologist's assessment report and progress notes. Second, knowing about the nervous system and where a lesion is (e.g., frontal lobe versus occipital lobe) helps the SLP anticipate likely patient problems and choose appropriate initial testing instruments. For example, a patient with a focal left hemisphere stroke will be tested differently than someone with diffuse brain injury due to a traumatic brain injury. Third, knowing about neurological etiologies, such as stroke, traumatic brain injury, and brain tumor, helps an SLP or audiologist predict the kinds of problems patients are likely to face. For example, a patient with occlusion of the middle cerebral artery will have a different symptom complex (e.g., speech and language) than will a patient with posterior cerebral artery occlusion (e.g., visuospatial). Fourth, a working knowledge of neuroscience helps SLPs and audiologists document patient change and determine the efficacy of various treatment methods in rewiring the brain for improved communication. Fifth and connected to the previous point, knowledge of neural plasticity (i.e., the brain's ability to change and adapt after injury) helps the SLP plan therapy in a way that takes advantage of this phenomenon. One principle of neuroplasticity is that repetition matters, meaning repeated experience can help the brain learn new skills. This insight can obviously be used in therapy by giving numerous repetitions of certain sounds or words, thus improving a patient's likelihood of learning and generalizing these new skills.

SLPs and audiologists must do their part in fostering good relationships with neurologists and other doctors; one important way of gaining their colleagues' respect is by being excellent at what they do. Nothing elicits respect like a job well done. Though SLPs and audiologists are autonomous professionals (i.e., they are not supervised by neurologists or other doctors), they depend on neurologists for many things, such as referrals and important neurological information on the patient (LaPointe, 1977). Tending to their relationships with these physicians not only helps SLPs and audiologists in these areas, but also ultimately helps patients receive the important and specialized services that only SLPs and audiologists can provide. I often tell my students that no one—not even neurologists—will know more about speech, language, hearing, or swallowing than they will once they are through graduate school and their clinical fellowship. This is not said out of pride, but rather out of reality; no one has as much clinical training in these areas as a licensed, certified SLP or audiologist, just like no one has as much knowledge of neurology as a neurologist.

Some readers might be thinking, "Well, that's all fine, but I'm not going to work in a hospital or with neurologists. I'm going to work in a public school. What does all this matter to me?" Manasco (2017) offers a helpful maxim: "When you hear hoof beats, think horses, not zebras" (p. 5). What this adage is saying is that horses are the most likely explanation, while zebras are the outliers, the unexpected possibilities. Imagine you are working in a public school and a child walks into your office. Most likely, the child was sent to your office because he or she has a developmental language or speech sound disorder (i.e., a horse). However, it is possible the child was referred for testing because he or she has had a severe concussion or a stroke (i.e., a zebra). At some point, a child will walk into your office and your knowledge of neurology and neurogenic communication disorders will be needed to properly assess, diagnose, and treat that child. As Manasco explains, "You must be able to recognize and treat those problems in your field that are very out of the ordinary or even extraordinary" (2017, p. 5).

A Broad Overview of the Nervous System

The Nervous System Is a Precious Resource

I remember watching the 2008 Summer Olympic Games on television with my 4-year-old daughters and seeing their joy and amazement as gymnasts Nastia

Liukin and Shawn Johnson moved with grace and precision on the vault, floor exercises, uneven bars, and balance beam (**FIGURE 1-2**). Nastia took the gold in the individual all-around and Shawn the silver. It was a proud moment for the U.S. Olympic squad and all Americans watching these amazingly skilled athletes contort their bodies in incredible ways. The precision, timing, and coordination of these athletes had come from years of training not only their muscles but also their nervous systems. Plans for motor (or movement) activity were developed through years of repetitive action. As the adage goes, "Practice makes perfect."

The nervous system is on full display in the works of our favorite composers and performers. They have fine-tuned their nervous systems through hours of practice to execute precisely the actions needed to perform a piece of music or create a piece of art. Itzhak Perlman (**FIGURE 1-3**), the famous violinist, began playing the violin at 3 years old and, although he contracted polio at an early age, practiced for numerous hours and became one of the world's most famous violinists. Great feats of the body are in part products of the nervous system. The nervous system is definitely a precious resource, one that works quietly in the background, unknown by us unless a disease develops.

FIGURE 1-2 A gymnast on a balance beam illustrating how years of practice hone the nervous system.

Courtesy of Bill Evans/U.S. Air Force.

FIGURE 1-3 Itzhak Perlman playing at the White House for President George W. Bush and First Lady Laura Bush.

Courtesy of Shealah Craighead/George W. Bush Presidential Library and Museum.

What Does Neurology Mean to Me?

The nervous system is like an automatic transmission in a car; one does not need to think about shifting the gears. The nervous system comes into the forefront when something goes wrong with it. A **neurological disorder** involves a disease in the nervous system that impairs a person's health, resulting in some level of disability. The World Health Organization's (WHO's) *International Classification of Functioning, Disability and Health* (ICF) defines disability as "a universal human experience, sometimes permanent, sometimes transient" that affects the health and functioning of a person (WHO, 2014). We should not think of people in two categories (healthy versus disabled), but rather remember that we are all on a spectrum with health at one end and disability at the other end. There are times in our lives when we experience more health and less disability, and vice versa.

Earlier generations used the terms *impairment*, *disability*, and/or *handicap* when discussing people who had health issues, and these terms are still widely used in everyday language (e.g., think of how most people refer to parking spaces with a wheelchair sign). WHO has attempted to change this language by using the alternative terms *function*, *activity*, and *participation*. The older terms of *impairment*, *disability*, and *handicap* come from the medical model of disability that puts an emphasis on the person's health condition, his or her limitations due to this condition, and cures or treatment. The medical model does not include the role of society in disability and the barriers a society can erect for those with disabilities (i.e., the social model of disability). The focus of the medical model is on biological and medical answers. WHO's use of alternative terms is an attempt to blend the social model of disability, which

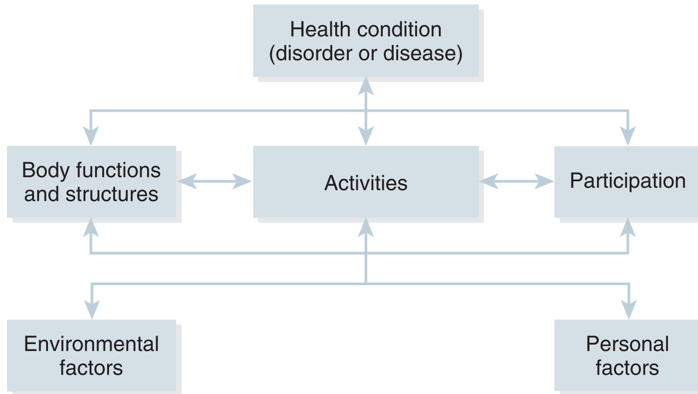

FIGURE 1-4 The interaction between functioning, disability, and health.

Modified from World Health Organization. (2011). *World report on disability*. Retrieved from http://whqlibdoc.who.int/publications/2011/9789240685215_eng.pdf

emphasizes the role of society and its barriers, with the medical model. WHO's model still has elements of the medical model by stressing a person's health condition (e.g., stroke) and how that condition has affected the structure and function of the body (e.g., paralysis). Issues with **function barriers** (formerly impairment) "are problems in body function or alterations in body structure" (WHO, 2011, p. 5). Examples of function issues include paralysis and blindness. In the area of communication disorders, examples include hearing loss and language impairment. **Activity barriers** (formerly disability) "are difficulties in executing activities" (WHO, 2011, p. 5), especially skills of daily living like walking or eating. For example, neurogenic communication disorders can lead to issues in the daily communication of needs and wants with other people or eating. Lastly, **participation barriers** (formerly handicap) "are problems with involvement in any area of life" (WHO, 2011, p. 5). These barriers include challenges participating in education and employment, often due to external barriers such as discrimination and transportation problems. It is important to note that not everyone who has a function barrier will have barriers in activity and/or participation. For example, a person who is deaf may technically have hearing dysfunction but have no issues with daily activities or involvement in other areas of life.

WHO's ICF also "looks beyond the idea of a purely medical or biological conceptualization of dysfunction, taking into account the other critical aspects of disability" (WHO, 2014), such as environmental and personal factors (**FIGURE 1-4**). Environmental factors describe the world in which people with neurological disorders live and interact. These factors can act as either facilitators or barriers and include products, technology, buildings, support, relationships, attitudes, services, systems, and policies. Personal factors relate directly to the person with a neurological disorder. For example, a person's motivation and self-esteem can play into his or her interaction with the environment (WHO, 2011). **FIGURE 1-5** illustrates WHO's ICF applied to someone who has suffered a spinal cord injury.

It is likely that you have an acquaintance, friend, or family member who suffers from some sort of nervous system problem, such as Alzheimer or Parkinson disease, which may disable or handicap the person. If so, then neurology has personal significance to you. In other words, neurology is not a study that is distant from us; it affects our personal lives, especially when our loved ones or we ourselves experience a neurological disorder.

Famous People With Neurological Conditions

Neurological disorders do not discriminate. They strike the old and the young, the rich and the poor, and people of every color, culture, and nationality.

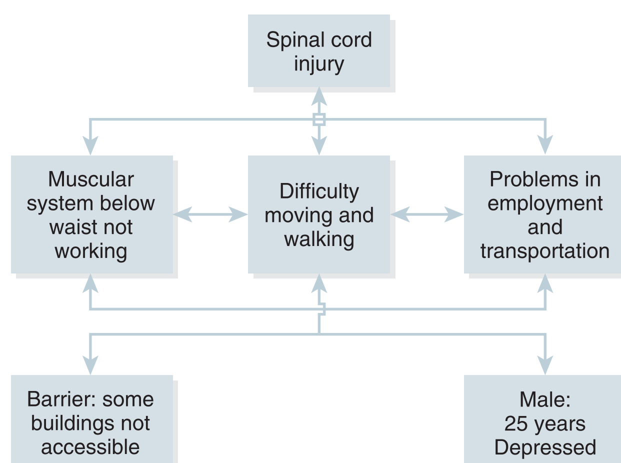

FIGURE 1-5 An example of the ICF applied to a case involving spinal cord injury.

Adapted from the Centers for Disease Control and Prevention. (n.d.). The ICF: An overview. Retrieved from https://www.cdc.gov/nchs/data/icd/icfoverview_finalforwho10sept.pdf

Many famous people have suffered from serious neurological conditions. Former president Ronald Reagan died from complications related to **Alzheimer disease**, a progressive neurological disorder that results in intellectual decline. Actor Michael J. Fox has **Parkinson disease**, a degenerative disorder of the central nervous system characterized by muscle rigidity and tremors. Actor Christopher Reeve suffered spinal cord injury in his upper neck after being thrown from a horse and was wheelchair bound and ventilator dependent until his death in 2004 from cardiac arrest. Stephen Hawking, the famous English physicist, was diagnosed at 21 years of age with an unusual form of amyotrophic lateral sclerosis (ALS; also known as Lou Gehrig disease); he struggled with this disease until his death in 2018 at 76 years old. Roy Horn, an entertainer from the famous Las Vegas tiger act known as Siegfried and Roy, suffered a stroke after his tiger Montecore bit him in the neck. Roy had fallen during a performance, and it is thought that Montecore was trying to pull him to safety. Most people suffer from neurological conditions privately, but these celebrities have had to endure their conditions in the public eye. Their willingness to share openly about their conditions has led to greater public awareness regarding conditions like ALS and Parkinson disease.

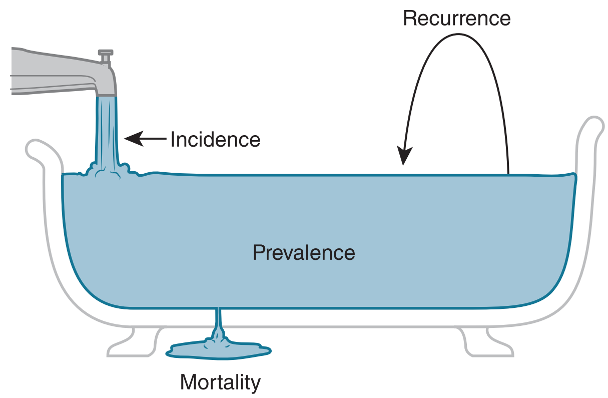

FIGURE 1-6 An illustration of important epidemiological terms.

Prevalence, Incidence, and Cost of Neurological Disorders

Statistics regarding the **incidence** (i.e., the number of new cases per year in a given population) and **prevalence** (i.e., the total number of current cases in a given population at a point in time) of neurological disorders are challenging to obtain due to the relatively few available studies (**FIGURE 1-6** illustrates these important epidemiological terms). One study by Hirtz et al. (2007), summarized in **FIGURE 1-7**, estimated the incidence and prevalence of select neurological disorders in the United States. Because population statistics change rapidly, Hirtz et al.'s information is out of date for some conditions; for example, the Centers for Disease Control and Prevention (2018) and Baio et al. (2018) report that the prevalence rate for children with autism spectrum disorder is now 16.8/1,000, or 1 in 59 children.

Whatever the statistics, the number of people suffering from neurological disorders is great. In fact, WHO estimates that nearly one in six people worldwide, or about 1 billion people, suffer from a neurological disease (Bertolote, 2007).

In addition to the personal hardships of people affected, there is also a tremendous financial cost associated with the assessment and treatment of neurological

A

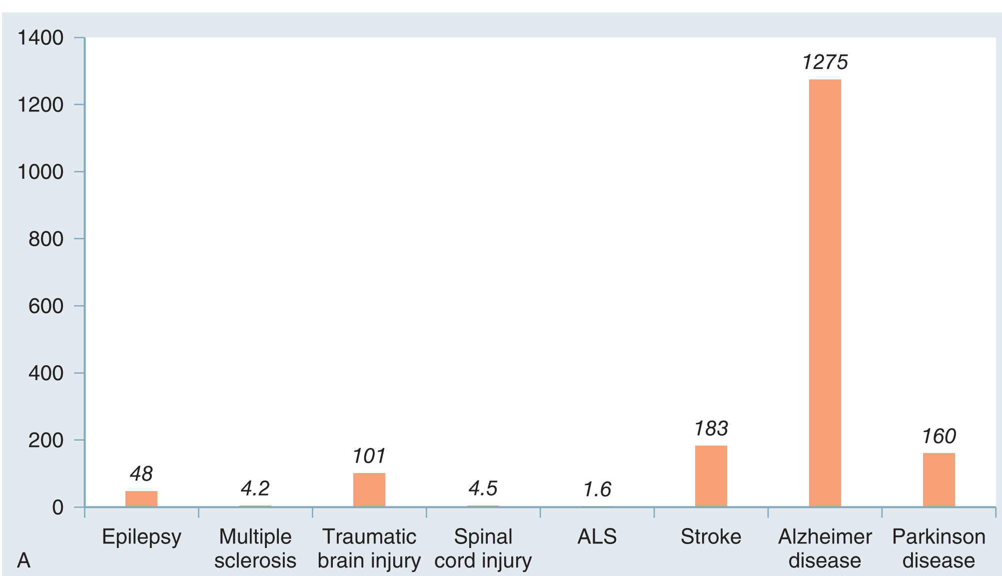

FIGURE 1-7A **A.** Incidence of select neurological disorders in the United States (new cases per 100,000).

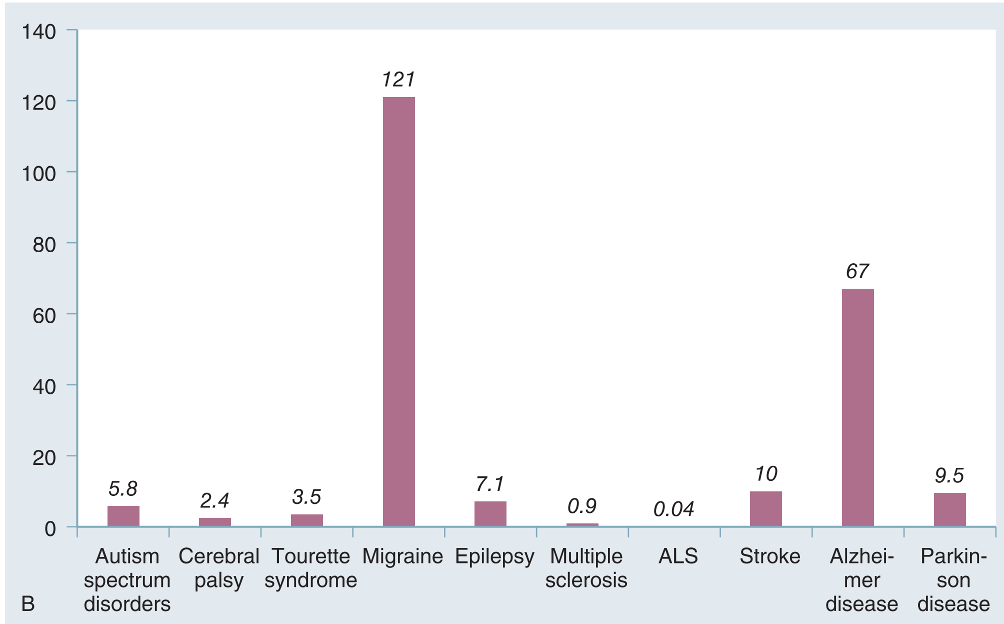

FIGURE 1-7B B. Prevalence of select neurological disorders in the United States (total cases per 1,000). ALS = amyotrophic lateral sclerosis.

Data from: Hirtz, D., Thurman, D. J., Gwinn-Hardy, K., Mohamed, M., Chaudhuri, A. R., & Zalutsky, R. (2007). How common are the "common" neurologic disorders? *Neurology, 68,* 332.

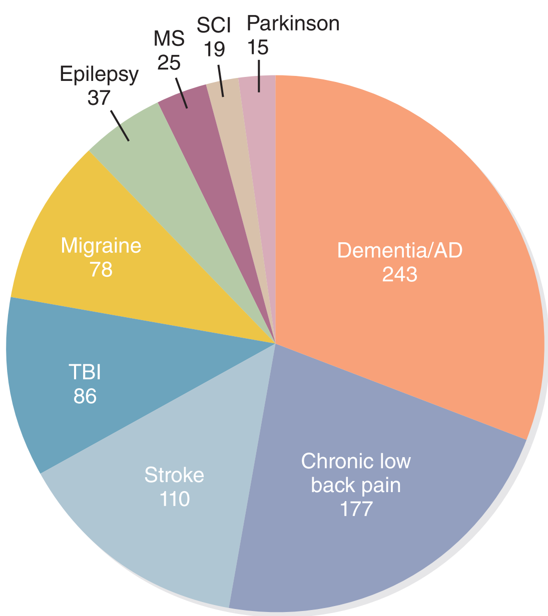

FIGURE 1-8 Annual cost of major neurological disorders in billions of dollars. AD = Alzheimer disease, MS = multiple sclerosis, SCI = spinal cord injury, TBI = traumatic brain injury.

Data from: Gooch, C. L., Pracht, E., & Borenstein, A. R. (2017). The burden of neurological disease in the United States: A summary report and call to action. *Annals of Neurology, 81*(4), 479–484.

disorders. Gooch, Pracht, and Borenstein (2017) report that the following disorders alone cost the United States approximately $800 billion per year: Alzheimer disease and other dementias, stroke, traumatic brain injury, chronic lower back pain, migraine, epilepsy, multiple sclerosis, spinal cord injury, and Parkinson disease (**FIGURE 1-8**). The treatment of Alzheimer disease led the list with an annual cost of approximately $243 billion.

Classification of Neurological Disorders

WHO has developed a classification system for diseases, including pathologies of the nervous system, called the International Statistical Classification of Diseases and Related Health Problems. This name is commonly shortened to the International Classification of Diseases and, because it is in its 10th edition, is abbreviated ICD-10. Under "Diseases of the Nervous System," there are 11 subcategories of neurological diseases (WHO, 2010). These categories are briefly described here:

Inflammatory diseases: These are neurological diseases caused by bacterial, viral, or parasitic pathogens. Two conditions under this category are encephalitis (brain infection) and meningitis (infection of membranes that surround the brain and spinal cord).

Systematic atrophies primarily affecting the central nervous system: Atrophy refers to a wasting away of something, in this case the nervous system. The progressive, hereditary disorder known as Huntington disease is an example of a condition in this category.

Extrapyramidal and movement disorders: The extrapyramidal system is that part of the nervous system that regulates our movements. The basal ganglia serve as a kind of control center for this system. Parkinson disease, a degenerative neurological disease involving rhythmic shaking, is an example.

Other degenerative diseases of the nervous system: Other conditions that are degenerative in nature,