Seeley's

ANATOMY & PHYSIOLOGY

Thirteenth Edition

Cinnamon VanPutte
Southern Illinois University School of Dental Medicine

Jennifer Regan
The University of Southern Mississippi

Andrew Russo
University of Iowa

Mc Graw Hill

SEELEY'S ANATOMY & PHYSIOLOGY, THIRTEENTH EDITION

This book is printed on acid-free paper.

1 2 3 4 5 6 7 8 9 LWI 27 26 25 24 23 22

ISBN 978-1-264-10388-1 (bound edition)
MHID 1-264-10388-3 (bound edition)
ISBN 978-1-264-42101-5 (loose-leaf edition)
MHID 1-264-42101-X (loose-leaf edition)

Portfolio Manager: *Matt Garcia*
Product Developer: *Melisa Seegmiller*
Marketing Manager: *Valerie Kramer*
Content Project Managers: *Ann Courtney/Brent dela Cruz*
Buyer: *Laura Fuller*
Designer: *David W. Hash*
Content Licensing Specialist: *Lori Hancock*
Cover Image: *Rattanasak Khuentana/Shutterstock*
Compositor: *MPS Limited*

Library of Congress Cataloging-in-Publication Data

Names: VanPutte, Cinnamon L., author.
Title: Seeley's anatomy & physiology / Cinnamon VanPutte, Southern Illinois University [and five others].
Other titles: Seeley's anatomy and physiology
Description: Thirteenth edition. | New York, NY : McGraw Hill, [2023] | Includes index.
Identifiers: LCCN 2021014005 | ISBN 9781264103881 (hardcover) | ISBN 9781264421015 (spiral bound)
Subjects: LCSH: Human physiology. | Human anatomy.
Classification: LCC QP34.5 .S4 2023 | DDC 612—dc23
LC record available at https://lccn.loc.gov/2021014005

mheducation.com/highered

ABOUT THE **Authors**

Howard Ash

Bridget Reeves

Andrew F. Russo

Cinnamon L. VanPutte

Associate Professor
Growth, Development and Structure
Southern Illinois University School of Dental Medicine

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.

Jennifer L. Regan

Teaching Professor
The University of Southern Mississippi

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.

Andrew F. Russo

Professor of Molecular Physiology and Biophysics
University of Iowa

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
Jennifer Regan
Andy Russo

Reviewers

Nahel Awadallah, *Nash Community College*

Jessica K. Baack, *Southwestern Illinois College*

Corinne Carey, *Southwestern Illinois College*

Maria Figueiredo-Pereira, *Hunter College, CUNY*

Sharada Gollapudi, *San Jacinto College South*

Clare Hays, *Metropolitan State University of Denver*

Shannon Larson, *College of Southern Nevada*

Cynthia Littlejohn, *The University of Southern Mississippi*

Lauren E. McDaniel, *Kansas State University*

Judy Metcalf, *Texas A&M University–Corpus Christi*

Jean Mitchell, *University of Florida College of Medicine and Northwest Florida State College*

Justicia Opoku, *University of Maryland, College Park*

Nicole Pinaire, *St. Charles Community College*

Ann Raddant, *University of Wisconsin–Milwaukee*

Achint Utreja, *Southern Illinois University School of Dental Medicine*

Nichole Watkins, *The University of Southern Mississippi*

Ronika Williams, *Coastal Bend College*

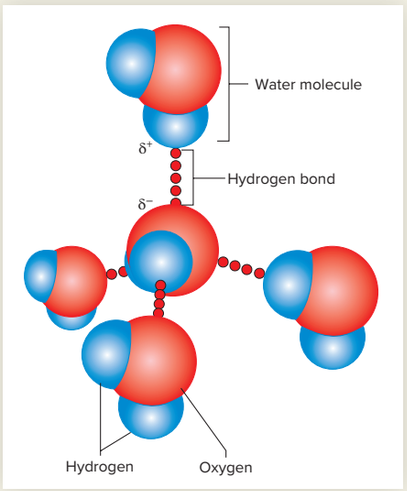
Brief **Contents**

Contents

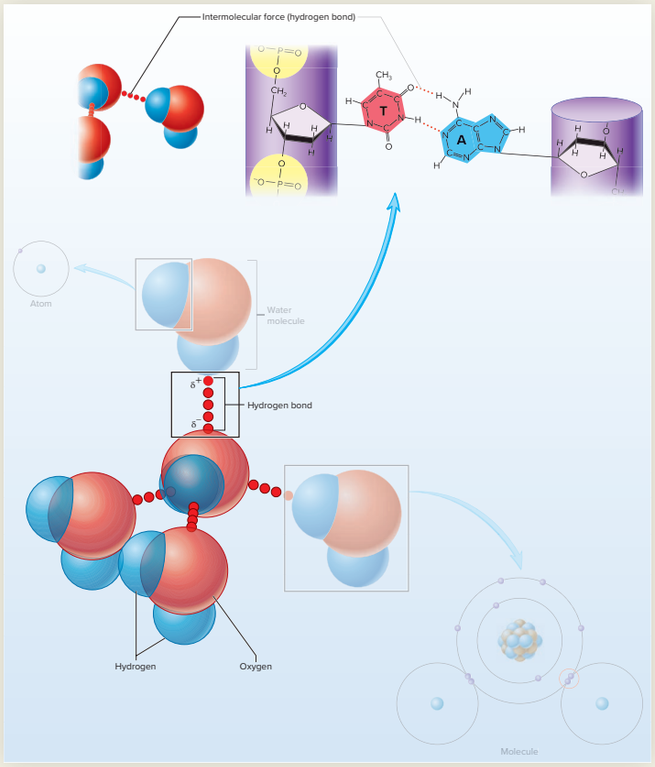
DYNAMIC NEW **Art** PROGRAM

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

12th Edition

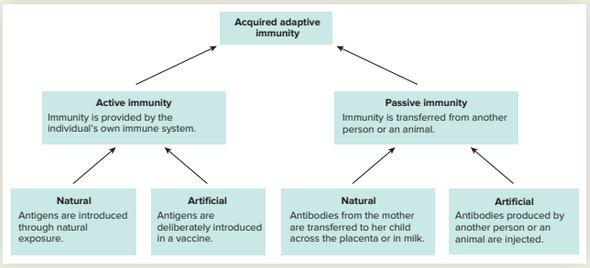


13th Edition

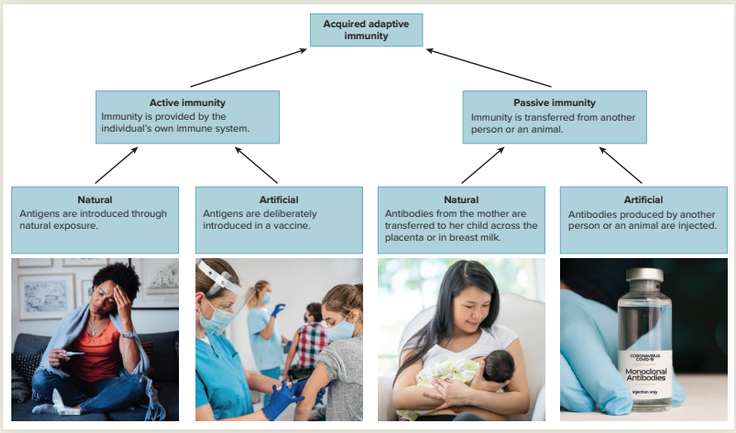


The previous version of this figure did not illustrate the connection between formation of polar covalent bonds and the potential for hydrogen bonds to occur. The new art builds from previous art illustrating polar covalent bond formation.

12th Edition

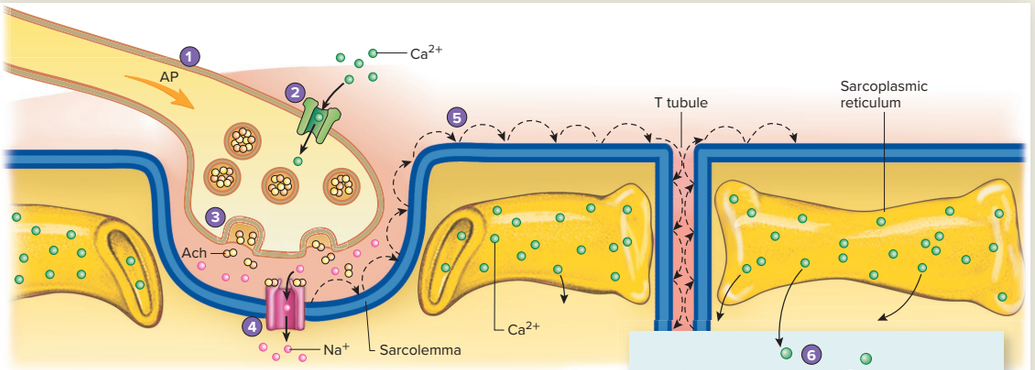


13th Edition



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

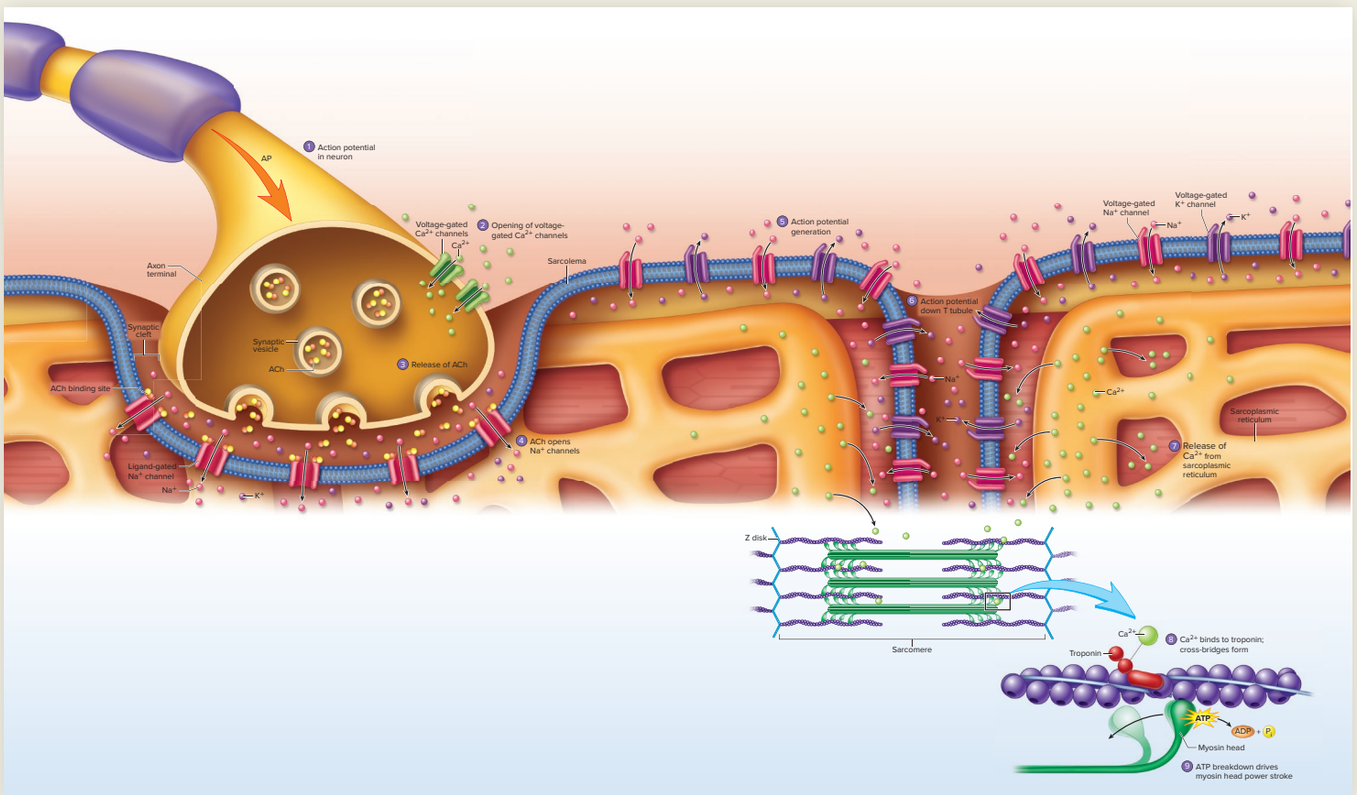
12th Edition



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?

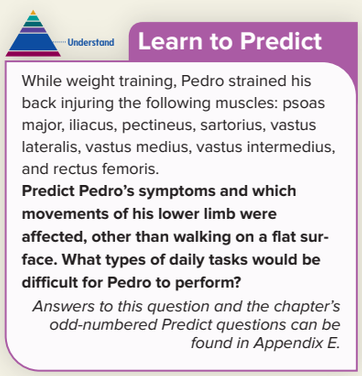
Seeley's Anatomy & Physiology is written for the two-semester anatomy and physiology course. The writing is comprehensive enough to provide the depth necessary for those courses not requiring prerequisites, and is presented with such clarity that it nicely balances the thorough coverage. Clear descriptions 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?

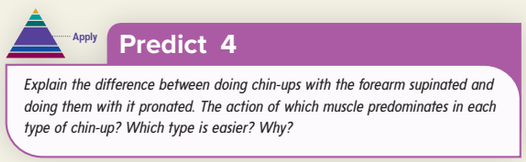
Seeley's Learning System—*Emphasis on Critical Thinking*

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.

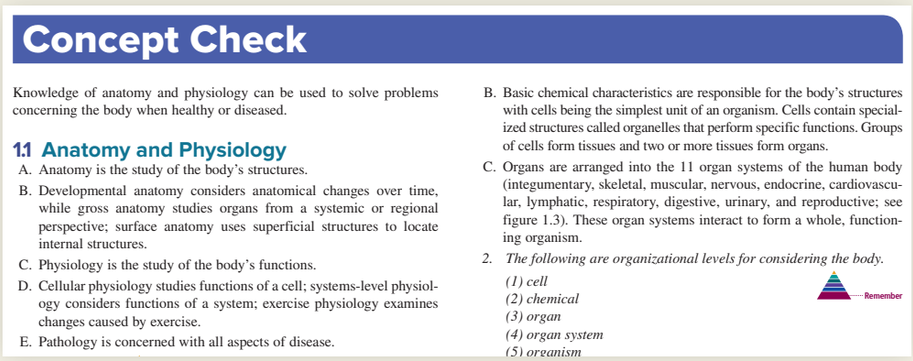
- Problem-solving perspective from the book's inception
- Pedagogy that builds student comprehension from knowledge to application (**Learn to Predict** questions, **Predict** questions, **Concept Check** questions)



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



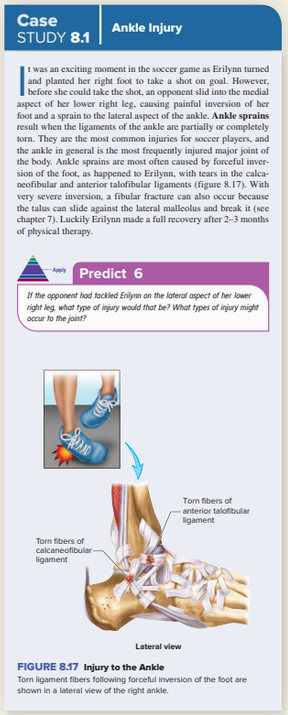
Predict Questions challenge students to use their understanding of new concepts to solve a problem. Answers to the odd-numbered Predict questions are provided in Appendix E, allowing students to evaluate their responses and to understand the logic used to arrive at the correct answer. All Predict question 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

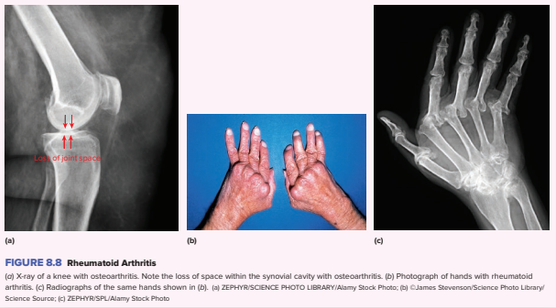
If the opponent had tackled Erilynn on the lateral aspect of her lower right leg, what type of injury would that be? What types of injury might occur to the joint?

Torn fibers of anterior talofibular ligament

Torn fibers of calcaneofibular ligament

Lateral view

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*).

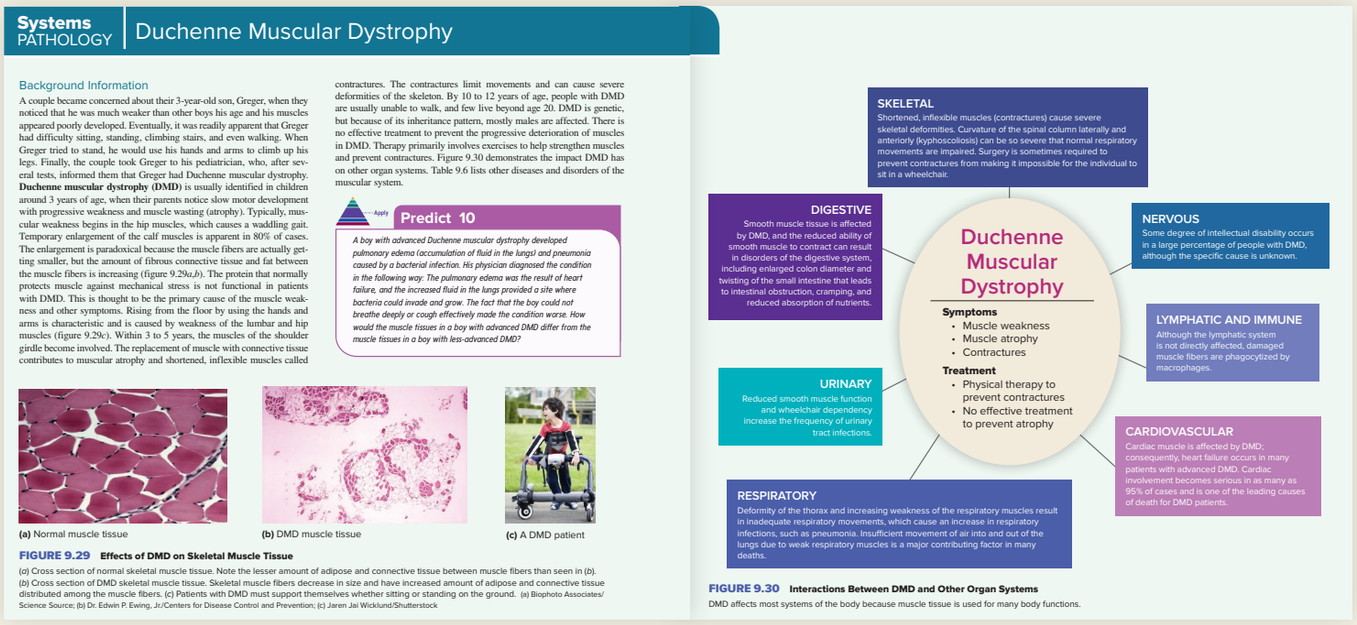
The initial cause of RA is unknown but may involve a transient infection or an autoimmune disease (an immune reaction to one's own tissues; see chapter 22) that develops against collagen. A genetic predisposition may also exist. Whatever the cause, the ultimate course appears to be immunological. In 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.

Loss of joint space

(a) (b) (c)

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

SKELETAL
Shortened, inflexible muscles (contractures) cause severe skeletal deformities. Curvature of the spinal column laterally and anteriorly (kyphoscoliosis) can be so severe that normal respiratory movements are impaired. Surgery is sometimes required to prevent contractures from making it impossible for the individual to sit in a wheelchair.

DIGESTIVE
Smooth muscle tissue is affected by DMD, and the reduced ability of smooth muscle to contract can result in disorders of the digestive system, including enlarged colon diameter and twisting of the small intestine that leads to intestinal obstruction, cramping, and reduced absorption of nutrients.

Duchenne Muscular Dystrophy

Symptoms
- Muscle weakness
- Muscle atrophy
- Contractures

Treatment
- Physical therapy to prevent contractures
- No effective treatment to prevent atrophy

NERVOUS
Some degree of intellectual disability occurs in a large percentage of people with DMD, although the specific cause is unknown.

LYMPHATIC AND IMMUNE
Although the lymphatic system is not directly affected, damaged muscle fibers are phagocytized by macrophages.

URINARY
Reduced smooth muscle function and wheelchair dependency increase the frequency of urinary tract infections.

CARDIOVASCULAR
Cardiac muscle is affected by DMD; consequently, heart failure occurs in many patients with advanced DMD. Cardiac involvement becomes serious in as many as 95% of cases and is one of the leading causes of death for DMD patients.

RESPIRATORY
Deformity of the thorax and increasing weakness of the respiratory muscles result in inadequate respiratory movements, which cause an increase in respiratory infections, such as pneumonia. Insufficient movement of air into and out of the lungs due to weak respiratory muscles is a major contributing factor in many deaths.

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.

Remote Proctoring & Browser-Locking Capabilities

New remote proctoring and browser-locking capabilities, hosted by Proctorio within Connect, provide control of the assessment environment by enabling security options and verifying the identity of the student.

Seamlessly integrated within Connect, these services allow instructors to control students’ assessment experience by restricting browser activity, recording students’ activity, and verifying students are doing their own work.

Instant and detailed reporting gives instructors an at-a-glance view of potential academic integrity concerns, thereby avoiding personal bias and supporting evidence-based claims.

McGraw Hill empowers students to learn and succeed in the Anatomy and Physiology course.

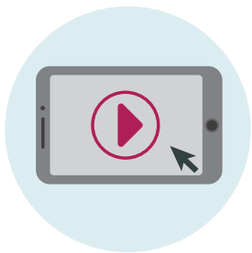
50% of the country's students are unable to pass the A&P course*

SMARTBOOK®

SmartBook provides personalized learning to individual student needs, continually adapting to pinpoint knowledge gaps and focus learning on concepts requiring additional study. The result? Students are highly engaged in the content and better prepared for lecture.

PREP

A&P Prep helps students thrive in college-level A&P by helping solidify knowledge in the key areas of cell biology, chemistry, study skills, and math. The result? Students are better prepared for the A&P course.



PhILS

Ph.I.L.S. 4.0 (Physiology Interactive Lab Simulations) software is the perfect way to reinforce key physiology concepts with powerful lab experiments. The result? Students gain critical thinking skills and are better prepared for lab.

Concept Overview Interactives are ground-breaking interactive animations that encourage students to explore key physiological processes and difficult concepts. The result? Students are engaged and able to apply what they've learned while tackling difficult A&P concepts.

PracticeATLAS

Practice Atlas for A&P is an interactive tool that pairs images of common anatomical models with stunning cadaver photography, allowing students to practice naming structures on both models and human bodies, anytime, anywhere. The result? Students are better prepared, engaged, and move beyond basic memorization.

*Statistic courtesy of The New England Journal of Higher Education

Virtual Labs

Connect Virtual Labs helps connect the dots between lab and lecture, boosts student confidence and knowledge, and improves student success rates. The result? Students are engaged, prepared, and utilize critical thinking skills.

Anatomy & Physiology Revealed® 4.0

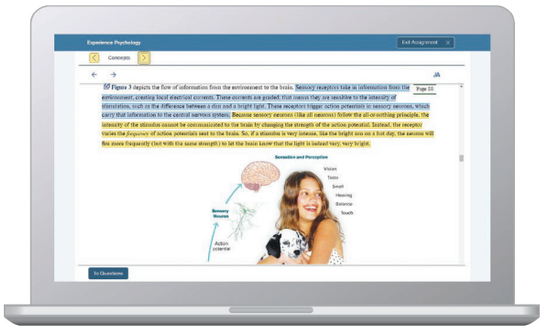
Anatomy & Physiology Revealed® (APR) 4.0 is an interactive cadaver dissection tool to enhance lecture and lab that students can use anytime, anywhere. The result? Students are prepared for lab, engaged in the material, and utilize critical thinking.

Instructors: Student Success Starts with You

Tools to enhance your unique voice

Want to build your own course? No problem. Prefer to use an OLC-aligned, prebuilt course? Easy. Want to make changes throughout the semester? Sure. And you'll save time with Connect's auto-grading too.

65%
Less Time Grading



Laptop: McGraw Hill; Woman/dog: George Doyle/Getty Images

Study made personal

Incorporate adaptive study resources like SmartBook® 2.0 into your course and help your students be better prepared in less time. Learn more about the powerful personalized learning experience available in SmartBook 2.0 at **www.mheducation.com/highered/connect/smartbook**

Affordable solutions, added value

Make technology work for you with LMS integration for single sign-on access, mobile access to the digital textbook, and reports to quickly show you how each of your students is doing. And with our Inclusive Access program you can provide all these tools at a discount to your students. Ask your McGraw Hill representative for more information.

Padlock: Jobalou/Getty Images

Solutions for your challenges

A product isn't a solution. Real solutions are affordable, reliable, and come with training and ongoing support when you need it and how you want it. Visit **www.supportateverystep.com** for videos and resources both you and your students can use throughout the semester.

Checkmark: Jobalou/Getty Images

SUPPORT AT every step

Students: Get Learning that Fits You

Effective tools for efficient studying

Connect is designed to help you be more productive with simple, flexible, intuitive tools that maximize your study time and meet your individual learning needs. Get learning that works for you with Connect.

Study anytime, anywhere

Download the free ReadAnywhere app and access your online eBook, SmartBook 2.0, or Adaptive Learning Assignments when it's convenient, even if you're offline. And since the app automatically syncs with your Connect account, all of your work is available every time you open it. Find out more at **www.mheducation.com/readanywhere**

"I really liked this app—it made it easy to study when you don't have your text-book in front of you."

- Jordan Cunningham,
  Eastern Washington University

Calendar: owattaphotos/Getty Images

Everything you need in one place

Your Connect course has everything you need—whether reading on your digital eBook or completing assignments for class, Connect makes it easy to get your work done.

Learning for everyone

McGraw Hill works directly with Accessibility Services Departments and faculty to meet the learning needs of all students. Please contact your Accessibility Services Office and ask them to email accessibility@mheducation.com, or visit **www.mheducation.com/about/accessibility** for more information.

Top: Jenner Images/Getty Images, Left: Hero Images/Getty Images, Right: Hero Images/Getty Images

CHAPTER 0

How to Be Successful in A&P

dotshock/Shutterstock

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.

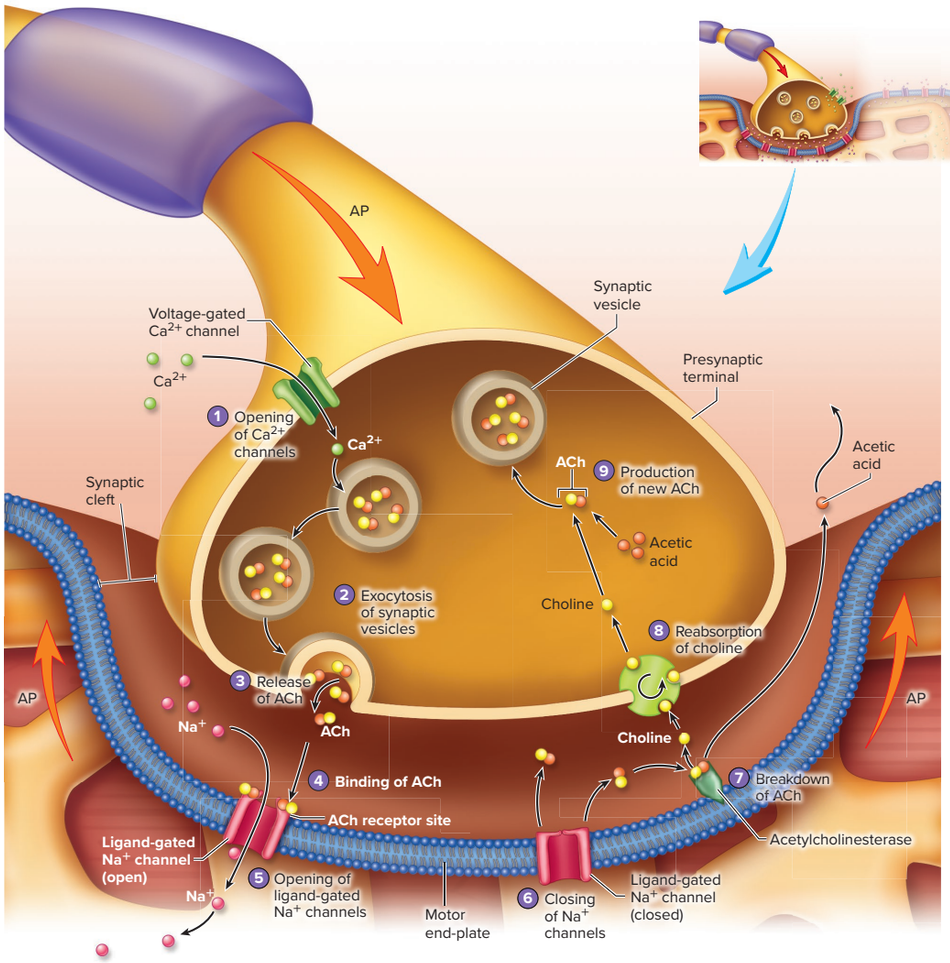
4. *Do Homework as If It Were the Test.* For most lecture exams you will not be allowed to use your notes, the textbook, or the Internet. So you need to practice for that situation. Don't simply copy answers onto your homework assignments. Instead, study first, then do the homework without assistance. 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.

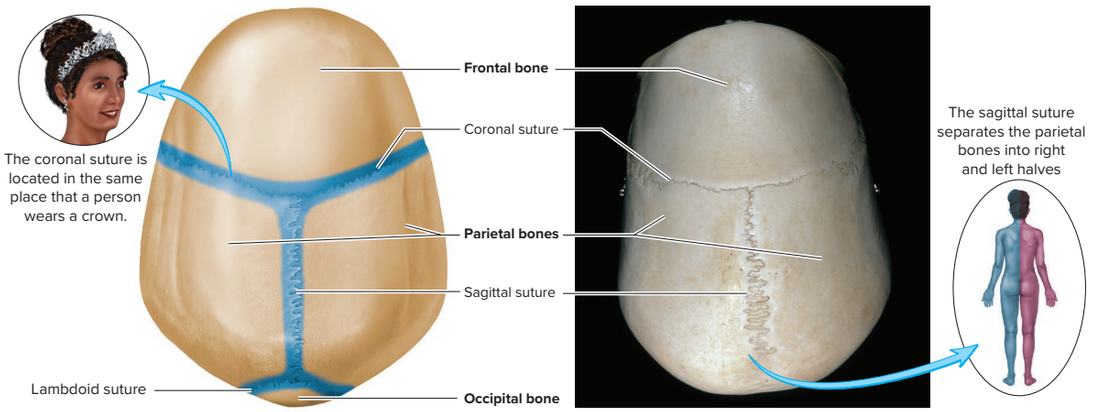
1. In-Text Numbering
   As you're reading, look for areas where we've tried to make complex topics clearer by numbering steps or components. This ensures that you don't miss a step or a part.

> 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^+.



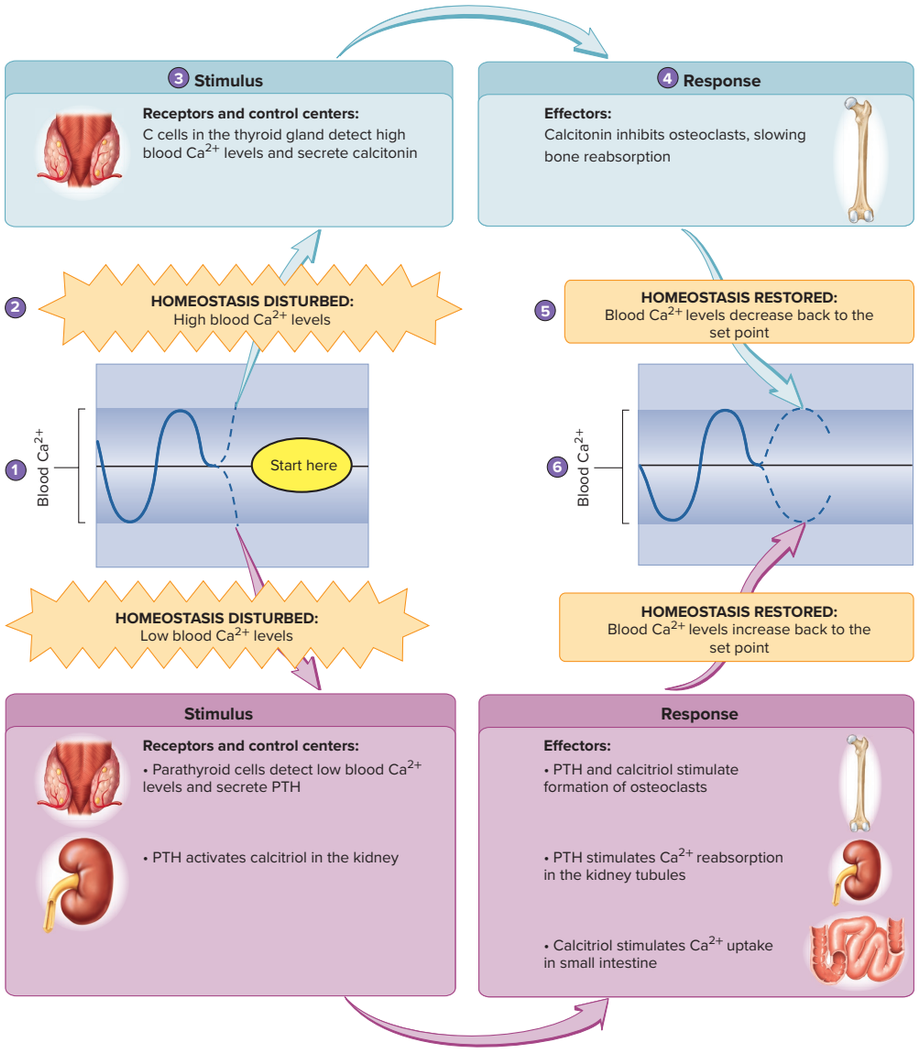
2. Process Figures
   For complex processes, we have process figures that break down the step-by-step sequence of events. The in-text explanations directly correlate to portions of the figure by the use of purple-circled numbers.

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.



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.

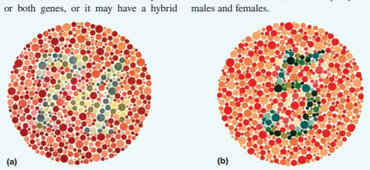


FIGURE 15.22 Color Blindness Charts
(a) A person with normal color vision can see the number 74, whereas a person with red-green color blindness sees the number 21. (b) A person with normal color vision can see the number 5, whereas a person with red-green color blindness sees the number 2. (a) Steve 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.

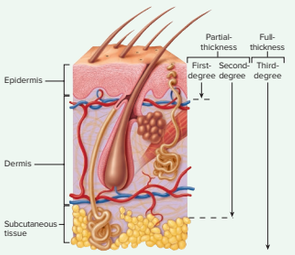


FIGURE 5.14 **Partial- and Full-Thickness Burns**

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

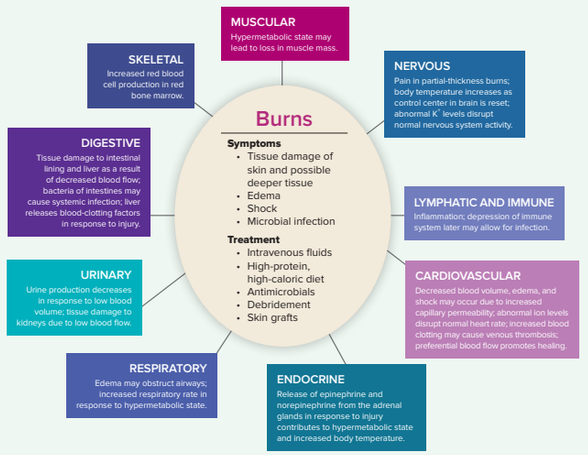


FIGURE 5.16 **Systems Interactions: Burns**
Burns affect more than just the skin. This diagram illustrates how the systems of the body are affected following a burn.

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.

Apply **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.

Understand **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.

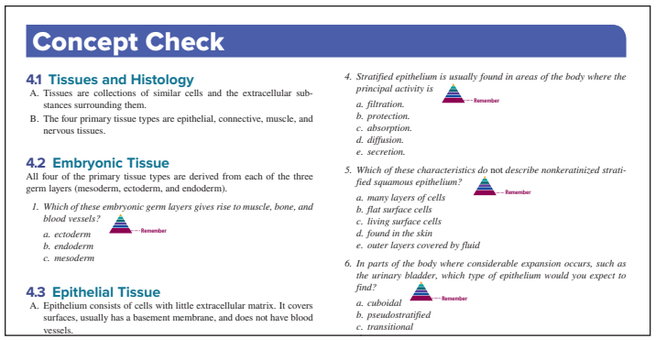
We read in this chapter that the muscles affected by Pedro's injury (psoas major, iliacus, pectineus, sartorius, vastus lateralis, vastus medius, vastus intermedius, and rectus femoris) are involved in flexing the hip, the knee, or both. Therefore, we can conclude that movements involving hip and knee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

Understand **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

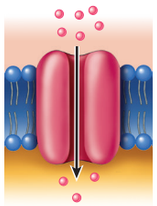
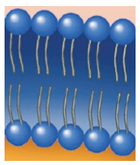
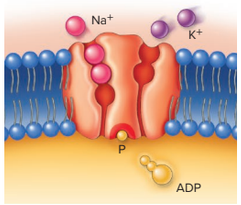
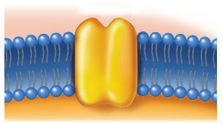
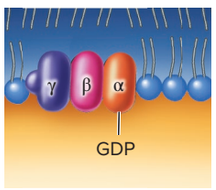
A. Epithelium consists of cells with little extracellular matrix. It covers surfaces, usually has a basement membrane, and does not have blood vessels.

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.

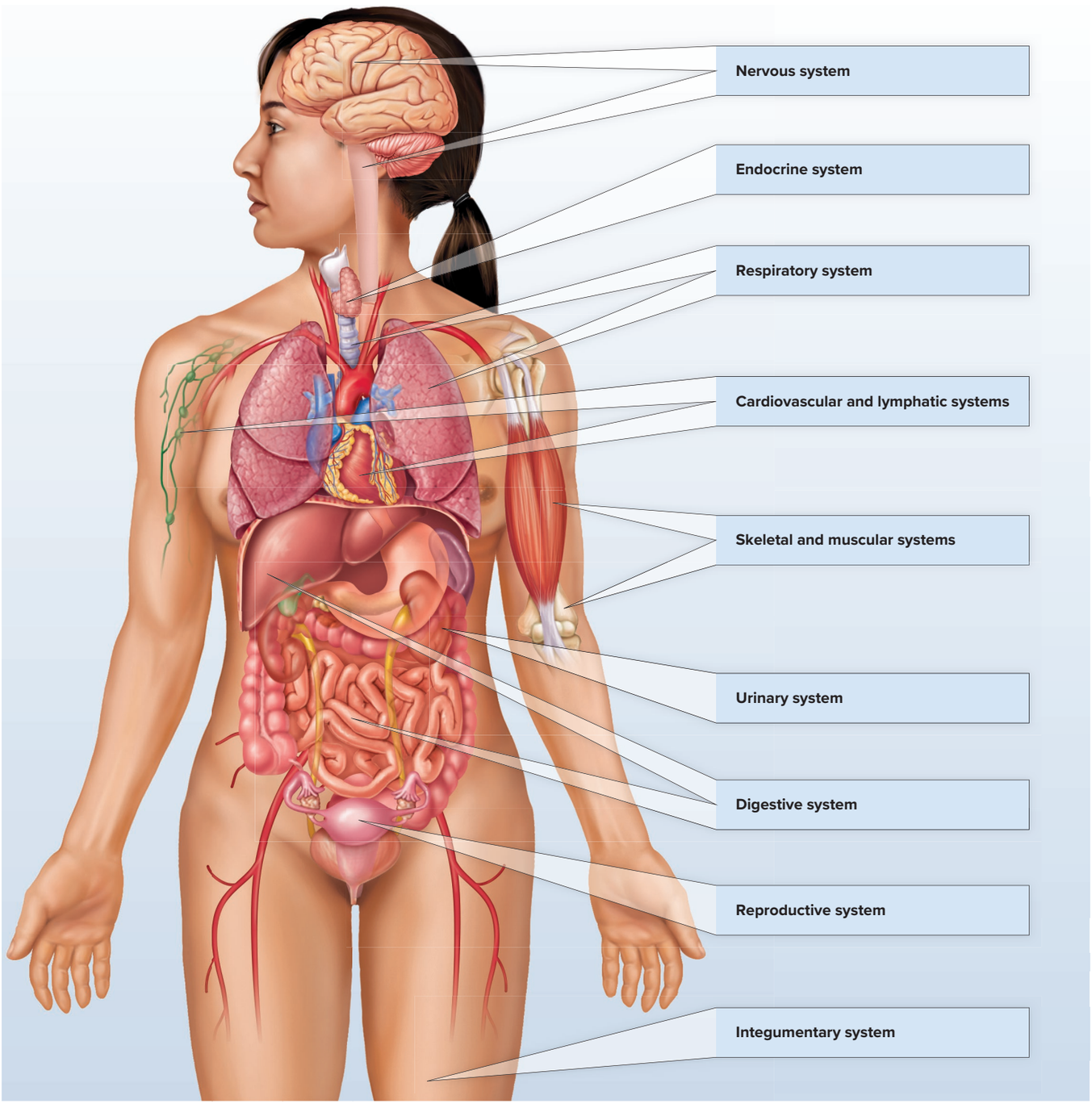
Symbol	Meaning
 and	Information and level flow
	Describe steps in a process
	To decrease or inhibit
	To increase or stimulate
	Channel proteins and ions Pink: Na^+ Purple: K^+ Green: Ca^{2+}
	Blue: Phospholipid bilayer of cell membrane Yellow: Cytoplasm/inside of cell
	Sodium-potassium (Na^+–K^+) pump
	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.

What lies ahead is an astounding adventure—learning about the structure and function of the human body and the intricate checks and balances that regulate it. Renzo's (the dancer featured in this chapter's Learn to Predict) blood sugar disorder is a good example of how important this system of checks and balances is in the body. Perhaps you have had the experience of oversleeping, rushing to your 8 a.m. class, and missing breakfast. Afterward, on the way to Anatomy & Physiology class, you bought an energy bar from a vending machine. Eating the energy bar helped you feel better. The explanation for these experiences is the process of homeostasis, the maintenance of a relatively constant internal environment, despite fluctuations in the external environment. For you, homeostasis was maintained, but for Renzo, there was a disruption in homeostasis. Throughout this textbook, the major underlying theme is homeostasis. As you think about Renzo's case, you will come to realize just how capable the human body is of an incredible coordination of thousands upon thousands of processes. Learning about human anatomy and physiology is important for understanding disease. The study of human anatomy and physiology is also important for students who plan a career in the health sciences because health professionals need a sound knowledge of structure and function in order to perform their duties. In addition, understanding anatomy and physiology prepares all of us to evaluate recommended treatments, critically review advertisements and reports in the popular literature, and rationally discuss the human body with health professionals and nonprofessionals.

1.1 Anatomy and Physiology

LEARNING OUTCOMES

After reading this section, you should be able to

A. **Define *anatomy*.**
B. **Describe the levels at which anatomy can be studied.**
C. **Define *physiology*.**
D. **Describe the levels at which physiology can be studied.**
E. **Explain the importance of the relationship between structure and function.**

In studying biological organisms, including humans, you will encounter four key concepts: (1) structure and function relationships, (2) movement of chemicals along gradients, (3) cell-to-cell communication, and (4) feedback loops. Throughout this chapter, we will highlight these key concepts. Then as you progress through the textbook, look for these key concepts. They will be discussed within every organ. system. **Anatomy** is the scientific discipline that investigates the body's structures—for example, the shape and size of bones. The word *anatomy* means to dissect or cut apart and separate the parts of the body for study. In addition, anatomy examines the relationship between the structure of a body part and its function. For example, the structure of a hammer informs us of its primary use: to deliver a hard blow to a small area of an object. Similarly, the fact that bone cells are surrounded by a hard, mineralized substance enables the bones to provide strength and support. This is the first of the four key concepts of anatomy and physiology: structure and function relationships. Understanding the relationship between structure and function makes it easier to understand and appreciate anatomy. Anatomy can be studied at different levels. **Developmental anatomy** studies the structural changes that occur between conception and adulthood. **Embryology** (em-bree-OL-oh-jee), a subspecialty of developmental anatomy, considers changes from conception to the end of the eighth week of development.

Learn to Predict

Renzo, a dancer, can perfectly balance on the ball of one foot, yet a slight movement in any direction causes him to adjust his position. The human body adjusts its balance among all its parts through a process called homeostasis.

Let's imagine that Renzo is unknowingly suffering from a blood sugar disorder. Normally, tiny collections of cells embedded in the pancreas regulate blood sugar by secreting the chemical insulin. Insulin increases the movement of sugar from the blood into his cells. However, Renzo has been losing a lot of weight, despite eating the same amount of food as always. He noticed that he's been fatigued, very thirsty, and urinating more than normal. Renzo went to see his doctor, who ordered some tests, including a blood glucose challenge. The results showed Renzo's blood sugar was higher than normal. After trying several treatments such as diet and prescription oral medication with little effect, Renzo was outfitted with an insulin pump. Now, his blood sugar levels are more consistent.

Develop an explanation for Renzo's blood sugar levels before and after his visit to the doctor.

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

Some structures, such as cells, are so small that they must be studied using a microscope. **Cytology** (sigh-TOL-oh-jee; *cyto,* cell) examines the structural features of cells, and **histology** (his-TOL-oh-jee; *hist,* tissue) examines tissues, which are composed of cells and the materials surrounding them.

Gross anatomy, the study of structures that can be examined without the aid of a microscope, can be approached either systemically or regionally. A **system** is a group of structures that have one or more common functions, such as the cardiovascular, nervous, respiratory, skeletal, or muscular systems. In systemic anatomy, the body is studied system by system. In regional anatomy, the body is studied area by area. Within each region, such as the head, abdomen, or arm, all systems are studied simultaneously. The regional approach is taken in many graduate programs at medical and dental schools. The systemic approach is used in this and most other introductory textbooks.

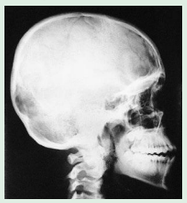
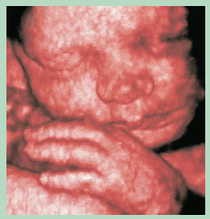
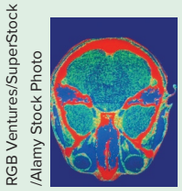
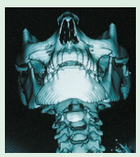
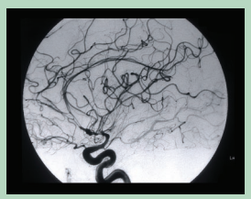
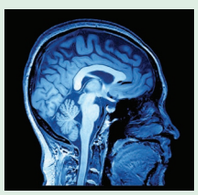
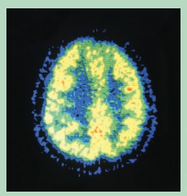
Surface anatomy involves looking at the exterior of the body to visualize structures deeper inside the body. For example, the sternum (breastbone) and bulges from the ribs can be seen and palpated (felt) on the front of the chest. Health professionals use these structures as anatomical landmarks to identify regions of the heart and points on the chest where certain heart sounds can best be heard. **Anatomical imaging** uses radiographs (x-rays), ultrasound, magnetic resonance imaging (MRI), and other technologies to create pictures of internal structures (table 1.1). Anatomical imaging has revolutionized medical science. Anatomical imaging allows medical personnel to look inside the body with amazing accuracy and without the trauma and risk of exploratory surgery. The risk of anatomical imaging is minimized by using the lowest possible number of doses providing the necessary information. No known risks exist from ultrasound or electromagnetic fields at the levels used for diagnosis. Both surface anatomy and anatomical imaging provide important information for diagnosing disease.

However, no two humans are structurally identical. **Anatomical anomalies** are physical characteristics that differ from the normal pattern. Anatomical anomalies can vary in severity from relatively harmless to life-threatening. For example, each kidney is normally supplied by one blood vessel, but in some individuals a kidney is supplied by two blood vessels. Either way, the kidney receives adequate blood. On the other hand, in the condition called "blue baby" syndrome, certain blood vessels arising from an infant's heart are not attached in their correct locations; blood is not effectively pumped to the lungs, and so the tissues do not receive adequate oxygen.

Physiology is the scientific investigation of the processes or functions of living things. There are two major goals when studying human physiology: (1) examining the body's responses to stimuli and (2) examining the body's maintenance of stable internal conditions within a narrow range of values in a constantly changing environment.

Like anatomy, physiology can be considered at many levels. **Cell physiology** examines the processes occurring in cells such as energy production from food, and **systemic physiology** considers the functions of organ systems. Types of systemic physiology are

TABLE 1.1 Anatomical Imaging

Imaging Technique	Clinical Examples
X-ray  Omikron/Science Source	This extremely short-wave electromagnetic radiation moves through the body, exposing a photographic plate to form a **radiograph** (RAY-dee-oh-graf). Radiographs create flat, two-dimensional (2D) image.
Ultrasound  Bernard Benoit/Science Photo Library/Science Source	**Ultrasound** uses high-frequency sound waves, which strike internal organs and bounce back to the receiver on the skin. Among other medical applications, ultrasound is commonly used to evaluate the condition of the fetus during pregnancy.
Computed Tomography (CT)  RGB Ventures/SuperStock /Alamy Stock Photo (a)  Ribotsky D.P.M./Custom Medical Stock Photo (b)	**Computed tomographic** (TOH-moh-GRAF-ik) **(CT) scans** are computer-analyzed x-ray images (*a*). Some computers are able to take several scans short distances apart and stack the slices to produce a 3D image of a body part (*b*).
Digital Subtraction Angiography (DSA)  Living Art Enterprises, LLC/Science Source	**Digital subtraction angiography** (an-jee-OG-rah-fee) **(DSA)** is one step beyond CT scanning. A radiopaque dye is injected into the blood, which allows for enhanced differences when compared to a noninjected scan.
Magnetic Resonance Imaging (MRI)  MriMan/Shutterstock	**Magnetic resonance imaging (MRI)** directs radio waves at a person lying inside a large electromagnetic field. An MRI is more effective at detecting some forms of cancer than a CT scan.
Positron Emission Tomography (PET)  Science Source	**Positron emission tomographic (PET) scans** can identify the metabolic states of various tissues. This technique is particularly useful in analyzing the brain. Radiation pinpoints cells that are metabolically active.

cardiovascular physiology, which focuses on the heart and blood vessels, and **neurophysiology,** which focuses on the function of the nervous system. Physiology often examines systems rather than regions because a particular function can involve portions of a system in more than one region. The second key concept of anatomy and physiology is integral to studying physiology as you will learn: Chemicals move along gradients. We will examine that more in chapter 3.

Studies of the human body must encompass both anatomy and physiology because structures, functions, and processes are interwoven. **Pathology** (pa-THOL-oh-jee) is the medical science dealing with all aspects of disease, with an emphasis on the cause and development of abnormal conditions, as well as the structural and functional changes resulting from disease. **Exercise physiology** focuses on the changes in function and structure caused by exercise.

ASSESS YOUR PROGRESS

Answers to these questions are found in the section you have just completed. Re-read the section if you need help in answering these questions.

1. *How does the study of anatomy differ from the study of physiology?*
2. *What is studied in gross anatomy? In surface anatomy?*
3. *What type of physiology is employed when studying the endocrine system?*
4. *Why are anatomy and physiology normally studied together?*

1.2 Biomedical Research

LEARNING OUTCOME

After reading this section, you should be able to

A. **Explain why it is important to study other organisms along with humans.**

Much of what we know about our own physiology is based on physiological studies of other organisms. Humans share many characteristics with other organisms. For example, studying single-celled bacteria has allowed scientists to utilize bacteria to synthesize certain human medicines such as insulin. However, some biomedical research cannot be accomplished using single-celled organisms or isolated cells. Sometimes other mammals must be studied, as evidenced by the great progress in open-heart surgery and kidney transplantation made possible by perfecting surgical techniques on other mammals before attempting them on humans. Strict laws govern the use of animals in biomedical research; these laws are designed to ensure minimal suffering on the part of the animal and to discourage unnecessary experimentation.

Although much can be learned from studying other organisms, the ultimate answers to questions about humans can be obtained only from humans because other organisms differ from humans in significant ways. A failure to appreciate the differences between humans and other animals led to many misconceptions by early scientists. One of the first great anatomists was a Greek physician, Claudius Galen (ca. 130–201). Galen described a large number of anatomical structures supposedly present in humans but observed only in other animals. For example, he described the liver as having five lobes. This is true for rats, but not for humans, who have four-lobed livers. The errors introduced by Galen persisted for more than 1300 years until a Flemish anatomist, Andreas Vesalius (1514–1564), who is considered the first modern anatomist, carefully examined human cadavers and began to correct the textbooks. This example should serve as a word of caution: Some current knowledge in molecular biology and physiology has not been confirmed in humans.

ASSESS YOUR PROGRESS

5. *Why is it important to recognize that humans share many, but not all, characteristics with other animals?*

1.3 Structural and Functional Organization of the Human Body

LEARNING OUTCOMES

After reading this section, you should be able to

A. **Name the six levels of organization of the body.**
B. **Describe the major characteristics of the six levels of organization.**
C. **List the 11 organ systems and identify their components.**
D. **Describe the major functions of each system.**

The body can be studied at six levels of organization: chemical, cell, tissue, organ, organ system, and whole organism (figure 1.1). As you move through levels, you will notice that each builds on the previous level. Disruption of this organized state can result in loss of functions or even death.

1. *Chemical level.* The structural and functional characteristics of all organisms are determined by their chemical makeup. The chemical level of organization involves how atoms, such as hydrogen and carbon, interact and combine to form molecules. This is important because a molecule's structure determines its function. For example, collagen molecules are strong ropelike protein fibers that give skin structural strength and flexibility. With aging, the structure of collagen changes, and the skin becomes fragile and more easily torn during everyday activities. We present a brief overview of chemistry in chapter 2.
2. *Cell level.* **Cells** are the basic structural and functional units of all living organisms. Combinations of molecules form cells. Structures inside cells called **organelles** (OR-gah-nellz; little organs) carry out particular functions, such as digestion and movement, for the cell. For example, the nucleus is an organelle that contains the cell's hereditary information, and mitochondria are organelles that manufacture

FUNDAMENTAL **Figure**

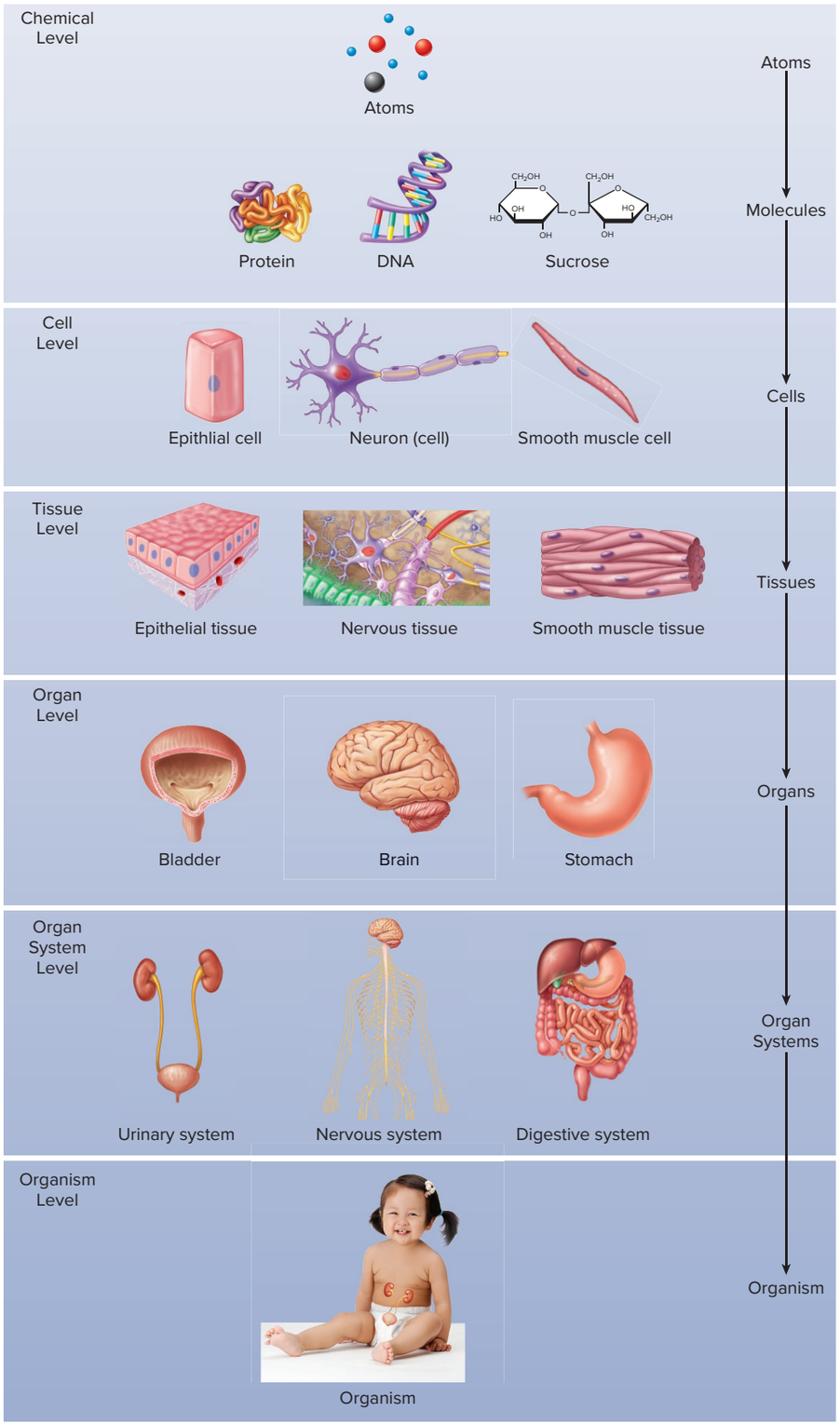


FIGURE 1.1 Levels of Organization for the Human Body

The simplest level of organization in the human body is the atom. Atoms combine to form molecules. Molecules aggregate into cells. Cells form tissues, which combine with other tissues to form organs. Organs work in groups called organ systems. All organ systems work together to form an organism.

(baby girl) BJI/Blue Jean Images/Getty Images

MICROBES In Your Body 1.1 — Getting to Know Your Bacteria

Did you know that you have as many microbial cells as human cells in your body? Astoundingly, for every cell in your body, there is at least one microbial cell. That's as many as 40 trillion microbial cells, which can collectively account for between 2 and 6 pounds of your body weight! A microbe is any life form that can only be seen with a microscope (for example, bacteria, fungi, and protozoa). All living organisms fit into one of three domains of living organisms: (1) Bacteria, (2) Archaea, and (3) Eukarya. The cells of organisms in each domain are unique. Bacterial cells' genetic material is not separated from the rest of the cell by a barrier. In addition, bacterial cells have far fewer separate structures made of membrane for carrying out the cell's metabolic processes than eukaryotic cells. Archaea cells are constructed similarly to bacteria; however, they share certain structures, called ribosomes, with eukaryotic cells. We discuss cell structure in detail in chapter 3. Commonly, the term *prokaryotic* is used to describe bacterial and archaea cells. Eukaryotic cells, which include human cells, have the most structural complexity with many smaller structures, called organelles, made with membrane. These smaller structures conduct the metabolic processes of the cell.

In addition to structural differences, there are many other differences far too numerous to adequately describe here. However, size differences between bacteria and archaea and cells of eukaryotes are quite evident with most eukaryotic cells being significantly larger than most prokaryotic cells. The total population of microbial cells on the human body is referred to as the microbiota, while the collection of all the microbial cell genes is known as the microbiome. The microbiota includes so-called good bacteria, which do not cause disease and may even help us. It also includes pathogenic, or "bad," bacteria.

With that many microbes in and on our bodies, you might wonder how they affect our health. To answer that question, the National Institutes of Health (NIH) initiated the Human Microbiome Project. Five significant regions of the human body were examined: the airway, skin, mouth, gastrointestinal tract, and vagina. This project identified over 5000 species and sequenced over 20 million unique microbial genes.

What did scientists learn from the Human Microbiome Project? Human health is dependent upon the health of our microbiota, especially the "good" bacteria. More specifically, the human microbiome is intimately involved in the development and maintenance of the immune system. And more evidence is mounting for a correlation between a host's microbiota, digestion, and metabolism. Researchers have suggested that microbial genes are more responsible for our survival than human genes. There are even a few consistent pathogens that are present without causing disease, suggesting that their presence may be good for us. However, there does not seem to be a universal healthy human microbiome. Rather, the human microbiome varies across life span, ethnicity, nationality, culture, and geographic location. Instead of being a detriment, this variation may actually be very useful for predicting disease. There seems to be a correlation between autoimmune and inflammatory diseases (Crohn disease, asthma, multiple sclerosis), which have become more prevalent, and a "characteristic microbiome community." Early research seems to indicate that any significant change in the profile of the microbiome of the human gut may increase a person's susceptibility to autoimmune diseases. It has been proposed that these changes may be associated with exposure to antibiotics, particularly in infancy. Fortunately, newer studies of microbial transplantations have shown that the protective and other functions of bacteria can be transferred from one person to the next. However, this work is all very new, and much research remains to be done.

Throughout this text, we will highlight specific instances in which our microbes influence our body systems. In light of the importance of our bodies' bacteria and other microbes, the prevalence of antibacterial soap and hand gel usage in everyday life may be something to think about.

Predict 1

Predict some possible consequences of high-dose, intravenous (IV) antibiotic administration on the homeostasis of a person's digestive function.

adenosine triphosphate (ATP), a molecule cells use for energy. Although cell types differ in their structure and function, they have many characteristics in common. Knowledge of these characteristics, as well as their variations, is essential to understanding anatomy and physiology. We discuss the cell in chapter 3.

3. *Tissue level.* Groups of cells combine to forms **tissues.** A tissue is composed of a group of similar cells and the materials surrounding them. The characteristics of the cells and surrounding materials determine the functions of the tissue. The body is made up of four basic tissue types: (1) epithelial, (2) connective, (3) muscle, and (4) nervous. We discuss tissues in chapter 4.
4. *Organ level.* Different tissues combine to form **organs.** An organ is composed of two or more tissue types that perform one or more common functions. Examples of organs include the urinary bladder, heart, stomach, and lung (figure 1.2).
5. *Organ system level.* Multiple organs combine to form an **organ system** (figure 1.3). An organ system is a group of organs that together perform a common function or set of functions and are therefore viewed as a unit. For example, the urinary system consists of the kidneys, ureters, urinary bladder, and urethra. The kidneys produce urine, which the ureters transport to the urinary bladder, where it is stored until being eliminated from the body through the urethra. In this text, we consider 11 major organ systems: (1) integumentary, (2) skeletal, (3) muscular, (4) nervous, (5) endocrine, (6) cardiovascular, (7) lymphatic, (8) respiratory, (9) digestive, (10) urinary, and (11) reproductive. Figure 1.3 presents a brief summary of these organ systems and their functions. Throughout this textbook, Systems Pathology essays present a specific disease state and consider how this affects the interactions of the organ systems.

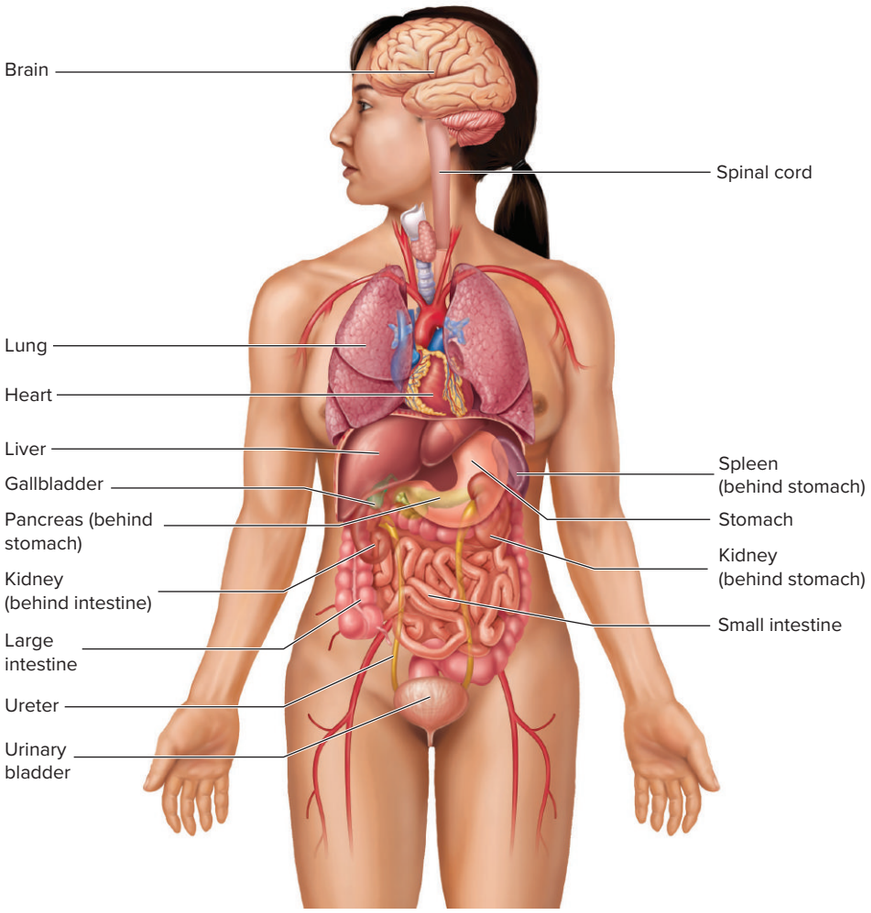


FIGURE 1.2 Major Organs of the Body
The body's major organs include the brain, lungs, heart, liver, pancreas, spleen, stomach, gallbladder, kidneys, large intestine, small intestine, urinary bladder, ureters, and urethra. APR

6. *Organism level.* An **organism** is any living thing considered as a whole—whether composed of one cell, such as a bacterium, or of trillions of cells, such as a human. The human organism is the combination of all the organ systems. These form a network of systems that are all mutually dependent on one another.

Understand

Predict 2

In one type of diabetes, the pancreas fails to produce insulin, a chemical normally made by pancreatic cells and released into the blood. List as many levels of organization as you can at which this disorder could be corrected.

ASSESS YOUR PROGRESS

6. *From simplest to complex, list and define the body's six levels of organization.*
7. *What are the four basic types of tissues?*
8. *Referring to figure 1.3, which two organ systems are responsible for regulating the other organ systems? Which two are responsible for support and movement?*

1.4 Characteristics of Life

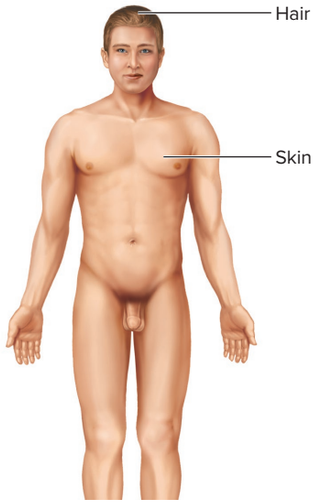
LEARNING OUTCOME

After reading this section, you should be able to

A. **List and define the six characteristics of life.**

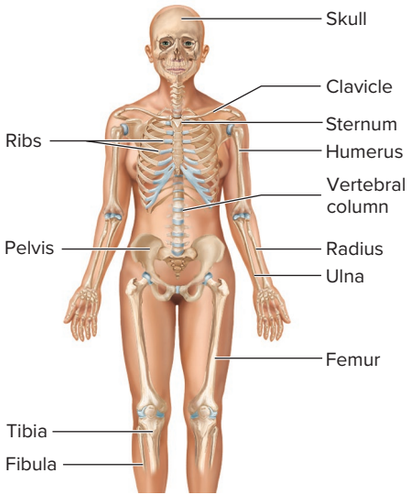
Humans are organisms, sharing characteristics with other organisms. The most important common feature of all organisms is life. This textbook recognizes six essential characteristics of life:

1. **Organization** refers to the specific interrelationships among the parts of an organism and how those parts interact to perform specific functions. As we discussed in section 1.3, there are six levels of organization in the body (see figure 1.1).



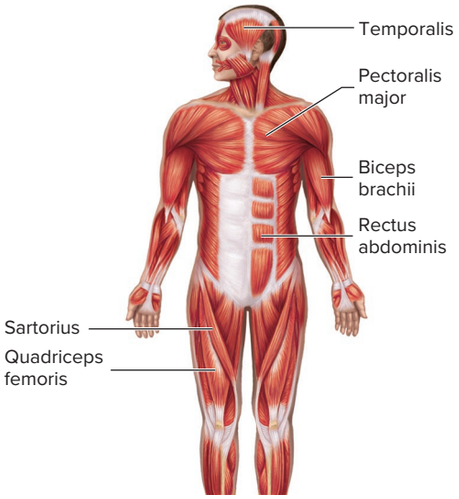
Integumentary System

Provides protection, regulates temperature, prevents water loss, and helps produce vitamin D. Consists of skin, hair, nails, and sweat glands.



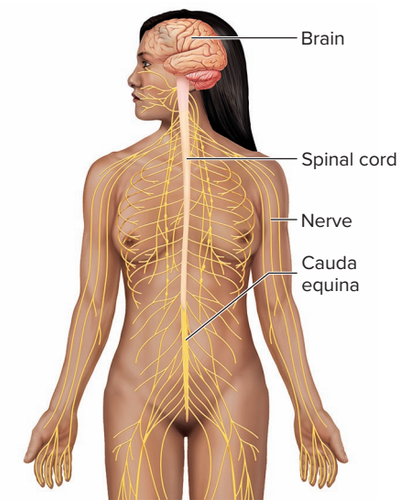
Skeletal System

Provides protection and support, allows body movements, produces blood cells, and stores minerals and adipose. Consists of bones, associated cartilages, ligaments, and joints.



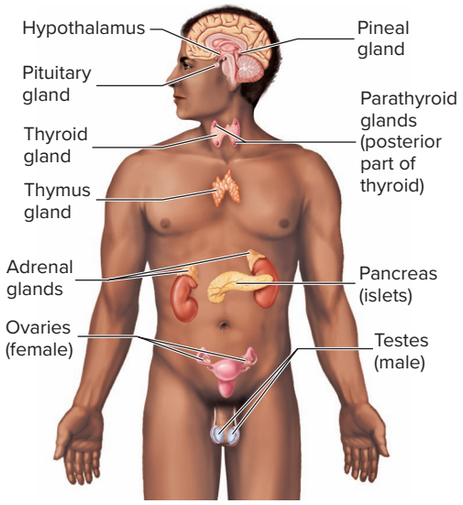
Muscular System

Produces body movements, maintains posture, and produces body heat. Consists of muscles attached to the skeleton by tendons.



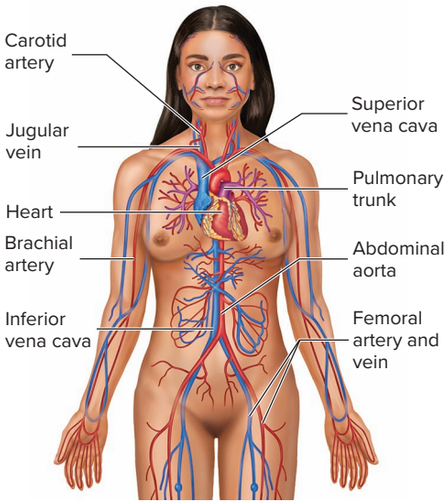
Nervous System

A major regulatory system that detects sensations and controls movements, physiological processes, and intellectual functions. Consists of the brain, spinal cord, nerves, and sensory receptors.



Endocrine System

A major regulatory system that influences metabolism, growth, reproduction, and many other functions. Consists of glands, such as the pituitary, that secrete hormones.



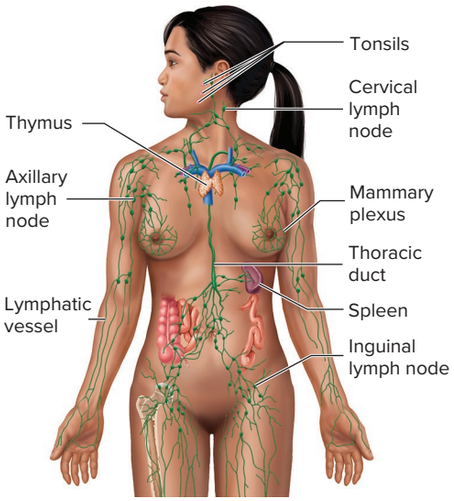
Cardiovascular System

Transports nutrients, waste products, gases, and hormones throughout the body; plays a role in the immune response and the regulation of body temperature. Consists of the heart, blood vessels, and blood.

FIGURE 1.3 Organ Systems of the Body

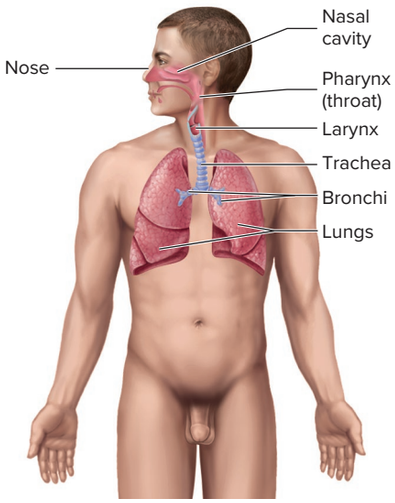
There are 11 body systems: integumentary, skeletal, muscular, lymphatic, respiratory, digestive, nervous, endocrine, cardiovascular, urinary, and reproductive.

2. **Metabolism** (meh-TAB-oh-lizm) is the ability to use energy and to perform other vital functions. Metabolism refers to all of the chemical reactions taking place in the cells and internal environment of an organism. For example, within our digestive system, we possess specialized proteins that break down food molecules (see figure 1.3). The organism then uses the nutrients from the food as a source of energy and raw materials to synthesize new molecules. Energy is also used to rearrange the shape of molecules. The shape of a molecule determines its function (recall the first key



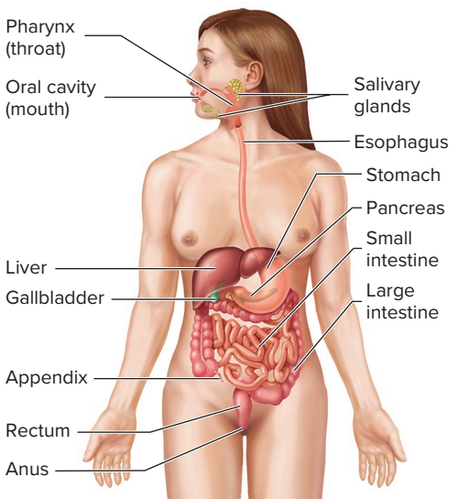
Lymphatic System

Removes foreign substances from the blood and lymph, combats disease, maintains tissue fluid balance, and absorbs dietary fats from the digestive tract. Consists of the lymphatic vessels, lymph nodes, and other lymphatic organs.



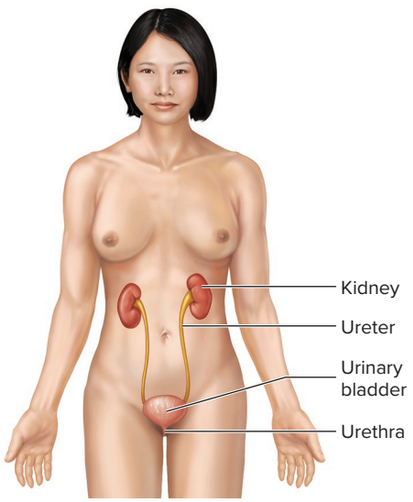
Respiratory System

Exchanges oxygen and carbon dioxide between the blood and air and regulates blood pH. Consists of the lungs and respiratory passages.



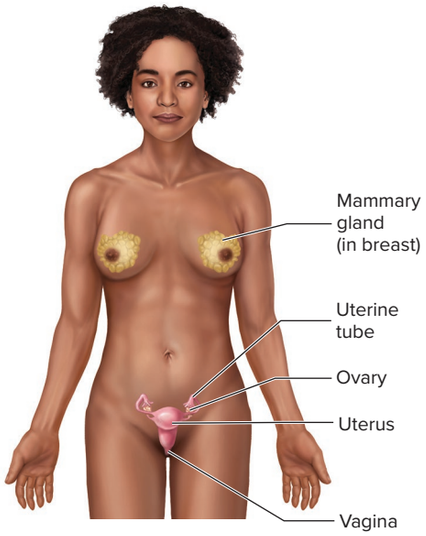
Digestive System

Performs the mechanical and chemical processes of digestion, absorption of nutrients, and elimination of wastes. Consists of the mouth, esophagus, stomach, intestines, and accessory organs.



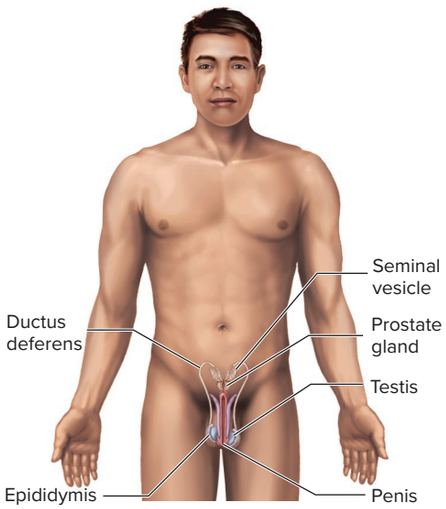
Urinary System

Removes waste products from the blood and regulates blood pH, ion balance, and water balance. Consists of the kidneys, urinary bladder, and ducts that carry urine.



Female Reproductive System

Produces oocytes and is the site of fertilization and fetal development; produces milk for the newborn; produces hormones that influence sexual function and behaviors. Consists of the ovaries, uterine tubes, uterus, vagina, mammary glands, and associated structures.



Male Reproductive System

Produces and transfers sperm cells to the female and produces hormones that influence sexual functions and behaviors. Consists of the testes, accessory structures, ducts, and penis.

FIGURE 1.3 **(continued)**

concept of anatomy and physiology). Some changes in molecular shape can allow certain cells to change shape. For example, specialized white blood cells can surround and engulf potentially dangerous foreign invaders, such as certain bacteria. Metabolism is necessary for other vital functions, such as responsiveness, growth, development, and reproduction.

3. **Responsiveness** is an organism's ability to sense changes in its external or internal environment and adjust to those changes. The third key concept of anatomy and physiology

is very important for responsiveness: cell-to-cell communication. The nervous and endocrine systems regulate responses to changes in the environment through cell-to-cell communication (see figure 1.3). Responses can include actions such as moving toward food or water and moving away from danger or poor environmental conditions. Organisms can also make adjustments that maintain their internal environment. For example, if the external environment causes the body temperature to rise, sweat glands produce sweat, which can lower body temperature down to the normal range.

4. **Growth** refers to an increase in the size or number of cells, which produces an overall enlargement of all or part of an organism. For example, a muscle enlarged by exercise is composed of larger muscle cells than those of an untrained muscle, and the skin of an adult has more cells than the skin of an infant. An increase in the materials surrounding cells can also contribute to growth. For instance, within the skeletal system, we see bones grow because of an increase in cell number and the deposition of mineralized materials around the cells (see figure 1.3).
5. **Development** includes the changes an organism undergoes through time, beginning with fertilization and ending at death. The greatest developmental changes occur before birth, but many changes continue after birth, and some go on throughout life. Development usually involves growth, but it also involves differentiation and morphogenesis. **Differentiation** involves changes in a cell's structure and function from an immature, generalized state to a mature, specialized state. For example, following fertilization, immature cells differentiate to become specific cell types, such as skin, bone, muscle, or nerve cells. These differentiated cells form tissues and organs. **Morphogenesis** (mohr-foh-JEN-eh-sis) is the change in shape of tissues, organs, and the entire organism.
6. **Reproduction** is the formation of new cells or new organisms. Reproduction of cells allows for growth and development. Reproduction allows all living organisms to pass on their genes to their offspring (see figure 1.3).

ASSESS YOUR PROGRESS

9. *What are the six characteristics of living things? Briefly explain each.*

10. *How does differentiation differ from morphogenesis?*

1.5 Homeostasis

LEARNING OUTCOMES

After reading this section, you should be able to

A. **Define *homeostasis.***
B. **Explain why homeostasis is important for proper body function.**
C. **Describe a negative-feedback mechanism and give an example.**
D. **Describe a positive-feedback mechanism and give an example.**

Homeostasis (hoh-mee-oh-STAY-sis) is the existence and maintenance of a relatively constant environment within the body. As our bodies undergo their everyday processes, we are continuously exposed to new conditions. Changes in our external environmental conditions can result in changes in our internal body conditions. Changes in internal body conditions are called **variables** because their values are not constant. To achieve and maintain homeostasis, the body must actively regulate responses to changes in variables. Variables include such conditions as body temperature, volume, chemical content and pH of body fluids, as well as many other variables. For our cells to function normally, all variables must be maintained within a narrow range.

This narrow range is referred to as a **normal range.** Homeostatic mechanisms normally maintain body conditions near an ideal normal value or **set point** (figure 1.4). Note that these mechanisms are not able to maintain body conditions *precisely* at the set point. Rather, body conditions increase and decrease slightly around the set point. Keep in mind that these fluctuations are minimal. For example, normal body temperature does not typically vary more than 1°F above or below normal. Our *average* body temperature is 98.6°F. Just as your home's thermostat does not keep the air temperature exactly at 75°F at all times, your body

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.

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)?

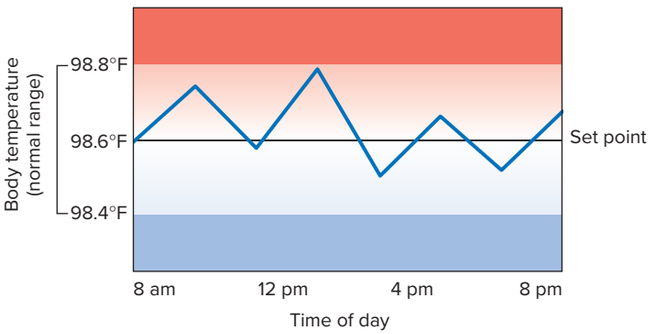


FIGURE 1.4 Fluctuation Around a Set Point
Body temperature is an example of a variable maintained near an ideal value, or set point.

conditions do not stay perfectly stable. As long as body conditions remain within the normal range, homeostasis is maintained.

It is the body's network of organ systems that helps keep the body's internal environment relatively constant. For example, the digestive, respiratory, cardiovascular, and urinary systems work together to ensure that each cell in the body receives adequate oxygen and nutrients, while also ensuring that waste products do not accumulate to toxic levels. Disease states can disrupt these processes and disturb homeostasis in such a way that death could result. Modern medicine attempts to understand disturbances in homeostasis and works to reestablish a normal range of values.

Feedback Loops

Homeostasis is regulated by **feedback loops.** Here we will examine our fourth key concept of anatomy and physiology: feedback loops. A feedback loop allows for a process to be regulated by the outcome. In biological systems, there are two types of feedback loops: (1) negative feedback and (2) positive feedback. Note that a common misconception is that negative feedback is the decrease of a body parameter, while positive feedback is the increase of a body parameter. For example, students sometimes think a drop in blood glucose levels is negative feedback and an increase in blood glucose is positive feedback. Rather, blood glucose increases and decreases are both controlled by negative feedback. As you read about each type of feedback loop, keep in mind that both types of feedback loops regulate the body's *responses* to either increased or decreased parameters.

Feedback loops have three components: (1) a **receptor,** which monitors the value of a variable by detecting stimuli; (2) a **control center,** such as a part of the brain, which determines the set point for the variable and receives input from the receptor about the variable; and (3) an **effector,** which generates the **response** that adjusts the value of a changed variable. A changed variable is a **stimulus** because it initiates a homeostatic mechanism.

Negative Feedback

Negative-feedback mechanisms are more commonly involved in maintenance of homeostasis than are positive-feedback mechanisms. In everyday terms, the word *negative* is used to mean "bad" or "undesirable." In the context of homeostasis mechanisms, negative means "to decrease." *Negative feedback* is when any deviation from the set point is made smaller or is resisted. In other words, the response by the effector is stopped once the variable returns to its set point (figure 1.5).

One of the most familiar examples of a negative-feedback mechanism is maintenance of body temperature. Normal body temperature is critical to our health because it allows molecules and enzymes to keep their normal shape so they can function optimally. An optimal body temperature prevents molecules from being destroyed. For example, picture the change in appearance of egg whites as they are cooked; the egg whites change from a transparent fluid to a white solid because heat changes the shape of the egg white molecules. Similarly, if the body were to be exposed to extreme heat, the shape of the molecules in the body could change, thus preventing them from functioning normally. Figure 1.6*a* demonstrates the steps in the negative-feedback mechanism regulating body temperature if it becomes too high. Normal body temperature depends on the

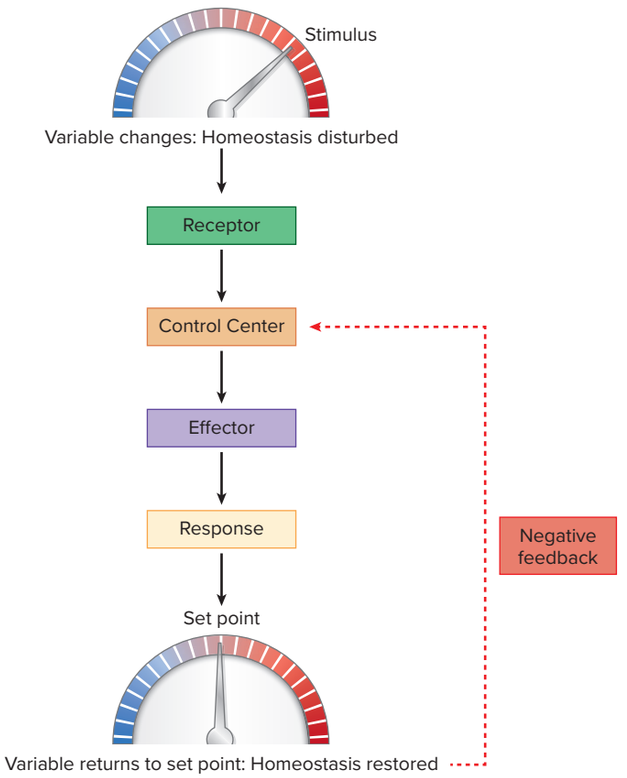
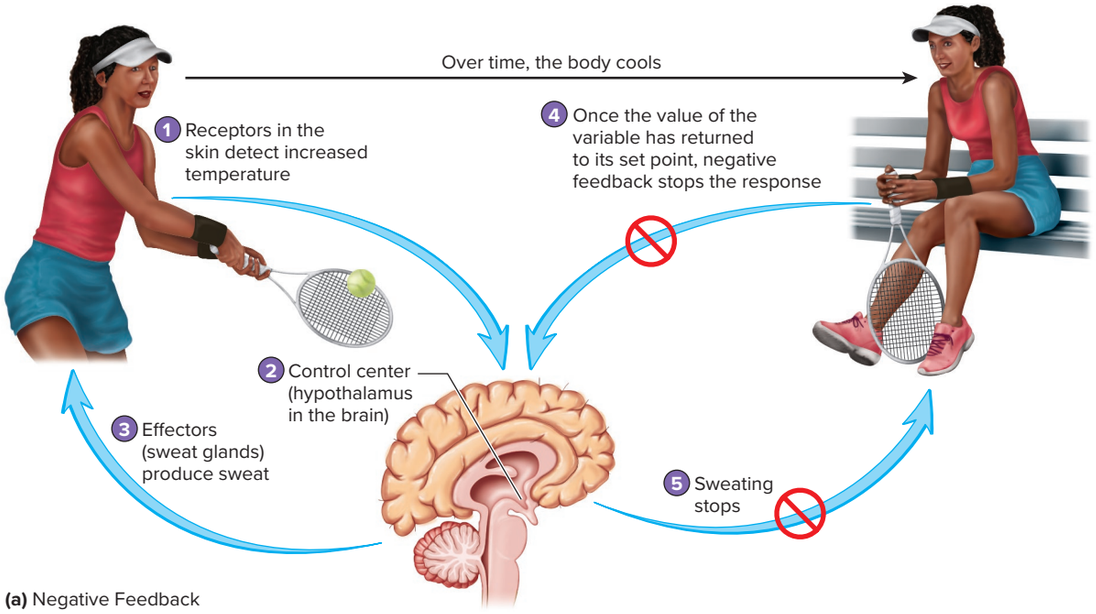


FIGURE 1.5 Feedback Loop
Feedback loops maintain homeostasis. Receptors signal the control center that a variable has deviated outside its normal range. The control center regulates the action of the effectors, which produce a response that returns the variable to the set point. In negative feedback, the return to set point stops the response.

FUNDAMENTAL **Figure**



(a) Negative Feedback

PROCESS **Figure 1.6**

Negative- and Positive Feedback Mechanism: Body Temperature

(*a*) Negative feedback is one of the mechanisms by which homeostasis is maintained. Receptors signal the control center, which regulates the action of the effectors. In the example, body temperature is too high, so sweating occurs. Negative feedback stops the sweating when the body temperature returns to normal. (*b*) Positive feedback is also a type of mechanism that works to maintain homeostasis. In this example, receptors signal the control center that the cervix is being stretched, which results in the control center sending signals to increase the contractions of the uterus. This cycle continues, becoming stronger over time until the baby is born.

Apply *Occasionally an individual will not be able to produce sweat and can overheat, potentially suffering a heat stroke. Within the context of the body temperature homeostatic mechanism, where might the disruption occur? Propose at least three ways sweat production might be inhibited when the body temperature rises above the set point.*

coordination of multiple structures, which are regulated by the control center (the hypothalamus in the brain).

1. Receptors in the skin (called thermoreceptors) monitor body temperature. If body temperature rises, the receptors send a message to the control center, the hypothalamus.
2. The control center compares the value of the variables against the set point.
3. If a response is necessary, the control center will stimulate the effectors to produce their response. Here, the sweat glands will secrete sweat.
4. Once the value of the variable has returned to the set point, the effectors do not receive any more information from the control center. For regulation of body temperature, this means that the secretion of sweat stops. These same steps can be used to help you answer the Learn to Predict question at the beginning of this chapter.

Often there is more than one effector for a particular homeostatic mechanism. In these cases, the control center must coordinate the effectors' responses. For example, cooling the body involves not only the production of sweat by the sweat glands, but also the action of the blood vessels to alter blood flow to the skin (see chapter 5). Once body temperature has returned to normal, the effectors stop. This is the hallmark of negative feedback—effectors stop their response once the variable has returned to it set point. They do not produce an infinite response (figure 1.7).

Understand

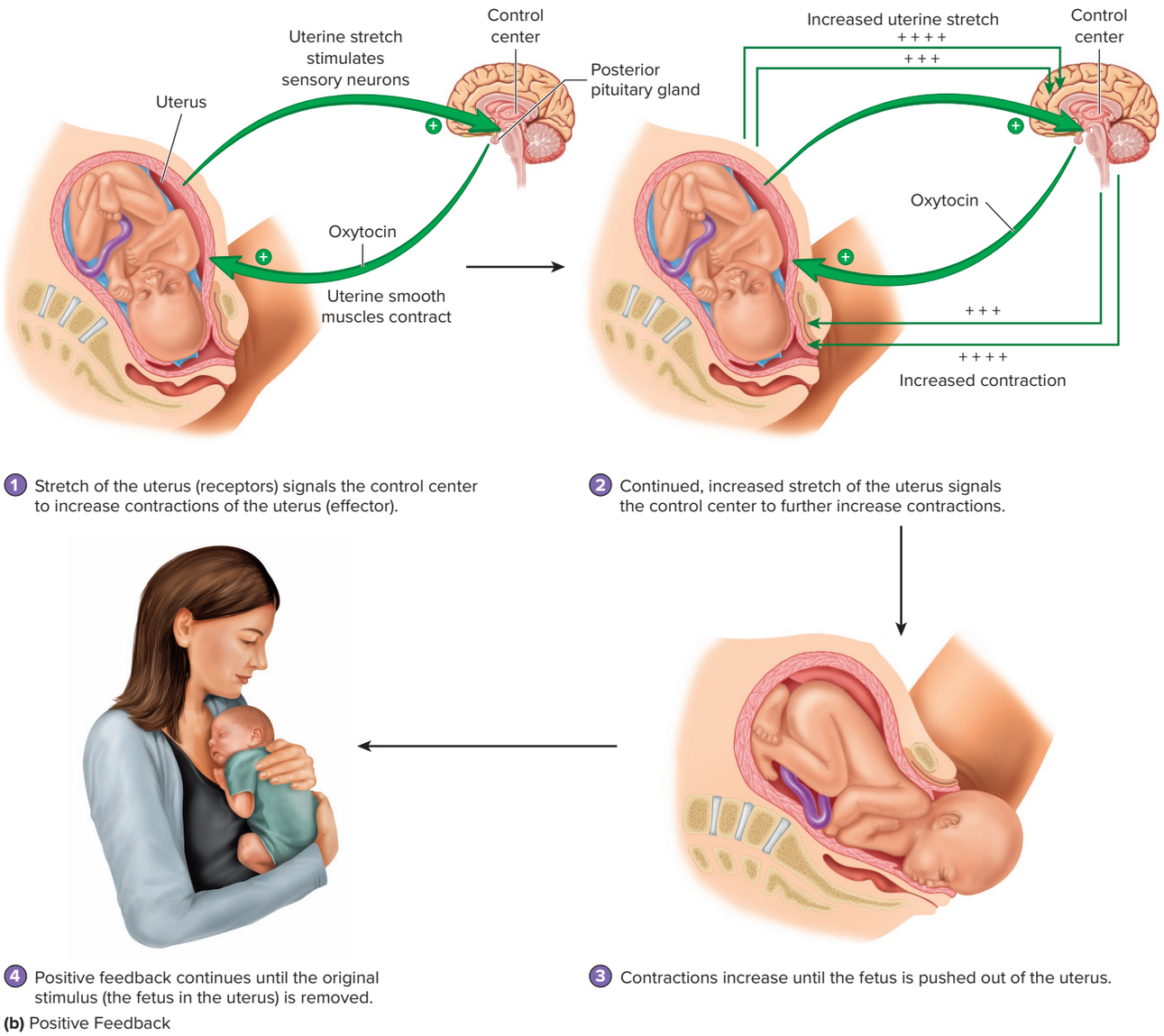
Predict 4

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?

Positive Feedback

Positive-feedback mechanisms occur when a response to the original stimulus results in the deviation from the set point becoming even greater. In other words, *positive* means "to increase." You may have experienced this: Perhaps you became embarrassed and realized your face was turning red, which caused you to become more embarrassed and your face turned even more red. Though not the typical physiological type of positive feedback, this example may help you understand the concept of positive feedback.

FUNDAMENTAL **Figure**



1 Stretch of the uterus (receptors) signals the control center to increase contractions of the uterus (effector).

2 Continued, increased stretch of the uterus signals the control center to further increase contractions.

3 Contractions increase until the fetus is pushed out of the uterus.

4 Positive feedback continues until the original stimulus (the fetus in the uterus) is removed.

(b) Positive Feedback

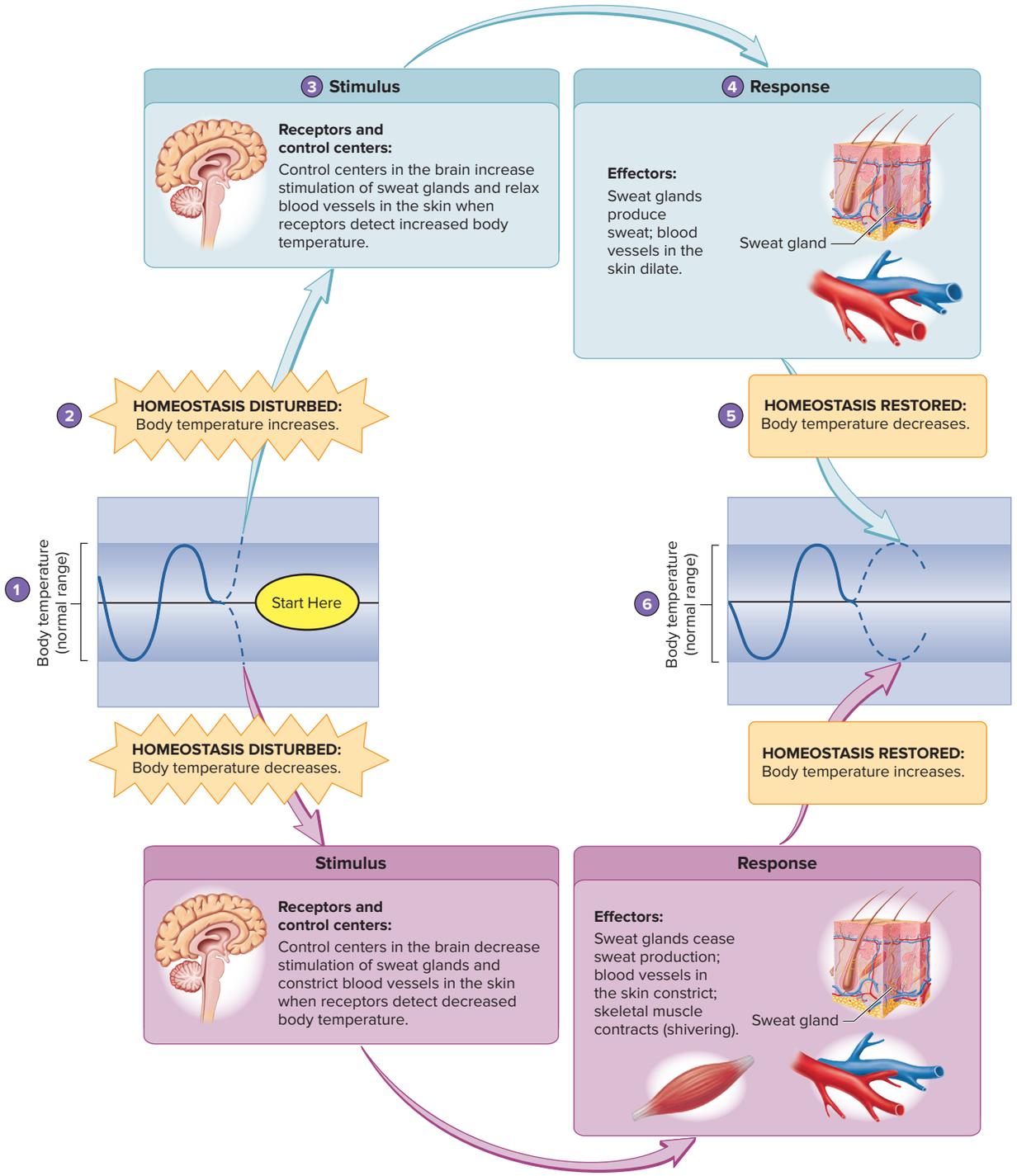
PROCESS **Figure 1.6** **(Continued)**

A physiological example of positive feedback occurs during blood loss. A chemical responsible for blood clot formation, called thrombin, stimulates production of even more thrombin. By continuing to produce thrombin, a disruption in homeostasis (blood loss) is resolved through a positive-feedback mechanism (blood clotting). But why doesn't this continued production of thrombin lead to the entire vascular system forming a clot? Because the clot formation process is self-limiting. Eventually, the chemicals needed for clot formation will be depleted in the area of blood loss and no further clotting can occur.

As shown in figure 1.6*b*, birth is another example of a normally occurring positive-feedback mechanism.

1. Near the end of pregnancy, the baby's larger size stretches the uterus, especially near its opening.
2. This stretching stimulates contractions of the uterine muscles.
3. The contractions push the baby against the opening and stretch it further. This stimulates additional contractions, which result in additional stretching.
4. This positive-feedback sequence ends only when the baby is delivered from the uterus and the stretching stimulus is eliminated.

This continued response is the hallmark of positive feedback—the effectors continue the response beyond the set point until the original stimulus is removed.



HOMEOSTASIS FIGURE 1.7 Negative-Feedback Control of Body Temperature

Throughout this book, all homeostasis figures have the same format as shown here. The changes caused by the increase of a variable outside the normal range are shown in the *top blue boxes,* and the changes caused by a decrease are shown in the *bottom pink boxes*. To help you learn how to interpret homeostasis figures, some of the steps in this figure are numbered. (1) Body temperature is within its normal range. (2) Body temperature increases outside the normal range, which causes homeostasis to be disturbed. (3) The body temperature control center in the brain responds to the change in body temperature. (4) The control center causes sweat glands to produce sweat and blood vessels in the skin to dilate. (5) These changes cause body temperature to decrease. (6) Body temperature returns to its normal range, and homeostasis is restored. Observe the responses to a decrease in body temperature outside its normal range by following the *bottom pink arrows*.

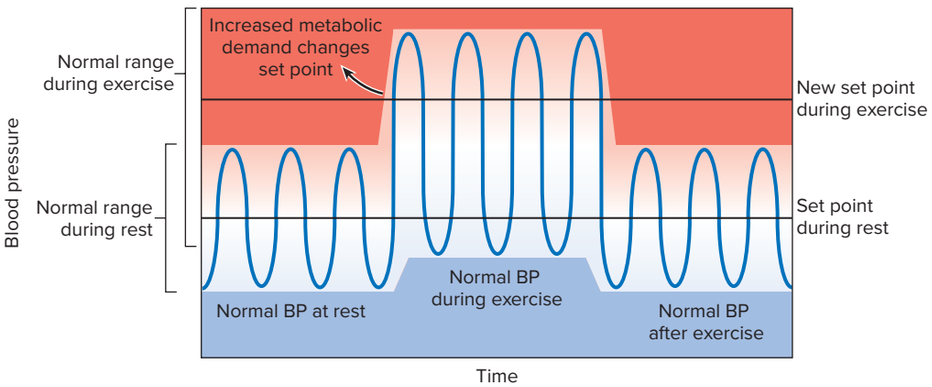


FIGURE 1.8 Changes in Blood Pressure During Exercise
During exercise, muscle tissue demands more oxygen. To meet this demand, blood pressure (BP) increases, resulting in an increase in blood flow to the tissues. The increased blood pressure is not an abnormal or nonhomeostatic condition but a resetting of the normal homeostatic range to meet the increased demand. The reset range is higher and broader than the resting range. After exercise ceases, the range returns to that of the resting condition.

There are two basic principles about homeostatic mechanisms to remember: (1) many disease states result from the failure of negative-feedback mechanisms to maintain homeostasis and (2) some positive-feedback mechanisms can be detrimental instead of helpful. One example of a detrimental positive-feedback mechanism is inadequate delivery of blood to cardiac (heart) muscle. Contraction of cardiac muscle generates blood pressure and the heart pumps blood to itself through a system of blood vessels on the outside of the heart. Just as with other tissues, blood pressure must be maintained to ensure adequate delivery of blood to the cardiac muscle. Following extreme blood loss, blood pressure decreases to the point that the delivery of blood to cardiac muscle is inadequate. As a result, cardiac muscle does not function normally. The heart pumps less blood, which causes the blood pressure to drop even further—a deviation further from the set point. The additional decrease in blood pressure further reduces blood delivery to cardiac muscle, and the heart pumps even less blood, which again decreases the blood pressure. The process self-propagates until the blood pressure is too low to sustain the cardiac muscle, the heart stops beating, and death results. In this example, we see the deviation from the heart rate set point becoming larger and larger—this is a positive-feedback mechanism. Thus, if blood loss is severe, negative-feedback mechanisms may not be able to maintain homeostasis, and the postive feedback of ever-decreasing blood pressure can develop. On the other hand, following a moderate amount of blood loss (e.g., after donating a pint of blood), *negative-feedback mechanisms* result in an *increase* in heart rate, which restores blood pressure.

Although homeostasis is the maintenance of a normal range of values, this does not mean that all variables remain within the same narrow range of values at all times. Sometimes a deviation from the usual range of values can be beneficial. For example, during exercise the normal range for blood pressure increases above the resting range (figure 1.8). The increase in blood pressure helps supply muscle cells with the greater amount of oxygen and nutrients needed to support increased activity during exercise.

Predict 5

Ashley is on the track team and is running an 800-meter race. Throughout the race, her respiratory rate increases rapidly. Does this represent negative or positive feedback? Explain.

ASSESS YOUR PROGRESS

11. *How do variables, set points, and normal ranges relate to homeostasis?*
12. *Distinguish between negative feedback and positive feedback.*
13. *What are the three components of a negative-feedback mechanism?*
14. *Give an example of how a negative-feedback mechanism maintains homeostasis.*
15. *Give an example of a positive-feedback mechanism that may be harmful to the body and an example of one that is not harmful.*

1.6 Terminology and the Body Plan

LEARNING OUTCOMES

After reading this section, you should be able to

A. **Describe a person in the anatomical position.**
B. **Define the directional terms for the human body and use them to locate specific body structures.**
C. **Know the terms for the parts and regions of the body.**
D. **Name and describe the three major planes of the body.**
E. **Name and describe the three major ways to cut an organ.**
F. **Describe the major trunk cavities and their divisions.**
G. **Locate organs in their specific cavity, abdominal quadrant, or region.**
H. **Describe the serous membranes, their locations, and their functions.**

As you study anatomy and physiology, you will be learning many new words. Knowing the derivation, or **etymology** (ET-ee-MOL-oh-jee), of these words can make learning them easy and fun. Most anatomical terms are derived from Latin or Greek. For example, *foramen* is a Latin word for "hole," and *magnum* means "large." The foramen magnum is therefore a large hole in the skull through which the spinal cord attaches to the brain.

Prefixes and suffixes can be added to words to expand their meaning. For example, the suffix *-itis* means an inflammation, so

FUNDAMENTAL **Figure**

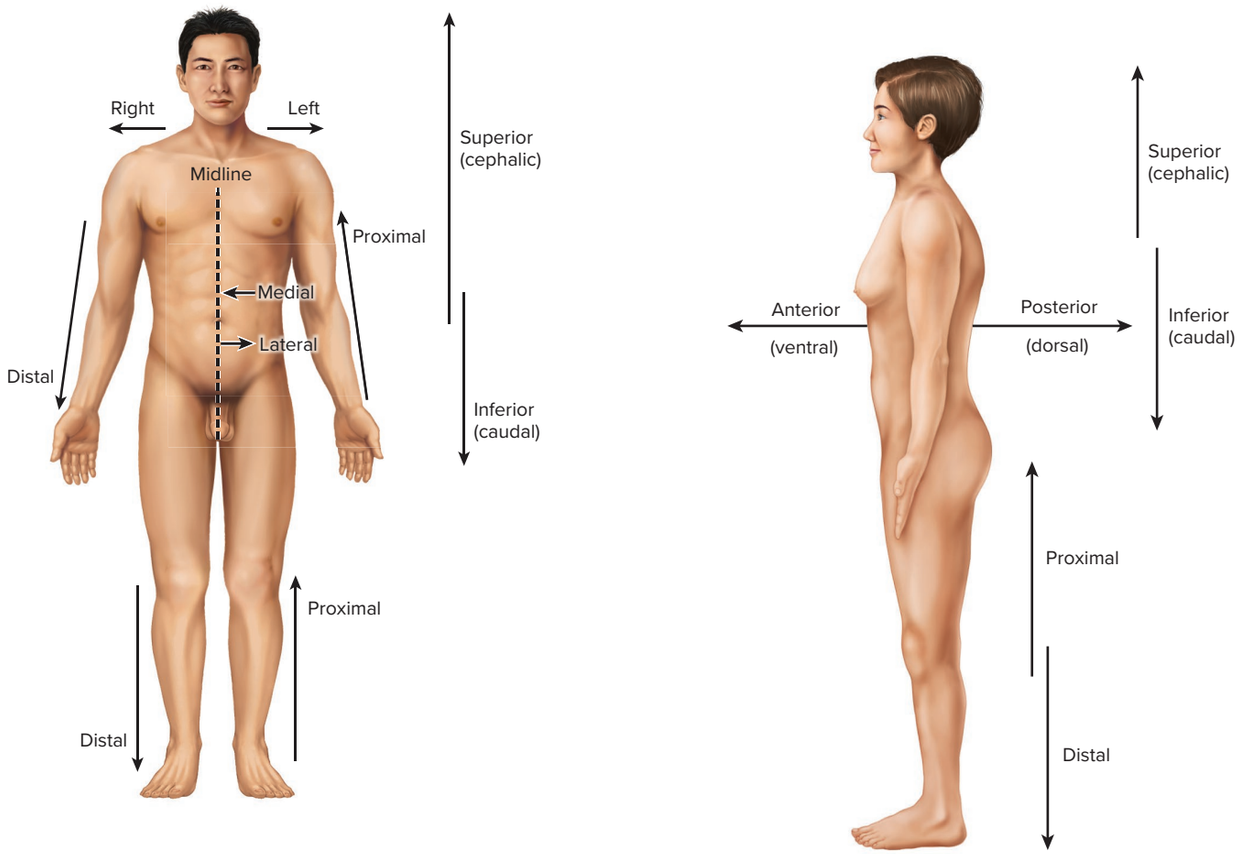


FIGURE 1.9 Directional Terms
All directional terms are in relation to the body in the anatomical position: a person standing erect with the face directed forward, the arms hanging to the sides, and the palms of the hands facing forward. APR

appendicitis is an inflammation of the appendix. As new terms are introduced in this text, their meanings are often explained. The glossary and the list of word roots, prefixes, and suffixes in appendix B of this textbook provide additional information about the new terms.

It is very helpful to learn these new words, so that your message is clear and correct when you speak to colleagues or write reports. Additionally, you will find many of the roots of words appearing over and over again. For example, in chapter 7, you will learn a specific region of the scapula called the *infraspinous fossa.* Later, in chapter 10, you learn that the muscle in that region is named the *infraspinatus.*

Body Positions

Anatomical position refers to a person standing erect with the face directed forward, the upper limbs hanging to the sides, and the palms of the hands facing forward (figure 1.9). A person is **supine** when lying face upward and **prone** when lying face downward.

In anatomical position, the head is above the feet, but if a person were to do a handstand, the head would be closer to the ground than the feet. However, we would still refer to the position of the head as being above the feet because the point of reference for anatomical structures is the body, not the position of the body structure compared to the earth.

Directional Terms

Directional terms describe parts of the body relative to each other. Important directional terms are illustrated in figure 1.9 and summarized in table 1.2. It is important to become familiar with these directional terms as soon as possible because you will see them repeatedly throughout this textbook. **Right** and **left** are used as directional terms in anatomical terminology. **Superior** means above, and **inferior** means below; **anterior** is used for "in front of," and **posterior** is used for "behind."

For human anatomy, the term *superior* is used interchangeably with the term *cephalic* (SE-FAL-ik; head), and the term *inferior* is used interchangeably with *caudal* (KAW-dal; tail). In

TABLE **1.2** **Directional Terms for Humans**

Term	Etymology*	Definition	Example
Right		Toward the right side of the body	Right ear
Left		Toward the left side of the body	Left eye
Superior	L. higher	A structure above another	The chin is superior to the navel.
Inferior	L. lower	A structure below another	The navel is inferior to the chin.
Cephalic	G. *kephale,* head	Closer to the head than another structure (usually synonymous with *superior*)	The chin is cephalic to the navel.
Caudal	L. *cauda,* a tail	Closer to the tail than another structure (usually synonymous with *inferior*)	The navel is caudal to the chin.
Anterior	L. before	The front of the body	The navel is anterior to the spine.
Posterior	L. *posterus,* following	The back of the body	The spine is posterior to the breastbone.
Ventral	L. *ventr-,* belly	Toward the belly (synonymous with *anterior*)	The navel is ventral to the spine.
Dorsal	L. *dorsum,* back	Toward the back (synonymous with *posterior*)	The spine is dorsal to the breastbone.
Proximal	L. *proximus,* nearest	Closer to the point of attachment to the body than another structure	The elbow is proximal to the wrist.
Distal	L. *di-* plus *sto,* to stand apart or be distant	Farther from the point of attachment to the body than another structure	The wrist is distal to the elbow.
Lateral	L. *latus,* side	Away from the midline of the body	The nipple is lateral to the breastbone.
Medial	L. *medialis,* middle	Toward the midline of the body	The nose is medial to the eye.
Superficial	L. *superficialis,* toward the surface	Toward or on the surface (not shown in figure 1.10)	The skin is superficial to muscle.
Deep	O.E. *deop,* deep	Away from the surface, internal (not shown in figure 1.10)	The lungs are deep to the ribs.

*Origin and meaning of the word: L., Latin; G., Greek; O.E., Old English.

animals that do not walk upright, such as a cat, the terms *cephalic* and *caudal* can be used to describe the relative position of anatomical structures on the trunk, but not on the limbs. In addition, *anterior* is synonymous with *ventral* (belly) and *posterior* is synonymous with *dorsal* (back).

Predict 6

The anatomical position of a cat *refers to the animal standing erect on all four limbs and facing forward. On the basis of the etymology of the directional terms, which two terms indicate movement toward the cat's head? What two terms mean movement toward the cat's back? Compare these terms with those referring to a human in the anatomical position.*

Proximal means "close to," whereas **distal** means "far from." These terms are used to refer to relative positions of structures, such as on the limbs. Each limb is attached at its proximal end to the body, and the distal end, such as the hand, is farther away. Proximal and distal can also describe a structure's position relative to another, such as the kidney structures the proximal and distal convoluted tubules. Their position is described relative to another kidney structure used for filtration.

Medial means "toward the midline," and **lateral** means "away from the midline." The nose is in a medial position in the face, and the eyes are lateral to the nose. **Superficial** describes a structure close to the surface of the body, and **deep** is toward the interior of the body. The skin is superficial to muscle and bone.

Predict 7

Use as many directional terms as you can to describe the relationship between your kneecap and your heel.

ASSESS YOUR PROGRESS

16. *What is anatomical position in humans? Why is it important?*
17. *What two directional terms indicate "toward the head" in humans? What are the opposite terms?*
18. *What two directional terms indicate "the back" in humans? What are the opposite terms?*
19. *Define the following directional terms and give the term that means the opposite:* proximal, lateral, *and* superficial.

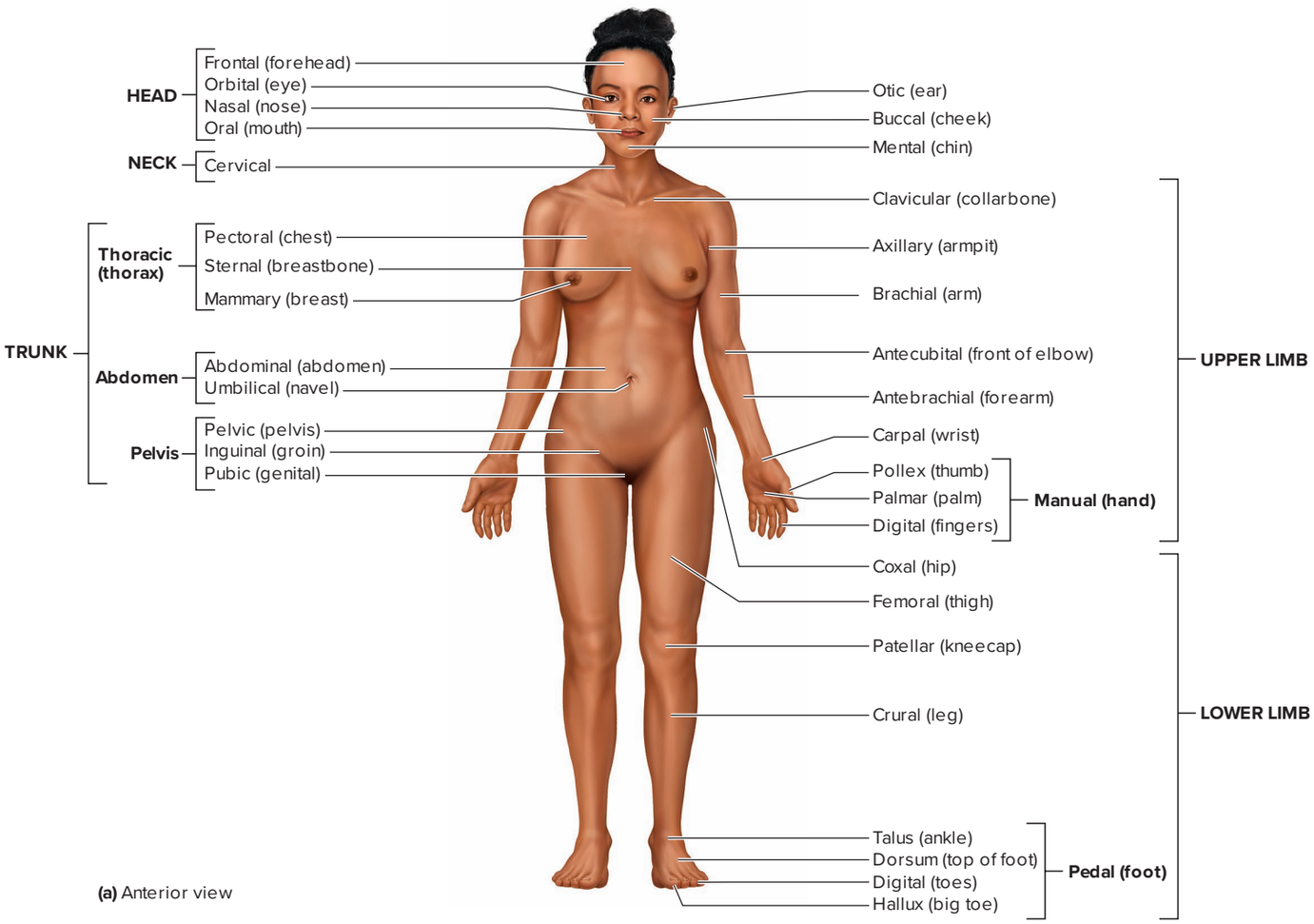


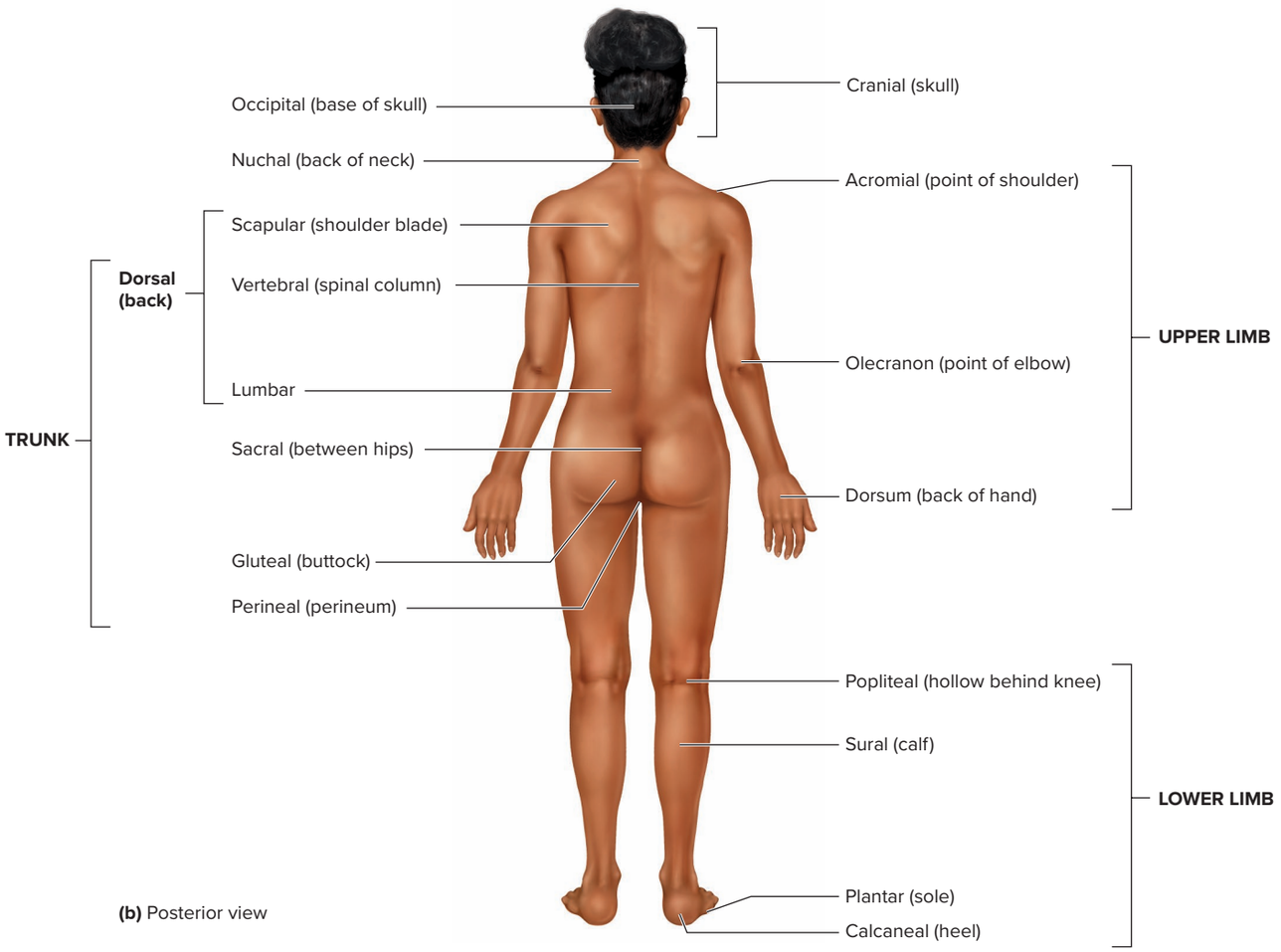
FIGURE 1.10 Body Parts and Regions
The anatomical and common (*in parentheses*) names are indicated for the major parts and regions of the body. (*a*) Anterior and (*b*) posterior views. APR

Body Parts and Regions

Health professionals use a number of terms when referring to different parts or regions of the body. Figure 1.10 (*a*, anterior; *b*, posterior) shows the anatomical terms, with the common terms in parentheses.

The central region of the body consists of the **head, neck,** and **trunk.** The trunk can be further divided into three regions: (1) the **thorax,** (2) the **abdomen,** and (3) the **pelvis.** The thorax is the chest cavity where the heart and lungs are located. The abdomen contains organs such as (1) the liver, (2) the stomach, and (3) the intestines. The pelvis contains the bladder and reproductive organs. The upper limb is divided into (1) the arm, (2) the forearm, (3) the wrist, and (4) the hand. The **arm** extends from the shoulder to the elbow, and the **forearm** extends from the elbow to the wrist. The lower limb is divided into (1) the thigh, (2) the leg, (3) the ankle, and (4) the foot. The **thigh** extends from the hip to the knee, and the **leg** extends from the knee to the ankle. Note that, contrary to popular usage, the terms *arm* and *leg* refer to only a part of the limb.

The abdomen is often subdivided superficially into **quadrants** by two imaginary lines—one horizontal and one vertical—that intersect at the navel (figure 1.11*a*). The quadrants formed are (1) the right-upper, (2) the left-upper, (3) the right-lower, and (4) the left-lower quadrants. In addition to these quadrants, the abdomen is sometimes subdivided into **regions** by four imaginary lines: two horizontal and two vertical. These four lines create a "virtual" tic-tac-toe grid on the abdomen, resulting in nine regions: (1) epigastric, (2) right and left hypochondriac, (3) umbilical, (4) right and left lumbar, (5) hypogastric, and (6) right and left iliac (figure 1.11*b*). Health professionals use the quadrants and regions as reference points for locating underlying organs. For example, the appendix is in the right-lower quadrant, and the pain of an acute appendicitis is usually felt there. Practice using these body part and region terms with the directional terms in figure 1.9. For example, "Your lungs (in the thorax) are _____ compared to your stomach (in the abdomen). The calcaneal region of the lower limb is _____ to the popliteal region of the lower limb.



(b) Posterior view

FIGURE 1.10 (continued)

Planes

At times, it is useful to describe the body as having imaginary flat surfaces, called **planes,** passing through it (figure 1.12). A plane divides, or sections, the body, making it possible to "look inside" and observe the body's structures.

1. A **sagittal** (SAJ-ih-tal) **plane** separates the body or a structure into right and left halves. The word *sagittal* means "the flight of an arrow" and refers to the way the body would be split by an arrow passing anteriorly to posteriorly.
2. A **median plane** is a sagittal plane that passes through the midline of the body, dividing it into equal right and left halves.
3. A **transverse** (**horizontal**) **plane** runs parallel to the ground, dividing the body into superior and inferior portions.
4. A **frontal** (**coronal**) (KOHR-oh-nal, koh-ROH-nal; crown) **plane** divides the body into front (anterior) and back (posterior) halves. For example, the coronal suture on the skull is located across the top, where a person might wear a crown.

Organs are often sectioned to reveal their internal structure (figure 1.13). A cut through the length of the organ is a **longitudinal section,** and a cut at a right angle to the length of an organ is a **transverse** (**cross**) **section.** If a cut is made across the the length of an organ at other than a right angle, it is called an **oblique section.**

ASSESS YOUR PROGRESS

20. *What makes up the central region of the body?*

21. *What is the difference between the arm and the upper limb? Between the leg and the lower limb?*

22. *What are the anatomical terms for the following common body terms—neck, mouth, hand, front of elbow, calf, sole?*

23. *In what quadrant would the majority of the stomach be located? In which region(s)?*

24. *List and describe the three planes of the body.*

25. *In what three ways can you cut an organ?*

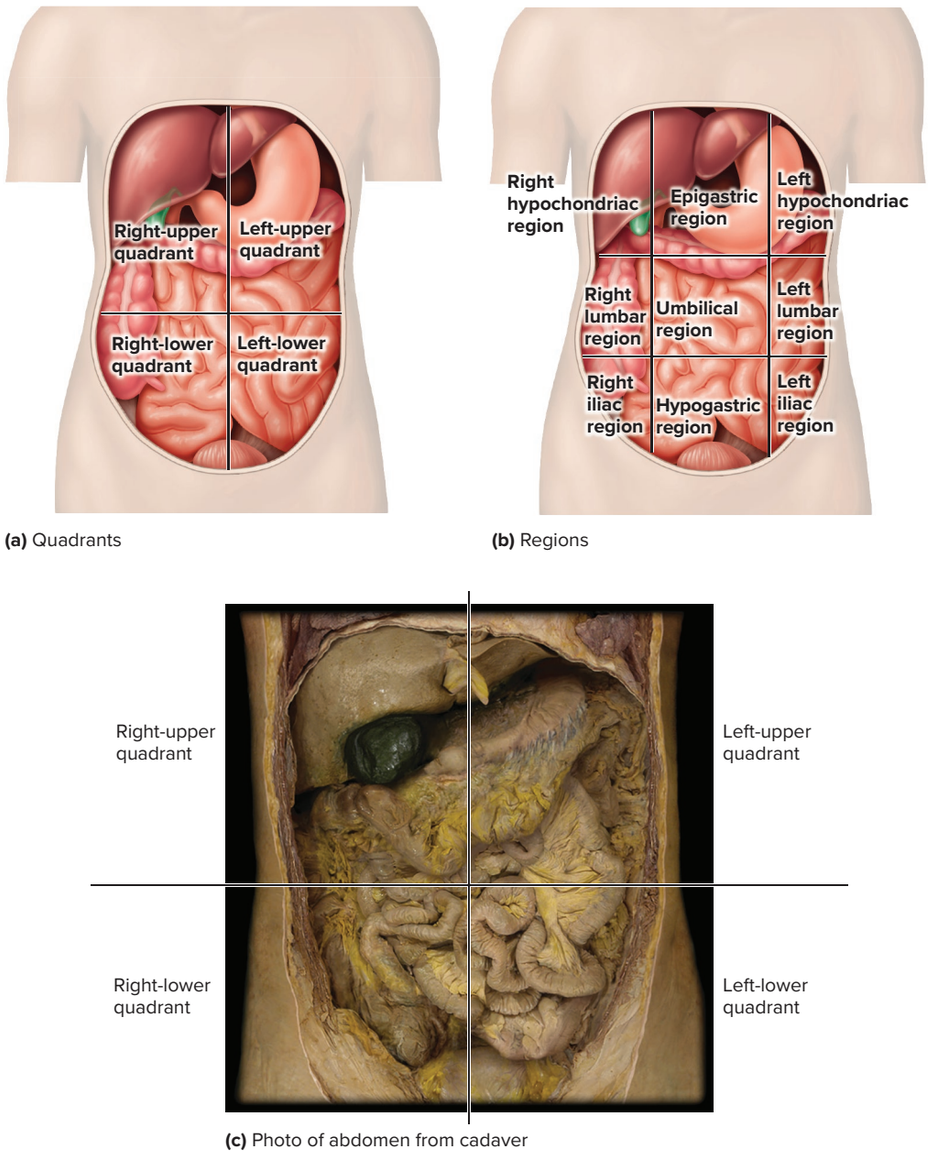


FIGURE 1.11 Subdivisions of the Abdomen

Lines are superimposed over internal organs to demonstrate the subdivisions they lie in. (*a*) Abdominal quadrants. (*b*) There are nine abdominal regions. (*c*) Cadaver photo of abdominal cavity. (c) McGraw Hill APR

Body Cavities

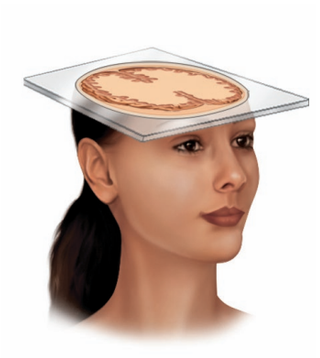
The body contains two types of internal cavities: (1) the dorsal body cavity and (2) the ventral body cavity (figure 1.14). These cavities, which are closed to the outside, contain our internal organs, providing protection for them. Some anatomy textbooks do not use the dorsal body cavity designation; however, in this textbook we have chosen to use the two internal body cavities model.

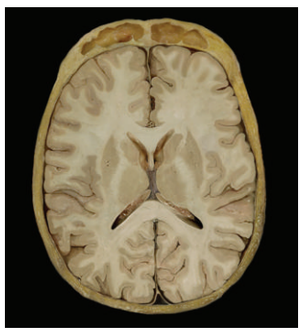
Dorsal Body Cavity

The dorsal body encloses the organs of the nervous system, the brain and spinal cord. The two subdivisions of the dorsal body cavity are (1) the cranial cavity, which houses the brain, and (2) the vertebral canal, which houses the spinal cord. Both the brain and spinal cord are covered by membranes called meninges (figure 1.14*a*). We discuss the anatomy of the nervous system further in chapters 12 and 13.

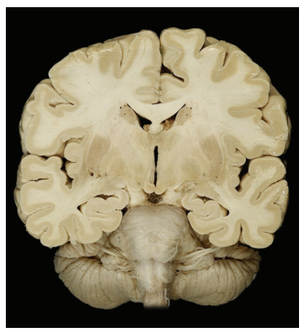
Ventral Body Cavity

The ventral body cavity houses the vast majority of our internal organs, collectively referred to as the **viscera** (VIS-er-ah; internal organs) (figure 1.14*b*). The ventral body cavity also has two major subdivisions, which are (1) the thoracic cavity and (2) the abdominopelvic cavity.

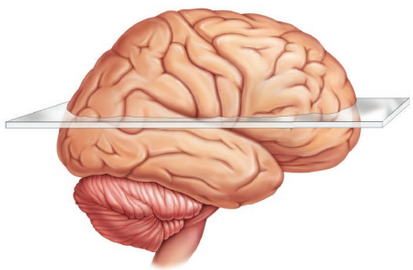




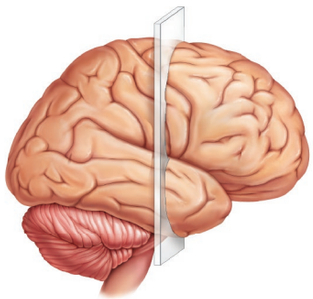
Transverse Section (from the top)



Coronal Section (from the front)

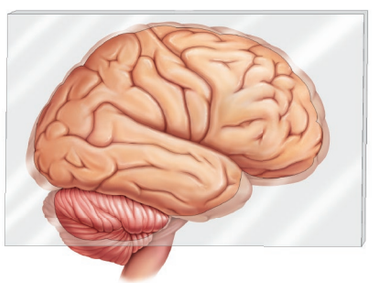


(a) Transverse Section



(b) Coronal Section

Sagittal Section (right and left halves)



(c) Sagittal Section

FIGURE 1.12 Planes Through the Body

Planes through the head are indicated by "glass" sheets. (*a*) Transverse sections are made to separate a structure into superior and inferior portions. (*b*) Coronal sections are made to separate a structure into anterior and posterior portions. (*c*) Sagittal sections are made to separate a structure into right and left halves. (a, b, c) McGraw Hill APR

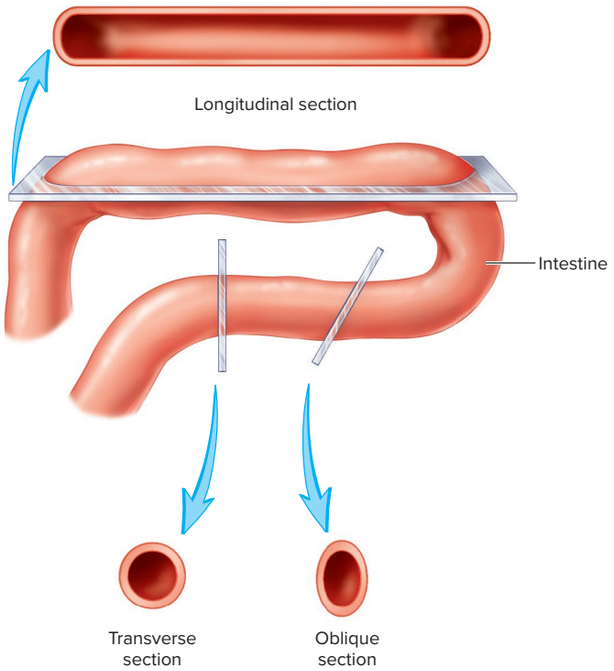


FIGURE 1.13 Planes Through an Organ
Planes through the small intestine are indicated by "glass" sheets. The views of the small intestine after sectioning are also shown. Although the small intestine is basically a tube, the sections appear quite different in shape.

The Thoracic Cavity

The **thoracic cavity** is more superior to the abdominopelvic cavity and houses primarily the heart and lungs, among other organs. This cavity is further subdivided into sections: (1) two lateral **pleural cavities,** each of which encloses a lung and is surrounded by the ribs, and (2) a medial **mediastinum** (MEE-dee-ah-STIE-num; middle wall), which houses the heart and its major blood vessels, in addition to the thymus, the trachea, and the esophagus.

The Abdominopelvic Cavity

The **abdominopelvic cavity** is enclosed by abdominal muscles and consists of (1) the more superior **abdominal cavity** and (2) the more inferior **pelvic cavity.** The organs of the abdominopelvic cavity are housed within the **peritoneal** (per-ih-toh-NEE-al; to stretch over) **cavity.** The abdominal cavity contains the majority of the digestive organs, such as the stomach, the intestines, and the liver, in addition to the spleen. The pelvic cavity continues below the pelvis and contains the urinary bladder, urethra, rectum of the large intestine, and reproductive organs.

Serous Membranes of the Ventral Body Cavity

The walls of the body cavities and the surface of internal organs are in contact with membranes called **serous** (SEER-us) **membranes.** These membranes are double layered. The layer that lines the walls of the cavities is called the

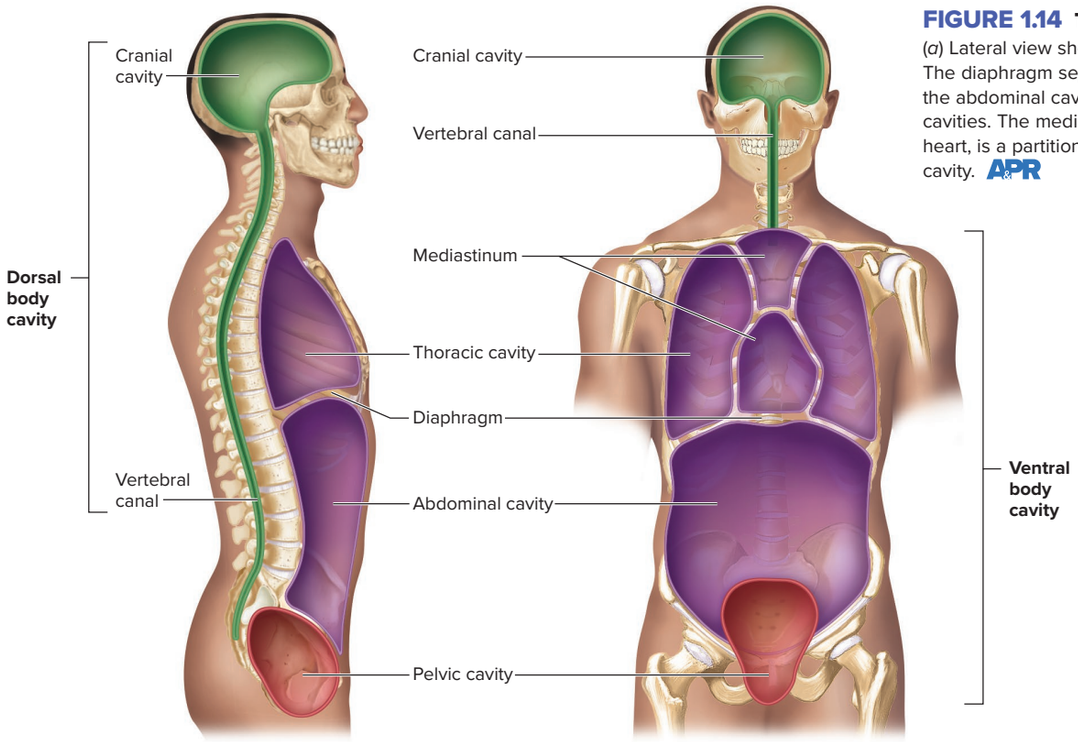


FIGURE 1.14 Trunk Cavities
(*a*) Lateral view showing the major trunk cavities. The diaphragm separates the thoracic cavity from the abdominal cavity. (*b*) Anterior view of the trunk cavities. The mediastinum, which includes the heart, is a partition of organs dividing the thoracic cavity. APR

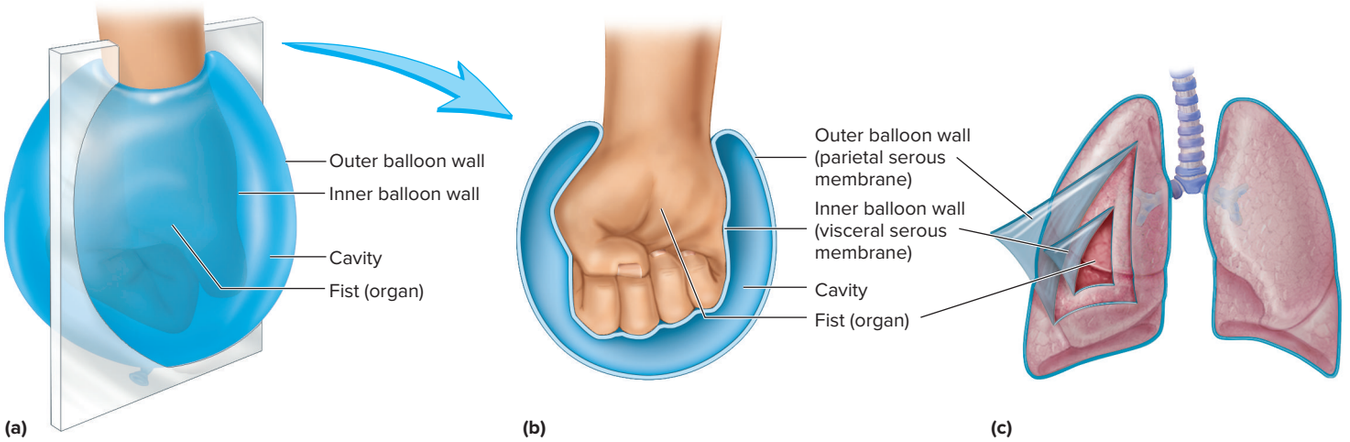


FIGURE 1.15 Serous Membranes

(*a*) A fist pushing into a balloon. A "glass" sheet indicates the location of a section through the balloon. (*b*) Interior view produced by the section in (*a*). The fist represents an organ, and the walls of the balloon represent the serous membranes. The inner wall of the balloon represents a visceral serous membrane in contact with the fist (organ). The outer wall of the balloon represents a parietal serous membrane. (c) The relationship of the parietal and serous membranes to the lungs. Figure 1.16 shows the relationship of the parietal and visceral membranes to the heart.

parietal (pa-RYE-ee-tal; wall) **serous membrane.** The layer covering the internal organs (the viscera) is the **visceral serous membrane.** To understand the relationship between the parietal and the visceral serous membranes, imagine pushing your fist (representing an organ) into a slightly deflated balloon (representing the membranes and the cavity) (figure 1.15). Because your fist represents the internal organs, the portion of the balloon in contact with your fist represents the visceral serous membrane, and the outer part of the balloon wall represents the parietal serous membrane. However, in the body, the parietal serous membrane is in close contact with the body cavity wall. Furthermore, in the body, there is no air between the visceral and parietal serous membranes as there is in the balloon; rather, the two membranes are separated by a thin film of serous fluid produced by the membranes. As organs move around in the cavities, the combination of serous fluid and smooth serous membranes reduces friction.

Thoracic Cavity Membranes

The serous membranes are named for the specific cavity and organs they are in contact with. They include:

1. Pericardial Cavity
   The pericardial cavity (peri = around; cardi = heart), containing the heart, is housed in the mediastinum. The parietal serous membrane is called the **parietal pericardium** and the visceral serous membrane is called the **visceral pericardium.** The space between the two pericardial membranes is called the **pericardial cavity** and is filled with **pericardial fluid** (figure 1.16*a*).
2. Pleural Cavities
   Each of the two pleural cavities (pleuron = side of body, rib) houses a lung. The parietal serous membrane lining the pleural cavities is called the **parietal pleura,** while the visceral serous membrane covering the lungs is called the **visceral pleura** (figure 1.16*b*). The space between the two pleural membranes is called the **pleural cavity** and is filled with **pleural fluid.**
3. Peritoneal Cavity
   The peritoneal cavity (peri = around; -tonos = stretched; stretched around) houses many internal organs, such as the liver, the digestive organs, and the reproductive organs. The parietal serous membrane in the peritoneal cavity is called the **parietal peritoneum.** The visceral serous membrane is called the **visceral peritoneum.** The space between the two serous membranes is the specific location of the **peritoneal cavity** and is filled with **peritoneal fluid** (figure 1.16*c*). In addition to covering organs, a double-folded sheet of visceral peritoneum attaches the digestive organs at certain points to the posterior abdominopelvic cavity wall. These regions of double-folded visceral peritoneum form the mesentery. The mesentery also provides a pathway for nerves and blood vessels to reach the digestive organs (figure 1.16*d*). The most notable mesenteric structure is an enormous pouch containing adipose tissue that is suspended from the inferior border of the stomach. In some people, this pouch contributes to their "big belly" (see chapter 24).

Some abdominal organs are tightly adhered to the posterior body wall and are covered by peritoneum only on their peritoneal cavity side. These organs have a **retroperitoneal** (RE-troh-PER-i-toh-NEE-uhl; behind the peritoneum) location and include the kidneys, ureters, adrenal glands, a large portion of the pancreas, parts of the large intestine, and the urinary bladder (see figure 1.16*c*). This will be further discussed in chapter 24.