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Seeley's

ANATOMY & PHYSIOLOGY

Thirteenth Edition

Cinnamon VanPutte
Jennifer Regan
Andrew Russo

Mc Graw Hill

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Southern Illinois University School of Dental Medicine

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Cinnamon has been teaching biology and human anatomy and physiology for over two decades. At SIU School of Dental Medicine she is the course director for the Integrated Biomedical Science courses and teaches physiology to first-year dental students and participates in dental-based physiology research. Cinnamon is an active member of several professional societies, including the Human Anatomy and Physiology Society (HAPS) and American Dental Education Association (ADEA). Her Ph.D. in zoology, with an emphasis in endocrinology, is from Texas A&M University. She worked in Dr. Duncan MacKenzie's lab, where she was indoctrinated in the major principles of physiology and the importance of critical thinking. The critical thinking component of *Seeley's Human Anatomy & Physiology* epitomizes Cinnamon's passion for the field of human anatomy and physiology; she is committed to maintaining this tradition of excellence. Cinnamon and her husband, Robb (also a biology professor), have two children: a daughter, Savannah, and a son, Ethan. Savannah is studying to become an elementary school teacher. Ethan is involved in 4-H and shows steers and lambs. He is working on his future endeavors. Cinnamon and her family live on a farm with her parents, Tom and Bobbie, where they raise sheep and cattle.

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For over 20 years, Jennifer has taught introductory biology, human anatomy and physiology, and genetics at the university and community college level. She has received the Instructor of the Year Award at both the departmental and college level while teaching at USM. In addition, she has been recognized for her dedication to teaching by student organizations such as the Alliance for Graduate Education in Mississippi and Increasing Minority Access to Graduate Education. Jennifer has dedicated much of her career to improving lecture and laboratory instruction at her institutions. Critical thinking and lifelong learning are two characteristics Jennifer hopes to instill in her students. She appreciates the Seeley approach to learning and is excited about contributing to further development of the textbook. She received her Ph.D. in biology at the University of Houston, under the direction of Edwin H. Bryant and Lisa M. Meffert. She is an active member of several professional organizations, including the Human Anatomy and Physiology Society. During her free time, Jennifer enjoys spending time with her husband, Hobbie, a GIS analyst supervisor. They have two sons, Patrick and Nicholas.

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Andrew has over 30 years of classroom experience with human physiology, neurobiology, molecular biology, and cell biology courses at the University of Iowa. He is a recipient of the Collegiate Teaching Award and the J.P. Long Teaching Award in Basic Sciences. He is currently the course director for a new medical school course called Mechanisms of Health and Disease that integrates physiology, histology, and genetics. He is a member of several professional societies, including the Society for Neuroscience. Andrew received his Ph.D. in biochemistry from the University of California at Berkeley. His research interests are focused on the molecular basis of migraine. His decision to join the author team for *Seeley's Human Anatomy & Physiology* is the culmination of a passion for teaching that began in graduate school. He is excited about the opportunity to hook students' interest in learning by presenting cutting-edge clinical and scientific advances. Andrew is married to Maureen, a physical therapist, and has three daughters, Erilynn, Becky, and Colleen, and six grandchildren. He enjoys all types of outdoor sports, especially bicycling, skiing, running, and open water swimming.

Dedication

This text is dedicated to the students of human anatomy and physiology. Helping students develop a working knowledge of anatomy and physiology is a satisfying challenge, and we have a great appreciation for the effort and enthusiasm of so many who want to know more. It is difficult to imagine anything more exciting, or more important, than being involved in the process of helping people learn about the subject we love so much.

Acknowledgments

A great deal of effort is required to produce a heavily illustrated textbook like *Seeley's Anatomy & Physiology*. Many hours of work are required to organize and develop the components of the textbook while also creating and designing illustrations, but no text is solely the work of the authors. It is not possible to adequately acknowledge the support and encouragement provided by our loved ones. They have had the patience and understanding to tolerate our absences and our frustrations. They have also been willing to provide assistance and unwavering support.

Many hands besides our own have touched this text, guiding it through various stages of development and production. We wish to express our gratitude to the staff of McGraw Hill for their help and encouragement. We appreciate the guidance and tutelage of portfolio manager Matthew Garcia. We are sincerely grateful to product developer Melisa Seegmiller for her careful scrutiny of the manuscript, her creative ideas and suggestions, and her tremendous patience and encouragement. Special thanks are also offered to copyeditor Sharon O'Donnell for her attention to detail and for carefully polishing our words. A special acknowledgment of gratitude is owed to content project manager Ann Courtney for her patience and detail-tracking abilities. Content licensing specialist Lori Hancock, designer David Hash, and assessment project manager Brent Dela Cruz, we thank you for your time spent turning our manuscript into a book and its accompanying digital program. The McGraw Hill employees with whom we have worked are excellent professionals. They have been consistently helpful and their efforts are truly appreciated. Their commitment to this project has clearly been more than a job to them.

Finally, we sincerely thank the past reviewers and instructors who have provided us time and time again with remarkable feedback. We have continued their recommendations in this edition, while remaining true to our overriding goal of writing a text that is comprehensive enough to provide the depth necessary for a two-semester course, yet ensuring it is presented with such clarity that it nicely balances the thorough coverage to be more student centered. Each feature incorporated into this edition has been carefully considered in how it may be used to support student learning and understanding.

It takes teamwork to ensure the highest accuracy and greatest clarity within a textbook of this magnitude. We would like to extend a very heartfelt thank you to our Board of Advisors for their feedback on our new art program. With their keen eyes and innovative ideas, we are very excited to present this edition of the text. However, without a strong foundation provided by the previous authors of this text, the changes we've made simply wouldn't be possible and so our gratitude to the founders of this text is ever-present.

Also, in this edition, we are very pleased to have been able to incorporate real student data points and input, derived from thousands of our LearnSmart users, to help guide our revision. LearnSmart Heat Maps provided a quick visual snapshot of usage of portions of the text and the relative difficulty students experienced in mastering the content. With these data, we were able to hone not only our text content but also the LearnSmart probes.

Cinnamon VanPutte

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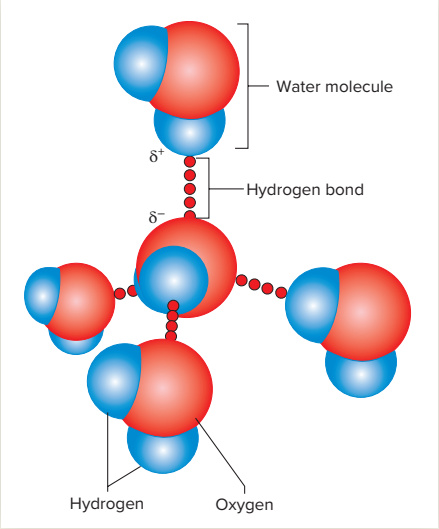
Brief **Contents**

Contents

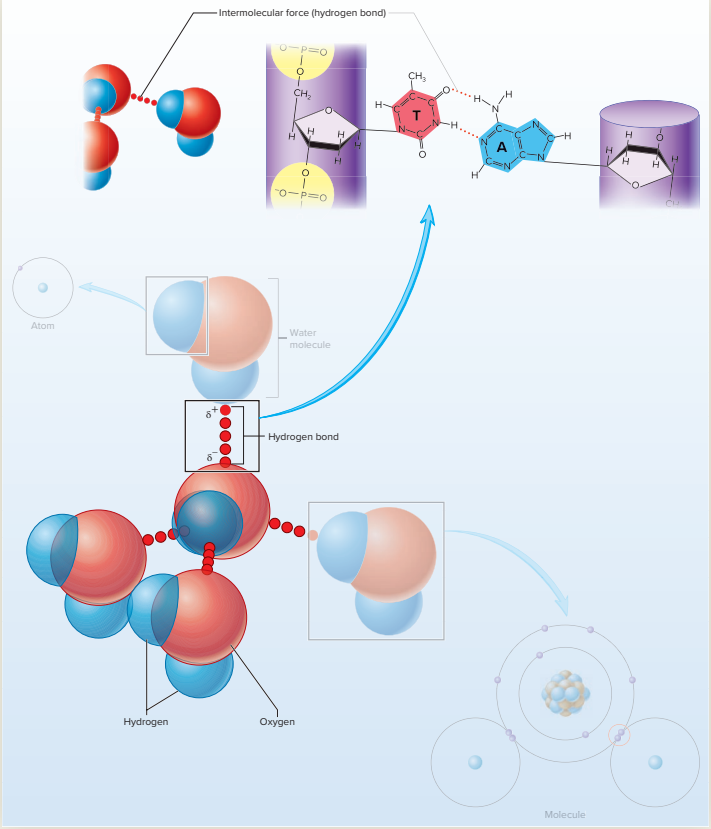
DYNAMIC NEW **Art** PROGRAM

Our new art program has created more vibrancy and more three-dimensionality to our art, making it look more realistic.

12th Edition

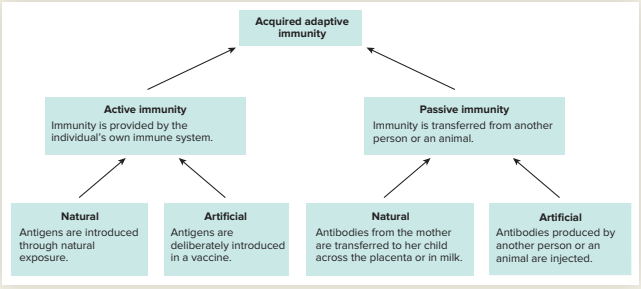


13th Edition



The previous version of this figure did not illustrate the connection between formation of polar covalent bonds and the potential for hydrogen bonds to occur. The new art builds from previous art illustrating polar covalent bond formation.

12th Edition



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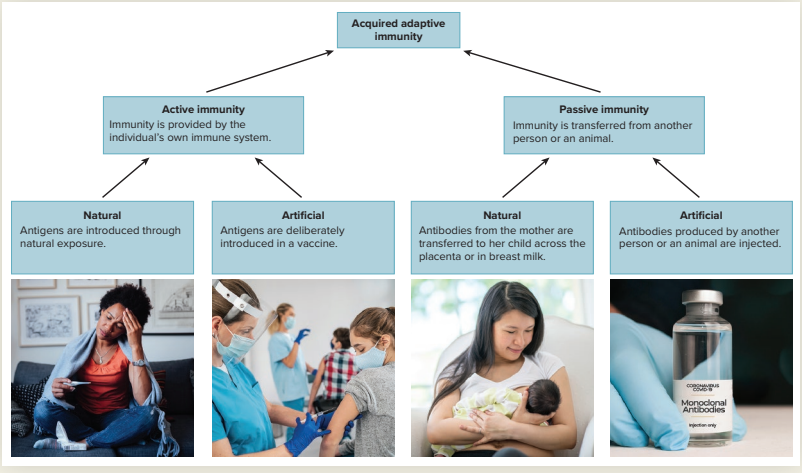
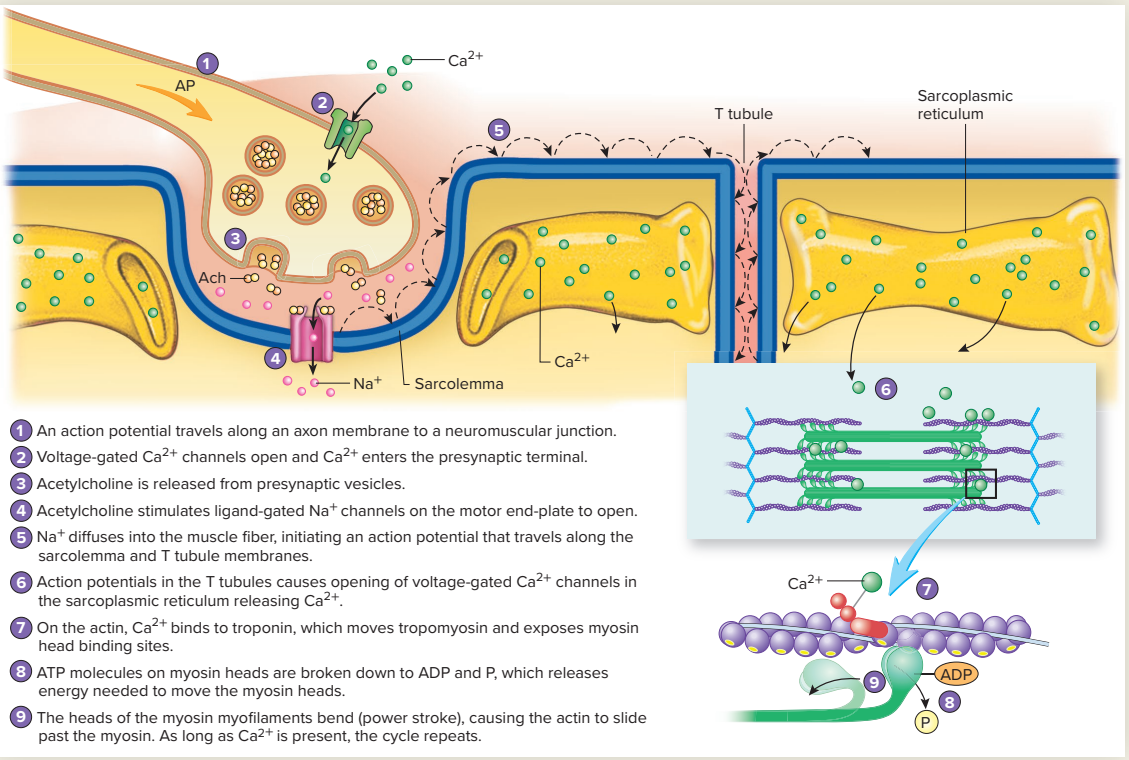


The 12/e version of this figure is a flat, two-dimensional, simplistic flow-chart. The 13/e version is colorful and engaging, as well as relatable. Having images that illustrate each component provides realistic context for students.

(Young woman feeling) Brothers91/Getty Images; (Doctor vaccinating girl) valentinrussanov/Getty Images; (Breastfeeding Mother) FatCamera/Getty Images; (Doctor holds a vial of monoclonal antibodies) Cristian Storto/Alamy Stock Photo

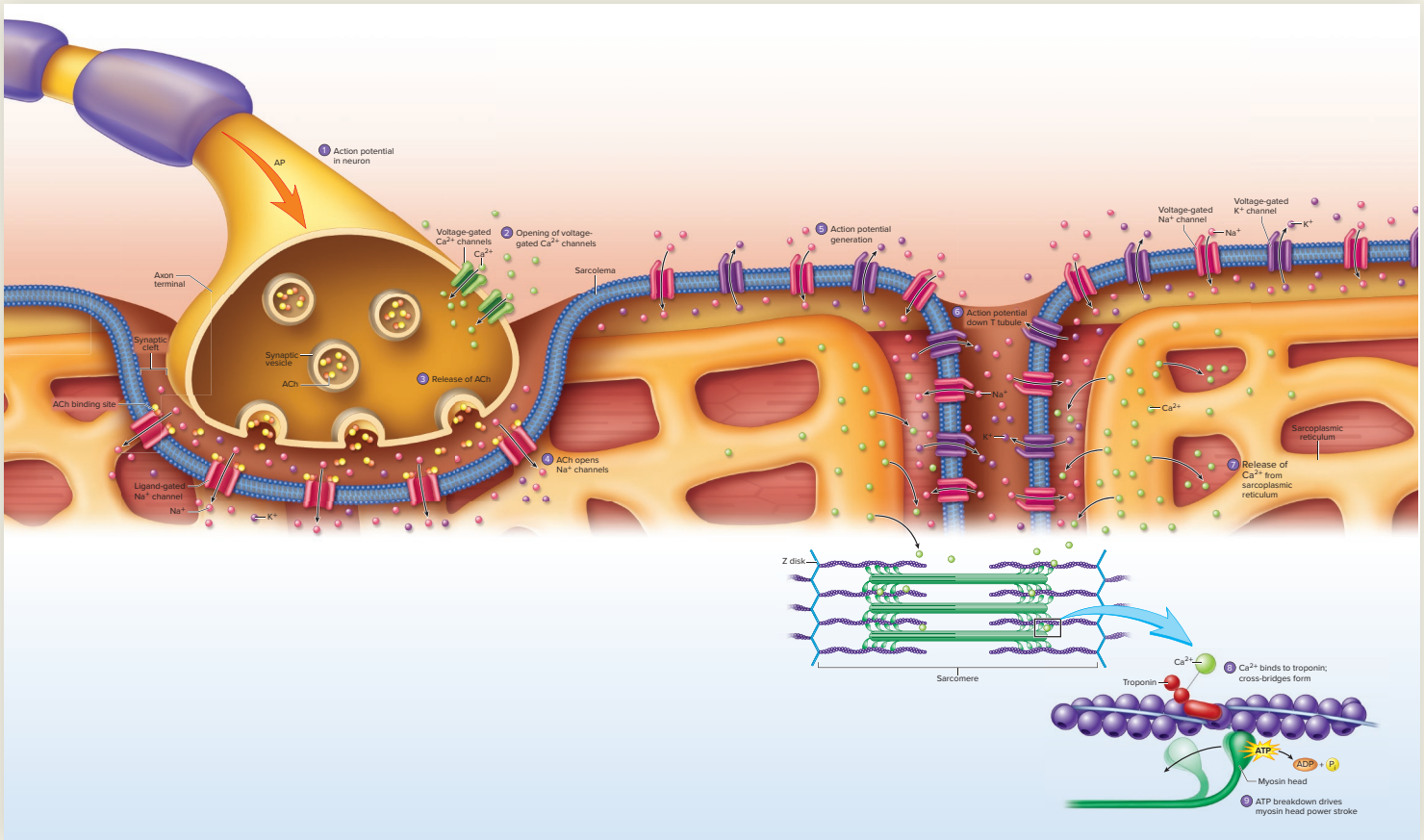
12th Edition



1. An action potential travels along an axon membrane to a neuromuscular junction.
2. Voltage-gated Ca^{2+} channels open and Ca^{2+} enters the presynaptic terminal.
3. Acetylcholine is released from presynaptic vesicles.
4. Acetylcholine stimulates ligand-gated Na^{+} channels on the motor end-plate to open.
5. Na^{+} diffuses into the muscle fiber, initiating an action potential that travels along the sarcolemma and T tubule membranes.
6. Action potentials in the T tubules causes opening of voltage-gated Ca^{2+} channels in the sarcoplasmic reticulum releasing Ca^{2+}.
7. On the actin, Ca^{2+} binds to troponin, which moves tropomyosin and exposes myosin head binding sites.
8. ATP molecules on myosin heads are broken down to ADP and P, which releases energy needed to move the myosin heads.
9. The heads of the myosin myofilaments bend (power stroke), causing the actin to slide past the myosin. As long as Ca^{2+} is present, the cycle repeats.

The 12/e version of this figure was two-dimensional, muted in color, and small, while the 13/e version of this figure is three-dimensional, vibrant in color, and a two-page spread to help students tie all the concepts together from beginning to end.

13th Edition



WHAT SETS Seeley's Anatomy & Physiology APART?

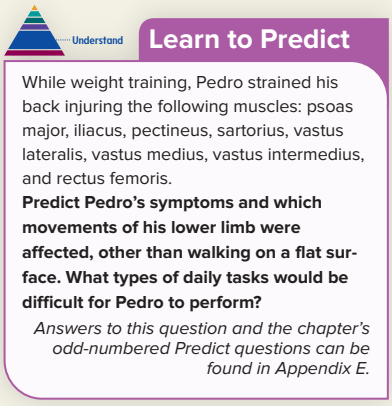
Seeley's Anatomy & Physiology is written for the two-semester anatomy and physiology course. The writing is comprehensive enough to provide the depth necessary for those courses not requiring prerequisites, and is presented with such clarity that it nicely balances the thorough coverage. Clear descriptions and exceptional illustrations combine to help students develop a firm understanding of the concepts of anatomy and physiology and understand how to use that information.

What Makes This Text a Market Leader?

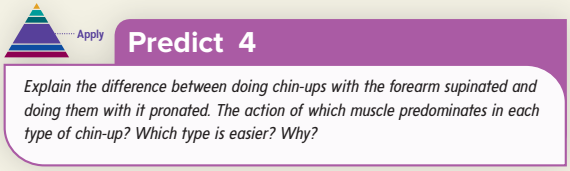
Seeley's Learning System—*Emphasis on Critical Thinking*

An emphasis on critical thinking is integrated throughout this textbook. This approach is found in questions that begin each chapter and those embedded within the narrative; in clinical material that is designed to bridge concepts explained in the text with real-life applications and scenarios; in end-of-chapter questions that go beyond rote memorization; and in a visual program that presents material in understandable, relevant images, with application questions that follow each Process Figure.

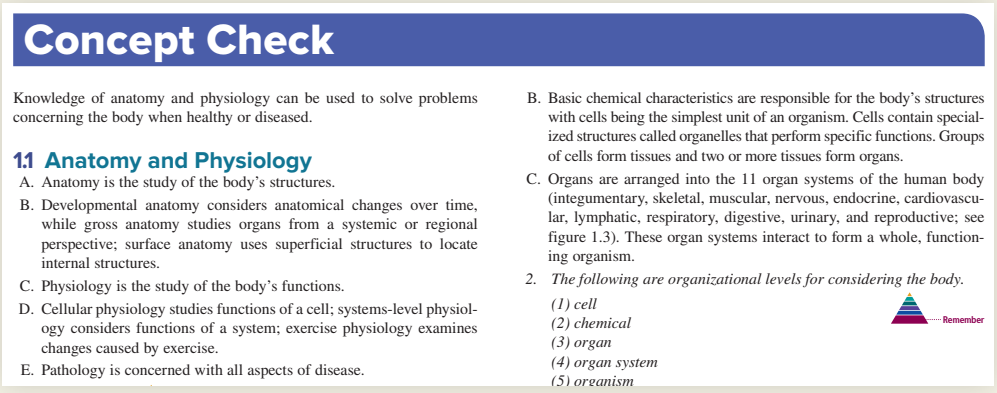
- Problem-solving perspective from the book's inception
- Pedagogy that builds student comprehension from knowledge to application (**Learn to Predict** questions, **Predict** questions, **Concept Check** questions)



Learn to Predict questions are found at the beginning of each chapter, with the corresponding answer located in Appendix E.



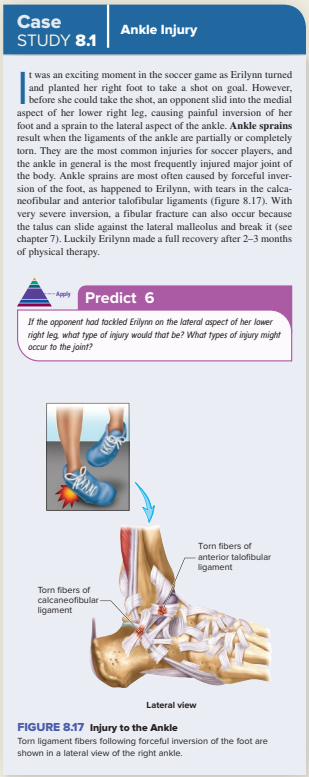
Predict Questions challenge students to use their understanding of new concepts to solve a problem. Answers to the odd-numbered Predict questions are provided in Appendix E, allowing students to evaluate their responses and to understand the logic used to arrive at the correct answer. All Predict question answers have been written in teaching style format to model the answer for students, to help them learn how to think critically.



Concept Check is a place to review and practice critical thinking. The chapter summary is interwoven with review and comprehension questions as well as critical thinking questions. To help students with cognitive load, the questions appear within the summary of the corresponding chapter section. The questions encourage students to build their anatomy and physiology knowledge while developing reasoning and critical thinking skills. Solution-style answers to odd-numbered questions appear in Appendix F.

Clinical Emphasis—*Case Studies Bring Relevance to the Reader*

- Chapter opening photos and scenarios have been correlated to provide a more complete story and begin critical thinking from the start of the chapter
- Learn to Predict and chapter Predict questions, with unique Learn to Predict answers
- Clinical Impact boxes (placed at key points in the text)
- Case Studies
- Clinical Genetics essays have been updated and streamlined for accuracy and impact
- Diseases and Disorders tables
- Systems Pathology boxes with System Interactions illustration



Case STUDY 8.1 Ankle Injury

It was an exciting moment in the soccer game as Erilynn turned and planted her right foot to take a shot on goal. However, before she could take the shot, an opponent slid into the medial aspect of her lower right leg, causing painful inversion of her foot and a sprain to the lateral aspect of the ankle. **Ankle sprains** result when the ligaments of the ankle are partially or completely torn. They are the most common injuries for soccer players, and the ankle in general is the most frequently injured major joint of the body. Ankle sprains are most often caused by forceful inversion of the foot, as happened to Erilynn, with tears in the calcaneofibular and anterior talofibular ligaments (figure 8.17). With very severe inversion, a fibular fracture can also occur because the talus can slide against the lateral malleolus and break it (see chapter 7). Luckily Erilynn made a full recovery after 2–3 months of physical therapy.

Predict 6

If the opponent had tackled Erilynn on the lateral aspect of her lower right leg, what type of injury would that be? What types of injury might occur to the joint?

FIGURE 8.17 Injury to the Ankle
Torn ligament fibers following forceful inversion of the foot are shown in a lateral view of the right ankle.

Clinical IMPACT 8.2 Arthritis

Osteoarthritis is the most common type of arthritis; over 85% of Americans age 70 and older are affected by osteoarthritis. This type of arthritis is a noninflammatory condition and is characterized by the gradual degeneration of the articular cartilage due to overuse or advancing age. Referring to osteoarthritis as "noninflammatory" can be confusing, especially when considering it is often treated with anti-inflammatory medications. As a practical rule of thumb, joints with osteoarthritis do not typically swell and feel warm to the touch. The pain and swelling associated with osteoarthritis is often isolated to the soft tissues around the joint. In addition, with osteoarthritis other tissues of the body are not generally affected as is the case with rheumatoid arthritis. Heredity or obesity can be contributing factors to development of osteoarthritis. Individuals with osteoarthritis experience symptoms such as pain within the affected joint or swelling of the soft tissues around the joint, which can cause the joint to be misshapen or reduce the range of motion. To diagnose osteoarthritis, a physician may perform any one of several procedures with the common theme of taking a sample of the tissue or fluid that makes up the joint to look for signs of damage. Treatment of osteoarthritis includes certain medications to reduce swelling and pain, physical therapy to strengthen the muscles around the affected joint, or surgery to fuse the existing bones of the joint, or to replace the damaged bone with a prosthetic joint. **Rheumatoid arthritis (RA)** is the second most common type of arthritis. It affects about 3% of all females and about 1% of all males in the United States. RA is a general, inflammatory connective tissue disorder that affects the skin, vessels, lungs, and other organs, but it is most pronounced in the joints. RA is severely disabling and most commonly destroys small joints, such as those in the hands and feet (figure 8.8*b,c*).

The initial cause of RA is unknown but may involve a transient infection or an autoimmune disease (an immune reaction to one's own tissues; see chapter 22) that develops against collagen. A genetic predisposition may also exist. Whatever the cause, the ultimate course appears to be immunological. In RA, the synovial fluid and associated connective tissue cells proliferate, forming a *pannus* (clothlike layer), which causes the joint capsule to become thickened and destroys the articular cartilage. In advanced stages, opposing joint surfaces can become fused. Table 8.3 contrasts osteoarthritis with rheumatoid arthritis.

FIGURE 8.8 Rheumatoid Arthritis
(*a*) X-ray of a knee with osteoarthritis. Note the loss of space within the synovial cavity with osteoarthritis. (*b*) Photograph of hands with rheumatoid arthritis. (*c*) Radiographs of the same hands shown in (*b*). (a) ZEPHYR/SCIENCE PHOTO LIBRARY/Alamy Stock Photo; (b) ©James Stevenson/Science Photo Library/Science Source; (c) ZEPHYR/SPL/Alamy Stock Photo

Clinical Impact boxes These in-depth boxed essays explore relevant topics of clinical interest. Subjects covered include pathologies, current research, sports medicine, exercise physiology, and pharmacology.

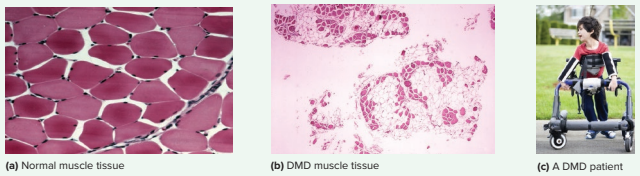
Systems PATHOLOGY Duchenne Muscular Dystrophy

Background Information

A couple became concerned about their 3-year-old son, Greger, when they noticed that he was much weaker than other boys his age and his muscles appeared poorly developed. Eventually, it was readily apparent that Greger had difficulty sitting, standing, climbing stairs, and even walking. When Greger tried to stand, he would use his hands and arms to climb up his legs. Finally, the couple took Greger to his pediatrician, who, after several tests, informed them that Greger had Duchenne muscular dystrophy. **Duchenne muscular dystrophy (DMD)** is usually identified in children around 3 years of age, when their parents notice slow motor development with progressive weakness and muscle wasting (atrophy). Typically, muscular weakness begins in the hip muscles, which causes a waddling gait. Temporary enlargement of the calf muscles is apparent in 80% of cases. The enlargement is paradoxical because the muscle fibers are actually getting smaller, but the amount of fibrous connective tissue and fat between the muscle fibers is increasing (figure 9.29*a,b*). The protein that normally protects muscle against mechanical stress is not functional in patients with DMD. This is thought to be the primary cause of the muscle weakness and other symptoms. Rising from the floor by using the hands and arms is characteristic and is caused by weakness of the lumbar and hip muscles (figure 9.29*c*). Within 3 to 5 years, the muscles of the shoulder girdle become involved. The replacement of muscle with connective tissue contributes to muscular atrophy and shortened, inflexible muscles called contractures. The contractures limit movements and can cause severe deformities of the skeleton. By 10 to 12 years of age, people with DMD are usually unable to walk, and few live beyond age 20. DMD is genetic, but because of its inheritance pattern, mostly males are affected. There is no effective treatment to prevent the progressive deterioration of muscles in DMD. Therapy primarily involves exercises to help strengthen muscles and prevent contractures. Figure 9.30 demonstrates the impact DMD has on other organ systems. Table 9.6 lists other diseases and disorders of the muscular system.

Predict 10

A boy with advanced Duchenne muscular dystrophy developed pulmonary edema (accumulation of fluid in the lungs) and pneumonia caused by a bacterial infection. His physician diagnosed the condition in the following way: The pulmonary edema was the result of heart failure, and the increased fluid in the lungs provided a site where bacteria could invade and grow. The fact that the boy could not breathe deeply or cough effectively made the condition worse. How would the muscle tissues in a boy with advanced DMD differ from the muscle tissues in a boy with less-advanced DMD?



(a) Normal muscle tissue **(b)** DMD muscle tissue **(c)** A DMD patient

FIGURE 9.29 Effects of DMD on Skeletal Muscle Tissue
(*a*) Cross section of normal skeletal muscle tissue. Note the lesser amount of adipose and connective tissue between muscle fibers than seen in (*b*). (*b*) Cross section of DMD skeletal muscle tissue. Skeletal muscle fibers decrease in size and have increased amount of adipose and connective tissue distributed among the muscle fibers. (*c*) Patients with DMD must support themselves whether sitting or standing on the ground. (a) Biophoto Associates/Science Source; (b) Dr. Edwin P. Ewing, Jr./Centers for Disease Control and Prevention; (c) Jaren Jai Wicklund/Shutterstock

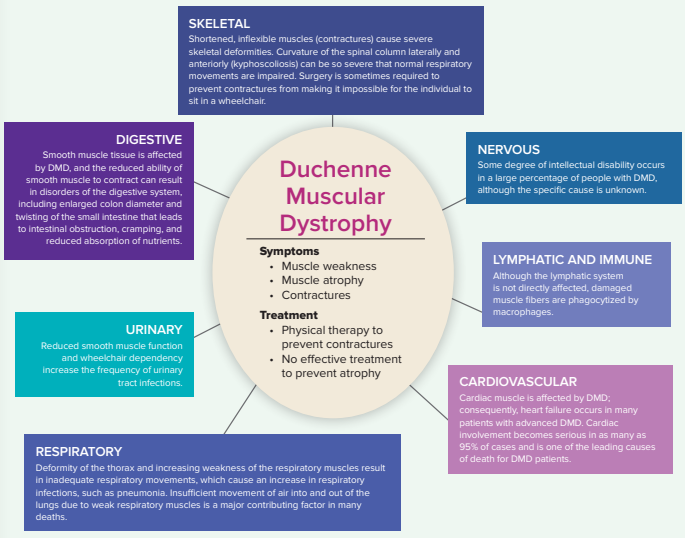


FIGURE 9.30 Interactions Between DMD and Other Organ Systems
DMD affects most systems of the body because muscle tissue is used for many body functions.

Systems Pathology boxes These two-page spreads explore a specific condition or disorder related to a particular body system. Presented in a simplified case study format, each Systems Pathology vignette begins with a patient history, followed by background information about the featured topic.

- **Microbes In Your Body** features discuss the many important and sometimes little-known roles of microbes and the physiology of homeostasis.

MICROBES In Your Body 22.1 — Do Our Gut Bacteria Drive Immune Development and Function?

"All disease begins in the gut." This quote from Hippocrates (460–377 B.C.), the father of Western medicine, is still relevant today. Over the last four decades, increasing numbers of people have suffered from allergies and autoimmune disorders. Researchers hypothesize that the increase in these conditions stems from inadequate development of immune function. In turn, they hypothesize that underdeveloped immune function is due to deficiencies in our gut microbiota. This has led to the Hygiene Hypothesis, which states that the increased use of antibiotics and antimicrobial chemicals damages the normal gut microbiota and other microbiota that are critical for immune system development and function.

Could the Hygiene Hypothesis explain the observed increases in allergies and autoimmune disorders? Much of the evidence for the importance of gut microbiota for immune function is derived from studies with germ-free mice. These lab-raised mice lack the natural microorganisms in their gut and in their body. As a result, the mice have multiple defects with their lymphatic tissues, such as fewer and smaller Peyer patches in the gut and fewer B and T lymphocytes. However, if scientists place intestinal or fecal microbiota from normal mice into the gut of germ-free mice, the immune tissues of the germ-free mice begin developing and functioning normally.

The importance of the gut in immune development is further supported by the fact that it contains the largest concentration of lymphatic tissue and microbiota in the human body. In the gut there are between 500 and 1000 species of bacteria, compared with a few hundred associated with the skin or fewer than 10 species associated with the conjunctiva of the eye. In humans, the gut microbiota begin to appear just before birth. As the baby passes through the birth canal, more microorganisms are transferred from the mother to the baby. The makeup of a baby's microbiota is influenced by many factors, including genetics, the mode of delivery (vaginal or C-section), antibiotic use, stress, and the mother's diet during late pregnancy. The first year of life is the most critical for the accumulation of gut bacteria, but this process continues through childhood. At about 10 years of age, a person's gut microbiota are established and remain similar in composition throughout life. Humans and their gut microbiota have a symbiotic relationship, in that the gut provides space and nutrients for the microbiota, which in turn provide their host with specialized nutrition, physiological regulators, and protection against pathogens. Because of these ever-present microbiota ("good" bacteria), human gut epithelial and immune cells must maintain tolerance to them yet still protect against invading gut pathogens ("bad" bacteria).

How do our cells distinguish between "good" and "bad" bacteria? As it turns out, gut microbiota help stimulate the development of immune cells by triggering the production of different receptors. These receptors are found in the plasma membranes of white blood cells, such as macrophages and neutrophils, as well as in the plasma membranes of intestinal epithelial cells. The surface of all bacterial cells has bacteria-specific molecules that can be recognized by the receptors of defense cells, which is what allows for distinction between "good" and "bad" microorganisms. Activation of the receptors triggers a cascade of events, which result in immune responses such as T-lymphocyte activation and the production of immunity chemicals. In addition, the "good" bacteria attack invading "bad" bacteria by secreting antimicrobial substances against them and competing with them for nutrients and space. Thus, without appropriate amounts and/or types of gut microbiota, the body's immune system may not have all of the messages that are essential for producing specific immune cells and chemicals that kill pathogenic intestinal microorganisms.

Medical professionals are interested in manipulating gut microbiota to reduce allergies and other diseases and to promote healing. First, and perhaps most importantly, is to get the desired population of gut microbiota started immediately in infancy through breastfeeding. Human breast milk contains carbohydrates that stimulate the growth of specific intestinal microbiota while preventing infection by some pathogens. And the use of prebiotics (nondigestible carbohydrates that promote the growth of healthy microbiota) and probiotics (live normal gut microbiota) is being actively explored for the treatment of problems that arise later in life. However, there is still much work to be done before we fully understand the extent to which gut microbiota are involved in human immune function.

Predict 2

In some underdeveloped countries, children are nutritionally deprived. Studies of twins in these countries have demonstrated that sometimes one of the twins thrives, whereas the other twin is malnourished. In the malnourished twin, the gut microbiota population is far less diverse and much smaller than that of the thriving twin. Using what you have learned about the role of gut microbiota in immune function, predict a possible developmental repercussion in the malnourished twin. Propose some possible solutions that might result in both twins having a normal gut microbe population.

- **Clinical Genetics** features have been updated and streamlined to provide the newest and most accurate information available.
- Online clinical study questions are based on clinical features within the text, including Microbes In Your Body and Systems Pathology vignettes, and are correlated with Learning Outcomes and HAPS Learning Objectives to further develop and measure higher-level thinking and application of learned content.

Clinical GENETICS 25.1 — Newborn Screening of Metabolic Disorders

Metabolic disorders, sometimes called inborn errors of metabolism, are a large class of genetic disorders that result in biochemical defects. Metabolic disorders affect the body's ability to break down or use nutrients needed for energy, growth, and repair. Too little synthesis of certain substances or a buildup of toxic compounds can cause significant health problems. Although the frequency of any given individual disorder is rare, the overall incidence of metabolic disorders is estimated to be up to 1 in 1000 births.

Early detection through newborn screening is vital. Metabolic disorders can hinder early mental and physical development. Depending on the disorder, specific treatment can prevent or limit harm if it is started early. In the United States, most states require the screening of newborns. However, there is no national standard for newborn screening, so the specific disorders for which tests are performed vary from state to state. Although over several hundred genetic disorders are known, most are so rare that it is not cost-effective to test for them.

Table 25.5 lists the most common blood tests performed for metabolic disorders. All of the disorders listed are autosomal recessive.

TABLE 25.5 Metabolic Disorders

Disorder	Description	Effect	Treatment
Phenylketonuria (PKU)	Inability to metabolize the amino acid phenylalanine (see chapter 29)	Intellectual disability	Restrict dietary phenylalanine.
Galactosemia	Inability to convert the sugar galactose to glucose, resulting in a buildup of galactose	Intellectual disability, growth deficiency, cataracts, severe infections, death	Eliminate milk and other dairy products from the diet. Galactose is one of two sugars in lactose (milk sugar).
Biotinidase deficiency	Inability to separate the vitamin biotin from other chemicals, resulting in a biotin deficiency	Seizures, hearing loss, optic atrophy, intellectual disability, poor muscle control	Take oral biotin supplements.
Maple syrup urine disease	Deficiency in an enzyme complex, resulting in an inability to metabolize the amino acids leucine, isoleucine, and valine	Intellectual disability in those surviving past 3 months of age	Restrict dietary intake of the affected amino acids.
Homocystinuria	Defect in methionine metabolism, leading to an accumulation of homocysteine	Dislocated lenses of the eyes, intellectual disability, skeletal abnormalities, abnormal blood clotting	Take high doses of vitamin B_6; eat methionine-restricted diet supplemented with cysteine.
Tyrosinemia	Deficiency in a series of enzymes that break down the amino acid tyrosine	Mild intellectual disability, language skill difficulties, liver and kidney failure	Restrict dietary tyrosine and phenylalanine.

Chapter-by-Chapter Changes

Global Changes

- Added Chapter 0 to assist students with studying techniques and provide an understanding of the language and conceptual framework of anatomy and physiology.
- Added Vision and Change information to relevant locations within the text. For example, when discussing membrane potentials, we point out that ion gradients follow the key concept of concentration gradients found within many systems.
- Added tips for students to aid them in answering the Learn to Predict questions at the beginning of the chapter by adding the statement, This information may help you in answering this chapter's Learn to Predict.
- Added some active learning activities. For example, in chapter 6, the students are prompted to soak a chicken bone in vinegar for some time and evaluate the change in texture. In chapter 3, the students are encouraged to sketch, using "dots," a representation of two solutions, each with a different pH, and then evaluate whether the more acidic solution had more "dots" (H^+).
- Replaced chapter opener photos with summary figures that provide an overview of the concepts presented in that chapter.
- Added roadmap figures (often a two-page spread) to help students see an entire concept from beginning to end. These roadmap figures then reappear throughout the chapter, with a particular portion of the figure (the one being discussed) highlighted.
- Changed pronunciations to phonetic (e.g., isometric [eye-soh-MET-rik]).
- Updated art throughout using more vibrant colors, modernized the images, created a more 3D image that doesn't look cartoony, and improved connections between separate ideas.
- Added Bloom's icons next to in-chapter questions.
- Moved "Effects of Aging" section to a boxed reading.
- Changed the "Summary" section to the "Concept Check" section with the review and comprehension questions and the critical thinking questions integrated into the corresponding section.
- Removed the purple circle text lists from process figures and integrated them into the narrative text. The purple circles remain in the figure art and have statement-style descriptors for the student to follow the process. The lengthy descriptions of the process are integrated into the narrative with corresponding purple circles to provide a complete explanation. This will help with projection of the figures in a lecture hall as well as cognitive load for the students.
- For accessibility, discontinued referring to objects within the line art by color only to help students with visual impairments, including students who are color blind.
- Used gender-neutral terms throughout (*male* and *female* rather than *man, boy, woman, girl*).

Chapter 1

- Added new chapter opener with an overview of the major body systems.
- Introduced four key concepts consistent with Vision and Change to be carried throughout the text.
- Modified table 1.1 to be one column and reduced the amount of text to reduce cognitive load.
- Modified figure 1.1 to correlate each level more clearly with the next.
- Moved section 1.4 "Biomedical Research" earlier in chapter to avoid interrupting the flow of the remaining chapter material.
- Revised section on homeostasis for clarity and accuracy based on reviewer feedback.
- Added a new figure to introduce feedback loops.
- Added art to figure 1.6 to explain positive-feedback mechanisms.
- Deleted former figure 1.7 based on reviewer feedback.
- Added some active learning activities to section on directional terms.

Chapter 2

- Added new chapter opener with an overview of interconnections between major concepts.
- Converted figure 2.7 to a process figure and added an image highlighting the electron density.
- Revised figure 2.9 to show connections between different bond types.

Chapter 3

- Added new chapter opener with an overview of major components of a cell.
- Revised table 3.1 to designate "cytoplasmic extensions."
- Added description of transcytosis.
- Added description of the polarity of the Golgi apparatus (*cis* v. *trans*).

- Added information about spliceosome in discussion of gene expression.
- Added prometaphase in discussion of mitosis.

Chapter 4

- Added new chapter opener summarizing tissue types throughout the body.
- Reorganized the introduction to section 4.1 for clarity.
- Added a new figure 4.1 to introduce the basic epithelial tissue types first.
- Revised descriptions of epithelial tissues for clarity.
- Revised tables 4.2, 4.3, and 4.4 to illustrate tissue types more clearly.
- Revised section on cell layers and cell shapes for clarity.
- Split former table 4.5 into two tables to separate simple and stratified.
- Revised section on cell connections for clarity.
- Rewrote section on glands to organize material to compare structure vs. mode of secretion.
- Added new table 4.5 to organize glands by structure and secretion mode.
- Combined old figures 4.3 and 4.4 into one figure for closer comparison.
- Revised tables 4.7–4.14 to illustrate tissue types more clearly.

Chapter 5

- Added new chapter opener with an overview of components of the integumentary system.
- Added some receptors to skin figure.
- Added new dermis figure identifying papillary and reticular layers and sensory receptors.
- Added new figure of types of injections.
- Added vitamin D production figure.

Chapter 6

- Added new chapter opener with an overview of bone anatomy.
- Added more micrographs of hyaline cartilage to figure 6.1.
- Added photomicrograph of osteoclast to figure 6.3.
- Added image of infant's legs to osteogenesis Clinical Genetics box.
- Replaced figure 6.16 with a more accurate depiction of this process.
- Added a photograph of a sectioned long bone to figure 6.8.
- Added photographs of different bone shapes to figure 6.9.
- Revised the introduction under calcium homeostasis for clarity.
- Added information about toll-like receptors to discussion of osteoclasts and osteoblast regulation of bone deposition and reabsorption.

Chapter 7

- Added new chapter opener with an overview of skeletal system functions.
- Added photographs to skull figures as well as some analogy images as learning devices (e.g., an image of crown placement to draw link for coronal suture).
- Replaced x-ray with MRI images in figure 7.13 for paranasal sinuses.
- Reorganized art of cervical vertebrae to compare atlas and axis directly as well to compare lateral and superior views of cervical vertebrae to each other.
- Added color coding to table 7.7 to better correlate each bone to overall location within skull and to all other colored skull images throughout chapter.
- Revised figure in table 7.9 to add a color gradient to spine to more readily differentiate between different regions of spinal column.
- Added x-rays of the other spinal deformations to Clinical Impact 7.1.
- Added color coding to figures 7.25–7.37 for better orientation of bone within overall skeleton.
- Added images of separated radius and ulna, and tibia and fibula.

Chapter 8

- Added new chapter opener with an overview of joint types.
- Added x-ray image of osteoarthritic knee to Clinical Impact 8.2.
- Added table 8.3 highlighting differences between osteoarthritis and rheumatoid arthritis.
- Combined figures 8.9–8.19 into one figure, separating them into angular movements, circular movements, and special movements.
- Added an x-ray to each joint image.

Chapter 9

- Added new chapter opener that provides organizational understanding of skeletal muscle structure.
- Added photomicrographs to table 9.1 for each muscle tissue type.
- Added photomicrograph of skeletal muscle cross section to figure 9.1.
- Revised figure 9.3 to clarify relationship between T tubules and terminal cisternae.

- Revised figure 9.5 into two-page spread to help students make connections between sarcomere structure, NMJ, and myofilament structure.
- Changed myosin head orientation in figure 9.6 to show contracted state.
- Added two-page spread on action potential generation, correlation with ion channels, and electrical output.
- Added Ca^{2+} channels to figure highlighting muscle relaxation.
- Updated figure 9.26 on mechanism of smooth muscle contraction.

Chapter 10

- Added new chapter opener with an overview of the muscles of the body.
- Added organizing bracket for muscle groups to figure 10.3*a,b*.
- Placed tables highlighting muscle functions on facing pages with the art of each group of muscles.
- Reorganized table 10.3 by body region (mouth, eye, neck, etc.).
- Reorganized table 10.19 by muscle group rather than directionally (e.g., gluteal group, adductor group, etc.).
- Replaced figures showing leg muscles with a figure organized by group as they are in table 10.19.

Chapter 11

- Added new chapter opener with an overview of the nervous system.
- Revised figure 11.2 to include visual references for sensory and motor divisions of the PNS.
- Added photomicrograph of neuromuscular junction to figure 11.3 neuron.
- Created new glial cell figures to summarize structure and function.
- Added two new summary figures of neuron communication highlighting action potential generation, action propagation, and synaptic communication.
- Revised figure 11.12 graded potential to include image of neuron for clarity.
- Updated figures 11.16 and 11.17 illustrating action propagation to include shaded areas indicating state of membrane potential changes.

Chapter 12

- Added new figure and text describing methods of classifying reflexes.
- Revised images of withdrawal reflex to be a more accurate representation.

Chapter 13

- Added new chapter opener that highlights the regions of the brain.
- Added labels to cranial nerves in table 13.5 for better reference.

Chapter 14

- Added new chapter opener with an overview of the integration of nervous system functions.
- Revised table 14.1 to provide specific examples of special senses receptors.
- Added new figure 14.5 illustrating the three major sensory pathways for better comparison.
- Added posterior view to figure 14.6 illustrating areas of referred pain on the body surface.
- Added new figure 14.10 illustrating the somatic motor pathways for better comparison.

Chapter 15

- Added new chapter opener with an overview of the special senses.
- Added new figure 15.13, which provides a summary of the physiology of vision.
- Revised figure 15.15 to match terminology of text and better represent tension levels in suspensory ligaments.
- Revised figure 15.20 to reinforce light conditions for each scenario.
- Used *external acoustic meatus* throughout description of the ear.

Chapter 16

- Added new chapter opener with an overview of the two divisions of the autonomic nervous system.
- Revised figure 16.1 to include all categories of tissues innervated by the ANS.
- Revised figures 16.2 and 16.4 to depict the CNS more accurately.
- Added new figure 16.5 to illustrate the sympathetic pathways.
- Added new figure 16.6 to illustrate the parasympathetic pathways.

Chapter 17

- Completely reorganized this chapter.
- Added new chapter opener with an overview of the major mechanisms of action in hormones.
- Revised figure 17.4 to show a side-by-side comparison of types of hormonal secretion controls.

- Redrew all the hormonal feedback figures in a more streamlined fashion as a flow chart, rather than being as loosely constructed.
- Revised figure 17.10 to demonstrate cytoplasmic receptors and thyroid hormone transporters.
- Revised figure 17.11 to include the three different types of alpha subunits.
- Revised figure 17.12 to include the phosphodiesterase icon.
- Redrew figure 17.13 to more accurately represent the tyrosine kinase receptor mechanism and structure.
- Redrew figure 17.15 (originally 17.11) to more clearly illustrate up- and down-regulation.
- Added information about hormone interactions as well as an illustration to the chapter.

Chapter 18

- Added new chapter opener with an overview of the interactions among all the components of a particular hormone system (thyroid hormones).
- Redrew figure 18.1 to more accurately reflect the correct vascular anatomy of the anterior pituitary.
- Revised figure 18.3 to more clearly show the release of neurohormones into the circulation.
- Redrew figure 18.4 to correlate ADH delivery to kidney more closely.
- Revised figure 18.7 to more visually represent muscle, bone, adipose, etc.
- Redrew figure 18.10 to be more clear.
- Added line art for regions of the adrenal cortex to figure 18.14.
- Revised figure 18.15 to show the breakdown of adrenal medulla actions on various tissues more clearly.
- Redrew figure 18.20 for clarity.
- Redrew figure 18.21 for clarity.

Chapter 19

- Added new chapter opener with an overview of blood composition.
- Added new process figure 19.6 to illustrate the role of EPO in red blood cell production.
- Revised process figure 19.7 to illustrate the breakdown of hemoglobin clearly.
- Revised process figure 19.15 to illustrate the sequence of events that often result in sensitization of an Rh-negative female.

Chapter 20

- Added new chapter opener with an overview of the heart anatomy.
- Added new figure 20.11, which provides a clearer representation of cardiac muscle.
- Revised process figure 20.12 with an overview of the conducting system of the heart as well as the electrical and mechanical events of contraction of the heart.
- Revised figure 20.15 to clearly illustrate refractory period and timing of maximum tension.
- Revised figure 20.18 to include images to better correlate events of the cardiac cycle.
- Revised table 20.1 to include ECG tracings of specific cardiac arrythmias.
- Revised discussion of ECG for clarity.
- Revised figure 20.20 to better illustrate the relationships among cardiac output, peripheral resistance, and mean arterial pressure.

Chapter 21

- Added new figure 21.2, which represents all major categories of blood vessels.
- Updated figures 21.14 and 21.15.
- Revised figure 21.25 to include additional information about blood pressure differences in various blood vessels.
- Updated figure 21.28 for clarity.
- Revised Clinical Impact on circulatory shock.

Chapter 22

- Revised “Lymphatic Tissue and Organs” section to include description of primary lymphatic organs and secondary lymphatic organs and tissues.
- Added new figure 22.10 with an overview of the components of immunity.
- Added images of cells to table 22.2.
- Added illustration of tissue damage to figure 22.12 for clarity.
- Added new figures representing MHC classes separately to better align with placement in text.
- Updated figure 22.20 to better illustrate the increase in immunity cells.
- Revised figure 22.23 to distinguish between primary and secondary immune response.
- Reorganized Section 22.5 “Adaptive Immunity” for clarity.
- Updated figure 22.6 to include images representing ways to acquire adaptive immunity.

Chapter 23

- Added new chapter opener with an overview of the functions of the respiratory system.
- Revised figure 23.1 to include alveoli and zones of the respiratory system.
- Changed the term *ventilation* to *pulmonary ventilation*.
- Changed the term *respiration* to *pulmonary gas exchange* or *tissue gas exchange*.

- Added color coding to the regions of the pharynx in figure 23.2 for clarity.
- Added line art to figure 23.4 showing vocal cord structure in high- vs. low-pitch sound production.
- Added a cross-sectional photomicrograph of the trachea to figure 23.5.
- Added an image of a cast of the tracheobronchial tree to figure 23.6.
- Added labels for the fissures as well as names of lung lobes to figure 23.8.
- Deleted table 23.1 and replaced with new figure demonstrating gas laws.
- Revised figure 23.11 to show changes in lung volume in a side-by-side manner with inspiration vs. expiration.
- Removed numbers from figure 23.13 and added them to a table to accompany the graph of lung volumes and lung capacities.
- Added labels to figure 23.15 for clarity.
- Created a two-page spread for figure 23.16 to help make connections between gas exchange at the tissues vs. the lungs.
- Deleted figure 23.17 because it was too simplistic.
- Added hemoglobin line art to cytoplasm of red blood cell to help students make the connection that O_2 binds to Hb within the red blood cell.
- Added values to figure 23.18 for Hb saturation at various P_{O_2}.
- Combined parts *a* and *b* for figure 23.19 to more clearly compare the curve shift to the right vs. a shift to the left.
- Updated the text in the "Generation of Rhythmic Pulmonary Ventilation" section to more accurately reflect the current understanding of the regulation of respiration.
- Redrew figure 23.20 to be more realistic and to more accurately reflect the effectors of the efferent nerves.
- Added a new figure for the chemoreceptor reflex to integrate the regulation of the respiratory rate.

Chapter 24

- Added new chapter opener with an overview of the functions of the digestive system.
- Deleted table 24.1 and replaced with the new figure 24.2 that is less visually intimidating to students.
- Updated the information on the mesentery to reflect its status as a continuous organ subdivided into six regions. This leads to the separation of the abdomen into two domains: the mesenteric domain and the nonmesenteric domain.
- Revised figure 24.5 to show the newly elucidated anatomy of the mesentery.
- Added a surface view of the tongue and its papillae to figure 24.6.
- Added tables to figure 24.6 with tooth numbers and names of the teeth to clean up the art.
- Deleted table 24.2 and replaced with new figure 24.9, which decreases the cognitive load.
- Placed figure 24.10 into a vertical format with brackets and labels to help discern the different stages of deglutition.
- Updated figure 24.11 to differentiate the various cell types in the gastric glands.
- Revised figure 24.12 to reflect the appropriate structure of a parietal cell.
- Throughout the chapter, made the arrow color for the vagus nerve one consistent color.
- Added color coding to figure 24.15 for the different regions of the small intestine.
- Revised the colon in figure 24.25 to show more detail and to include the vasculature.
- Combined section 24.10 to include the liver, pancreas, and gallbladder.
- Simplified figure 24.27 for clarity.
- Added a two-page spread linking region of the digestive system with specific nutrients digested within the portion.
- Redrew figure 24.35 to correlate source of fluid with reabsorbed fluid.

Chapter 25

- Added new chapter opener highlighting the concept of macronutrients.
- Updated discussion of *Dietary Guidelines for Americans*.
- Included terms *dispensable* and *indispensable* in discussion of essential nutrients.
- Revised description of amino acids to include description of conditionally essential amino acids.
- Added new Process figure 25.4 with an overview of the use of the three major nutrients (carbohydrates, lipids, and proteins) for ATP production.
- Revised figure 25.14 to better represent text, including description of lipogenesis.

Chapter 26

- Added new chapter opener summarizing the functions of the urinary system.
- Updated figure 26.1 to include more detail internally for kidney anatomy.
- Changed terminology to include *glomerular capsule, nephron loop, cortical radiate artery* or *vein, renal threshold,* and *transport maximum*.
- Added figure summarizing urine flow from kidneys to urinary bladder.
- Added electron micrographs to figure 26.5.
- Added photomicrographs to figure 26.6.
- Added a flow chart for blood flow through kidney to figure 26.7.

- Revised figure 26.8 to be more realistic to summarize the three steps in urine production.
- Revised figure 26.9 to look more realistic for calculation of filtration pressures.
- Added an orientation inset to figures 26.10–26.13 that correlates with a two-page spread summarizing events in urine production.
- Added interstitial fluid gradient background to figure 26.14.
- Revised figure 26.17 RAAS art to include organ icons to help students make those connections.
- Added an image of an aquaporin to figure 26.19.
- Added comparison of male vs. female urethra to figure 26.22.

Chapter 27

- Added new chapter opener summarizing the movements of ions and fluid into and out of the cell.
- Added new figure 27.1 to visually represent the distribution of water throughout the body.
- Added new figure 27.2 to visually represent the distribution of ions between the intracellular and extracellular fluid.
- Added line art to figure 27.3 to illustrate the different forces within the capillary.
- Reorganized section 27.1 and deleted section 27.2.
- Added headings “Fluid Input” and “Fluid Output.”
- Added a figure on the baroreceptor reflex to integrate with fluid input.
- Reorganized section on thirst to regulation of intake vs. regulation of output.
- Added a summary figure on changes in blood osmolality to replace deleted table 27.5.
- Rearranged tables containing information about abnormal ion levels so that there can be a side-by-side comparison of *hypo-* vs. *hyper-*.
- Reorganized each section on a particular ion to discuss the material in the same order: Function, Regulation, Imbalances.
- Deleted figures 27.9 and 27.10.
- Created new section “Hormonal Mechanisms Regulating Body Fluid Composition.”
- Deleted table 27.11.
- Rearranged the “Acid-Base Imbalances” section so all “acidosis” information is together and under the “Acidosis” head and all “alkalosis” information is together and under the “Alkalosis” head.

Chapter 28

- Added new figure 28.1 as an overview of the organs of the male and female reproductive systems.
- Added new chapter opener comparing spermatogenesis and oogenesis.
- Removed information about reproductive hormones and effects in females from table 28.1 and used it to create new table 28.2 so that the information is located in the proper area of the chapter.
- Added new figure and description of oogenesis, with a separate panel for ovarian follicle development.
- Revised description of ovarian cycle for clarity.
- Revised figure 28.19 to include panel labels for easier referencing in text.
- Revised figure 28.20 for clarity and to better correlate with description in text.
- Converted table 28.4 to new figure.

Chapter 29

- Added new chapter opener and figure 29.1 illustrating the life stages.
- Added description of *SRY* gene in discussion of development of male reproductive system.

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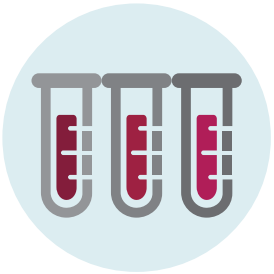

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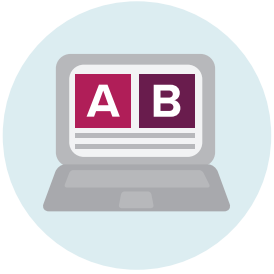

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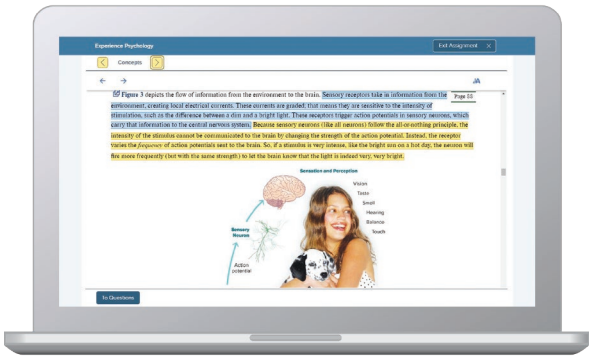

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CHAPTER 0

How to Be Successful in A&P

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Hello, Students! Author Cinnamon VanPutte would like to share something with you: She failed her college organic chemistry course. Later, she retook it and earned an "A." Why does this matter to you? We hope this helps you understand that your authors have been there. Yes, we've earned an "A" in hard classes—but we also know what it is to struggle in a class. We've had to retool our study habits; we've had to learn how to effectively use a textbook. These experiences have helped inform our approach to this textbook, and we hope this helps you. We know that many of you will sail right through A&P and would have done so even without reading this success guide, while others may be retaking A&P for the second or third time. By taking the time to read this guide, you have already taken a positive first step toward succeeding in A&P. You have entered a partnership with your instructor and us, the authors. If you utilize the tips, techniques, and information that we, as well as your instructors, are providing to you, we know you will learn a lot of information and you will be positioned to succeed in this course.

0.1 The World of A&P

If you search online for "hardest classes in college," A&P will show up on many lists. But don't worry! We are here to help! We have each taught A&P for more than 20 years and have seen countless students, who were very nervous on the first day, successfully move through the course—all the while gaining self-assurance, confidence, and a deep understanding of the fundamental concepts needed to perform well in the course.

The study of A&P entails a lot of information. Depending on the particular course, the first semester of A&P may start with a discussion of matter and chemical bonds, and end with the complexities of the nervous system (such as action potentials). Truthfully, this means progressing from introductory material to more advanced material within a single semester.

In addition, you will be learning the vocabulary of A&P, which means you are essentially learning a foreign language—you might even feel like you're learning more new vocabulary than if you were actually learning a foreign language! In an effort to make this task easier, our textbook provides phonetic pronunciations of these vocabulary terms, similar to those found on Facebook for people's names. For example, the gluteus maximus pronunciation would be: GLOO-tee-us MAX-ih-mus. We think this type of guide will help you learn the terminology very readily and be more confident speaking the language—if you can say it out loud, then you can probably spell it and are better poised to remember it.

It's also important to realize that the information in A&P cannot be effectively understood through memorization alone. Several of the physiology concepts require that you use critical thinking skills. Many of you may be planning careers in science or health professions, such as nursing or pharmacy—professions in which the ability to problem solve is essential. In this book we will help you develop critical thinking skills and thus a deeper understanding of complex concepts.

0.2 Developing Critical Thinking Skills

So, what is required to develop critical thinking skills? What are critical thinking skills? To understand these questions, we need to explore the difference between simple memorization—what you may have always called "studying"—and **conceptual learning.** Many of you have enjoyed much success in high school and in some of your early introductory-level college classes through "studying." However, to be successful

in most A&P classes, you will also need to develop skills for conceptual learning. The basis for this difference is best described using Bloom's taxonomy, originally published by B. Bloom and colleagues in 1956. Over time, Bloom's taxonomy has been modified and can be best thought of as a model for the gradual increase in the amount of abstract thought required to achieve a particular level of learning. The simplest, most concrete level of learning is *remembering*, or simply memorizing. As you climb the levels of Bloom's, your ability to put ideas into your own words (*understanding*) and then to solve problems you've never seen before (*applying*) increases. Thus, as you gain these skills, you are now *learning* the material and can answer **how** and **why** a particular process happens, and you can predict outcomes to unfamiliar scenarios. This textbook will guide you in developing those skills.

To do this, you will begin to use **metacognition** in your learning. *Metacognition* was first defined by Flavell in 1976 as "thinking about your own thinking"—in other words, deciding whether you truly understand and can apply fundamental physiological and anatomical principles. We are going to provide you with five metacognitive learning strategies to ensure your success in A&P.

0.3 Five Metacognitive Learning Strategies

What will you need to do to achieve the goal of being successful in A&P? There are five specific tasks you can employ to be successful in A&P. These tasks are adapted from the book *Teach Students How to Learn* by S. Y. McGuire. They are the following:

1. Attend every class session and take notes with a pen and paper.
2. Read, read, read!
3. Work with other students.
4. Do homework as if it were the test.
5. Engage in concentrated study sessions.

We will address each of these tasks in the remainder of this success guide with specific information on how to use this textbook.

0.4 Using the Five Metacognitive Learning Strategies with This Textbook

1. *Attendance and Note-Taking*. It is essential that you attend each class session. As you can see, this book has 29 chapters, each of which covers a topic for which you could take an entire semester class, or more! Your instructor will decide what material you will cover. Some instructors may expect you to glean specific information directly from the book. Therefore, to make sure you hear, firsthand, all the information and messages your instructor presents in class, it is critical you be in class. Then, while in class, take notes by hand! Students who handwrite their notes outperform students who take notes with their laptops. The difference is that taking notes by hand requires you to use your own words, which helps you remember the information better. After the class session, it is also helpful to take notes by hand directly from the assigned chapters.
2. *Read, Read, Read!* Possibly one of the biggest misconceptions regarding reading a textbook is that it is no different from reading a novel—which couldn't be farther from the truth. Reading a science textbook involves a slow and systematic process. There are three types of reading strategies you'll need to employ to get the most information from each chapter: (a) preview, (b) prepare for active reading, (c) actively read.
   a. Preview
   Previewing a chapter is like watching a movie trailer or reading the description of a book to see what it's about and whether it interests you. Skim the section headings. Each system chapter of this textbook is laid out in the following way:
   Anatomy of the System
   Organs
   Histology
   Functions of the System
   Major Functions
   Integration of Functions for Homeostasis
   Some sections are further subdivided into specialized topics to walk you through a process step-by-step.
   While you're previewing the chapter, pay attention to bolded terms, phonetic pronunciations, and word origins. Root words tell a lot of information about a process or structure; for example, *hyper-* indicates higher or above, and *hypo-* indicates lower or below, and they are used both anatomically and physiologically.
   b. Prepare for Active Reading
   As you're previewing, or as a next step, write out questions you'd like answered as you read. The bold terms can be used as a guide to the questions.
   c. Actively Read
   After you've previewed the chapter and have done the preparations for active reading, the next step is to actively read. This can be done one paragraph, or one concept in SmartBook 2.0, at a time. Write notes in your own words as you read. Add a paragraph, or concept, at a time, all the while adding ideas from the previous paragraph. In this way, you're "taking one bite at a time" of the chapter's information. This helps your brain integrate information and keeps it from suffering information overload. As you actively read, there are several features that are consistent throughout this text that can serve as guideposts for you. We present these features in the section "Textbook Features and Figure Colors and Symbols."
3. *Work with Other Students Enrolled in the Same Class.* Author C. VanPutte would like to share something else with you: She did not fully comprehend the concept of osmosis until she taught her first college-level class. Once she had to explain the concept out loud and in her own words, a light

clicked on! So, form study groups! Assign each other topics on which to lecture to the group. Write practice exams for each other. Sometimes your peers can help you as much as, or perhaps more than, the instructor.

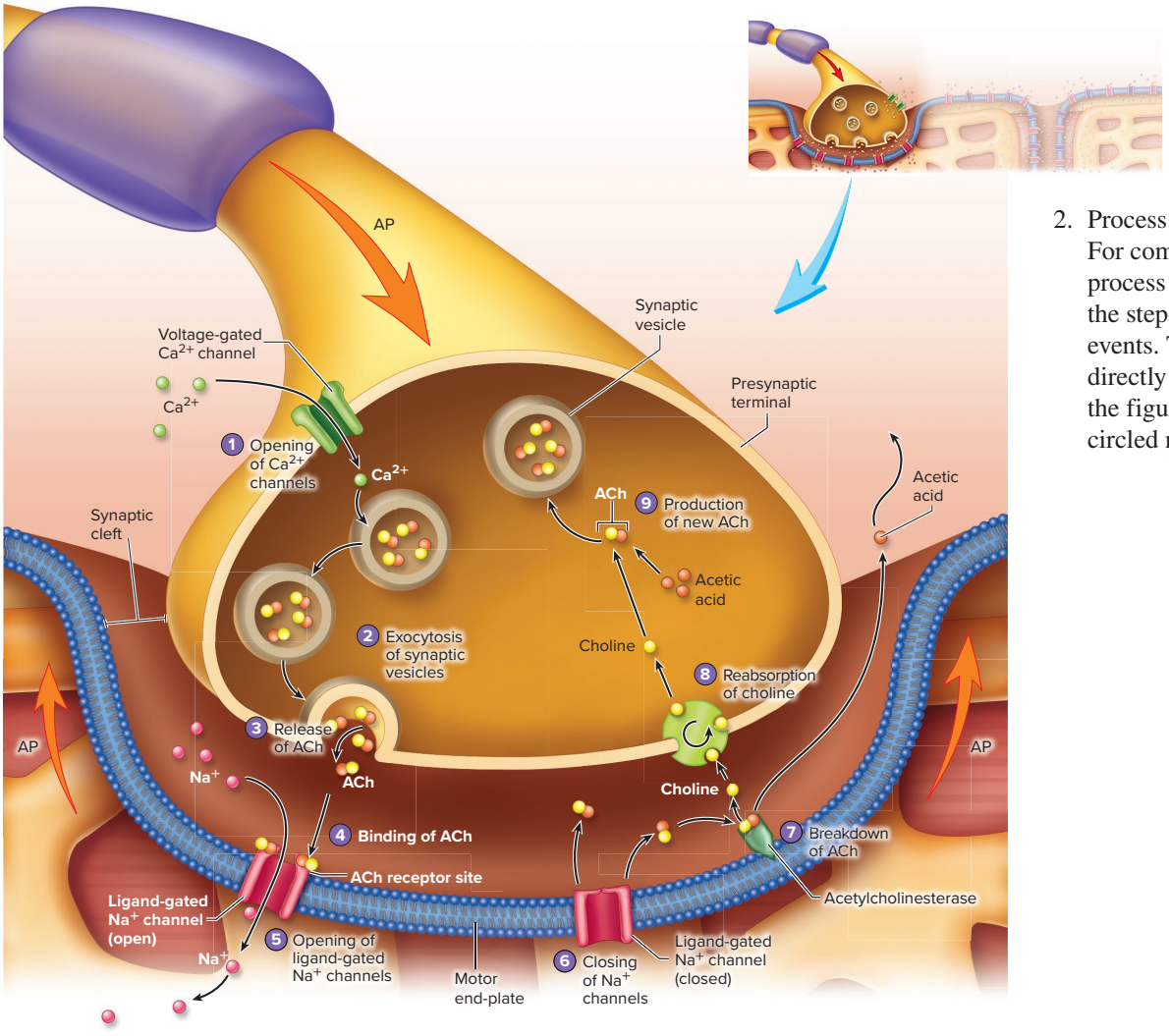
4. *Do Homework as If It Were the Test.* For most lecture exams you will not be allowed to use your notes, the textbook, or the Internet. So you need to practice for that situation. Don't simply copy answers onto your homework assignments. Instead, study first, then do the homework without assistance. If you get stuck, use your resources. For example, you could do a "recharge" in SmartBook 2.0, or visit your instructor during their office hours.
5. *Utilize Multiple, Intense, Short Study Sessions.* Our brains work more efficiently when we stay focused for a relatively brief period of time: approximately 30–50 minutes. Staring blankly at your notes for 3 hours is not helpful. Therefore, decide what you're going to focus on, then study with intent for 30–50 minutes. Studying with intent involves actively engaging with the material. This can include making a concept map, expanding on your notes and rephrasing them, writing out a summary, and simply thinking about the material. Take a short 10- to 15-minute break, then briefly review what you just studied. Do this 3–5 times a day for each class in which you're enrolled.

0.5 Textbook Features and Figure Colors and Symbols

Throughout this textbook you will see certain repeating features and symbols. These symbols are always a particular color; however, for our students with vision disabilities, these colored symbols are also uniquely labeled.

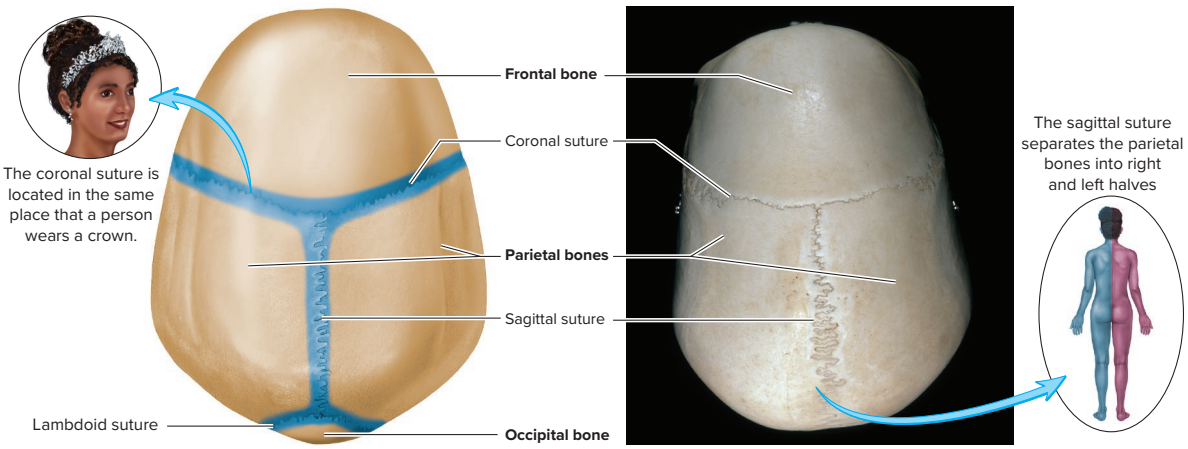
1. In-Text Numbering
   As you're reading, look for areas where we've tried to make complex topics clearer by numbering steps or components. This ensures that you don't miss a step or a part.

> In an unstimulated cell, this charge difference is called the **resting membrane potential.** Although we call it the resting membrane potential, the cell is more like a sprinter in starting blocks; it is ready to respond at a moment's notice. The resting membrane potential is the result of three factors: (1) The concentration of K^+ inside the cell membrane is higher than that outside the cell membrane, (2) the concentration of Na^+ outside the cell membrane is higher than that inside the cell membrane, and (3) the cell membrane is more permeable to K^+ than to Na^+.



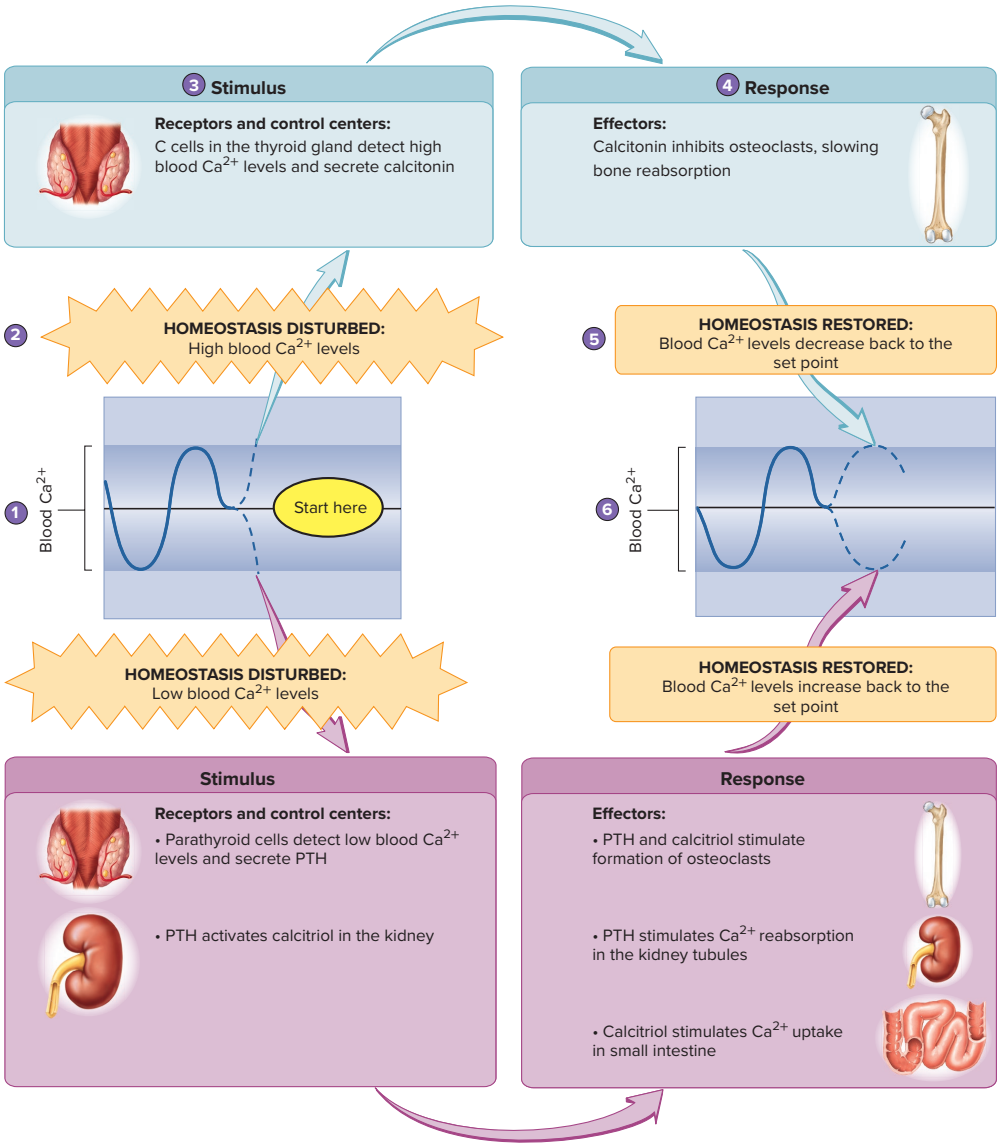
2. Process Figures
   For complex processes, we have process figures that break down the step-by-step sequence of events. The in-text explanations directly correlate to portions of the figure by the use of purple-circled numbers.

3. Side-by-Side Anatomy Figures
   In certain anatomy figures, we have placed a photograph next to an artistic rendering. This allows for accurate interpretation of artist-generated figures.



Superior view Biology Pics/Science Source

4. Homeostasis Figures
   These figures walk you through certain critical physiological mechanisms involved in the maintenance of homeostasis. Icons depict the particular organs discussed, in order to help strengthen associations between anatomy and physiology.



5. Clinical Content
   a. Clinical Impact: explore interesting clinical aspects of the body system being discussed. These are like commercial breaks in the reading, allowing you to relate the content to a "real-world" example.

Clinical IMPACT 12.3

Sciatic Nerve Damage

If a person sits on a hard surface for a considerable time, the sciatic nerve may be compressed against the ischial portion of the hip bone. When the person stands up, he or she feels a tingling sensation, described as "pins and needles," throughout the lower limb and often remarks that the limb has "gone to sleep." This condition is temporary, but the sciatic nerve can be seriously injured in a number of ways. A ruptured intervertebral disk or pressure from the uterus during pregnancy may compress the roots of the sciatic nerve. Other causes of sciatic nerve damage include hip injury, compression of the nerve by the piriformis muscle (piriformis syndrome), and an improperly administered injection in the hip region (see Clinical Impact 7.3).

   b. Microbes in Your Body: highlight the role of microbes in maintaining homeostasis. With the ever-expanding understanding of the microbiome, these provide some context of the connection between homeostasis and the microbiome.

MICROBES In Your Body 20.1 How Bacteria Affect Cardiac Muscle

You've learned that the majority of bacteria are either harmless or an integral part of our well-being. Unfortunately, there are a handful of pathogenic bacteria that can interfere with the body's homeostasis.

Most people associate bacterial pneumonia with the lungs only. However, in the medical community, it is well known that pneumonia can cause serious heart problems. In fact, cardiac problems cause 70% of the deaths in individuals with other types of severe bacterial infections. Most bacterial pneumonia is caused by the bacterium *Streptococcus pneumoniae*, but until recently the mechanism by which this pathogen damages the heart had not been well understood. It seems that these bacteria induce the cells lining blood vessels to endocytose them and deposit them in cardiac muscle tissue. There, the bacteria release a toxin, called pneumolysin, that kills the cardiac muscle cells. These areas of dead cardiac muscle are called microlesions. In addition, during recovery from the infection, scars may form within the myocardium. Thus, the bacteria physically damage the heart, which interrupts the electrical signal necessary for cardiac muscle contraction. In addition, simply treating pneumonia with the traditional antibiotic ampicillin may actually worsen damage to the heart. Ampicillin causes the bacterial cell walls to burst, which releases a surge of pneumolysin, creating even more microlesions. Use of an antibiotic that does not destroy the bacterial cell walls will help reduce cardiac muscle death. Further, a vaccine against the bacterial molecule that induces the bacterial transport and against pneumolysin has shown great promise in minimizing the tissue damage caused by these bacteria.

Although pathogenic bacteria exist, modern medicine continues to make great strides to reduce their damaging effects on our bodies. In addition, the more we learn about our microbiome, the more effectively we may be able to prevent bacterial infections from occurring in the first place.

Apply **Predict 4**

Given that S. pneumoniae *microlesions interrupt the electrical activity that flows between cardiac muscle cells, the heart can experience severe stress and may malfunction or stop contracting altogether. Using what you learned about skeletal muscle contraction, would microlesions in skeletal muscle cause the same type of reaction as in cardiac muscle?*

   c. Clinical Genetics: describe the underlying gene alterations for certain diseases. These provide some clarity for otherwise confounding situations. For example, emphysema isn't always self-induced by smoking; there is an underlying genetic basis for some individuals who develop this disease.

Clinical GENETICS 15.1 Color Blindness

Color blindness results from the dysfunction of one or more of the three photopigments (red, green, blue) involved in color vision. If one pigment is dysfunctional and the other two are functional, the condition is called **dichromatism.** An example of dichromatism is red-green color blindness (figure 15.22).

Red-green color blindness is common in males, but not females. About 7% of males have some degree of color blindness, which is over eight times more common than in females. The basis for this male prevalence is that the genes for the red and green photopigments are arranged in tandem on the X chromosome (see chapter 29). Because males have only one X chromosome, they are more likely to be affected by an X-linked mutation than females, who have a higher probability of having a good gene on one of their two X chromosomes.

The vast majority, over 95%, of color blindness involves red-green color vision, not blue vision. The reason can be traced to the tandem arrangement of the red and green photopigment genes. Not only are the two genes next to each other, but they are also nearly identical; differences in only 3 of the 360 amino acids determine the red versus green wavelength absorption characteristics. Because the red and green genes are so similar and adjacent to each other, it is relatively easy for mistakes to occur during development as DNA is replicated and exchanged between chromosomes (see chapter 29). Hence, an X chromosome may lack one or both genes, or it may have a hybrid gene containing exons from both red and green genes, which may or may not alter their degree of functionality. The blue photopigment gene is rarely associated with color blindness because it is not adjacent to another photopigment gene. It is also not X-linked, so it is equally rare in males and females.

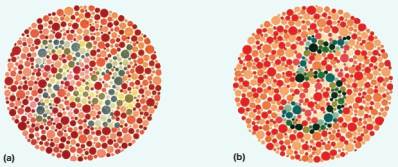


FIGURE 15.22 Color Blindness Charts
(*a*) A person with normal color vision can see the number 74, whereas a person with red-green color blindness sees the number 21. (*b*) A person with normal color vision can see the number 5, whereas a person with red-green color blindness sees the number 2. (a) Steve Allen/Brand X Pictures/Getty Images; (b) Prisma Bildagentur AG/Alamy Stock Photo

Reproduced from Ishihara's Tests for Colour Blindness published by Kanehara & Co., Ltd., Tokyo, Japan, but tests for color blindness cannot be conducted with this material. For accurate testing, the original plates should be used.

   d. Case studies: these allow you to be the expert! The case studies present a clinical situation and then ask you to problem solve to predict the connections.

Case STUDY 1.1 Orthostatic Hypotension

Molly is a 75-year-old widow who lives alone. For 2 days, she had a fever and chills and mainly stayed in bed. On rising to go to the bathroom, she felt dizzy, fainted, and fell to the floor. Molly quickly regained consciousness and managed to call her son, who took her to the emergency room, where a physician diagnosed orthostatic hypotension.

Orthostasis literally means "to stand," and *hypotension* refers to low blood pressure; thus, **orthostatic hypotension** is a significant drop in blood pressure upon standing. When a person moves from lying down to standing, blood "pools" within the veins below the heart because of gravity, and less blood returns to the heart. Consequently, blood pressure drops because the heart has less blood to pump.

Apply **Predict 3**

Although orthostatic hypotension has many causes, in older people it can be due to age-related decreases in neural and cardiovascular responses. Decreased fluid intake while feeling ill and sweating due to a fever can result in dehydration. Dehydration can decrease blood volume and lower blood pressure, increasing the likelihood of orthostatic hypotension.

a. Describe the normal response to a decrease in blood pressure on standing.

b. What happened to Molly's heart rate just before she fainted? Why did Molly faint?

c. How did Molly's fainting and falling to the floor help establish homeostasis (assuming she was not injured)?

   e. Aging: describe changes to the body systems as we age. Currently, approximately 15% of the U.S. population is comprised of adults older than 65. This percentage will rise to about 21% by the year 2030, and health-care professionals will need an understanding of the aging process.

EFFECTS OF AGING ON THE RESPIRATORY SYSTEM

Most aspects of the respiratory system are affected by aging. However, even though vital capacity, maximum pulmonary ventilation rates, and gas exchange decrease with age, older people can engage in light to moderate exercise because the respiratory system has a large reserve capacity.

Vital capacity declines with age because of a decreased ability to fill the lungs (inspiratory reserve volume) and a decreased ability to empty the lungs (expiratory reserve volume). As a result, maximum minute volume rates are reduced, which in turn limits the ability to perform intense exercise. These changes are related to weakening of respiratory muscles and to reduced compliance of the thoracic cage caused by the stiffening of cartilage and ribs. Lung compliance increases with age because parts of the alveolar walls are lost, which reduces lung recoil. No significant age-related changes take place in lung elastic fibers or surfactant.

Alveolar ducts and many of the larger bronchioles expand in diameter with age, which increases residual volume. Larger bronchioles and alveolar ducts create more dead space, lowering the amount of air available for gas exchange (alveolar ventilation). In addition, gas exchange across the respiratory membrane is reduced because parts of the alveolar walls are lost, creating less surface area available for gas exchange. A gradual rise in resting tidal volume with age compensates for these changes.

With age, mucus accumulates within the respiratory passageways because it becomes more viscous and because there are fewer cilia. As a consequence, older people are more susceptible to respiratory infections and bronchitis. Table 23.2 describes several other diseases and disorders of the respiratory system that can occur during any stage of life.

   f. Systems Pathologies: discuss a disorder or disruption in a particular body system. These readings are a deeper look into clinical correlations than the clinical impacts. They will help you make a connection between studying anatomy and physiology and situations you may encounter in a health-care setting.

Systems PATHOLOGY | Burns

A **burn** is injury to a tissue caused by heat, cold, friction, chemicals, electricity, or radiation. Burns are classified according to the extent of surface area involved and the depth of the burn.

On the basis of depth, burns are classified as either partial-thickness or full-thickness burns (figure 5.14). **Partial-thickness burns** are subdivided into first- and second-degree burns. **First-degree burns** involve only the epidermis and may result in redness, pain, and slight edema (swelling). **Second-degree burns** damage the epidermis and dermis. Minimal dermal damage causes redness, pain, edema, and blisters.

Full-thickness burns are also called **third-degree burns.** The epidermis and dermis are completely destroyed, and tissue just below the skin may be involved. Third-degree burns are often surrounded by first- and second-degree burns. Although the areas that have first- and second-degree burns are painful, the region of third-degree burn is usually painless because the sensory receptors have been destroyed.

Fourth-degree burns are extremely severe burns that affect tissues deeper than the subcutaneous tissue, often damaging tendons, fascia, muscle, and bone. Because of the severity of tissue damage, fourth-degree burns often require amputation or removal of damaged tissue.

Sam received severe burns across his body after he fell asleep while smoking. He was admitted to the emergency room and later transferred to the burn unit in critical condition, suffering from shock (figure 5.15). Large volumes of intravenous fluids were administered and Sam's condition improved. He was given a high-protein, high-caloric diet, as well as topical antimicrobial drugs to treat infection of his wounds the first few weeks of treatment. Sam developed venous thrombosis in his left leg, which required additional treatment. Later, his physician recommended debridement of his wounds.

When large areas of skin are severely burned, there are systemic effects that can be life-threatening (figure 5.16). Within minutes of a major burn injury, there is increased permeability of the capillaries. This increased permeability occurs at the burn site and throughout the body, resulting in loss of fluid and electrolytes (see chapter 2) at the burn wound and into tissue spaces. The loss of fluid decreases blood volume, which decreases the heart's ability to pump blood. The resulting decrease in blood delivery to tissues can cause tissue damage, shock, and even death. Treatment consists of administering intravenous fluid at a faster rate than it leaks out of the capillaries, though fluid continues to leak into tissue spaces, causing pronounced **edema** (swelling). Capillary permeability returns to normal typically within 24 hours, reducing the need for intravenous fluids.

Substances released from the burn may alter capillary permeability as well as cause cells to function abnormally. Burn injuries result in an almost immediate hypermetabolic state, which persists until wound closure. Two other factors contributing to the increased metabolism are (1) a resetting of the temperature control center in the brain to a higher temperature and (2) hormones released by the endocrine system (e.g., epinephrine and norepinephrine from the adrenal glands), which can increase cell metabolism. The increased metabolism can result in a loss of 30–40% of the patient's preburn weight, requiring a specialized diet to compensate. Compared with a normal body temperature of approximately 37°C (98.6°F), a typical burn patient may have a body temperature of 38.5°C (101.3°F) despite the higher loss of water by evaporation from the burn.

Because burns damage and sometimes completely destroy the skin, microorganisms can cause infections. Burn patients are maintained in an aseptic (sterile) environment in an attempt to prevent the entry of microorganisms into the wound. They are also given antimicrobial drugs, which kill microorganisms or suppress their growth.

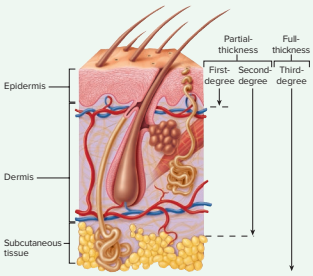


FIGURE 5.14 **Partial- and Full-Thickness Burns**

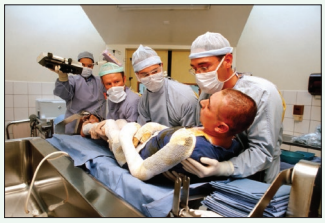


FIGURE 5.15 **Patient in a Burn Unit**
Phanie/Science Source

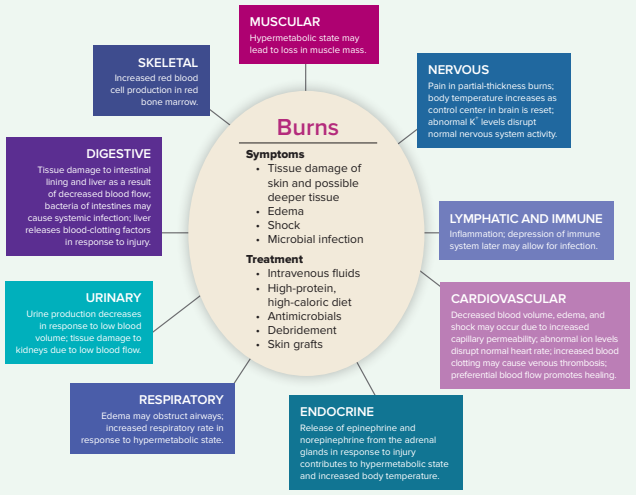


FIGURE 5.16 **Systems Interactions: Burns**
Burns affect more than just the skin. This diagram illustrates how the systems of the body are affected following a burn.

Debridement (dah-BREED-ment, day-breed-MON), the removal of dead tissue from the burn, helps prevent infections by cleaning the wound and removing tissue in which infections could develop. Skin grafts, performed within a week of the injury, also help close the wound and prevent the entry of microorganisms.

Despite these efforts, infections are still the major cause of death for burn victims. Depression of the immune system during the first or second week after the injury contributes to the high infection rate. The greater the magnitude of the burn, the greater the depression of the immune system and the greater the risk for infection.

Venous thrombosis, the development of a clot in a vein, is another complication of burns. Blood normally forms a clot when exposed to damaged tissue, such as at a burn site, but clotting can also occur elsewhere, such as in veins, where clots can block blood flow, resulting in tissue destruction. The concentration of chemicals that cause clotting (called clotting factors) increases for two reasons: (1) Loss of fluid from the burn patient concentrates the chemical and (2) the liver releases an increased amount of clotting factors.

Predict 5

When Sam was first admitted to the burn unit, the nurses carefully monitored his urine output. Why does that make sense in light of his injuries?

6. Critical Thinking Practice
   The textbook presents you with multiple opportunities to practice applying the information you've learned to particular situations. Critical thinking questions require a higher-order level of thinking than simple fact-based questions. The Bloom's taxonomy icon indicates the level at which a given question is ranked.

   a. Learn to Predict
      This feature appears at the beginning of each chapter and integrates information from earlier chapters or asks you to think about a scenario as you read the chapter. Answers to odd-numbered questions are provided in appendix E. Answers to even-numbered questions are provided online. The answers are written in a solution-style format. We walk you through the logic of each answer.

Learn to Predict

While weight training, Pedro strained his back injuring the following muscles: psoas major, iliacus, pectineus, sartorius, vastus lateralis, vastus medius, vastus intermedius, and rectus femoris.

Predict Pedro's symptoms and which movements of his lower limb were affected, other than walking on a flat surface. What types of daily tasks would be difficult for Pedro to perform?

Answers to this question and the chapter's odd-numbered Predict questions can be found in Appendix E.

Chapter 10

Learn to Predict

The description of Pedro's injury provided specific information about the regions of the body affected: the left hip and thigh. These facts will help us determine Pedro's symptoms and predict the movements that may be affected by his injury.

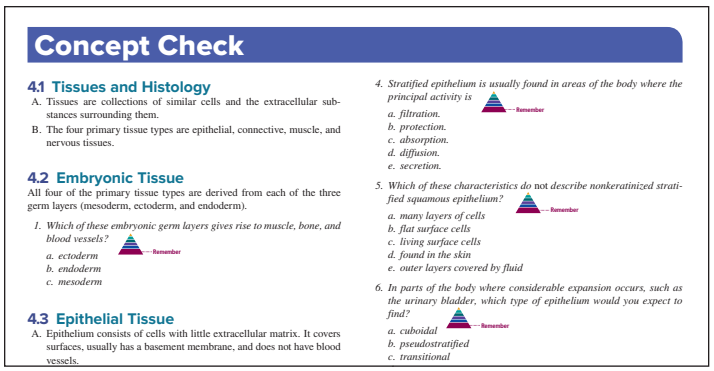
We read in this chapter that the muscles affected by Pedro's injury (psoas major, iliacus, pectineus, sartorius, vastus lateralis, vastus medius, vastus intermedius, and rectus femoris) are involved in flexing the hip, the knee, or both. Therefore, we can conclude that movements involving hip and knee flexion, such as walking

   b. Predict
      Predict questions are distributed throughout each chapter and pertain to information presented prior to each question. The same solution-style format answers to the odd-numbered questions are provided.

Predict 4

What effect would swimming in cool water have on body temperature regulation? What would happen if a negative-feedback mechanism did not return the value of a variable, such as body temperature, to its normal range?

c. Concept Check
This section integrates a chapter review with remember-level questions as well as critical thinking questions. Critical thinking questions typically require a higher-order level of thinking than the Predict questions. Answers to the questions in this section are provided, including solution-style-format answers for the critical thinking questions.



Concept Check

4.1 Tissues and Histology

A. Tissues are collections of similar cells and the extracellular substances surrounding them.

B. The four primary tissue types are epithelial, connective, muscle, and nervous tissues.

4.2 Embryonic Tissue

All four of the primary tissue types are derived from each of the three germ layers (mesoderm, ectoderm, and endoderm).

1. *Which of these embryonic germ layers gives rise to muscle, bone, and blood vessels?* Remember
   a. ectoderm
   b. endoderm
   c. mesoderm

4.3 Epithelial Tissue

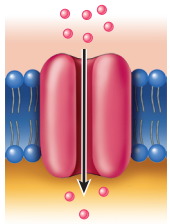
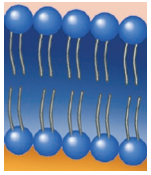
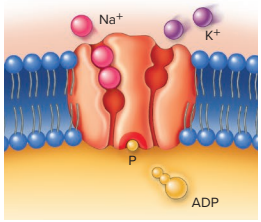
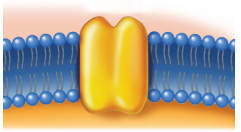
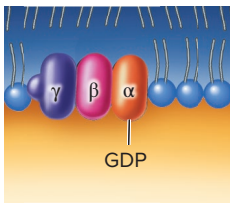
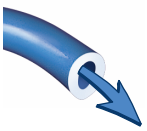
A. Epithelium consists of cells with little extracellular matrix. It covers surfaces, usually has a basement membrane, and does not have blood vessels.

4. *Stratified epithelium is usually found in areas of the body where the principal activity is* Remember
   a. filtration.
   b. protection.
   c. absorption.
   d. diffusion.
   e. secretion.

5. *Which of these characteristics do not describe nonkeratinized stratified squamous epithelium?* Remember
   a. many layers of cells
   b. flat surface cells
   c. living surface cells
   d. found in the skin
   e. outer layers covered by fluid

6. *In parts of the body where considerable expansion occurs, such as the urinary bladder, which type of epithelium would you expect to find?* Remember
   a. cuboidal
   b. pseudostratified
   c. transitional

7. Figure Colors and Symbols
Following are symbols used consistently to indicate the same structure or event in all chapters. If in some chapters a symbol is given a different usage, that usage for the symbol is always labeled or defined.

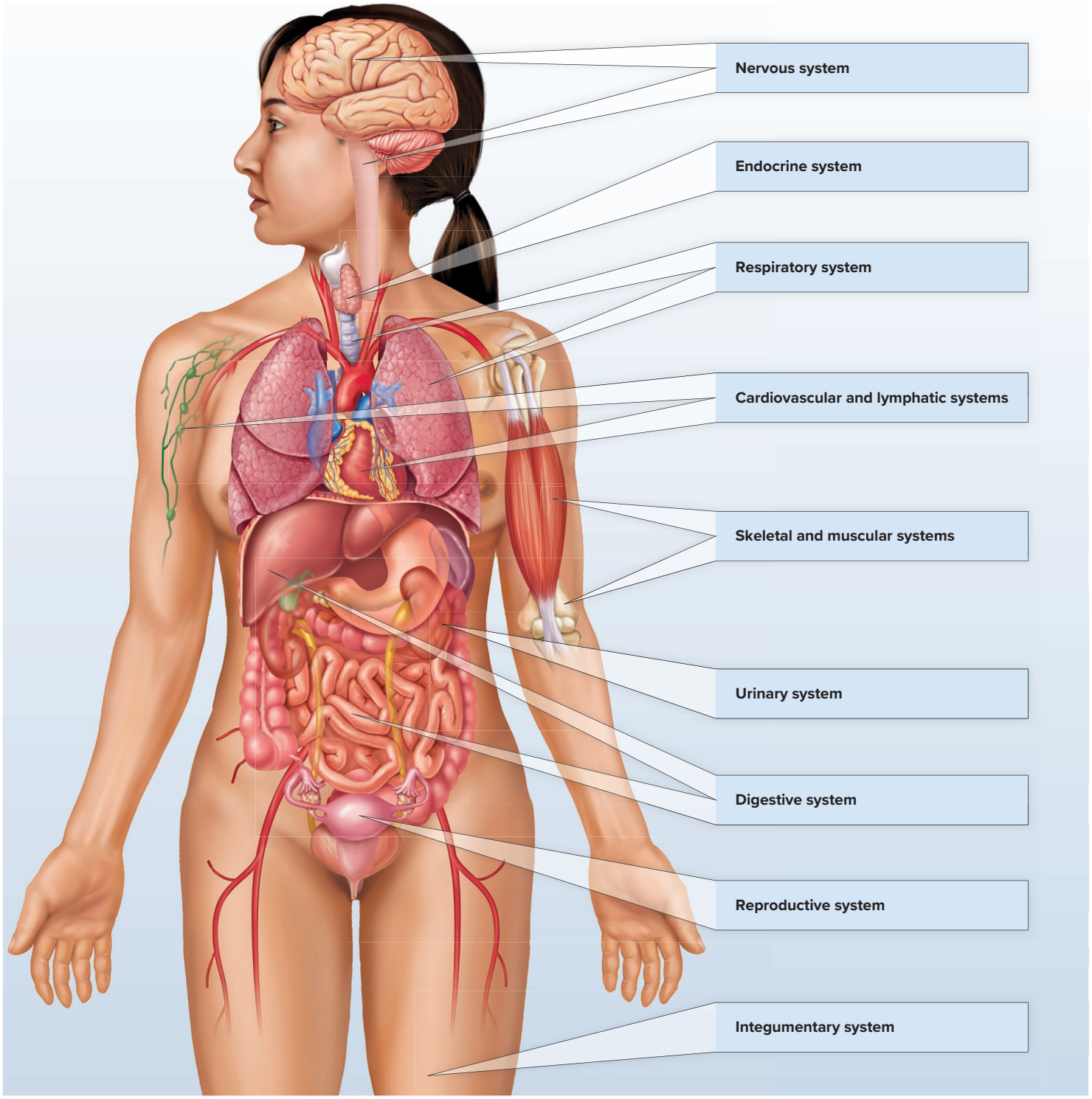
Symbol	Meaning
	Information and level flow
	Describe steps in a process
	To decrease or inhibit
	To increase or stimulate
	Channel proteins and ions Pink: Na^+ Purple: K^+ Green: Ca^{2+}
	Blue: Phospholipid bilayer of cell membrane Yellow: Cytoplasm/inside of cell
	Sodium-potassium (Na^+–K^+) pump
	Acetylcholine
	Sympathetic nervous system
	Parasympathetic nervous system
	Action potential
	Generic ligand
	Generic ligand receptor
	G protein
	Veins with deoxygenated blood
	Arteries with oxygenated blood

Conclusions

In our teaching we have seen, time and time again, that the students who put in the effort and utilize the activities described in this guide consistently outperform the students who do not. Thus, it will be your perseverance, sometimes called *grit*—and not how "smart" you are—that will enable your success. Encourage yourself, believe in yourself, and never quit.

CHAPTER 1

The Human Organism



The human body is a complex system. The structures in the body work in concert to maintain homeostasis, a balance in the body's internal environment.