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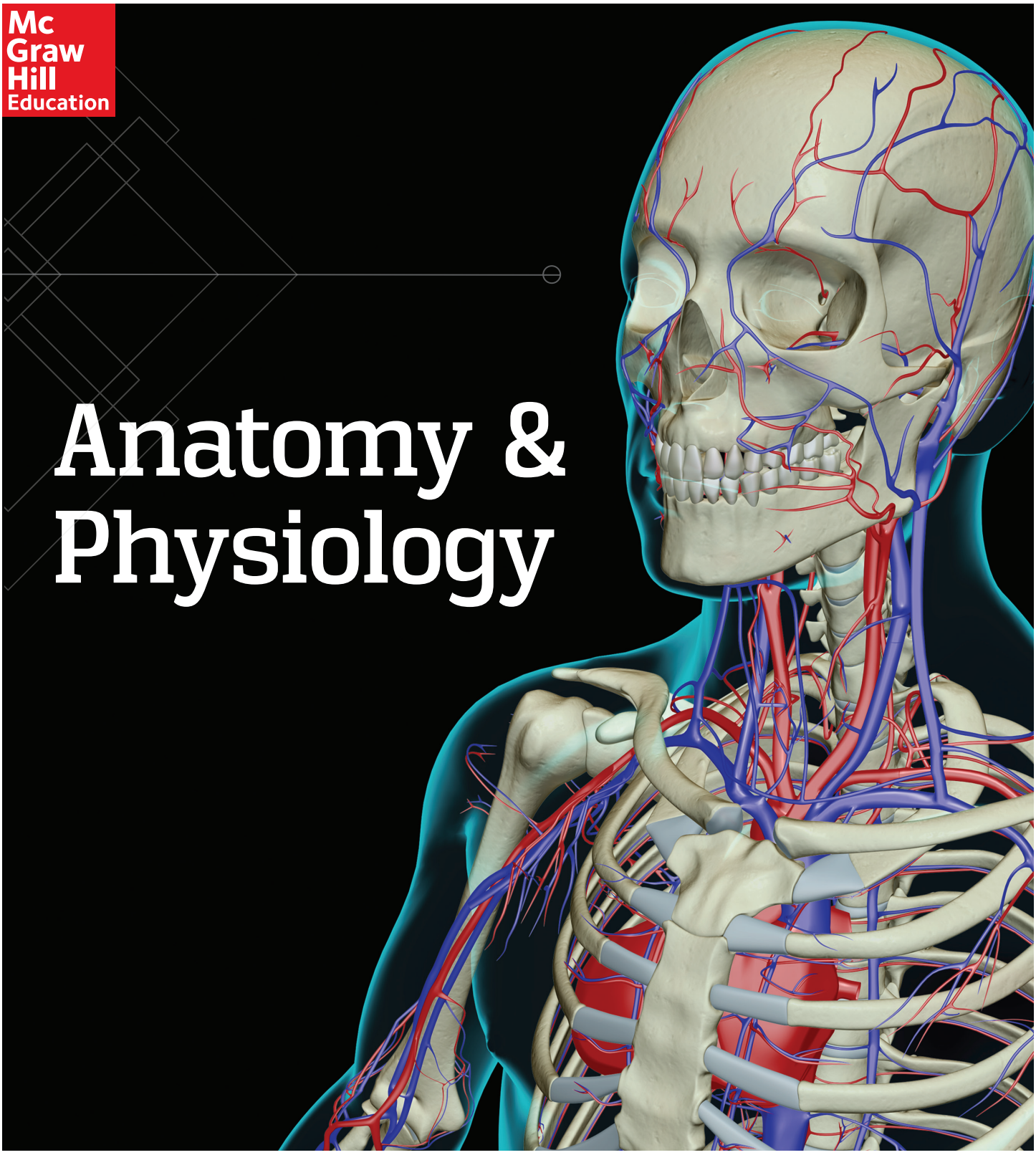
# Anatomy & Physiology



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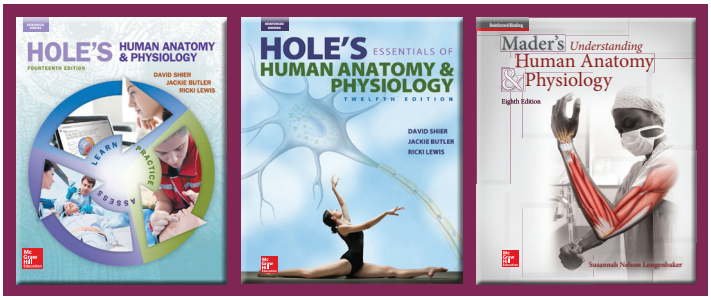

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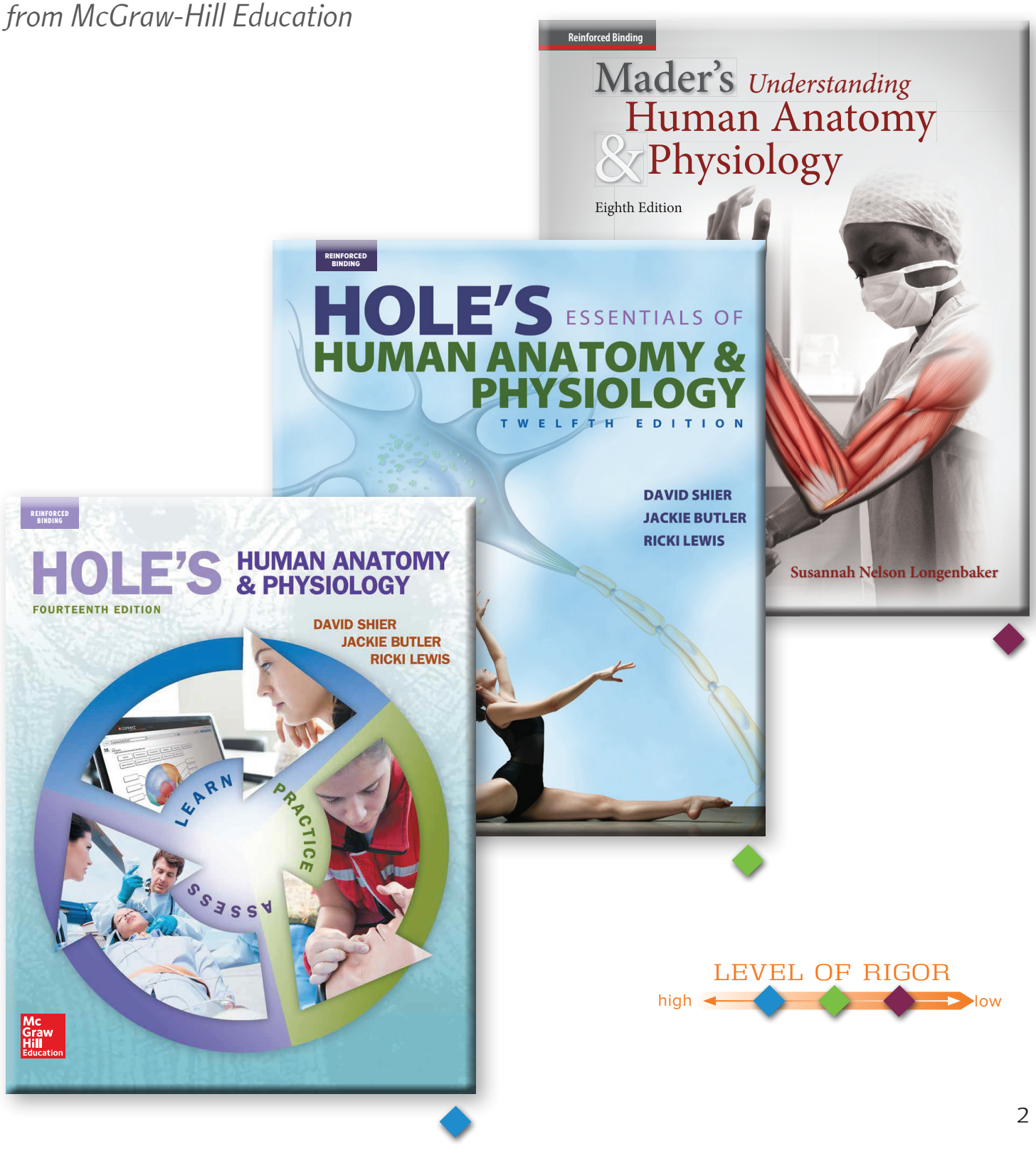



LEVEL OF RIGOR

high ◆ ◆ ◆ low

# Pique curiosity and inspire deeper exploration

*With introductory and comprehensive options*

At McGraw-Hill Education, we understand the challenge of finding the perfect resources to teach Anatomy and Physiology your way. To help you meet the challenge, we provide a variety of print, digital and hybrid resources at introductory and comprehensive levels to support you and your students, no matter how you teach the course.

Introductory courses are called so for a reason. They provide a shorter, (often, a semester-long) foundational level introduction to the subject.

Comprehensive courses typically provide a longer (often, a year-long) and more in-depth study of the subject matter.

## CONTENTS

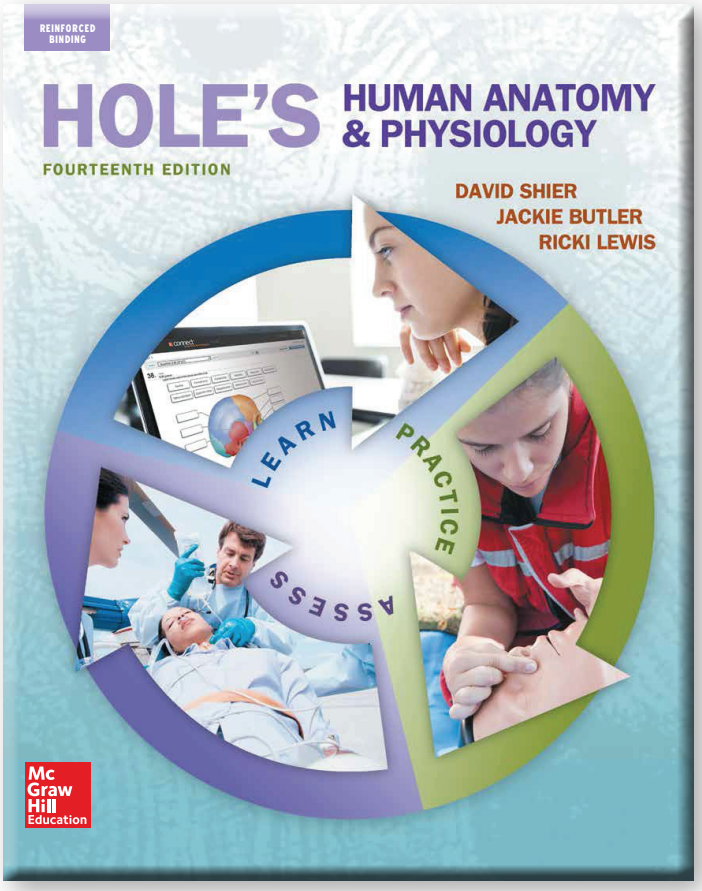


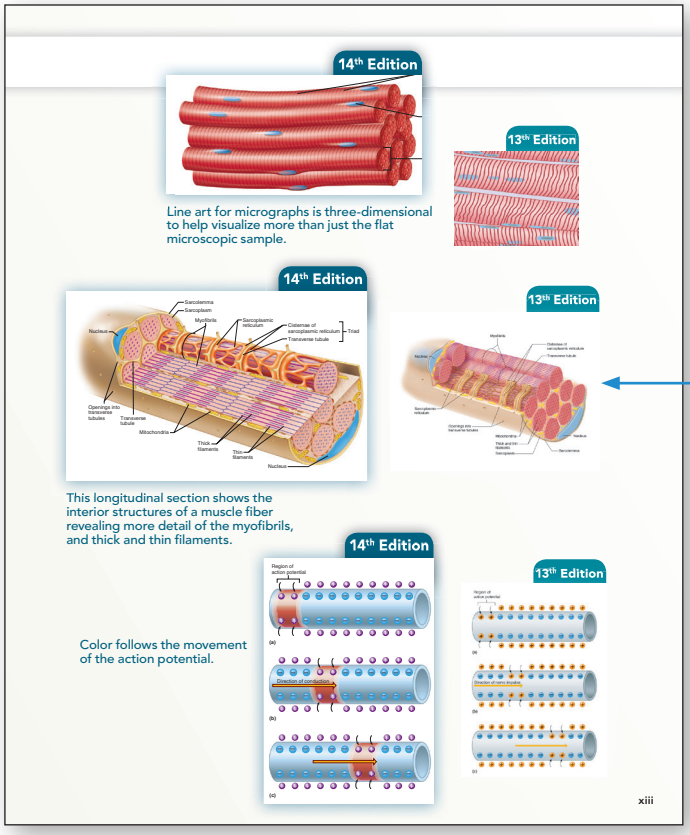
# More in-depth coverage

LEVEL OF RIGOR
high — low

## *Hole's Human Anatomy & Physiology*

*Hole's Human Anatomy & Physiology* is our most in-depth Anatomy and Physiology text and is best suited for a comprehensive Anatomy and Physiology course. The integrated learning system, Learn, Practice, Assess, used in the text helps to set students up for success. Each chapter opens with Learning Outcomes, contains many opportunities to Practice throughout, and closes with Assessments that are closely tied to the Learning Outcomes. *Hole's Human Anatomy & Physiology* includes 2 chapters on the skeletal system and 3 chapters on the nervous system as well as expanded, in-depth coverage of all topics within each chapter.

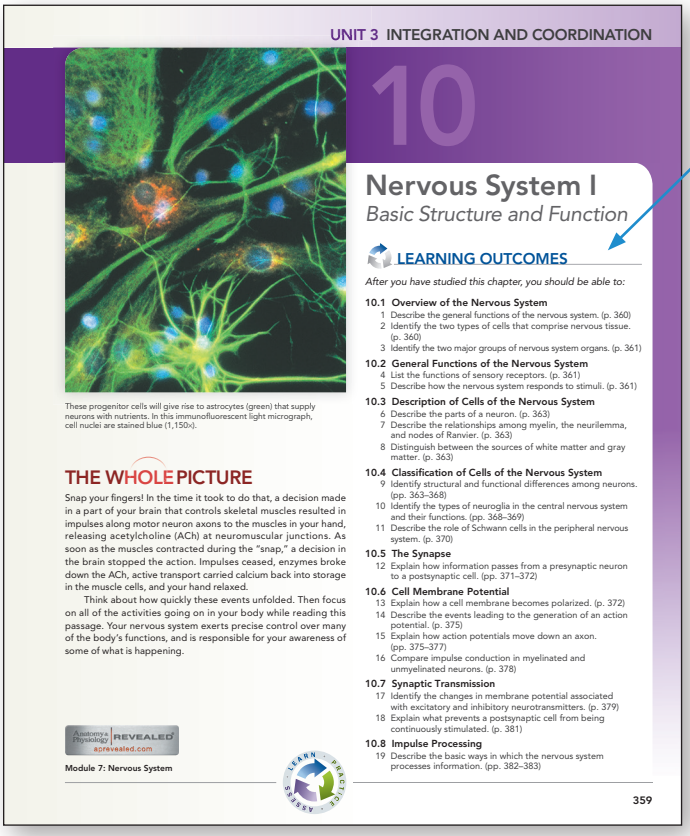



Every piece of art has been updated in this edition to make it more vibrant, three-dimensional, and instructional.

# Hole's Human Anatomy & Physiology

Each chapter includes **Learning Outcomes** that gives students an overview of the key concepts in each chapter that they will need to understand.



UNIT 3 INTEGRATION AND COORDINATION

10

## Nervous System I

*Basic Structure and Function*

These progenitor cells will give rise to astrocytes (green) that supply neurons with nutrients. In this immunofluorescent light micrograph, cell nuclei are stained blue (1,150×).

### THE WHOLE PICTURE

Snap your fingers! In the time it took to do that, a decision made in a part of your brain that controls skeletal muscles resulted in impulses along motor neuron axons to the muscles in your hand, releasing acetylcholine (ACh) at neuromuscular junctions. As soon as the muscles contracted during the "snap," a decision in the brain stopped the action. Impulses ceased, enzymes broke down the ACh, active transport carried calcium back into storage in the muscle cells, and your hand relaxed.

Think about how quickly these events unfolded. Then focus on all of the activities going on in your body while reading this passage. Your nervous system exerts precise control over many of the body's functions, and is responsible for your awareness of some of what is happening.

Anatomy & Physiology REVEALED 2.0 apcrevealed.com

Module 7: Nervous System

### LEARNING OUTCOMES

*After you have studied this chapter, you should be able to:*

**10.1 Overview of the Nervous System**
1 Describe the general functions of the nervous system. (p. 360)
2 Identify the two types of cells that comprise nervous tissue. (p. 360)
3 Identify the two major groups of nervous system organs. (p. 361)

**10.2 General Functions of the Nervous System**
4 List the functions of sensory receptors. (p. 361)
5 Describe how the nervous system responds to stimuli. (p. 361)

**10.3 Description of Cells of the Nervous System**
6 Describe the parts of a neuron. (p. 363)
7 Describe the relationships among myelin, the neurilemma, and nodes of Ranvier. (p. 363)
8 Distinguish between the sources of white matter and gray matter. (p. 363)

**10.4 Classification of Cells of the Nervous System**
9 Identify structural and functional differences among neurons. (pp. 363–368)
10 Identify the types of neuroglia in the central nervous system and their functions. (pp. 368–369)
11 Describe the role of Schwann cells in the peripheral nervous system. (p. 370)

**10.5 The Synapse**
12 Explain how information passes from a presynaptic neuron to a postsynaptic cell. (pp. 371–372)

**10.6 Cell Membrane Potential**
13 Explain how a cell membrane becomes polarized. (p. 372)
14 Describe the events leading to the generation of an action potential. (p. 375)
15 Explain how action potentials move down an axon. (pp. 375–377)
16 Compare impulse conduction in myelinated and unmyelinated neurons. (p. 378)

**10.7 Synaptic Transmission**
17 Identify the changes in membrane potential associated with excitatory and inhibitory neurotransmitters. (p. 379)
18 Explain what prevents a postsynaptic cell from being continuously stimulated. (p. 381)

**10.8 Impulse Processing**
19 Describe the basic ways in which the nervous system processes information. (pp. 382–383)

359

## 10.3 Description of Cells of the Nervous System

Neurons vary in size and shape. They may differ in the lengths and sizes of their axons and dendrites and in the number of processes. Despite this variability, neurons share certain features. Every neuron has a **cell body,** dendrites, and an axon. Figure 10.3 shows some of the other structures common to neurons.

A neuron's cell body (soma or perikaryon) contains granular cytoplasm, mitochondria, lysosomes, a Golgi apparatus, and many microtubules. A network of fine threads called **neurofilaments** extends into the axon and supports it. Scattered throughout the cytoplasm are many membranous packets of **chromatophilic substance** (Nissl bodies), which consist mainly of rough endoplasmic reticulum. Cytoplasmic inclusions in neurons include glycogen, lipids, and pigments such as melanin. Near the center of the neuron cell body is a large, spherical nucleus with a conspicuous nucleolus.

Dendrites are typically highly branched, providing receptive surfaces with which processes from other neurons communicate. (In some types of neurons, the cell body provides such a receptive surface.) Some dendrites have tiny, thornlike spines (dendritic spines) on their surfaces, which are contact points for other neurons.

A neuron may have many dendrites, but no more than one axon. In most neurons the axon arises from the cell body as a cone-shaped thickening called the *axon hillock*. The cytoplasm of the axon includes many mitochondria, microtubules, and neurofibrils (ribosomes are found only in the cell body). The axon may give off branches, called *collaterals*. Near its end, an axon may have many fine extensions, each with a specialized ending called an *axon terminal*. The axon terminal ends as a *synaptic knob* close to the receptive surface of another cell, separated only by a space called the **synaptic cleft.** The general pattern is that neurons receive input through the dendrites and the cell body, and send output in the form of an impulse conducted away from the cell body, down the axon.

An axon, in addition to conducting impulses, conveys biochemicals and organelles, which can be quite a task in these long cells. In this activity, called *axonal transport*, movement occurs in both directions between the cell body and the ends of the axon. For example, enzymes required for neurotransmitter synthesis are produced in the cell body and transported to the axon terminals. Old organelles and other cellular components may be transported in the reverse direction to be recycled. It is a highly regulated process.

In the PNS, neuroglia called **Schwann cells** encase the large axons of peripheral neurons in lipid-rich sheaths. These tight coverings form as Schwann cell membranes wind and wrap around axons. The layers are composed of **myelin** (mī'ĕ-lin), which consists of several types of lipids and proteins. Myelin gives the cell membranes of Schwann cells a higher proportion of lipid than other cell membranes. This coating is called a *myelin sheath*. The parts of the Schwann cells that contain most of the cytoplasm and the nuclei remain outside the myelin sheath and comprise a **neurilemma** (nur"ĭlem'ah), or *neurilemmal sheath*, which surrounds the myelin sheath. Narrow gaps in the myelin sheath between Schwann cells are called **nodes of Ranvier** (fig. 10.4).

Schwann cells also enclose, but do not wind around, the smallest axons of peripheral neurons. Consequently, these axons do not have myelin sheaths. Instead, the axon or a group of axons may lie partially or completely in a longitudinal groove of a Schwann cell.

Axons that have myelin sheaths are called *myelinated* (medullated) axons, and those that do not have these sheaths are *unmyelinated axons* (fig. 10.5). Myelinated axons conduct impulses rapidly compared to unmyelinated axons. Groups of myelinated axons appear white. The *white matter* in the brain and spinal cord gets its color from masses of myelinated axons. In the CNS, myelin is produced by a type of neuroglia called an **oligodendrocyte** rather than by a Schwann cell. In the brain and spinal cord, myelinated axons do not have neurilemmae.

Unmyelinated nerve tissue appears gray. Thus, the *gray matter* in the CNS contains many unmyelinated axons and neuron cell bodies. Clinical Application 10.2 discusses multiple sclerosis, a condition in which neurons in the brain and spinal cord lose their myelin.

### PRACTICE

4 Describe a neuron.
5 Explain how an axon in the peripheral nervous system becomes myelinated.

Myelin begins to form on axons during the fourteenth week of prenatal development. At the time of birth, many axons are not completely myelinated. All myelinated axons have begun to develop sheaths by the time a child starts to walk, and myelination continues into adolescence.

Excess myelin seriously impairs nervous system functioning. In Tay-Sachs disease, deficiency of a lysosomal enzyme causes myelin to accumulate, burying neurons in lipid. An affected child begins to show symptoms by six months of age, gradually losing sight, hearing, and muscle function until death occurs by age four. Thanks to genetic screening among people of eastern European descent and other groups who are most likely to carry this mutation, Tay-Sachs disease is extremely rare.

Too little myelin is devastating, too. Clinical Application 3.2 (p. 74) describes adrenoleukodystrophy, in which myelin vanishes in the brains and spinal cords of boys.

## 10.4 Classification of Cells of the Nervous System

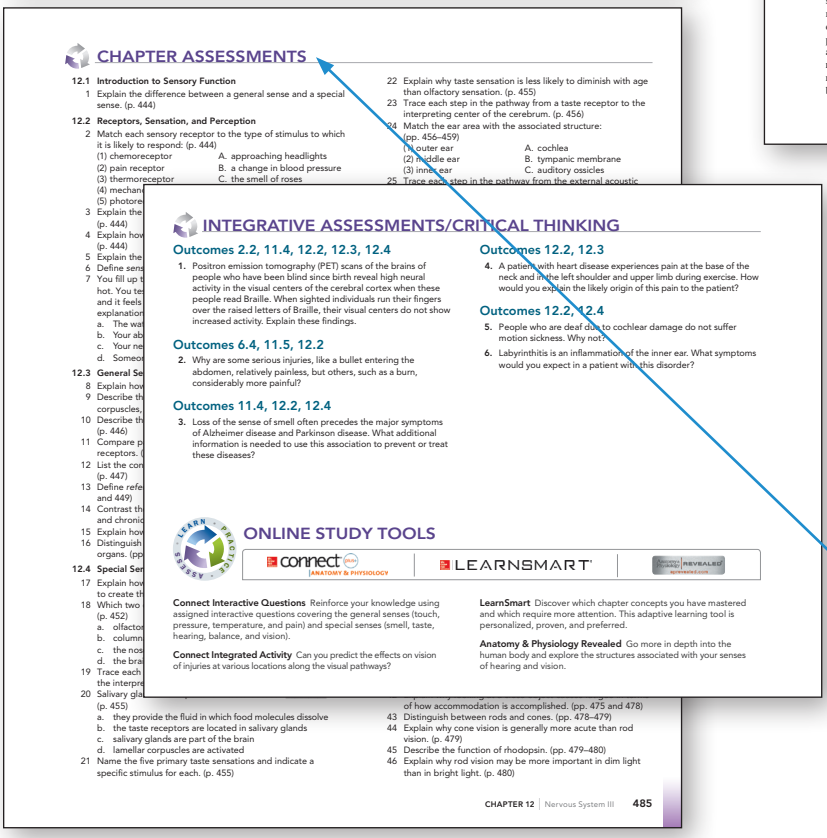
The cells of nervous tissue (neurons and neuroglia) are intimately related. They descend from the same neural stem cells and remain associated throughout their existence.

### Classification of Neurons

Neurons can be classified into three major groups based on *structural differences*, as figure 10.6 shows. Each type of neuron is specialized to conduct an impulse in one direction.

CHAPTER 10 | Nervous System I 363

Each section is followed by **Practice** questions. These questions test student understanding and comprehension of the material covered in the section.



### CHAPTER ASSESSMENTS

**12.1 Introduction to Sensory Function**
1 Explain the difference between a general sense and a special sense. (p. 444)

**12.2 Receptors, Sensation, and Perception**
2 Match each sensory receptor to the type of stimulus to which it is likely to respond: (p. 444)
(1) chemoreceptor — A. approaching headlights
(2) pain receptor — B. a change in blood pressure
(3) thermoreceptor — C. the smell of roses
(4) mechan…
(5) photore…
3 Explain the… (p. 444)
4 Explain how… (p. 444)
5 Explain the…
6 Define sens…
7 You fill up t… hot. You te… and it feels… explanation…
a. The wat…
b. Your ab…
c. Your ne…
d. Someo…

**12.3 General Se…**
8 Explain how…
9 Describe th… corpuscles,…
10 Describe th… (p. 446)
11 Compare p… receptors. (…
12 List the cor… (p. 447)
13 Define refe… and 449)
14 Contrast th… and chronic…
15 Explain how…
16 Distinguish… organs. (pp…

**12.4 Special Sen…**
17 Explain how… to create th…
18 Which two … (p. 452)
a. olfactor…
b. column…
c. the nos…
d. the bra…
19 Trace each… the interpre…
20 Salivary gla… (p. 455)
a. they provide the fluid in which food molecules dissolve
b. the taste receptors are located in salivary glands
c. salivary glands are part of the brain
d. lamellar corpuscles are activated
21 Name the five primary taste sensations and indicate a specific stimulus for each. (p. 455)
22 Explain why taste sensation is less likely to diminish with age than olfactory sensation. (p. 455)
23 Trace each step in the pathway from a taste receptor to the interpreting center of the cerebrum. (p. 456)
24 Match the ear area with the associated structure: (pp. 456–459)
(1) outer ear — A. cochlea
(2) middle ear — B. tympanic membrane
(3) inner ear — C. auditory ossicles
25 Trace each step in the pathway from the external acoustic…

### INTEGRATIVE ASSESSMENTS/CRITICAL THINKING

**Outcomes 2.2, 11.4, 12.2, 12.3, 12.4**
1. Positron emission tomography (PET) scans of the brains of people who have been blind since birth reveal high neural activity in the visual centers of the cerebral cortex when these people read Braille. When sighted individuals run their fingers over the raised letters of Braille, their visual centers do not show increased activity. Explain these findings.

**Outcomes 6.4, 11.5, 12.2**
2. Why are some serious injuries, like a bullet entering the abdomen, relatively painless, but others, such as a burn, considerably more painful?

**Outcomes 11.4, 12.2, 12.4**
3. Loss of the sense of smell often precedes the major symptoms of Alzheimer disease and Parkinson disease. What additional information is needed to use this association to prevent or treat these diseases?

**Outcomes 12.2, 12.3**
4. A patient with heart disease experiences pain at the base of the neck and in the left shoulder and upper limb during exercise. How would you explain the likely origin of this pain to the patient?

**Outcomes 12.2, 12.4**
5. People who are deaf due to cochlear damage do not suffer motion sickness. Why not?
6. Labyrinthitis is an inflammation of the inner ear. What symptoms would you expect in a patient with this disorder?

### ONLINE STUDY TOOLS

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**Connect Interactive Questions** Reinforce your knowledge using assigned interactive questions covering the general senses (touch, pressure, temperature, and pain) and special senses (smell, taste, hearing, balance, and vision).

**Connect Integrated Activity** Can you predict the effects on vision of injuries at various locations along the visual pathways?

**LearnSmart** Discover which chapter concepts you have mastered and which require more attention. This adaptive learning tool is personalized, proven, and preferred.

**Anatomy & Physiology Revealed** Go more in depth into the human body and explore the structures associated with your senses of hearing and vision.

of how accommodation is accomplished. (pp. 475 and 478)
43 Distinguish between rods and cones. (pp. 478–479)
44 Explain why cone vision is generally more acute than rod vision. (p. 479)
45 Describe the function of rhodopsin. (pp. 479–480)
46 Explain why rod vision may be more important in dim light than in bright light. (p. 480)

CHAPTER 12 | Nervous System III 485

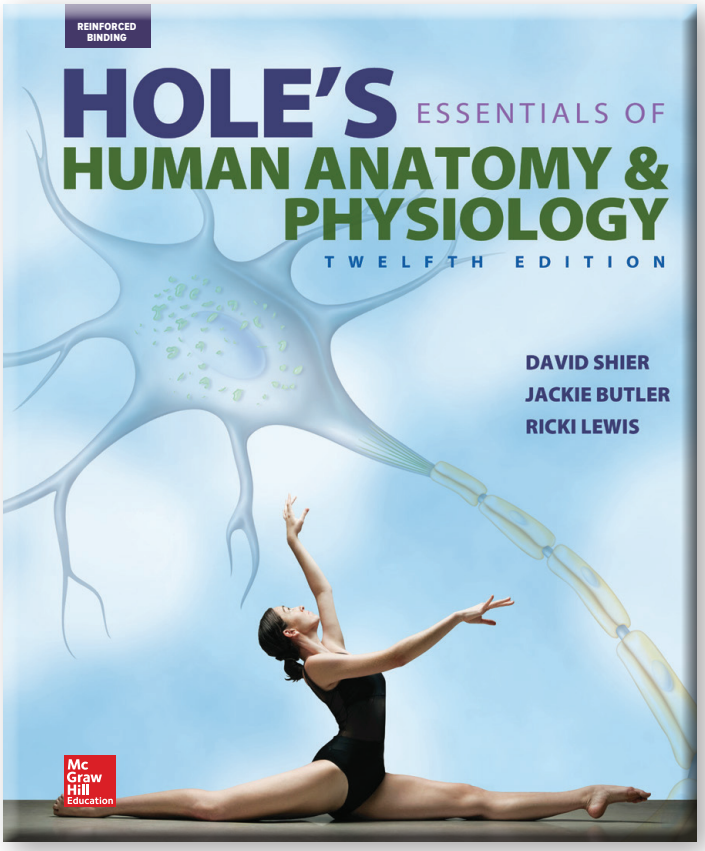
Each chapter concludes with end of chapter material that "assesses" what students have learned through the chapter. These assessments check student understanding of chapter learning outcomes.

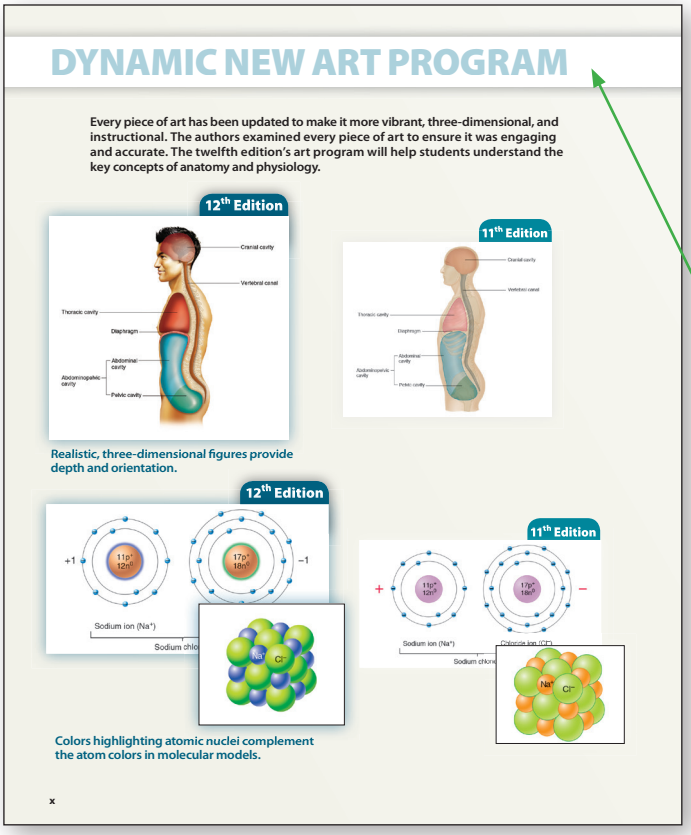
# Integrated learning system—Learn, Practice, Assess

LEVEL OF RIGOR
high low

*Hole's Essentials of Human Anatomy & Physiology*

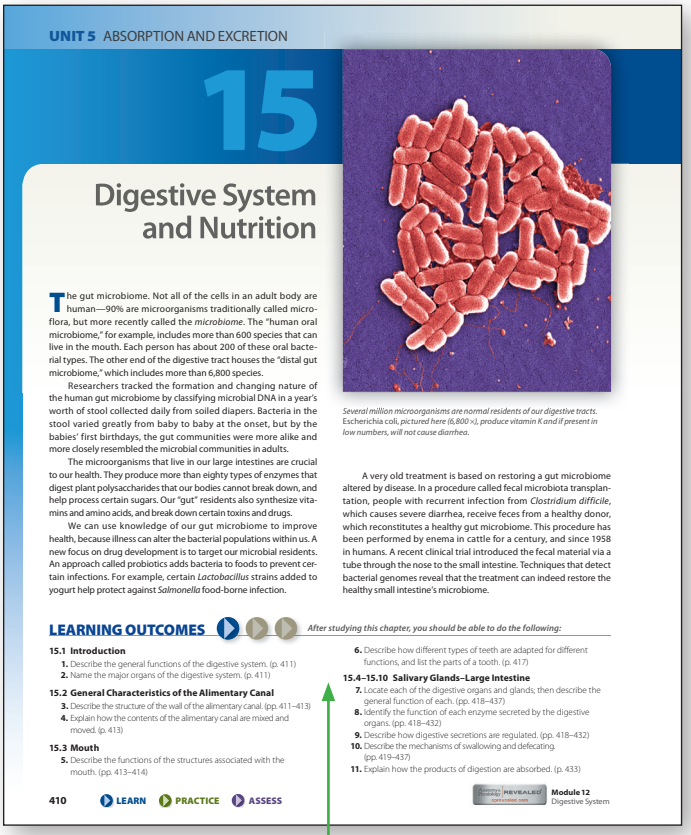
Written by the same experienced author team as *Hole's Human Anatomy & Physiology*, *Hole's Essentials of Human Anatomy & Physiology* is ideal for an introductory Anatomy and Physiology course. This text assumes no prior science knowledge, and supports core topics with clinical applications, making difficult concepts relevant to students. Like *Hole's Human Anatomy & Physiology*, *Hole's Essentials* offers the same integrated learning system, Learn, Practice, Assess, used in the text helps to set students up for success. Each chapter opens with Learning Outcomes, contains many opportunities to Practice throughout, and closes with Assessments that are closely tied to the Learning Outcomes.




Every piece of art has been updated in this edition to make it more vibrant, three-dimensional, and instructional. The twelfth edition's art program will help students understand the key concepts of anatomy and physiology.

# Hole's Essentials of Human Anatomy & Physiology



UNIT 5 ABSORPTION AND EXCRETION

15

## Digestive System and Nutrition

The gut microbiome. Not all of the cells in an adult body are human—90% are microorganisms traditionally called microflora, but more recently called the *microbiome*. The "human oral microbiome," for example, includes more than 600 species that can live in the mouth. Each person has about 200 of these oral bacterial types. The other end of the digestive tract houses the "distal gut microbiome," which includes more than 6,800 species.

Researchers tracked the formation and changing nature of the human gut microbiome by classifying microbial DNA in a year's worth of stool collected daily from soiled diapers. Bacteria in the stool varied greatly from baby to baby at the onset, but by the babies' first birthdays, the gut communities were more alike and more closely resembled the microbial communities in adults.

The microorganisms that live in our large intestines are crucial to our health. They produce more than eighty types of enzymes that digest plant polysaccharides that our bodies cannot break down, and help process certain sugars. Our "gut" residents also synthesize vitamins and amino acids, and break down certain toxins and drugs.

We can use knowledge of our gut microbiome to improve health, because illness can alter the bacterial populations within us. A new focus on drug development is to target our microbial residents. An approach called probiotics adds bacteria to foods to prevent certain infections. For example, certain *Lactobacillus* strains added to yogurt help protect against *Salmonella* food-borne infection.

*Several million microorganisms are normal residents of our digestive tracts. Escherichia coli, pictured here (6,800 ×), produce vitamin K and if present in low numbers, will not cause diarrhea.*

A very old treatment is based on restoring a gut microbiome altered by disease. In a procedure called fecal microbiota transplantation, people with recurrent infection from *Clostridium difficile*, which causes severe diarrhea, receive feces from a healthy donor, which reconstitutes a healthy gut microbiome. This procedure has been performed by enema in cattle for a century, and since 1958 in humans. A recent clinical trial introduced the fecal material via a tube through the nose to the small intestine. Techniques that detect bacterial genomes reveal that the treatment can indeed restore the healthy small intestine's microbiome.

### LEARNING OUTCOMES

*After studying this chapter, you should be able to do the following:*

**15.1 Introduction**
1. Describe the general functions of the digestive system. (p. 411)
2. Name the major organs of the digestive system. (p. 411)

**15.2 General Characteristics of the Alimentary Canal**
3. Describe the structure of the wall of the alimentary canal. (pp. 411–413)
4. Explain how the contents of the alimentary canal are mixed and moved. (p. 413)

**15.3 Mouth**
5. Describe the functions of the structures associated with the mouth. (pp. 413–414)
6. Describe how different types of teeth are adapted for different functions, and list the parts of a tooth. (p. 417)

**15.4–15.10 Salivary Glands–Large Intestine**
7. Locate each of the digestive organs and glands; then describe the general function of each. (pp. 418–437)
8. Identify the function of each enzyme secreted by the digestive organs. (pp. 418–432)
9. Describe how digestive secretions are regulated. (pp. 418–432)
10. Describe the mechanisms of swallowing and defecating. (pp. 419–437)
11. Explain how the products of digestion are absorbed. (p. 433)



Module 12 Digestive System

Each chapter includes **Learning Outcomes** that gives students an overview of the key concepts in each chapter that they will need to understand.

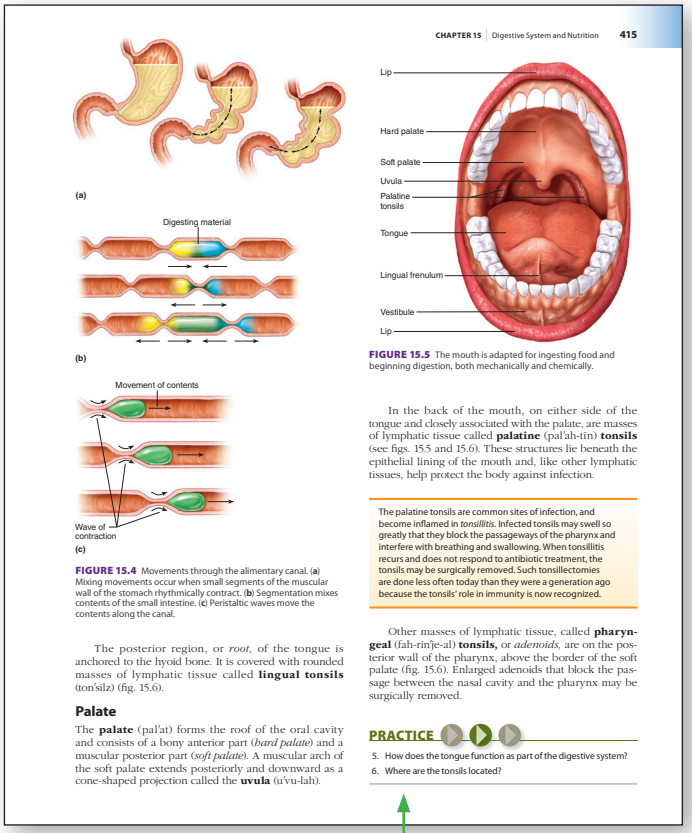







**FIGURE 15.4** Movements through the alimentary canal. (**a**) Mixing movements occur when small segments of the muscular wall of the stomach rhythmically contract. (**b**) Segmentation mixes contents of the small intestine. (**c**) Peristaltic waves move the contents along the canal.

The posterior region, or *root*, of the tongue is anchored to the hyoid bone. It is covered with rounded masses of lymphatic tissue called **lingual tonsils** (ton'silz) (fig. 15.6).

### Palate

The **palate** (pal'at) forms the roof of the oral cavity and consists of a bony anterior part (*hard palate*) and a muscular posterior part (*soft palate*). A muscular arch of the soft palate extends posteriorly and downward as a cone-shaped projection called the **uvula** (u'vu-lah).




**FIGURE 15.5** The mouth is adapted for ingesting food and beginning digestion, both mechanically and chemically.

In the back of the mouth, on either side of the tongue and closely associated with the palate, are masses of lymphatic tissue called **palatine** (pal'ah-tin) **tonsils** (see figs. 15.5 and 15.6). These structures lie beneath the epithelial lining of the mouth and, like other lymphatic tissues, help protect the body against infection.

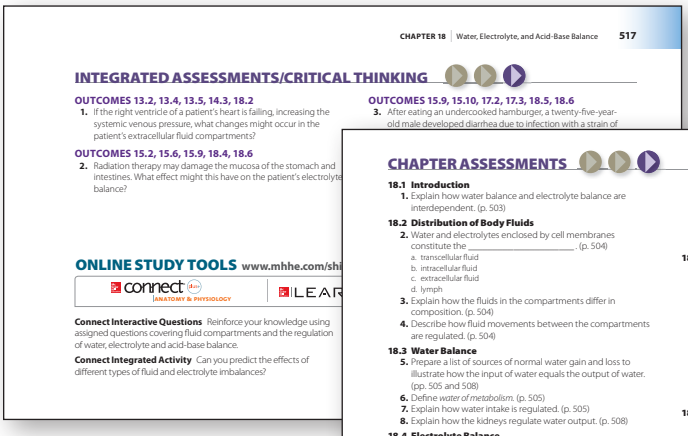
The palatine tonsils are common sites of infection, and become inflamed in *tonsillitis*. Infected tonsils may swell so greatly that they block the passageways of the pharynx and interfere with breathing and swallowing. When tonsillitis recurs and does not respond to antibiotic treatment, the tonsils may be surgically removed. Such tonsillectomies are done less often today than they were a generation ago because the tonsils' role in immunity is now recognized.

Other masses of lymphatic tissue, called **pharyngeal** (fah-rin'je-al) **tonsils,** or *adenoids,* are on the posterior wall of the pharynx, above the border of the soft palate (fig. 15.6). Enlarged adenoids that block the passage between the nasal cavity and the pharynx may be surgically removed.

### PRACTICE

5. How does the tongue function as part of the digestive system?
6. Where are the tonsils located?

Each section is followed by **Practice** questions. These questions test student understanding and comprehension of the material covered in the section.





### INTEGRATED ASSESSMENTS/CRITICAL THINKING

**OUTCOMES 13.2, 13.4, 13.5, 14.3, 18.2**

1. If the right ventricle of a patient's heart is failing, increasing the systemic venous pressure, what changes might occur in the patient's extracellular fluid compartments?

**OUTCOMES 15.2, 15.6, 15.9, 18.4, 18.6**

2. Radiation therapy may damage the mucosa of the stomach and intestines. What effect might this have on the patient's electrolyte balance?

**OUTCOMES 15.9, 15.10, 17.2, 17.3, 18.5, 18.6**

3. After eating an undercooked hamburger, a twenty-five-year-old male developed diarrhea due to infection with a strain of

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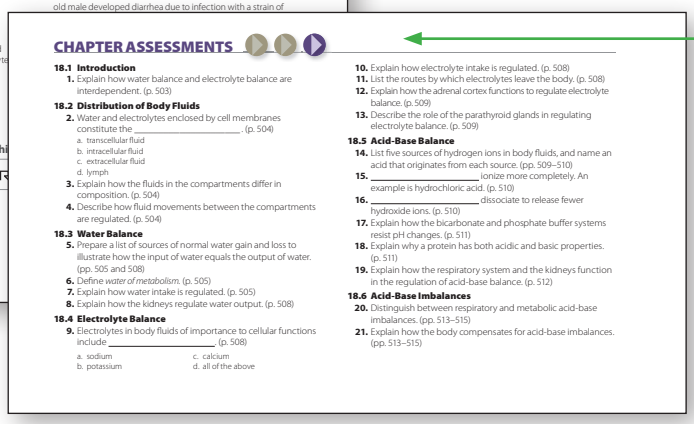
**Connect Interactive Questions** Reinforce your knowledge using assigned questions covering fluid compartments and the regulation of water, electrolyte and acid-base balance.

**Connect Integrated Activity** Can you predict the effects of different types of fluid and electrolyte imbalances?



### CHAPTER ASSESSMENTS

**18.1 Introduction**
1. Explain how water balance and electrolyte balance are interdependent. (p. 503)

**18.2 Distribution of Body Fluids**
2. Water and electrolytes enclosed by cell membranes constitute the _____. (p. 504)
   a. transcellular fluid
   b. intracellular fluid
   c. extracellular fluid
   d. lymph
3. Explain how the fluids in the compartments differ in composition. (p. 504)
4. Describe how fluid movements between the compartments are regulated. (p. 504)

**18.3 Water Balance**
5. Prepare a list of sources of normal water gain and loss to illustrate how the input of water equals the output of water. (pp. 505 and 508)
6. Define *water of metabolism*. (p. 505)
7. Explain how water intake is regulated. (p. 505)
8. Explain how the kidneys regulate water output. (p. 508)

**18.4 Electrolyte Balance**
9. Electrolytes in body fluids of importance to cellular functions include _____. (p. 508)
   a. sodium
   b. potassium
   c. calcium
   d. all of the above
10. Explain how electrolyte intake is regulated. (p. 508)
11. List the routes by which electrolytes leave the body. (p. 508)
12. Explain how the adrenal cortex functions to regulate electrolyte balance. (p. 509)
13. Describe the role of the parathyroid glands in regulating electrolyte balance. (p. 509)

**18.5 Acid-Base Balance**
14. List five sources of hydrogen ions in body fluids, and name an acid that originates from each source. (pp. 509–510)
15. _____ ionize more completely. An example is hydrochloric acid. (p. 510)
16. _____ dissociate to release fewer hydroxide ions. (p. 510)
17. Explain how the bicarbonate and phosphate buffer systems resist pH changes. (p. 511)
18. Explain why a protein has both acidic and basic properties. (p. 511)
19. Explain how the respiratory system and the kidneys function in the regulation of acid-base balance. (p. 512)

**18.6 Acid-Base Imbalances**
20. Distinguish between respiratory and metabolic acid-base imbalances. (pp. 513–515)
21. Explain how the body compensates for acid-base imbalances. (pp. 513–515)

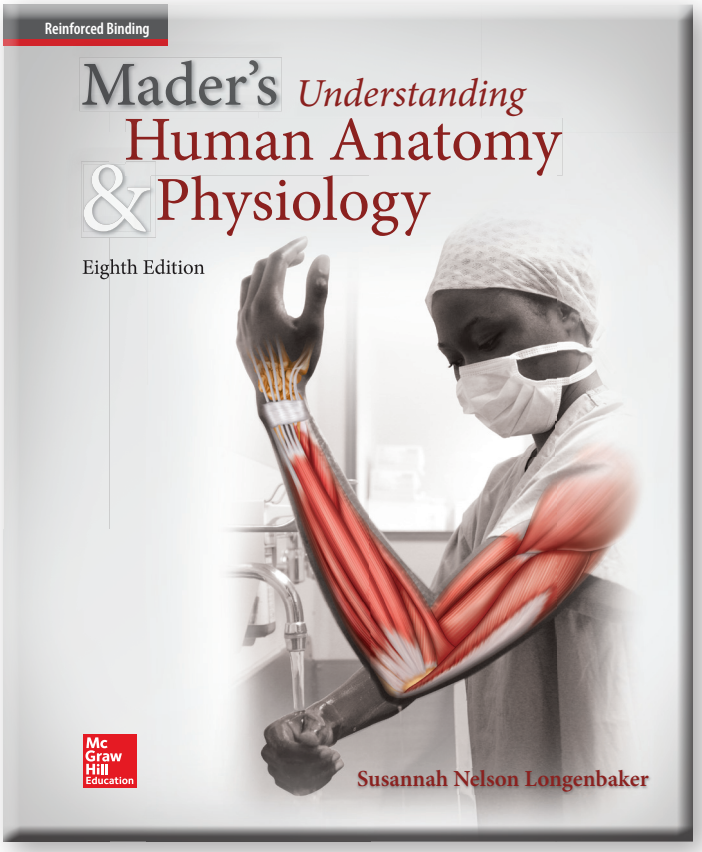
Each chapter concludes with end of chapter material that "assesses" what students have learned through the chapter. These assessments check student understanding of chapter learning outcomes.

# Clearly written, direct, and user-friendly

LEVEL OF RIGOR
high — low

## *Mader's Understanding Human Anatomy & Physiology*

*Mader's Understanding Human Anatomy & Physiology* is the most accessible of the two introductory Anatomy & Physiology programs. Designed to help entry-level students understand and enjoy the principles of human anatomy and physiology, this text, originally authored by Dr. Sylvia Mader who is well known for her franchise of biology texts and her approachable writing style, now continues under the authorship of Susannah Longenbaker. The accessible writing style and art program are key to making this text approachable for many types of students. This edition is enriched with new clinical information, terminology and classroom-tested features such as "Focus on Forensics" readings and in-text "Content Check-Up" questions.





Cell Structure and Function

CHAPTER 3

Need another reason to quit using tobacco? The fine, hairlike cilia you see on these cells from the trachea, or windpipe, are exquisitely tailored organelles with an important protective function. Sticky mucus covering the tracheal walls traps harmful pollutants like dust and mold spores before they can reach the lungs. Cilia push the mucus upward toward the throat, and you can either spit it out or swallow it. In either case, the mucus and trapped pollutants are usually harmless. Now consider this: nicotine (remember, it's an alkaloid poison!) temporarily poisons delicate cilia. A deep, hacking smoker's cough becomes the only way to clear mucus from the airways. You'll find tips to help you stop smoking in Chapter 14.

Learning Outcomes — After you have studied this chapter, you should be able to:

**3.1 Cellular Organization (p. 41)**
1. Name the three main parts of a human cell.
2. Describe the structure and function of the plasma membrane.
3. Describe the structure and function of the nucleus.
4. Describe the structures and roles of the endoplasmic reticulum and the Golgi apparatus in the cytoplasm.
5. Describe the structures of lysosomes and the role of these organelles in the breakdown of molecules.
6. Describe the structure of mitochondria and their role in producing ATP.
7. Describe the structures of centrioles, cilia, and flagella and their roles in cellular movement.
8. Describe the structures and function of the cytoskeleton.

**3.2 Crossing the Plasma Membrane (p. 49)**
9. Describe how substances move across the plasma membrane, and distinguish between passive and active transport.

**3.3 The Cell Cycle (p. 53)**
10. Describe the phases of the cell cycle.
11. As a part of interphase, describe the process of DNA replication.
12. As a part of interphase, also describe how cells carry out protein synthesis.
13. Describe the phases of mitosis, and explain the function of mitosis.

**Visual Focus**
The Cell (p. 42)

**Medical Focus**
Dehydration and Water Intoxication (p. 52)

**Focus on Forensics**
DNA Fingerprinting (p. 58)

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**Learning Outcomes** at the beginning of each chapter help students understand what they should know after studying the chapter.

# Mader's Understanding Human Anatomy & Physiology

## I.C.E. — IN CASE OF EMERGENCY

### Lung Collapse

Imagine that you're a military medic who's called upon to respond when troops have been injured due to a bomb blast. As you arrive at the scene, two fallen soldiers need your attention. One has an open chest wound, caused by shrapnel cutting his chest. The second was nearby when the blast occurred, but has no obvious wounds. Yet, both have the same symptoms: sharp pain when they inhale, difficulty speaking, and a feeling of breathlessness. Both soldiers' blood pressure is low and pulse is rapid, indicating that they might slip into shock. You take a quick history from both victims and from their buddies.

Right away, you suspect each soldier has *atelectasis*—the technical term for a collapsed lung. As you'll recall, the lungs are held up against the chest wall by the attraction force of surface tension. If air enters the thorax, surface tension will fail, and the lungs will collapse. The first soldier's chest wound is allowing air from the atmosphere to enter the thorax. A section of the second soldier's lung burst as a result of the high pressure from the bomb blast, and air has filled his thorax from the hole in his lung. When the lungs collapse, the air filling the chest compresses the heart and prevents it from filling with blood. This is termed *tension pneumothorax*, or air in the thorax. You'll need to act fast, or both victims will slip into shock.

With the help of the first soldier's buddies, you put a special air-tight pressure bandage over his open chest wound, which will prevent additional air from entering the wound and help stop bleeding. Next, you'll start his intravenous solution (IV). By listening to the second soldier's chest with your stethoscope, you'll be able to tell where the lung has collapsed because it will sound hollow. When you trained as a medic, you learned to do a *thoracocentesis*, and you'll rapidly insert a catheter between the soldier's ribs to let the trapped air out into the atmosphere. Now your patients are ready for their helicopter trip to a field hospital for more advanced care.

If the trachea is blocked because of illness or the accidental swallowing of a foreign object, it is possible to insert a breathing tube by way of an incision made in the trachea. This tube acts as an artificial air intake and exhaust duct. The operation is called a **tracheostomy.**

#### The Bronchial Tree

The trachea divides into right and left primary **bronchi** (sing., **bronchus**), which lead into the right and left lungs (see Fig. 14.1). The primary bronchi then branch into secondary bronchi: one for each lobe of the lung. Thus, there are three secondary bronchi for the right lung, which has three lobes. Two secondary bronchi supply the left lung, which has only two lobes in order to allow room for the heart. Each secondary bronchus then divides into smaller tertiary bronchi. These smaller bronchi are supported by smaller plates of cartilage, in place of the cartilage rings of the trachea. **Bronchioles** are the smallest conducting airways. They lack cartilage support, but possess a ciliated epithelium and a well-developed smooth muscle layer. During an asthma attack, the smooth muscle of the bronchioles contracts, causing bronchiolar constriction and characteristic wheezing. Each bronchiole leads to an elongated space enclosed by a multitude of air pockets, or sacs, called **alveoli** (sing., **alveolus**). The components of the bronchial tree beyond the primary bronchi, including the alveoli, compose the lungs.

### The Lungs

The **lungs** are paired, cone-shaped organs. Each fills its own pleural cavity inside the thoracic cavity, separated by the mediastinum. Recall that the mediastinum is the central compartment that separates the thoracic cavity. It contains the heart and its major vessels, primary bronchi, thymus gland, trachea, and esophagus (see Chapter 1, page 7). The apex is the superior narrow portion of a lung, and the base is the inferior broad portion that curves to fit the dome-shaped diaphragm, the muscle of respiration that separates the thoracic cavity from the abdominal cavity. The lateral surfaces of the lungs follow the contours of the ribs in the thoracic cavity.

Each lobe of the lung is further divided into lobules, and each lobule has a bronchiole supplying many alveoli. Pulmonary arteries travel alongside the bronchi; likewise, pulmonary arterioles parallel the bronchioles. Each pulmonary arteriole then further branches to form **pulmonary capillaries.** Pulmonary capillaries surround and cover each alveolus of the lung. Elastic connective tissue binds the air passages to the blood vessels within each lung; this elastic tissue helps the lungs return to their resting position, or *recoil*, when a person exhales.

Each lung is enclosed by a double layer of serous membrane called the **pleurae** (sing., **pleura**). The visceral pleura adheres to the surface of the lung; the parietal pleura lines the inside of the thoracic cavity. The pleurae produce a lubricating serous fluid that reduces friction and allows the two layers to slide across one another. Serous fluid, a water-based solution, also creates **surface tension:** the tendency for water molecules to cling to each other (due to hydrogen bonding between the molecules) and to form a droplet (see section 2.2). Surface tension holds the two pleural layers together, thus holding the lungs open against the chest wall.

#### The Alveoli

With each inhalation, air passes through the bronchial tree to the alveoli. An alveolar sac is made up of simple squamous epithelium



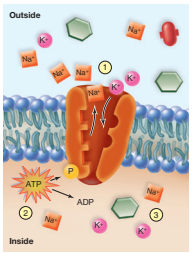
membrane. During **facilitated diffusion** (facilitated transport), a molecule (e.g., an amino acid or glucose) is transported across the plasma membrane from the side of higher concentration to the side of lower concentration. The cell doesn't need to expend energy for this type of transport because the molecules are moving down their concentration gradient.

**Begin Thinking Clinically**

**If the disease diabetes isn't well controlled, the concentration of glucose found in blood soars after meals. The protein carriers can't transport it all into cells. What happens to that extra glucose?**

*Answer and discussion in Appendix B.*

During **active transport,** a molecule is moving contrary to the normal direction—that is, from lower to higher concentration (Fig. 3.11). For example, iodine collects in the cells of the thyroid gland; sugar is completely absorbed from the gut by cells that line the digestive tract; and sodium ($Na^+$) is sometimes almost completely withdrawn from urine by cells lining kidney tubules. Active transport requires a protein carrier and the use of cellular energy obtained from the breakdown of ATP. When ATP is broken down, energy is released, and in this case the energy is used by a carrier to carry out active transport. Therefore, it is not surprising that cells involved in active transport have a large number of mitochondria near the plasma membrane at which active transport is occurring.




AP|R **Figure 3.11 Active transport through a plasma membrane.** Active transport allows a molecule to cross the membrane from lower concentration to higher concentration. (1) Molecule enters carrier. (2) Breakdown of ATP induces a change in shape that (3) drives the molecule across the membrane.

Proteins involved in active transport often are called pumps because just as a water pump uses energy to move water against the force of gravity, proteins use energy to move substances against their concentration gradients. One type of pump that is active in all cells but is especially associated with nerve and muscle cells moves sodium ions ($Na^+$) to the outside of the cell and potassium ions ($K^+$) to the inside of the cell.

The passage of salt (NaCl) across a plasma membrane is of primary importance in cells. First, sodium ions are pumped across a membrane; then, chloride ions simply diffuse through channels that allow their passage. Chloride ion channels malfunction in persons with **cystic fibrosis,** and this leads to the symptoms of this inherited (genetic) disorder.

### Endocytosis and Exocytosis

During **endocytosis,** a portion of the plasma membrane forms an inner pocket to envelop a substance, and then the membrane pinches off to form an intracellular vesicle (see Fig. 3.5, *left*). Two forms of endocytosis exist: **phagocytosis,** or "cell eating," is a mechanism that allows the cell to ingest solid particles. White blood cells consume bacterial cells by phagocytosis. Once inside the cell, the bacterial cell can be destroyed. **Pinocytosis,** or "cell drinking," allows the cell to consume solutions. An infant's intestinal lining ingests breast milk by pinocytosis, allowing the mother's protective antibodies to enter the baby's bloodstream.

During **exocytosis,** a vesicle fuses with the plasma membrane as secretion occurs (see Fig. 3.5, *right*). This is the way insulin leaves insulin-secreting cells, for instance. Table 3.2 summarizes the various ways molecules cross the plasma membrane.

**Content CHECK-UP!**

4. Which process requires cellular ATP energy?
   a. osmosis
   b. facilitated diffusion (facilitated transport)
   c. active transport
   d. simple diffusion
5. A researcher studying the white blood cells of a patient infected with tuberculosis (TB) bacteria notices the bacteria are in *vesicles* in the cytoplasm. How did the bacteria come to be inside the cell?
   a. pinocytosis
   b. phagocytosis
   c. exocytosis
6. The cell organelle that is needed to destroy the TB bacterium discussed in question 5 is a:
   a. ribosome.
   b. lysosome.
   c. centrosome.

*Answers in Appendix B.*



## MEDICAL FOCUS

### *Dehydration and Water Intoxication*

**Dehydration** is due to a loss of water. The solute concentration in extracellular fluid increases—that is, tissue fluid becomes hypertonic to cells, and water leaves the cells, so that they crenate. A common cause of dehydration is excessive sweating, perhaps during exercise, without any replacement of the water lost. Dehydration can also be a side effect of any illness that causes prolonged vomiting or diarrhea.

The signs of moderate dehydration are a dry mouth, sunken eyes, and skin that will not bounce back after light pinching. If dehydration becomes severe, the pulse and breathing rate are rapid, the hands and feet are cold, and the lips are blue. Although dehydration leads to weight loss, deliberately dehydrating to lose weight is extremely dangerous and can be fatal.

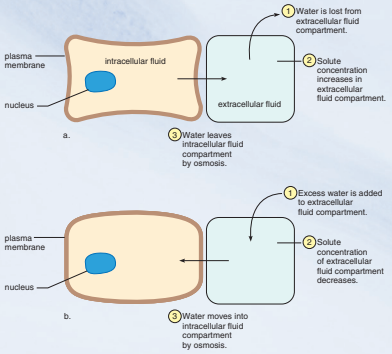



**Figure 3A Dehydration versus water intoxication. a.** If extracellular fluid loses too much water, cells lose water by osmosis and become dehydrated. **b.** If extracellular fluid gains too much water, cells gain water by osmosis and water intoxication occurs.

**Water intoxication** may be caused by excessive consumption of pure water. The tissue fluid becomes hypotonic to the cells, and water enters the cells. Water intoxication can lead to pulmonary edema (excess tissue fluid in the lungs) and swelling in the brain. In extreme cases, it is fatal. Water intoxication is not nearly as common in adults as is dehydration. It can result from a mental disorder termed *psychogenic polydipsia.* Another cause can be the intake of too much pure water during vigorous exercise: for example, a marathon race. Marathoners who collapse and have nausea and vomiting after a race may be suffering from water intoxication. The cure, an intravenous solution containing high amounts of sodium, is the opposite of that for dehydration. Therefore, it is important that physicians be able to diagnose water intoxication in athletes who have had an opportunity to drink fluids over a period of a few hours. To prevent both dehydration and water intoxication, athletes should replace lost fluids continuously. Pure water is a good choice if the exercise period is short. Low-sodium solutions, such as sports drinks, are a good choice for longer-duration events like marathons.



Unsurpassed Clinical Coverage is evident all through this text. Features such as **I.C.E.: In Case of Emergency** and **Medical Focus** are written to relate the very latest research and developments in applied aspects of anatomy and physiology to important concepts in the text. These features engage students in real-life scenarios that challenge them to use, and expand upon, their recently acquired knowledge.

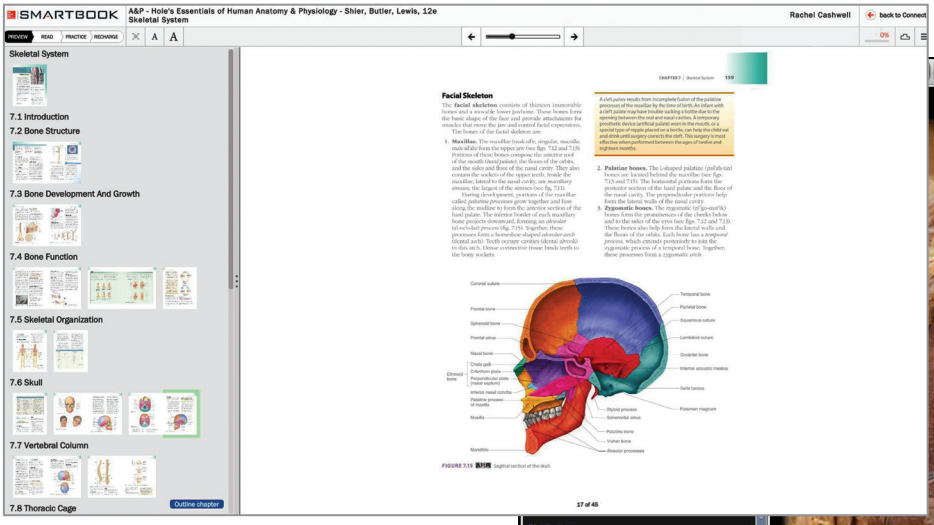
Built-in study aids such as the **Content Check-Up** features allow students to test themselves over major sections of text before continuing.

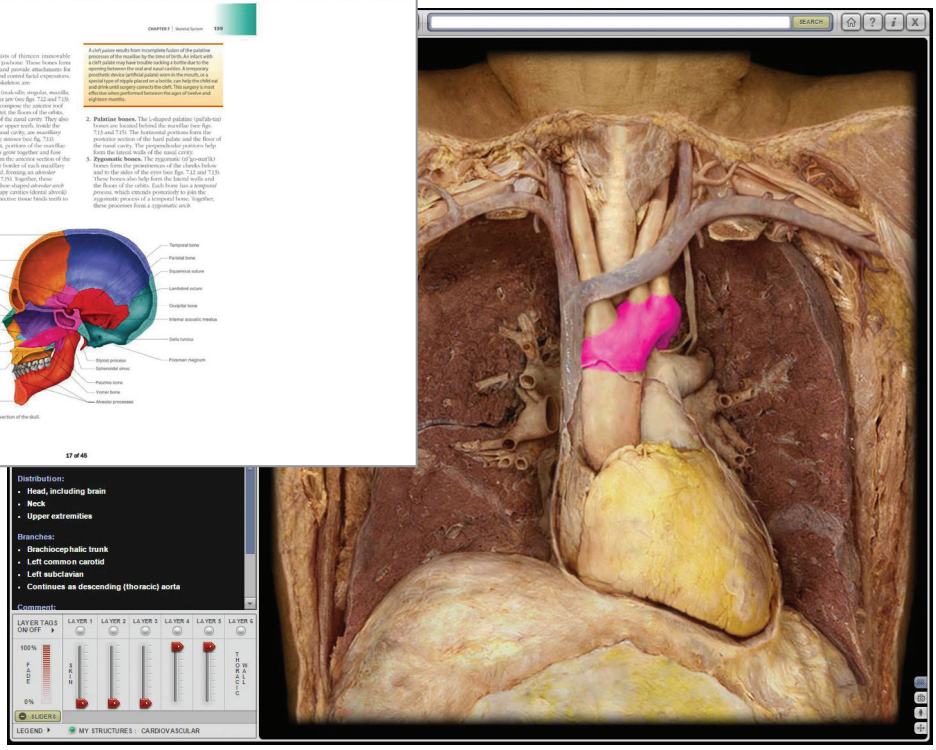
# Support Materials Available Through Connect

*SmartBook, LearnSmart and Anatomy & Physiology Revealed*

## SmartBook and LearnSmart

***SmartBook*** is the first and only adaptive eBook designed to change the way students read and learn. Built on the proven ***LearnSmart*** engine, ***SmartBook*** identifies what a student does or does not know and adapts in real time to help students learn faster and study more efficiently. Teachers can leverage ***LearnSmart's*** robust reporting tools, including metacognitive reports and most challenging learning objective reports, to identify areas in which students are struggling and provide targeted remediation to enhance learning.



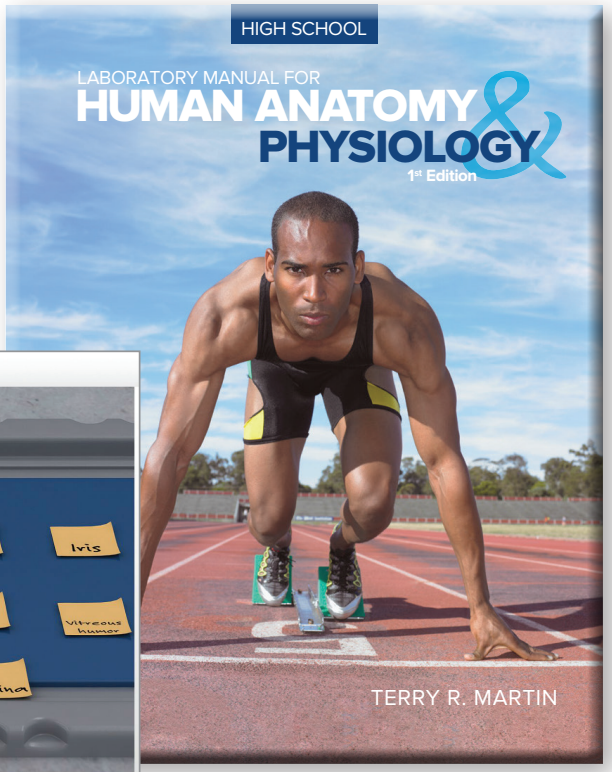




## Anatomy & Physiology Revealed

***Anatomy & Physiology Revealed*** is the ultimate online interactive cadaver dissection experience. This state-of-the-art program uses cadaver photos combined with a layering technique that allows the student to peel away layers of the human body to reveal structures beneath the surface. This program covers important topics from chemistry to organ systems, with animations, audio pronunciations, and comprehensive quizzing along the way.

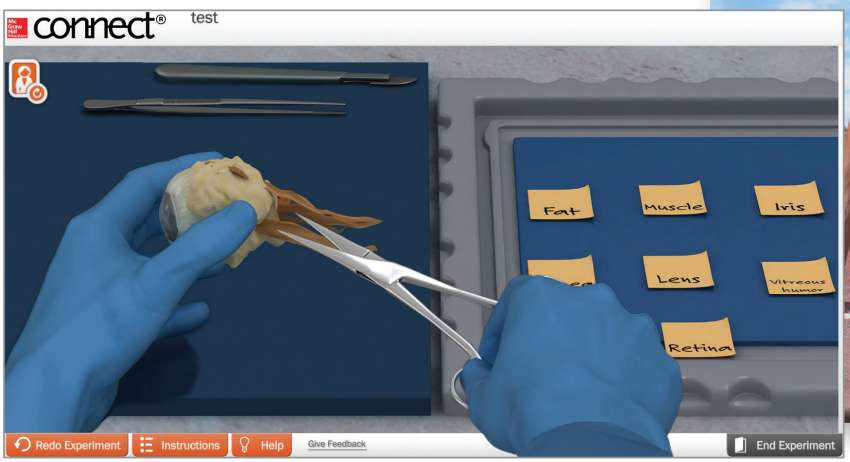
# Traditional and Online Laboratory Options

## *High School Lab Manual*




**Your print companion providing support for traditional classroom lab work.**

The ***High School Laboratory Manual for Human Anatomy & Physiology*** is a streamlined lab manual ideal for the high school classroom. It contains 28 hands-on laboratory activities to complement any Anatomy & Physiology course.




## *LearnSmart Labs*

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3. A virtual coach provides subtle hints when needed, asks questions about the student's choices, and allows the student to reflect upon and correct those mistakes. *

* - LearnSmart Labs is only available with *Hole's Essentials of Anatomy & Physiology* and *Hole's Human Anatomy & Physiology*