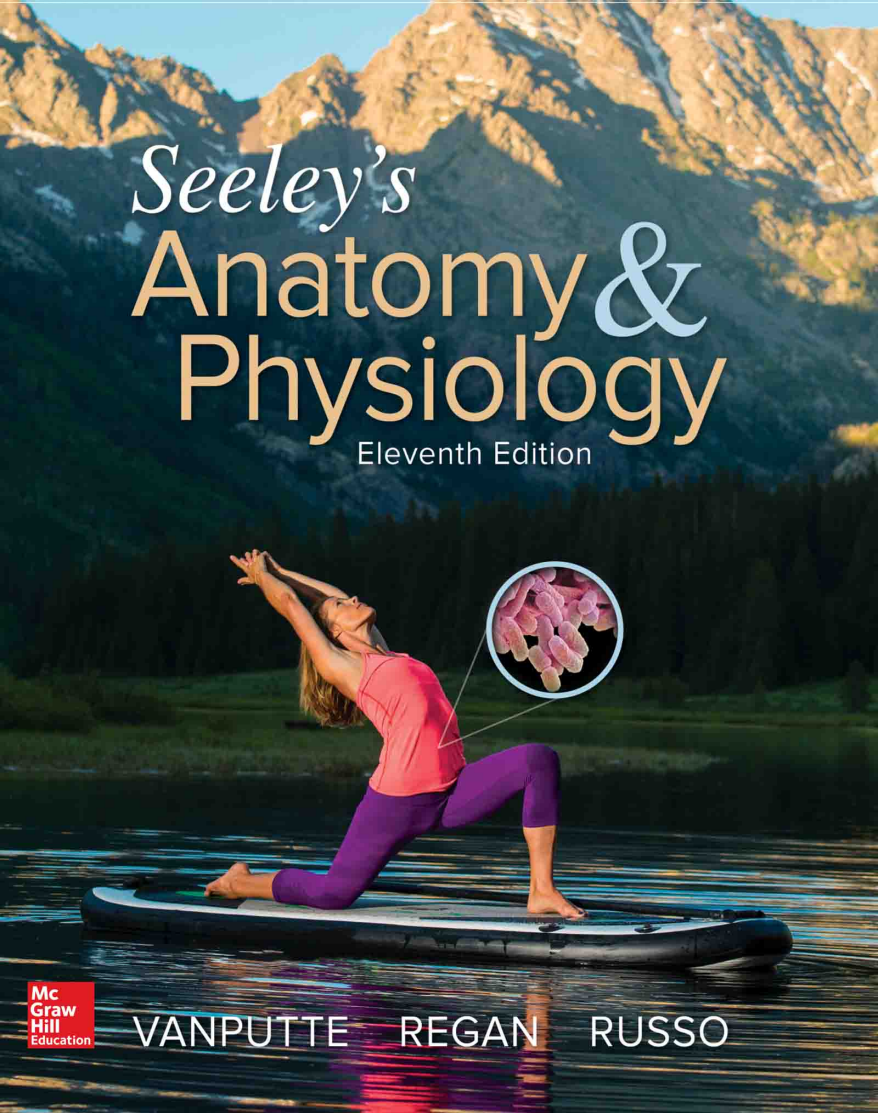
Seeley's Anatomy & Physiology

Eleventh Edition



VANPUTTE REGAN RUSSO

Mc Graw Hill Education

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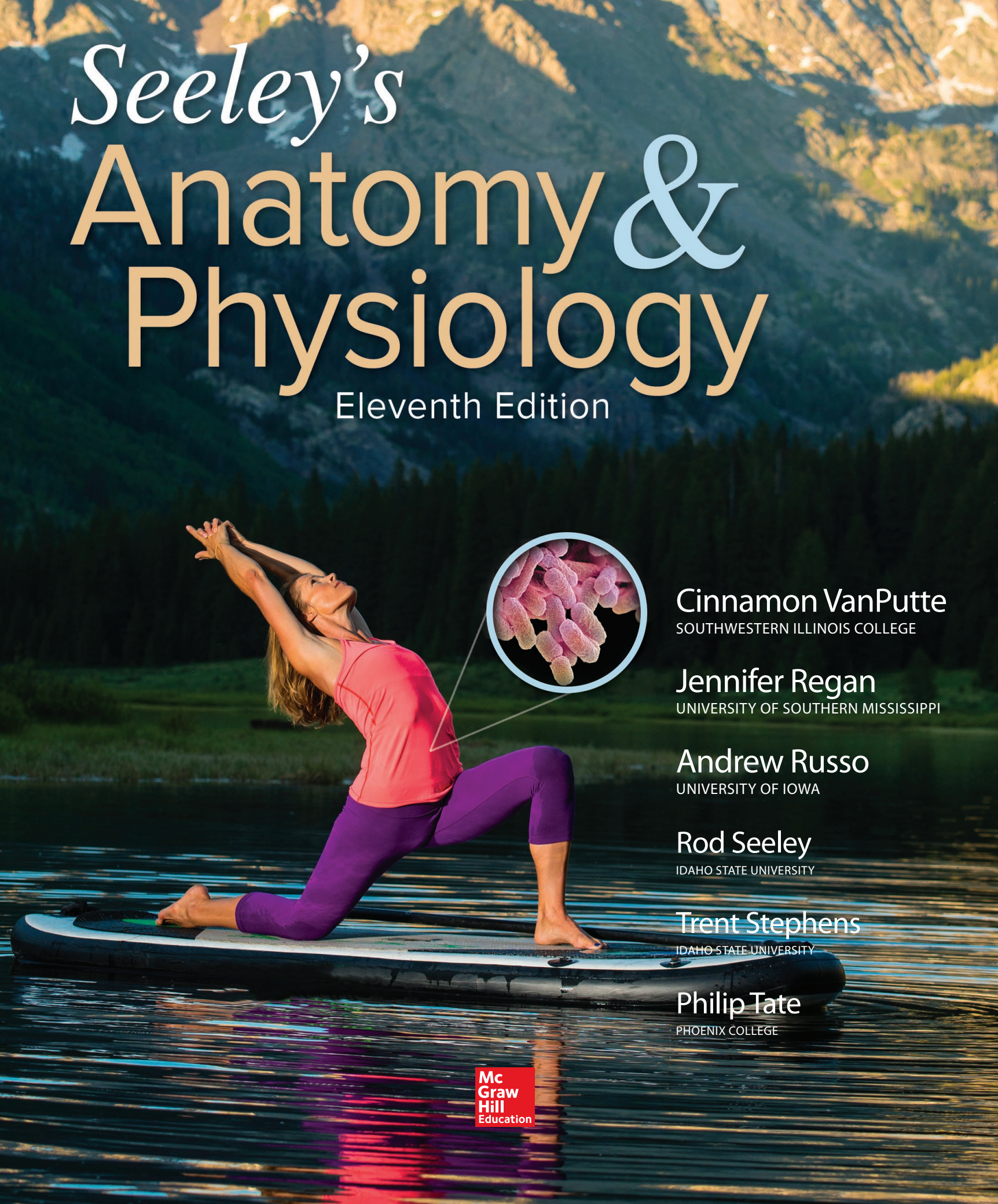

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SEELEY'S ANATOMY & PHYSIOLOGY, ELEVENTH EDITION

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ABOUT THE **Authors**

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Professor of Biology
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Cinnamon has been teaching biology and human anatomy and physiology since 1998. She is a member of the faculty at Southwestern Illinois College and is an active member of several professional societies, including the Human Anatomy & Physiology Society (HAPS). 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 the Seeley titles 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, have two children: a daughter, Savannah, and a son, Ethan. She and her family, including her parents, Tom and Bobbie Moore, live on a farm where they raise Simmental cattle, Suffolk sheep, and a flock of 20 chickens.

Jennifer L. Regan

Instructor
University of Southern Mississippi

For over 15 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, and two sons, Patrick and Nicholas.

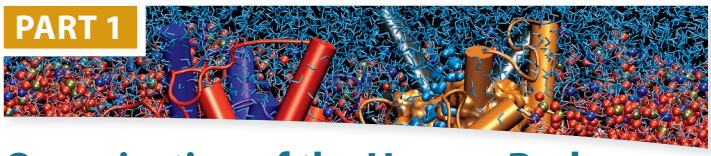
Andrew F. Russo

Professor of Molecular Physiology and Biophysics
University of Iowa

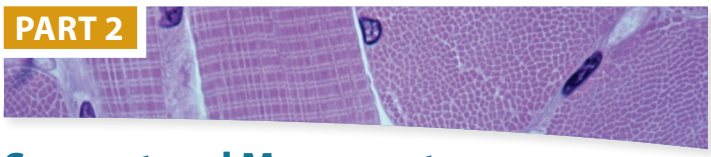
Andrew has over 20 years of classroom experience with human physiology, neurobiology, molecular biology, and cell biology courses at the University of Iowa. He is a recipient of the Collegiate Teaching Award and the J.P. Long Teaching Award in Basic Sciences. He is currently the course director for a 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. Andy is married to Maureen, a physical therapist, and has three daughters, Erilynn, Becky, and Colleen, and three grandchildren. He enjoys all types of outdoor sports, especially bicycling, skiing, running, and open water swimming.

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.

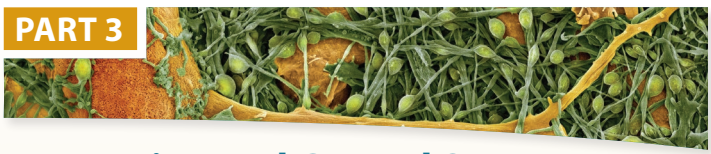
Brief Contents



PART 1 Organization of the Human Body

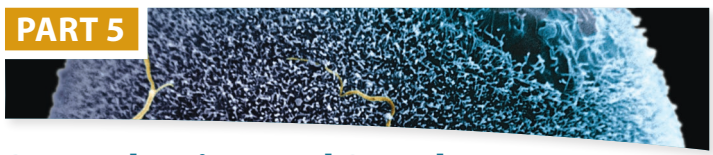


PART 2 Support and Movement



PART 3 Integration and Control Systems

PART 4 Regulation and Maintenance



PART 5 Reproduction and Development

Appendices

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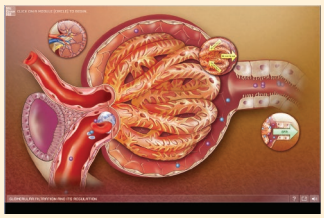
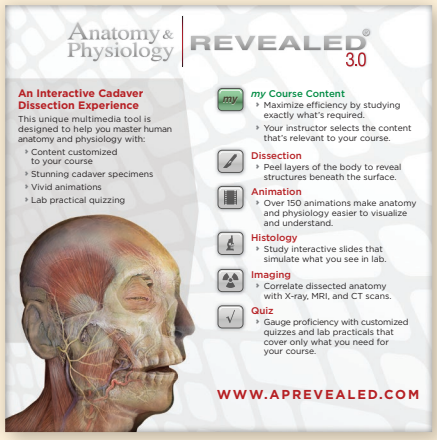
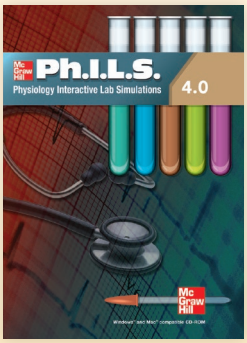


Concept Overview Interactive modules have assessable, auto graded learning activities in Connect®, can be used as a self study tool for students and are also provided separately to instructors as classroom presentation tools.

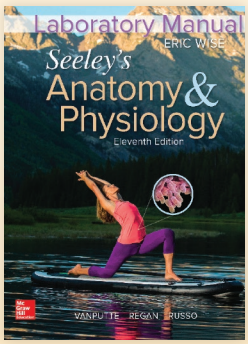


Anatomy & Physiology Revealed® is now available in Cat and Fetal Pig versions!



Physiology Interactive Lab Simulations (Ph.I.L.S.) 4.0

Ph.I.L.S. 4.0 is the perfect way to reinforce key physiology concepts with powerful lab experiments. Created by Dr. Phil Stephens at Villanova University, this program offers ***42 laboratory simulations*** that may be used to supplement or substitute for wet labs. All 42 labs are self-contained experiments—no lengthy instruction manual required. Users can adjust variables, view outcomes, make predictions, draw conclusions, and print lab reports. This easy-to-use software offers the flexibility to change the parameters of the lab experiment. There are no limits!



Laboratory Manual

The Laboratory Manual to accompany *Seeley's Anatomy & Physiology*, authored by Eric Wise of Santa Barbara City College, contains 43 laboratory exercises that are integrated closely with the textbook. Each exercise demonstrates the anatomical and physiological facts and principles presented in the textbook by investigating specific concepts in greater detail. Key features of the lab manual include over 12 new cat dissection photos and many new human cadaver images, step-by-step explanations and a complete materials list for each experiment, precisely labeled, full-color drawings and photographs, self-contained presentations with the essentials background needed to complete each exercise, and extensive lab reports at the end of every exercise.

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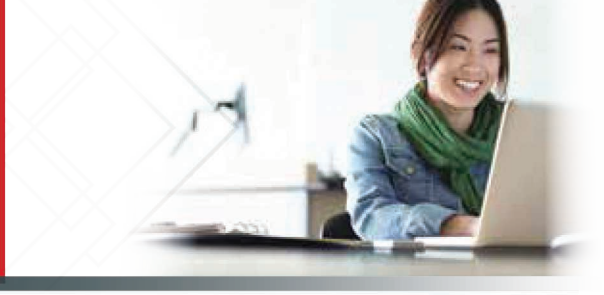

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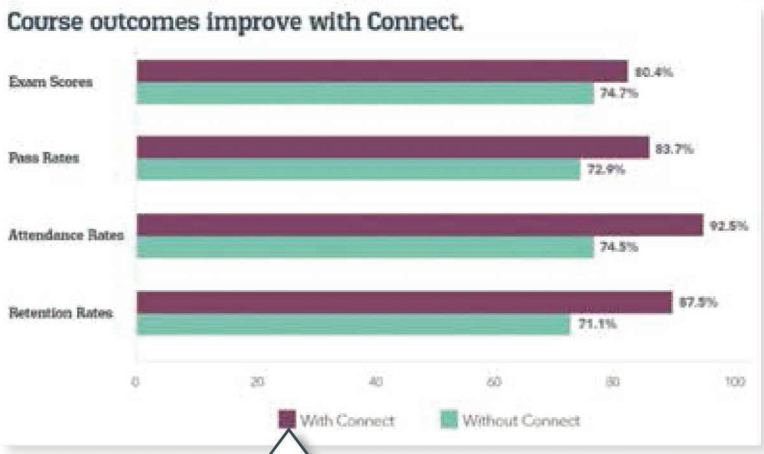

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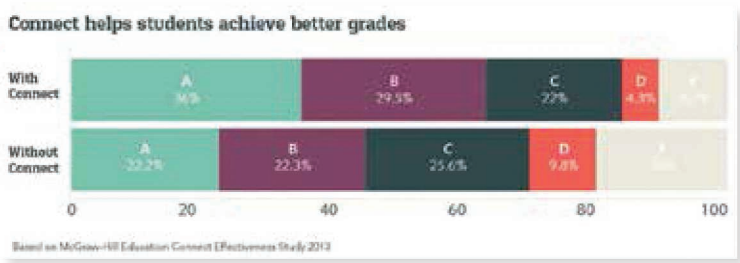

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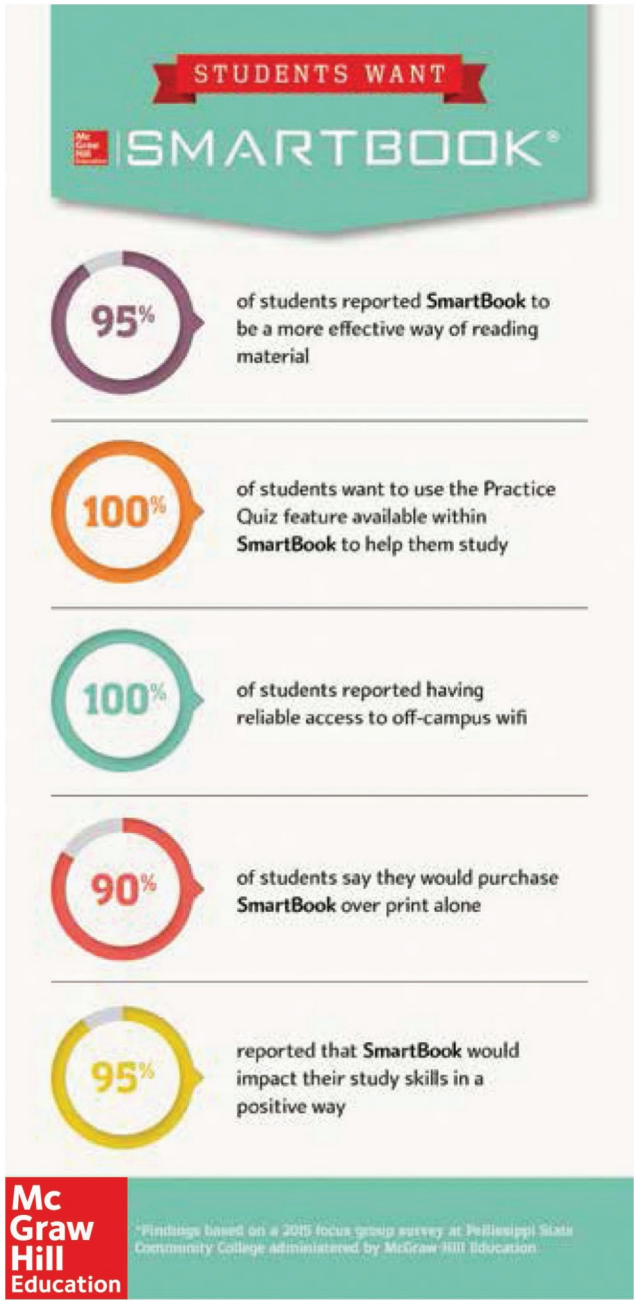
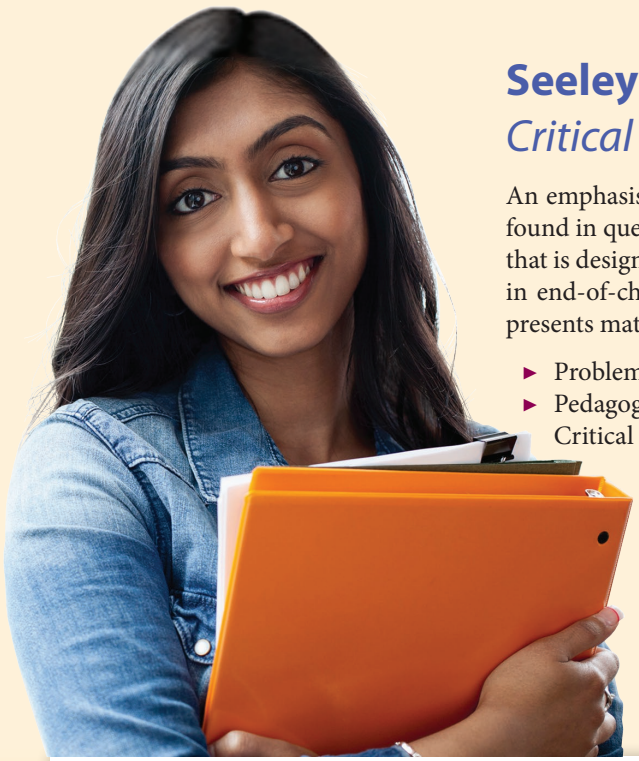


WHAT SETS **Seeley** APART?

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 yet 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 to teach them how to use that information.

What Makes this Text a Market Leader?



Seeley Learning System—*Emphasis on Critical Thinking*

An emphasis on critical thinking is integrated throughout this textbook. This approach can be found in questions starting each chapter and 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.

- Problem-solving perspective from the book's inception
- Pedagogy builds student comprehension from knowledge to application (Predict questions, Critical Thinking questions, and Learn To Predict Answer)

Predict Questions challenge students to use their understanding of new concepts to solve a problem. Answers to the questions are provided at the end of the book, allowing students to evaluate their responses and to understand the logic used to arrive at the correct answer. All Predict question answers have been rewritten in teaching style format to model the answer for the student. Helps students learn how to think critically.

CRITICAL THINKING

1. How would body function be affected if the sternal synchondroses and the sternocostal synchondrosis of the first rib were to become synostoses?
2. Using an articulated skeleton, describe the type of joint and the movement(s) possible for each of the following joints:
   a. joint between the zygomatic bone and the maxilla
   b. ligamentous connection between the coccyx and the sacrum
   c. elbow joint
3. For each of the following muscles, describe the motion(s) produced when the muscle contracts. It may be helpful to use an articulated skeleton.
   a. The biceps brachii muscle attaches to the coracoid process of the scapula (one head) and to the radial tuberosity of the radius. Name two movements that the muscle accomplishes in the forearm.
   b. The rectus femoris muscle attaches to the anterior inferior iliac spine and the tibial tuberosity. How does contraction move the thigh? The leg?
   c. The supraspinatus muscle is located in and attached to the supraspinatus fossa of the scapula. Its tendon runs over the head of the humerus to the greater tubercle. When it contracts, what movement occurs at the glenohumeral (shoulder) joint?
   d. The gastrocnemius muscle attaches to the medial and lateral condyles of the femur and to the calcaneus. What movement of the leg results when this muscle contracts? Of the foot?
4. At first, Donnie's wife accused her once active 25-year-old husband of trying to get out of housework by constantly complaining about pain and stiffness in his lower back. But over the next 5 months, the pain and stiffness increased and seemed to be spreading up his vertebral column. The family doctor referred Donnie to a rheumatologist, who diagnosed ankylosing spondylitis (AS). AS, a chronic inflammation of joints at points where ligaments, tendons, and joint capsule insert into bone, causes fibrosis (the development of scar tissue), ossification, and fusion of joints. Combine your knowledge about bone growth, repair, and anatomy from chapters 6 and 7 and joint structure and function from this chapter to identify the category of joints primarily affected by AS, and explain how chronic inflammation of Donnie's joints led to their fusion.

Answers in appendix F

Predict 4

What combination of movements at the shoulder and elbow joints allows a person to move the right upper limb from the anatomical position to touch the right side of the head with the fingertips?

Critical Thinking These innovative exercises encourage students to apply chapter concepts to solve a problem. These questions help build student's knowledge of anatomy & physiology while developing reasoning and critical thinking skills.

Clinical IMPACT

Acquired Immunodeficiency Syndrome

Acquired immunodeficiency syndrome (AIDS) is a life-threatening disease caused by the **human immunodeficiency virus (HIV).** HIV is transmitted from an infected person to a noninfected person in body fluids, such as blood, semen, or vaginal secretions. The major methods of transmission are through unprotected sexual contact, through contaminated needles used by intravenous drug users, through tainted blood products, and from a pregnant woman to her fetus. Evidence indicates that household, school, and work contacts do not result in transmission. Reduced exposure to HIV is the best prevention for its transmission. Practices such as abstinence, the use of latex condoms, monogamy, and avoiding sharing needles are effective ways to reduce exposure to HIV. Medical professionals should also use care when handling body fluids, such as wearing latex gloves.

HIV infection begins when a protein on the surface of the virus, called gp120, binds to a CD4 molecule on the surface of a cell. The CD4 molecule is found primarily on helper T cells, and it normally enables helper T cells to adhere to other lymphocytes—for example, during antigen presentation. Certain monocytes, macrophages, neurons, and glial cells also have CD4 molecules. Once attached to the CD4 molecules, the virus injects its genetic material (RNA) and enzymes into the cell and begins to replicate. Copies of the virus are manufactured using the organelles and materials within the cell. Replicated viruses escape from the cell and infect other cells.

Following infection by HIV, within 3 weeks to 3 months, many patients develop mononucleosis-like symptoms, such as fever, sweats, fatigue, muscle and joint aches, headache, sore throat, diarrhea, rash, and swollen lymph nodes. Within 1–3 weeks, these symptoms disappear as the immune system responds to the virus by producing antibodies and activating cytotoxic T cells that kill HIV-infected cells. However, the immune system is not able to eliminate HIV completely, and by about 6 months a kind of "set point" is achieved in which the virus continues to replicate at a low but steady rate. This chronic stage of infection lasts, on average, 8–10 years, and the infected person feels good and exhibits few, if any, symptoms.

Although helper T cells are infected and destroyed during the chronic stage of HIV infection, the body responds by producing large numbers of helper T cells. Nonetheless, over a period of years the HIV numbers gradually increase, and helper T cell numbers decrease. Normally, approximately 1200 helper T cells are present per cubic millimeter of blood. An HIV-infected person is diagnosed with AIDS when one or more of the following conditions appear: The helper T cell count falls below 200 cells/mm^3, an opportunistic infection occurs, or Kaposi sarcoma develops.

Opportunistic infections involve organisms that normally do not cause disease but do so when the immune system is depressed. Without helper T cells, cytotoxic T- and B-cell activation is impaired, and adaptive resistance is suppressed. Examples of opportunistic infections include pneumocystis (noo-mō-sis'tis) pneumonia (caused by an intracellular fungus, *Pneumocystis carinii*), tuberculosis (caused by an intracellular bacterium, *Mycobacterium tuberculosis*), syphilis (caused by a sexually transmitted bacterium, *Treponema pallidum*), candidiasis (kan-di-dī'ă-sis; a yeast infection of the mouth or vagina caused by *Candida albicans*), and protozoans that cause severe, persistent diarrhea. Kaposi sarcoma is a type of cancer that produces lesions in the skin, lymph nodes, and visceral organs. AIDS symptoms resulting from the effects of HIV on the nervous system include loss of motor activity, behavioral changes, progressive dementia, and possibly psychosis.

A cure for AIDS has yet to be discovered. Management of AIDS can be divided into two categories: (1) management of secondary infections or malignancies associated with AIDS and (2) control of HIV replication.

The first effective treatment of AIDS was the drug azidothymidine (AZT; az'i-dō-thī'mi-dēn), also called zidovudine (zī-dō'voo-dēn), which prevents HIV replication. AZT can delay the onset of AIDS but does not appear to increase the survival time of AIDS patients. However, the number of babies who contract AIDS from their HIV-infected mothers can be dramatically reduced by giving AZT to the mothers during pregnancy and to the babies following birth.

The current treatment for suppressing HIV replication is **highly active antiretroviral therapy (HAART).** This therapy uses multiple drugs from at least two classes of antivirals. Treatment involves combining multiple drugs, because HIV is unlikely to develop resistance to all drugs. This strategy has proven very effective in reducing the death rate from AIDS and partially restoring health in some individuals.

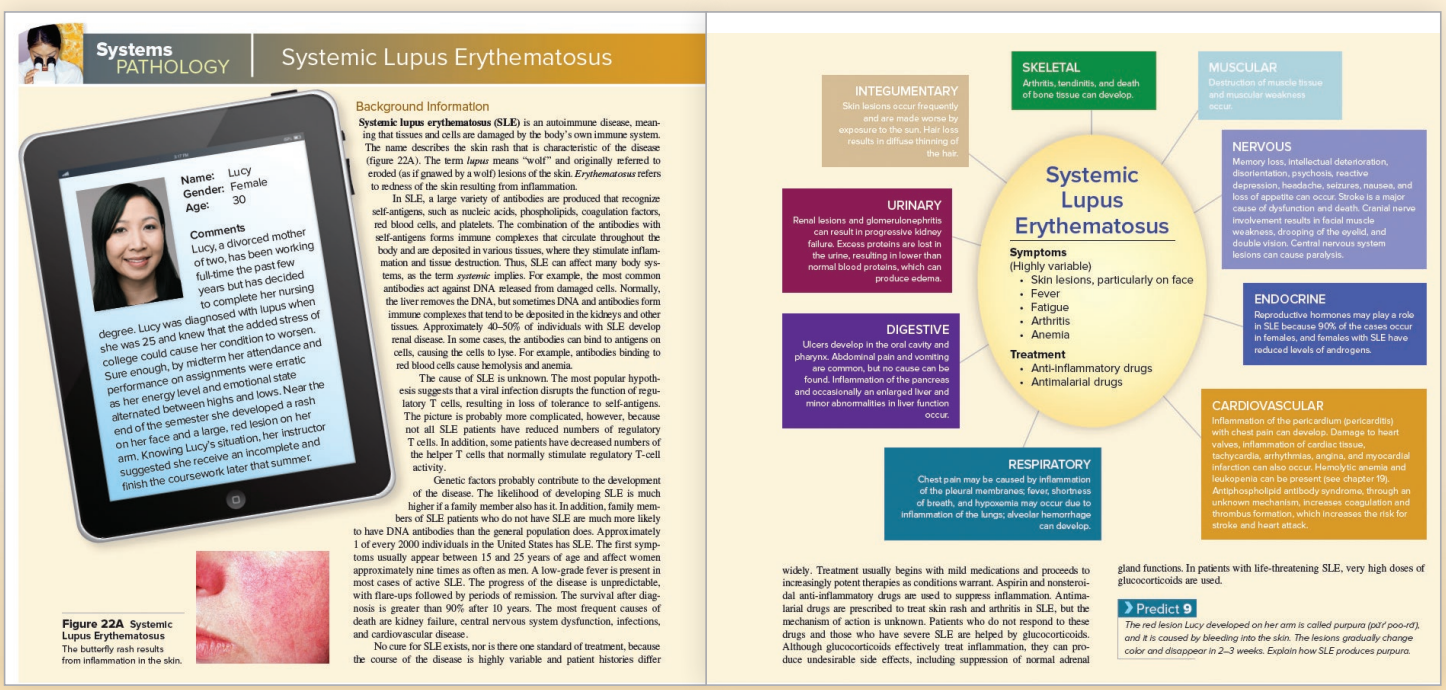
Effective treatment for AIDS is not the same as a cure. Even if viral load decreases to the point that the virus is undetected in the blood, the virus still remains in cells throughout the body. The virus may eventually mutate and escape drug suppression. The long-term goal for deterring AIDS is to develop a vaccine that prevents HIV infection.

Because of improved treatment, people with HIV/AIDS can now live for many years. Thus, HIV/AIDS is being viewed increasingly as a chronic disease, not a death sentence. Working together, a multidisciplinary team of occupational therapists, physical therapists, nutritionists/dieticians, psychologists, infectious disease physicians, and others can help patients with HIV/AIDS have a better quality of life.

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.

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 Pathologies with System Interactions



Systems PATHOLOGY

Systemic Lupus Erythematosus

Name: Lucy
Gender: Female
Age: 30

Comments
Lucy, a divorced mother of two, has been working full-time the past few years but has decided to complete her nursing degree. Lucy was diagnosed with lupus when she was 25 and knew that the added stress of college could cause her condition to worsen. Sure enough, by midterm her attendance and performance on assignments were erratic as her energy level and emotional state alternated between highs and lows. Near the end of the semester she developed a rash on her face and a large, red lesion on her arm. Knowing Lucy's situation, her instructor suggested she receive an incomplete and finish the coursework later that summer.

Figure 22A Systemic Lupus Erythematosus
The butterfly rash results from inflammation in the skin.

Background Information

Systemic lupus erythematosus (SLE) is an autoimmune disease, meaning that tissues and cells are damaged by the body's own immune system. The name describes the skin rash that is characteristic of the disease (figure 22A). The term *lupus* means "wolf" and originally referred to eroded (as if gnawed by a wolf) lesions of the skin. *Erythematosus* refers to redness of the skin resulting from inflammation.

In SLE, a large variety of antibodies are produced that recognize self-antigens, such as nucleic acids, phospholipids, coagulation factors, red blood cells, and platelets. The combination of the antibodies with self-antigens forms immune complexes that circulate throughout the body and are deposited in various tissues, where they stimulate inflammation and tissue destruction. Thus, SLE can affect many body systems, as the term *systemic* implies. For example, the most common antibodies act against DNA released from damaged cells. Normally, the liver removes the DNA, but sometimes DNA and antibodies form immune complexes that tend to be deposited in the kidneys and other tissues. Approximately 40–50% of individuals with SLE develop renal disease. In some cases, the antibodies can bind to antigens on cells, causing the cells to lyse. For example, antibodies binding to red blood cells cause hemolysis and anemia.

The cause of SLE is unknown. The most popular hypothesis suggests that a viral infection disrupts the function of regulatory T cells, resulting in loss of tolerance to self-antigens. The picture is probably more complicated, however, because not all SLE patients have reduced numbers of regulatory T cells. In addition, some patients have decreased numbers of the helper T cells that normally stimulate regulatory T-cell activity.

Genetic factors probably contribute to the development of the disease. The likelihood of developing SLE is much higher if a family member also has it. In addition, family members of SLE patients who do not have SLE are much more likely to have DNA antibodies than the general population does. Approximately 1 of every 2000 individuals in the United States has SLE. The first symptoms usually appear between 15 and 25 years of age and affect women approximately nine times as often as men. A low-grade fever is present in most cases of active SLE. The progress of the disease is unpredictable, with flare-ups followed by periods of remission. The survival after diagnosis is greater than 90% after 10 years. The most frequent causes of death are kidney failure, central nervous system dysfunction, infections, and cardiovascular disease.

No cure for SLE exists, nor is there one standard of treatment, because the course of the disease is highly variable and patient histories differ widely. Treatment usually begins with mild medications and proceeds to increasingly potent therapies as conditions warrant. Aspirin and nonsteroidal anti-inflammatory drugs are used to suppress inflammation. Antimalarial drugs are prescribed to treat skin rash and arthritis in SLE, but the mechanism of action is unknown. Patients who do not respond to these drugs and those who have severe SLE are helped by glucocorticoids. Although glucocorticoids effectively treat inflammation, they can produce undesirable side effects, including suppression of normal adrenal gland functions. In patients with life-threatening SLE, very high doses of glucocorticoids are used.

INTEGUMENTARY
Skin lesions occur frequently and are made worse by exposure to the sun. Hair loss results in diffuse thinning of the hair.

SKELETAL
Arthritis, tendinitis, and death of bone tissue can develop.

MUSCULAR
Destruction of muscle tissue and muscular weakness occur.

NERVOUS
Memory loss, intellectual deterioration, disorientation, psychosis, reactive depression, headache, seizures, nausea, and loss of appetite can occur. Stroke is a major cause of dysfunction and death. Cranial nerve involvement results in facial muscle weakness, drooping of the eyelid, and double vision. Central nervous system lesions can cause paralysis.

URINARY
Renal lesions and glomerulonephritis can result in progressive kidney failure. Excess proteins are lost in the urine, resulting in lower than normal blood proteins, which can produce edema.

Systemic Lupus Erythematosus

Symptoms
(Highly variable)
- Skin lesions, particularly on face
- Fever
- Fatigue
- Arthritis
- Anemia

Treatment
- Anti-inflammatory drugs
- Antimalarial drugs

ENDOCRINE
Reproductive hormones may play a role in SLE because 90% of the cases occur in females, and females with SLE have reduced levels of androgens.

DIGESTIVE
Ulcers develop in the oral cavity and pharynx. Abdominal pain and vomiting are common, but no cause can be found. Inflammation of the pancreas and occasionally an enlarged liver and minor abnormalities in liver function occur.

CARDIOVASCULAR
Inflammation of the pericardium (pericarditis) with chest pain can develop. Damage to heart valves, inflammation of cardiac tissue, tachycardia, arrhythmias, angina, and myocardial infarction can also occur. Hemolytic anemia and leukopenia can be present (see chapter 19). Antiphospholipid antibody syndrome, through an unknown mechanism, increases coagulation and thrombus formation, which increases the risk for stroke and heart attack.

RESPIRATORY
Chest pain may be caused by inflammation of the pleural membranes; fever, shortness of breath, and hypoxemia may occur due to inflammation of the lungs; alveolar hemorrhage can develop.

Predict 9
The red lesion Lucy developed on her arm is called purpura (pûr' poo-rə), and it is caused by bleeding into the skin. The lesions gradually change color and disappear in 2–3 weeks. Explain how SLE produces purpura.

Systems Pathologies boxes These 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.

Exceptional Art—*Always created from the student perspective*

A picture is worth a thousand words—especially when you're learning anatomy and physiology. Because words alone cannot convey the nuances of anatomy or the intricacies of physiology, *Seeley's Anatomy & Physiology* employs a dynamic program of full-color illustrations and photographs that support and further clarify the textual explanations:

- Fundamental figures teamed with special online support and now linked to APR
- Homeostasis figures were revised to draw a correlation from the text description of feedback system components to the figure. Maintains consistency throughout each organ system
- All figures were visually linked to create consistency throughout the text. The same colors are always used for the same type of arrow, cytoplasm in a cell, symbols for ions, and molecules, etc.
- Step-by-step process figures
- Atlas-quality cadaver images
- Illustrated tables
- Photos side-by-side with illustrations
- Color saturation of art makes the art more engaging
- Macro-to-micro art

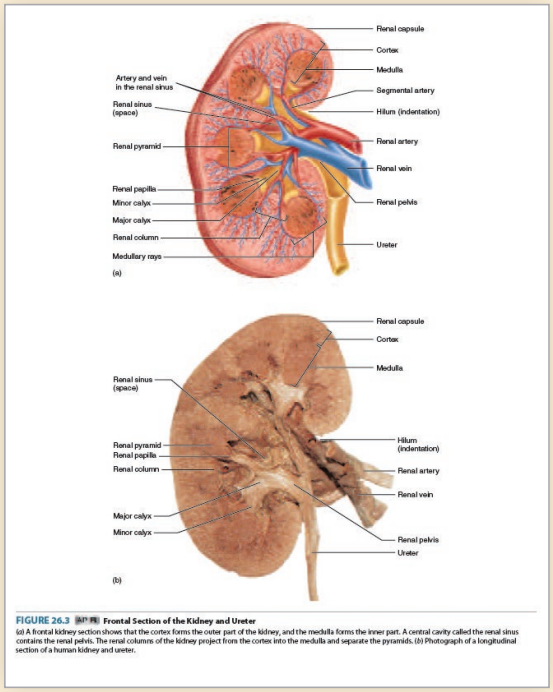


FIGURE 26.3 Frontal Section of the Kidney and Ureter
(a) A frontal kidney section shows that the cortex forms the outer part of the kidney, and the medulla forms the inner part. A central cavity called the renal sinus contains the renal pelvis. The renal columns of the kidney project from the cortex into the medulla and separate the pyramids. (b) Photograph of a longitudinal section of a human kidney and ureter.

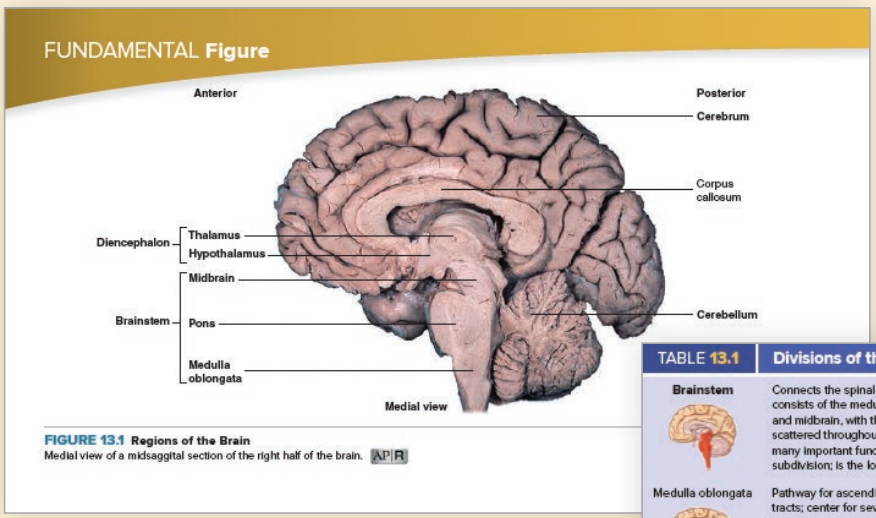


FIGURE 13.1 Regions of the Brain
Medial view of a midsaggital section of the right half of the brain. APR

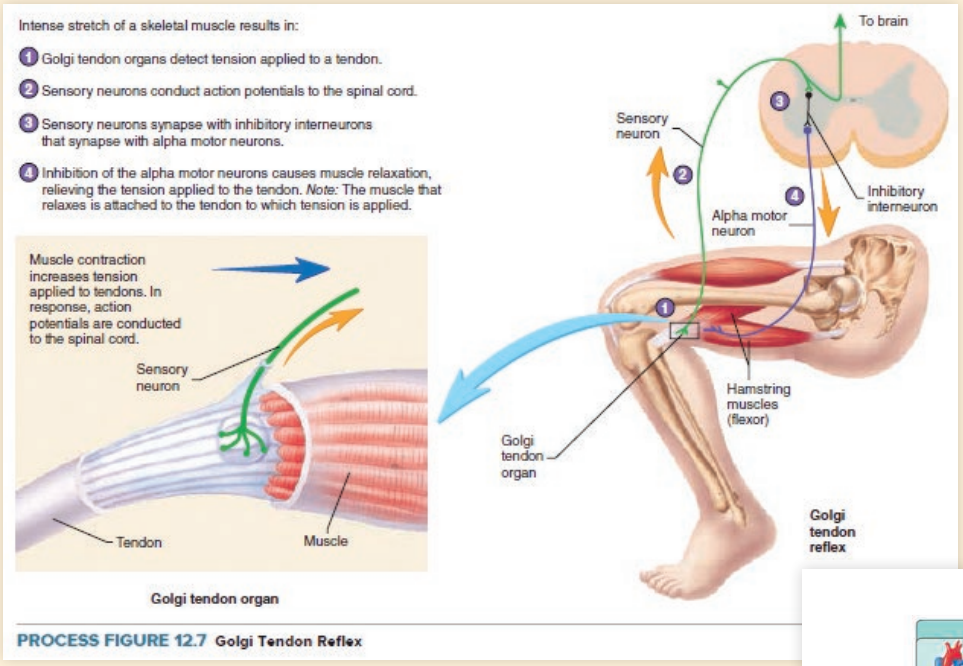
TABLE 13.1 Divisions of the Brain and Their Functions

Brainstem	Connects the spinal cord to the cerebrum; consists of the medulla oblongata, pons, and midbrain, with the reticular formation scattered throughout the three regions; has many important functions, as listed under each subdivision; is the location of cranial nerve nuclei	**Cerebellum**	Controls muscle movement and tone; governs balance; regulates extent of intentional movement; involved in learning motor skills
Medulla oblongata	Pathway for ascending and descending nerve tracts; center for several important reflexes (e.g., heart rate, breathing, swallowing, vomiting)	**Diencephalon**	Connects the brainstem to the cerebrum; has many relay and homeostatic functions, as listed under each subdivision
Pons	Contains ascending and descending nerve tracts; relays information between cerebrum and cerebellum; site of reflex centers	Thalamus	Major sensory relay center; influences mood and movement
Midbrain	Contains ascending and descending nerve tracts; serves as visual reflex center; part of auditory pathway	Subthalamus	Contains nerve tracts and nuclei
Reticular formation	Scattered throughout brainstem; controls many brainstem activities, including motor control, pain perception, rhythmic contractions, and the sleep-wake cycle	Epithalamus	Contains nuclei responding to olfactory stimulation and contains pineal gland
		Hypothalamus	Major control center for maintaining homeostasis and regulating endocrine function
		Cerebrum	Controls conscious perception, thought, and conscious motor activity; can override most other systems
		Basal nuclei	Controls muscle activity and posture; largely inhibits unintentional movement when at rest
		Limbic system	Autonomic response to smell, emotion, mood, memory, and other such functions

Clearly labeled photos of dissected human cadavers provide detailed views of anatomical structures, capturing the intangible characteristics of actual human anatomy that can be appreciated only when viewed in human specimens.

Specialized Figures Clarify Tough Concepts

Studying anatomy and physiology does not have to be an intimidating task mired in memorization. *Seeley's Anatomy & Physiology* uses two special types of illustrations to help students not only learn the steps involved in specific processes, but also apply the knowledge as they predict outcomes in similar situations. Process figures organize the key occurrences of physiological processes in an easy-to-follow format. Homeostasis figures summarize the mechanisms of homeostasis by diagramming how a given system regulates a parameter within a narrow range of values.

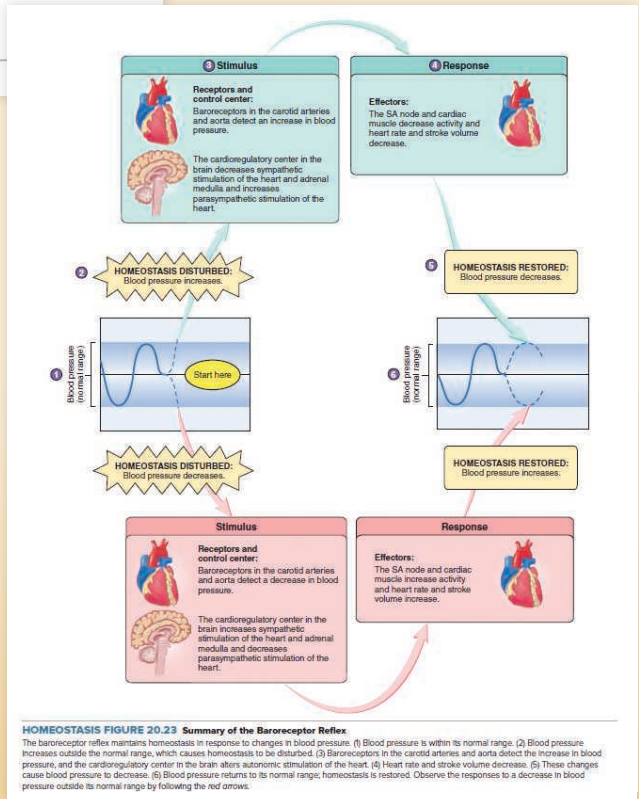


PROCESS FIGURE 12.7 Golgi Tendon Reflex

Step-by-Step Process Figures Process figures break down physiological processes into a series of smaller steps, allowing readers to build their understanding by learning each important phase. Numbers are placed carefully in the art, permitting students to zero right in to where the action described in each step takes place.

NEW Correlated With APR! Homeostasis figures with in-art explanations and organ icons

- These specialized flowcharts illustrating the mechanisms that body systems employ to maintain homeostasis have been refined and improved in the eleventh edition.
- More succinct explanations
- Small icon illustrations included in boxes depict the organ or structure being discussed.
- All homeostasis figures were revised to draw a correlation from the text description of feedback system components to the figure. Maintains consistency throughout each organ system.



HOMEOSTASIS FIGURE 20.23 Summary of the Baroreceptor Reflex
The baroreceptor reflex maintains homeostasis in response to changes in blood pressure. (1) Blood pressure is within its normal range. (2) Blood pressure increases outside the normal range, which causes homeostasis to be disturbed. (3) Baroreceptors in the carotid arteries and aorta detect the increase in blood pressure, and the cardioregulatory center in the brain alters autonomic stimulation of the heart. (4) Heart rate and stroke volume decrease. (5) These changes cause blood pressure to decrease. (6) Blood pressure returns to its normal range; homeostasis is restored. Observe the responses to a decrease in blood pressure outside its normal range by following the *red arrows*.

Learn to Predict and Learn to Predict Answer—
Helping students learn how to think

Learn to Predict

While weight training, Pedro strained his back and damaged a vertebral disk. The bulged disk placed pressure on the left side of the spinal cord, compressing the third lumbar spinal nerve, which innervates the following muscles: psoas major, iliacus, pectineus, sartorius, vastus lateralis, vastus medius, vastus intermedius, and rectus femoris. As a result, action potential conduction to these muscles was reduced. **Using your new knowledge about the histology and physiology of the muscular system from chapter 9 and combining it with the information about gross muscle anatomy in this chapter, 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?**

Photo: The man in this photo has clearly defined muscles. Which muscles can you identify?

- Part of the overall critical thinking Predict questions that appear throughout each chapter, a special Learn to Predict question now opens every chapter. This specifically written scenario takes knowledge acquired from previous chapters and ties it into content in the current chapter.

Answer

Learn to Predict **From page 313**

The description of Pedro's injury provided specific information about the regions of the body affected: the left hip and thigh. In addition, we are told that the injury affected action potential conduction to the muscles of these regions. These facts will help us determine Pedro's symptoms and predict the movements that may be affected by his injury.

Chapter 9 described the relationship between action potential conduction and the force of muscle contractions. The reduction in action potential conduction to the muscles of the hip and thigh reduced the stimulation of these muscles, reducing the contraction force. As a result of his injury, we can predict that Pedro experienced weakness in his left hip and thigh, limiting his activity level.

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 up and down stairs, would be affected. Any tasks that require Pedro to walk up and down stairs would be more difficult for him. Sitting and standing may also be affected, but the weakness in Pedro's left hip and thigh may be compensated for by increased muscle strength on his right side.

Answers to the rest of this chapter's Predict questions are in appendix G.

- The Learn to Predict Answer box at the end of each chapter teaches students step-by-step how to answer the chapter-opening critical thinking question. This is foundational to real learning and is a crucial part of helping students put facts together to reach that "aha" moment of true comprehension.

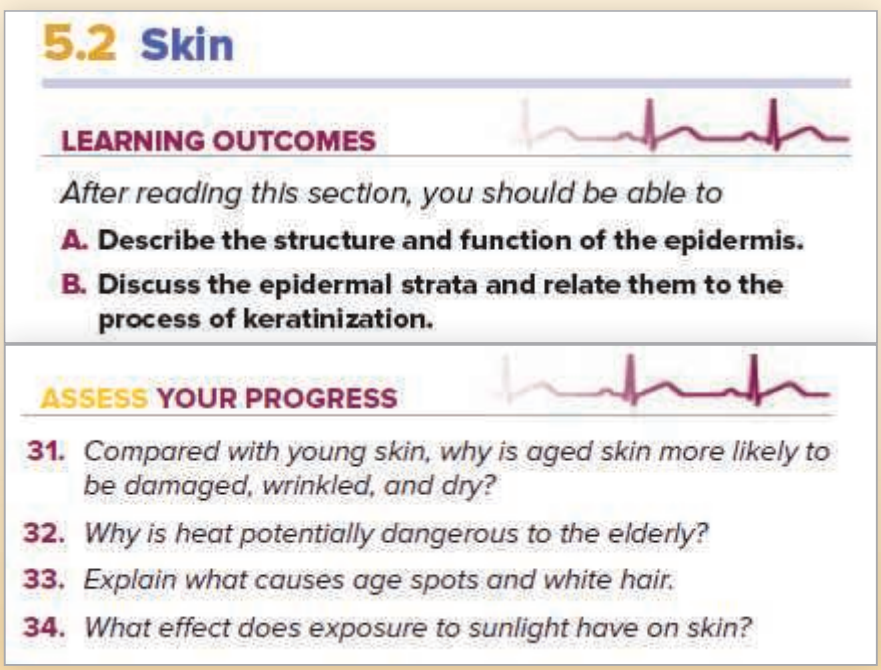
ELEVENTH EDITION
Changes

What's New and Improved?

The eleventh edition of *Seeley's Anatomy & Physiology* is the result of extensive analysis of the text. The outcome is a retention of the beloved features that foster student understanding with an emphasis on a sharper focus within many sections, affording an even more logical flow within the text. Throughout every chapter the writing style is clean and more accessible to students.

Learning Outcomes and Assessment—*Helping instructors track student progress*

- **UPDATED!** Learning Outcomes are carefully written and labeled to outline expectations for each section
- **UPDATED!** Online student questions and test bank questions are correlated with Learning Outcomes to further scaffold and measure student progress and understanding
- **NEW!** Microbes In Your Body feature discussing the many important, and sometimes little known, roles of microbes and the physiology of homeostasis
- **UPDATED!** The Clinical Genetics feature has been updated and streamlined to provide the newest and most accurate information available
- **NEW!** Online clinical study questions are based from clinical features within the text including Microbes in your Body and System Pathologies, and are correlated with Leaning Outcomes and HAPS Learning Objectives to further develop and measure higher level thinking and application of learned content
- **NEW!** LearnSmart Based questions help further correlate and emphasize related content and scaffold learning.



5.2 Skin

LEARNING OUTCOMES

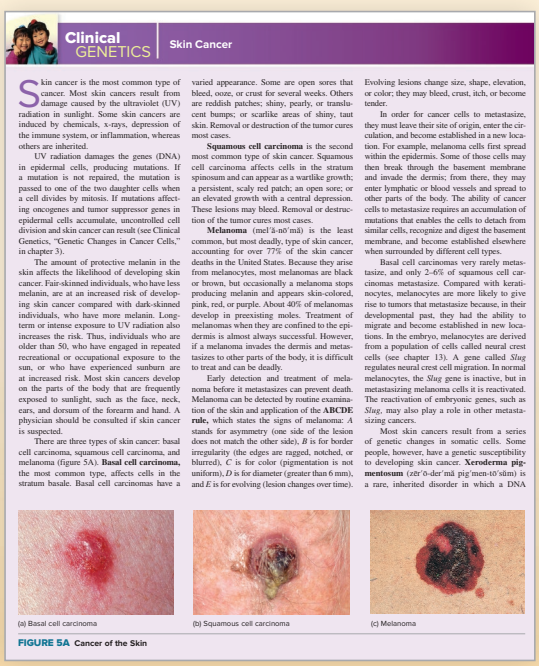
After reading this section, you should be able to

A. Describe the structure and function of the epidermis.

B. Discuss the epidermal strata and relate them to the process of keratinization.

ASSESS YOUR PROGRESS

31. Compared with young skin, why is aged skin more likely to be damaged, wrinkled, and dry?
32. Why is heat potentially dangerous to the elderly?
33. Explain what causes age spots and white hair.
34. What effect does exposure to sunlight have on skin?



Clinical GENETICS — Skin Cancer

Skin cancer is the most common type of cancer. Most skin cancers result from damage caused by the ultraviolet (UV) radiation in sunlight. Some skin cancers are induced by chemicals, x-rays, depression of the immune system, or inflammation, whereas others are inherited.

UV radiation damages the genes (DNA) in epidermal cells, producing mutations. If a mutation is not repaired, the mutation is passed to one of the two daughter cells when a cell divides by mitosis. If mutations affecting oncogenes and tumor suppressor genes in epidermal cells accumulate, uncontrolled cell division and skin cancer can result (see Clinical Genetics, "Genetic Changes in Cancer Cells," in chapter 3).

The amount of protective melanin in the skin affects the likelihood of developing skin cancer. Fair-skinned individuals, who have less melanin, are at an increased risk of developing skin cancer compared with dark-skinned individuals, who have more melanin. Long-term or intense exposure to UV radiation also increases the risk. Thus, individuals who are older than 50, who have engaged in repeated recreational or occupational exposure to the sun, or who have experienced sunburn are at increased risk. Most skin cancers develop on the parts of the body that are frequently exposed to sunlight, such as the face, neck, ears, and dorsum of the forearm and hand. A physician should be consulted if skin cancer is suspected.

There are three types of skin cancer: basal cell carcinoma, squamous cell carcinoma, and melanoma (figure 5A). **Basal cell carcinoma,** the most common type, affects cells in the stratum basale. Basal cell carcinomas have a varied appearance. Some are open sores that bleed, ooze, or crust for several weeks. Others are reddish patches; shiny, pearly, or translucent bumps; or scarlike areas of shiny, taut skin. Removal or destruction of the tumor cures most cases.

Squamous cell carcinoma is the second most common type of skin cancer. Squamous cell carcinoma affects cells in the stratum spinosum and can appear as a wartlike growth; a persistent, scaly red patch; an open sore; or an elevated growth with a central depression. These lesions may bleed. Removal or destruction of the tumor cures most cases.

Melanoma (mel'ă-nō'mă) is the least common, but most deadly, type of skin cancer, accounting for over 77% of the skin cancer deaths in the United States. Because they arise from melanocytes, most melanomas are black or brown, but occasionally a melanoma stops producing melanin and appears skin-colored, pink, red, or purple. About 40% of melanomas develop in preexisting moles. Treatment of melanomas when they are confined to the epidermis is almost always successful. However, if a melanoma invades the dermis and metastasizes to other parts of the body, it is difficult to treat and can be deadly.

Early detection and treatment of melanoma before it metastasizes can prevent death. Melanoma can be detected by routine examination of the skin and application of the **ABCDE rule,** which states the signs of melanoma: *A* stands for asymmetry (one side of the lesion does not match the other side), *B* is for border irregularity (the edges are ragged, notched, or blurred), *C* is for color (pigmentation is not uniform), *D* is for diameter (greater than 6 mm), and *E* is for evolving (lesion changes over time). Evolving lesions change size, shape, elevation, or color; they may bleed, crust, itch, or become tender.

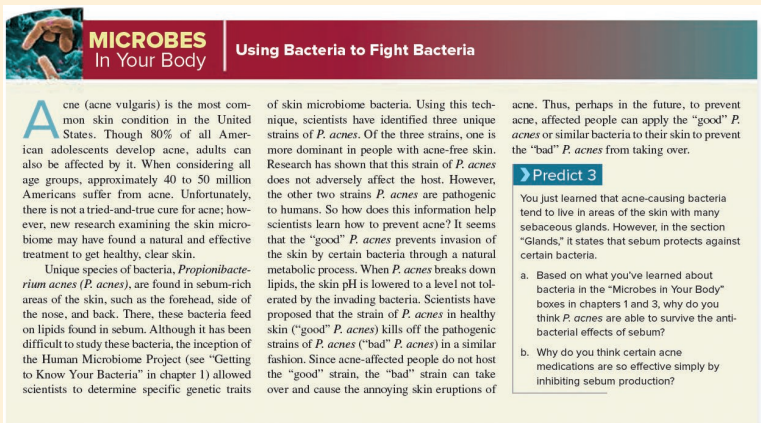
In order for cancer cells to metastasize, they must leave their site of origin, enter the circulation, and become established in a new location. For example, melanoma cells first spread within the epidermis. Some of those cells may then break through the basement membrane and invade the dermis; from there, they may enter lymphatic or blood vessels and spread to other parts of the body. The ability of cancer cells to metastasize requires an accumulation of mutations that enables the cells to detach from similar cells, recognize and digest the basement membrane, and become established elsewhere when surrounded by different cell types.

Basal cell carcinomas very rarely metastasize, and only 2–6% of squamous cell carcinomas metastasize. Compared with keratinocytes, melanocytes are more likely to give rise to tumors that metastasize because, in their developmental past, they had the ability to migrate and become established in new locations. In the embryo, melanocytes are derived from a population of cells called neural crest cells (see chapter 13). A gene called *Slug* regulates neural crest cell migration. In normal melanocytes, the *Slug* gene is inactive, but in metastasizing melanoma cells it is reactivated. The reactivation of embryonic genes, such as *Slug*, may also play a role in other metastasizing cancers.

Most skin cancers result from a series of genetic changes in somatic cells. Some people, however, have a genetic susceptibility to developing skin cancer. **Xeroderma pigmentosum** (zēr'ō-der'mă pig'men-tō'sŭm) is a rare, inherited disorder in which a DNA

(a) Basal cell carcinoma (b) Squamous cell carcinoma (c) Melanoma

FIGURE 5A Cancer of the Skin



MICROBES In Your Body | **Using Bacteria to Fight Bacteria**

Acne (acne vulgaris) is the most common skin condition in the United States. Though 80% of all American adolescents develop acne, adults can also be affected by it. When considering all age groups, approximately 40 to 50 million Americans suffer from acne. Unfortunately, there is not a tried-and-true cure for acne; however, new research examining the skin microbiome may have found a natural and effective treatment to get healthy, clear skin.

Unique species of bacteria, *Propionibacterium acnes (P. acnes)*, are found in sebum-rich areas of the skin, such as the forehead, side of the nose, and back. There, these bacteria feed on lipids found in sebum. Although it has been difficult to study these bacteria, the inception of the Human Microbiome Project (see "Getting to Know Your Bacteria" in chapter 1) allowed scientists to determine specific genetic traits of skin microbiome bacteria. Using this technique, scientists have identified three unique strains of *P. acnes*. Of the three strains, one is more dominant in people with acne-free skin. Research has shown that this strain of *P. acnes* does not adversely affect the host. However, the other two strains *P. acnes* are pathogenic to humans. So how does this information help scientists learn how to prevent acne? It seems that the "good" *P. acnes* prevents invasion of the skin by certain bacteria through a natural metabolic process. When *P. acnes* breaks down lipids, the skin pH is lowered to a level not tolerated by the invading bacteria. Scientists have proposed that the strain of *P. acnes* in healthy skin ("good" *P. acnes*) kills off the pathogenic strains of *P. acnes* ("bad" *P. acnes*) in a similar fashion. Since acne-affected people do not host the "good" strain, the "bad" strain can take over and cause the annoying skin eruptions of acne. Thus, perhaps in the future, to prevent acne, affected people can apply the "good" *P. acnes* or similar bacteria to their skin to prevent the "bad" *P. acnes* from taking over.

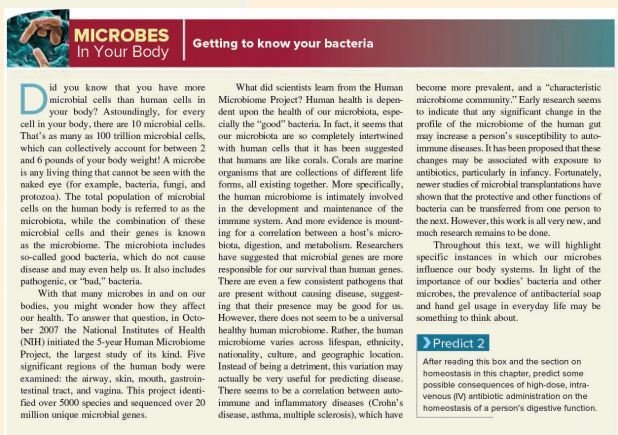
Predict 3

You just learned that acne-causing bacteria tend to live in areas of the skin with many sebaceous glands. However, in the section "Glands," it states that sebum protects against certain bacteria.

a. Based on what you've learned about bacteria in the "Microbes in Your Body" boxes in chapters 1 and 3, why do you think *P. acnes* are able to survive the antibacterial effects of sebum?

b. Why do you think certain acne medications are so effective simply by inhibiting sebum production?

◀ This feature helps students to understand the important role microbes play in helping various systems of the body to maintain homeostasis.



MICROBES In Your Body | **Getting to know your bacteria**

Did you know that you have more microbial cells than human cells in your body? Astoundingly, for every cell in your body, there are 10 microbial cells. That's as many as 100 trillion microbial cells, which can collectively account for between 2 and 6 pounds of your body weight! A microbe is any living thing that cannot be seen with the naked eye (for example, bacteria, fungi, and protozoa). The total population of microbial cells on the human body is referred to as the microbiota, while the combination of these microbial cells and their 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.

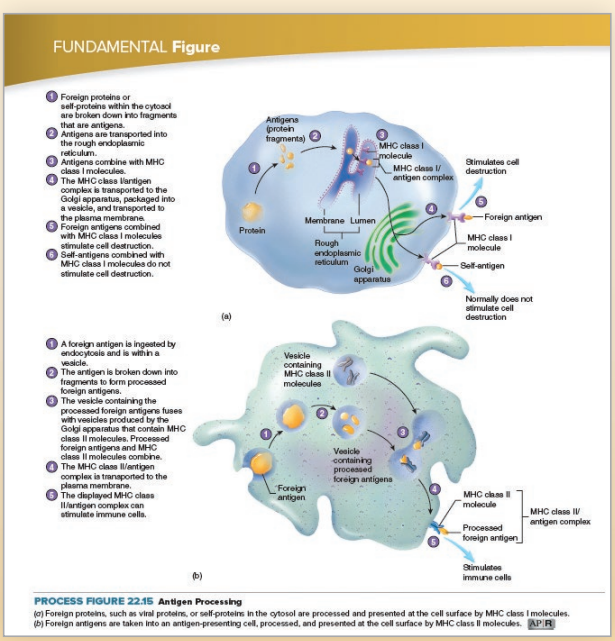
With that many microbes in and on our bodies, you might wonder how they affect our health. To answer that question, in October 2007 the National Institutes of Health (NIH) initiated the 5-year Human Microbiome Project, the largest study of its kind. Five significant regions of the human body were examined: 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. In fact, it seems that our microbiota are so completely intertwined with human cells that it has been suggested that humans are like corals. Corals are marine organisms that are collections of different life forms, all existing together. 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 lifespan, 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's 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 2

After reading this box and the section on homeostasis in this chapter, predict some possible consequences of high-dose, intravenous (IV) antibiotic administration on the homeostasis of a person's digestive function.



PROCESS FIGURE 22.15 Antigen Processing
(a) Foreign proteins, such as viral proteins, or self-proteins in the cytosol are processed and presented at the cell surface by MHC class I molecules. (b) Foreign antigens are taken into an antigen-presenting cell, processed, and presented at the cell surface by MHC class II molecules. APR

Fundamental Figures— *Integrated with special Connect® assets!*

- Special icons now link fundamental figures with corresponding modules within APR
- Additional online Connect® resources support these important figures
- Grouped together, the fundamental figures represent an excellent summary and study tool

Chapter-by-Chapter Changes

Chapter 1

- The "Learn to Predict" questions were separated from the vignette for clarity.
- Added a "Microbes in Your Body" boxed reading.
- Rewrote section on negative feedback for clarity and in response to heat map data and reviewer feedback.
- Added a predict question on negative feedback because it is a fundamental concept.
- Provided a clear example of the value of etymology and anatomical terminology to provide a point of reference for students to see the value of hard work.
- Revised figure 1.15 to add a photo of serous membranes to provide clarity.
- Revised figure 1.16 to add a photo of mesentery for clarity.

Chapter 2

- Major revision and expansion of the section on Electrons and Chemical Bonding. New text describes how electron shells and electronegativity underlie bond formation. A new figure (figure 2.4) illustrating this concept has been added. In addition, figure 2.6 and table 2.4 have been modified.
- Clinical impact on atomic particles has been shortened to focus on practical applications of X-rays.
- Synthesis and Decomposition Reactions were rewritten along with a simplification of figure 2.10 to focus on the key details of hydration and dehydration reactions.
- Reversible Reactions was rewritten and an analogy using a football team was added to clarify the concepts of reversible reactions and equilibrium.
- The properties of water were rewritten to emphasize the distinction between adhesion and cohesion and to emphasize the physiological functions of water in body temperature, protection, and as a mixing medium.
- Protein Structure section has been rewritten with a new summary paragraph added to highlight the key points of primary to quaternary structures. In addition, description of an enzyme active site has been rewritten and expanded to include how knowledge of the structure of an active site can be used to design drugs to treat diseases, such as Gleevec® for cancer treatment.

Chapter 3

- Added a "Microbes in Your Body" boxed reading.
- Added Clinical Impact box on Tays-Sachs disease.
- Added new section 3.11, Cellular Aspects of Aging.

Chapter 4

- Functions of epithelial tissues have been rewritten to emphasize dual role of the epithelium as a barrier while also permitting passage of molecules, along with improved labeling of epithelial tissues showing lateral surfaces in figure 4.1.
- Cells of Connective Tissue has been rewritten to better distinguish the cells involved in matrix formation, maintenance, remodeling.
- Structure and function of components of the extracellular matrix have been clarified, especially ground substance, reticular fibers, and proteoglycans. In addition, terminology has been made consistent (intercellular matrix changed to extracellular matrix in table 4.7).
- Clarification of the concept and functions of tissue membranes.

Chapter 5

- Added a "Microbes in Your Body" boxed reading.
- Converted Clinical Impact Burns to new section 5.6, Burns.

Chapter 6

- The "Learn to Predict" questions were separated from the vignette for clarity.
- Added a "Microbes in Your Body" boxed reading.
- Provided hierarchical organization reminders and referenced previous chapters where helpful (e.g., section 6.2 referred to chapter 1 to remind students of cellular development).
- Topic sentences added to many paragraphs to help students focus on concepts.
- Added a new predict question to section 6.3 where previously there was none.
- Reorganized section on spongy and compact bone for clarity.

- Added Vitamin D_3 as a calcium homeostasis hormone to section 6.9.
- Revised and updated the Systems Pathology boxed reading, "Osteoporosis" to include new thoughts and research on proton pump inhibitors and new medications.

Chapter 7

- The "Learn to Predict" questions were separated from the vignette for clarity.
- Changed the primary term from "coxal" to "hip" to reflect the more widely accepted and used term.
- Added an x-ray of a normal spine for clarity to the Clinical Impact "Abnormal Spinal Curvatures."
- Revised Clinical Impact boxed reading "Herniated Intervertebral Disk." Added an MRI image of fused cervical vertebrae.
- Revised the Clinical Impact boxed reading "Carpal Tunnel Syndrome" to add a clearer image of the median nerve passage. Also, information was revised to reflect the most up-to-date information as to causes of the syndrome.
- Throughout, revised skeletal art for clarity and to increase the realism to help students more readily apply the text information to actual skulls and other anatomical models.

Chapter 8

- Fibrous joint revisions include addition of realignment of teeth by braces as an example of type of movement allowed by gomphoses fibrous joint.
- Cartilaginous joint revisions include adding the importance of intervertebral disks as shock absorbers between vertebrae.
- Synovial joint revisions were made to clarify the structure and function of the fibrous capsule, synovial membrane and synovial fluid. In addition, the definition of a meniscus as a type of articular disk has been clarified and the importance of articular disks in joint protection has been emphasized.
- Some types of movement have been clarified with new examples and updated. Circular movements have been exemplified by shaking of the head "no." Circumduction has been clarified as movement of the arm in an "arc" when throwing a baseball. Opposition has been updated to include all fingers, not just the little finger.
- A major revision of the Flexion and Extension section updated the definition of these movements from anatomical coordinates (coronal plane) to the more commonly accepted angle of the joint. In addition, the section now introduces hyperextension as extension beyond 180 degrees that can be either a normal movement (like looking up at the stars) or an abnormal movement that results in injury. A new figure 8.9 illustrates flexion, extension, and hyperextension of the elbow, knee, neck, and wrist.
- Major revision of the temporomandibular joint to update the current view of the steps involved in opening and motions of the jaw that allow chewing and grinding in mastication. In addition, the Clinical Impact on TMJ Disorders has been updated with new perspectives on therapies.
- Relevant information from several Clinical Impacts (shoulder, elbow, arch) has been moved into the text.
- Mechanisms that strengthen the hip joint have been emphasized.

Chapter 9

- Major reorganization of chapter outline. The sections were placed to fall in a more logical sequence. This reduced repetitious information.
- Used heat map to target areas of difficulty for students.
- Figure 9.3 was redrawn in a hierarchical organization so students can keep track of the relationships amongst fiber and muscle structures.
- The section on energy sources was completely revised and updated.
- Table 9.4 (formerly 9.3) was split into a process figure comparing resting and exercising muscles and a table specifying nutrients and products for each of the three main pathways for ATP production.
- The "Learn to Predict" questions were separated from the vignette for clarity.

Chapter 10

- Heat map data was utilized to identify sections in the chapter, which are difficult for students. These sections were edited for clarity.
- The "Learn to Predict" questions were separated from the vignette for clarity.
- Much of the terminology was clarified. For example, reminders about structures and their makeup were provided: tendons and ligaments, agonists and antagonists, fixators of prime movers, etc.
- Clarified examples of types of lever systems seen within the muscular system.
- Some figures had cadaver photos added (e.g., figure 10.7 and 10.21).
- Clarified the muscles classified as the rotator cuff.
- Clarified usage of movements at joints.
- Updated "coxal" to "hip."

Chapter 11

- The "Learn to Predict" questions were separated from the vignette for clarity.
- "Neuroglia" and "neuroglial" were changed to "glia" and "glial" to more accurately reflect the modern usage.
- Revised figure 11A for a more logical and clear layout.
- Some boxed readings were converted into chapter text to draw attention to this important information.
- Rewrote the analogy for the all-or-none principle of action potentials to be a more modern example for students to relate to.

- The boxed reading on abnormal membrane potentials was converted into regular text to highlight this material.
- The analogy for saltatory conduction of action potentials was rewritten to be more relatable to everyday life.

Chapter 12

- The Stretch Reflex section has been rewritten to match the Process Figure. Importantly, the section now begins with the readily recognized knee jerk reflex to describe the stretch reflex. The knee jerk had previously been a Clinical Impact.
- Reciprocal innervation has been rewritten to emphasize that it reinforces the withdrawal reflex by allowing the coordinated contraction of flexor muscles and relaxation of the opposing extensor muscles.
- Text was rewritten so that information on innervation and function was consistently introduced upfront for each nerve.
- Clinical Impacts were updated (Bionic Sensors), renamed to highlight the relevant disorder (Crutch Paralysis, Funny Bone), or integrated into the text (Carpal Tunnel Syndrome).

Chapter 13

- Development of the CNS now includes an expanded description of the notochord. In addition, the anatomical terms in table 13.2 are now matched to the text.
- Reticular formation role in arousal and awareness is now included.
- Hypothalamic functions have been clarified.
- Clinical Impact on traumatic brain injuries has been updated to include professional athletes and portions have been integrated into the text since this is an increasingly relevant pathology.
- The clinical importance of hemorrhagic bleeding has been emphasized by moving this information from a Clinical Impact into the main text in the Blood Supply to the Brain section.
- The clinical importance of the blood-brain barrier has been emphasized by inclusion of material previously in the Clinical Impact on Drugs and the Blood-Brain Barrier.

Chapter 14

- The section on Sensation has been revised with changes in Table 14.1. For example, the field sobriety test as an example of proprioception has been added.
- Likewise, the section on Sensory Receptors has similarly been revised.
- The section on Sensory Pathways, especially the Anterolateral System, has been revised to more closely follow the figures.
- Figures 14.8, 14.9, and 14.10 have been clarified by inclusion of numbers to more easily follow the sensory pathway. Figure 14.10 has been simplified by removing anatomical sections not included in the posterior spinocerebellar tract.
- Projection in the somatic sensory cortex has been rewritten and an example of knowing where to slap a mosquito has been added.
- Clinical Impact on ALS has been updated to include rates of progression of the disease, with the example of Stephen Hawking.

Chapter 15

- Improved accuracy of Neural Pathways for Olfaction.

Chapter 16

- Revised section 16.6, Functional Generalizations About the Autonomic Nervous System, to fully describe each generalization relative to the information presented in the chapter.

Chapter 17

- The "Learn to Predict" questions were separated from the vignette for clarity.
- Rewrote the analogy about the difference between the nervous system and the endocrine system using twitter as a delivery system.
- Table 17.2 was completely revised for clarity. New figures for hormone molecules replaced the previous figures. The table is also now more clearly laid out.
- Figure 17.5 was edited to show a portion of the blood stream and the relationship for Ca^{2+}-regulating hormone secretion.
- The boxed reading of agonists and antagonists was integrated into the chapter text to better highlight this information.

Chapter 18

- Used heat map to target areas of difficulty for students.
- Explanations were clarified and comparisons to everyday situations and structures were made to allow for greater understanding.
- Etymologies were given where helpful.
- The "Learn to Predict" questions were separated from the vignette for clarity.
- Clarified the explanation of releasing and inhibiting hormones.
- Revised figure 18.12 for consistency.
- Revised figure 18.7 for consistency.
- Added a "Microbes in Your Body" boxed reading.

Chapter 19

- Revised figure 19.1 clearly identifying buffy coat in centrifuged blood sample.
- Revised ABO Blood Group to better explain the nomenclature of antigens, antibodies, and blood types.

Chapter 20

- Added a "Microbes in Your Body" boxed reading.
- Updated Clinical Impact, Cardiopulmonary Resuscitation (CPR)
- Revised Cardiac Muscle description, comparing and contrasting structure of cardiac muscle cells to skeletal muscle cells
- Revised figure 20.12, providing a clear depiction of cardiac muscle cell anatomy
- Revised figure 20.14, adding information about muscle tension changes associated with stimulation in both cardiac muscle and skeletal muscle.
- Corrected the description of the dicrotic notch, adding information about the dicrotic wave.

Chapter 21

- Revised Capillary Exchange and Regulation of Interstitial Fluid Volume to more accurately and sequentially represent the factors affecting Net Filtration Pressure.
- Revised figure 21.36 to better represent fluid volume differences.
- Corrected descriptions of septic shock and blood poisoning in Clinical Impact, Circulatory Shock.

Chapter 22

- Added a "Microbes in Your Body" boxed reading.
- Updated figures 22.18, 22.21, and 22.25 to show plasma cells producing antibodies.
- Updated Clinical Impact, Acquired Immunodeficiency Syndrome.

Chapter 23

- Used heat map to target areas of difficulty for students.
- The "Learn to Predict" questions were separated from the vignette for clarity.
- The description of the anatomy in section 23.2 was heavily revised for clarity.
- Revised figure 23.13 to look more realistic.
- Heavily revised the section "Pleural Pressure" in section 23.3 for logical flow and clearer explanations.
- "Minute ventilation" was changed to "minute volume" to more accurately reflect the widely accepted term.
- Heavily revised section 23.5 for clarity.
- Heavily revised section 23. 6 for clarity.
- Figure 23.22 was revised for consistency.

Chapter 24

- Neural control of the muscularis and the enteric nervous system of the digestive tract have been clarified.
- Clinical Impact on Dental Caries has been integrated into the text.
- Mumps has been updated to include the efficacy of the measles/mumps/rubella (MMR) vaccination program.
- The Salivary Glands section has been revised and updated to emphasize the protective functions and de-emphasize the relatively minor digestive functions of saliva.
- Lipid emulsification has been rewritten to emphasize the role of bile.

Chapter 25

- Updated nutrition label information to represent newest FDA recommendations
- Revised anaerobic respiration description to better explain lactate production

Chapter 26

- The "Learn to Predict" questions were separated from the vignette for clarity.
- Revised section 26.1 for clarity.
- Heavily revised section 26.2 for a more clear and simple explanation of the relationship amongst these structures.
- Added a clear definition of a countercurrent mechanism to section 26.3.
- Revised the explanation of ADH secretion for clarity.
- The boxed reading on urine concentration was integrated into the chapter text for clarity.
- Added a "Microbes in Your Body" boxed reading.
- The Clinical Impact boxed reading on Urinary Bladder Control was rewritten for improved understanding.
- The Clinical Impact boxed reading on Polycystic Kidney Disease was revised to become a Clinical Genetics boxed reading.

Chapter 27

- The "Learn to Predict" questions were separated from the vignette for clarity.
- Figure 27.3 was revised for consistency.
- Figure 27.4 was revised for consistency.
- Section 27.3 introduction was rewritten to help students relate to knowledge they had learned in previous chapters.
- Figure 27.8 was revised for consistency.
- Figure 27.9 was revised for consistency.
- Figure 27.10 was revised for consistency.
- Figure 27.12 was revised for consistency.
- The Clinical Impact boxed reading Acidosis and Alkalosis was integrated into the chapter text to highlight this important information.

Chapter 28

- Added a "Microbes in Your Body" boxed reading.
- Added new Section 28.2, Meiosis.
- Clearly define menstrual, ovarian, and uterine cycle.

Chapter 29

- Updated Clinical Impact, Fetal Monitoring, to include new cell-free fetal DNA testing for chromosomal abnormalities.
- Updated Clinical Genetics, The Human Genome Project.

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.

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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.

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 this data, we were able to hone not only our text content but also the LearnSmart probes.

Cinnamon VanPutte
Jennifer Regan
Andy Russo

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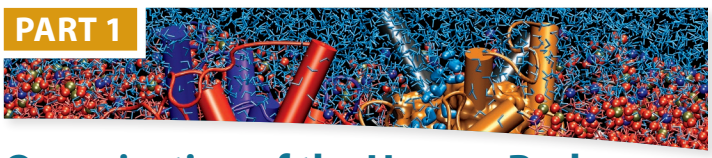
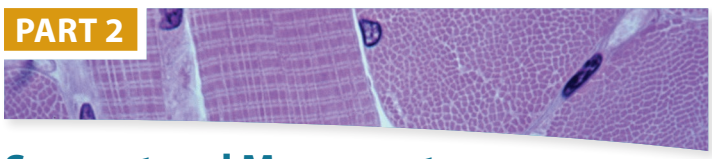


Organization of the Human Body



Support and Movement

1

The Human Organism

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") response to eating the energy bar is a good example of how important this system of checks and balances is in the body. Perhaps you have had a similar experience, but with a different outcome. You have overslept, rushed to your 8 a.m. class, and missed breakfast. Afterwards, on the way to Anatomy & Physiology class, you bought an energy bar from the vending machine. Eating the energy bar helped you feel better. The explanation for these experiences is the process of homeostasis; for you, homeostasis was maintained, but for Renzo, there was a disruption in homeostasis. Throughout this book, 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. Knowing human anatomy and physiology is also the basis for understanding disease. The study of human anatomy and physiology is 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.

Learn to Predict

Renzo, the dancer in the photo, is perfectly balanced, yet a slight movement in any direction would cause 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 suffering from a blood sugar disorder. Earlier, just before this photo was taken, he'd eaten an energy bar. As an energy bar is digested, blood sugar rises. Normally, tiny collections of cells embedded in the pancreas respond to the rise in blood sugar by secreting the chemical insulin. Insulin increases the movement of sugar from the blood into his cells. However, Renzo did not feel satisfied from his energy bar. He felt dizzy and was still hungry, all symptoms he worried could be due to a family history of diabetes. Fortunately, the on-site trainer tested his blood sugar and noted that it was much higher than normal. After a visit to his regular physician, Renzo was outfitted with an insulin pump, and his blood sugar levels are now more consistent.

After reading about homeostasis in this chapter, create an explanation for Renzo's blood sugar levels before and after his visit to the doctor.

1.1 Anatomy and Physiology

LEARNING OUTCOMES

After reading this section, you should be able to

A. Define *anatomy* and describe the levels at which anatomy can be studied.

B. Define *physiology* and describe the levels at which physiology can be studied.

C. Explain the importance of the relationship between structure and function.

Anatomy is the scientific discipline that investigates the body's structures—for example, the shape and size of bones. In addition, anatomy examines the relationship between the structure of a body part and its function. Thus, the fact that bone cells are surrounded by a hard, mineralized substance enables the bones to provide strength and support. 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-brē-ol′ō-jē), a subspecialty of developmental anatomy, considers changes from conception to the end of the eighth week of development.

Some structures, such as cells, are so small that they must be studied using a microscope. **Cytology** (sī-tol′ō-jē; *cyto,* cell) examines the structural features of cells, and **histology** (his-tol′ō-jē; *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 most 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 parts of 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. Some scientists estimate that the past 20 years have seen as much progress in clinical medicine as occurred in all of medicine's previous history. Anatomical imaging has made a major contribution to that progress. Anatomical imaging allows medical personnel to look inside the body with amazing accuracy and without the trauma and risk of exploratory surgery. Although most of the technology used in anatomical imaging is very new, the concept and earliest technology are quite old. In 1895, Wilhelm Roentgen (1845–1923) became the first medical scientist to use **x-rays** to see inside the body. The rays were called x-rays because no one knew what they were. Whenever the human body is exposed to x-rays, ultrasound, electromagnetic fields, or radioactively labeled substances, a potential risk exists. This risk must be weighed against the medical benefit. Numerous studies have been conducted and are still being done to determine the effects of diagnostic and therapeutic exposure to x-rays. The risk of anatomical imaging is minimized by using the lowest possible 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. The major goals when studying human physiology are to understand and predict the body's responses to stimuli and to understand how the body maintains conditions within a narrow range of values in a constantly changing environment.

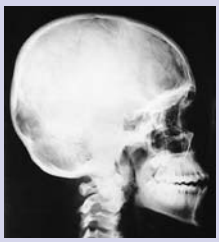
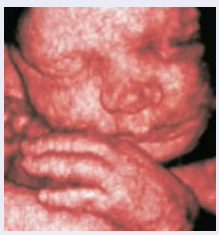
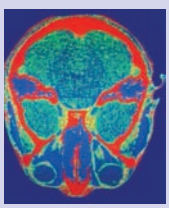
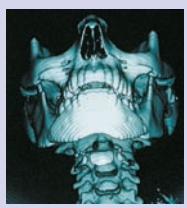
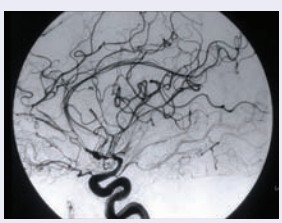
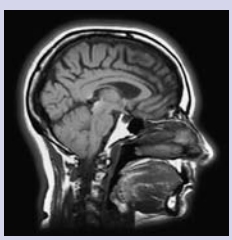
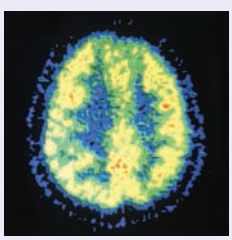
Like anatomy, physiology can be considered at many levels. **Cell physiology** examines the processes occurring in cells, and **systemic physiology** considers the functions of organ systems. **Neurophysiology** focuses on the nervous system, and **cardiovascular physiology** deals with the heart and blood vessels. Physiology often examines systems rather than regions because a particular function can involve portions of a system in more than one region.

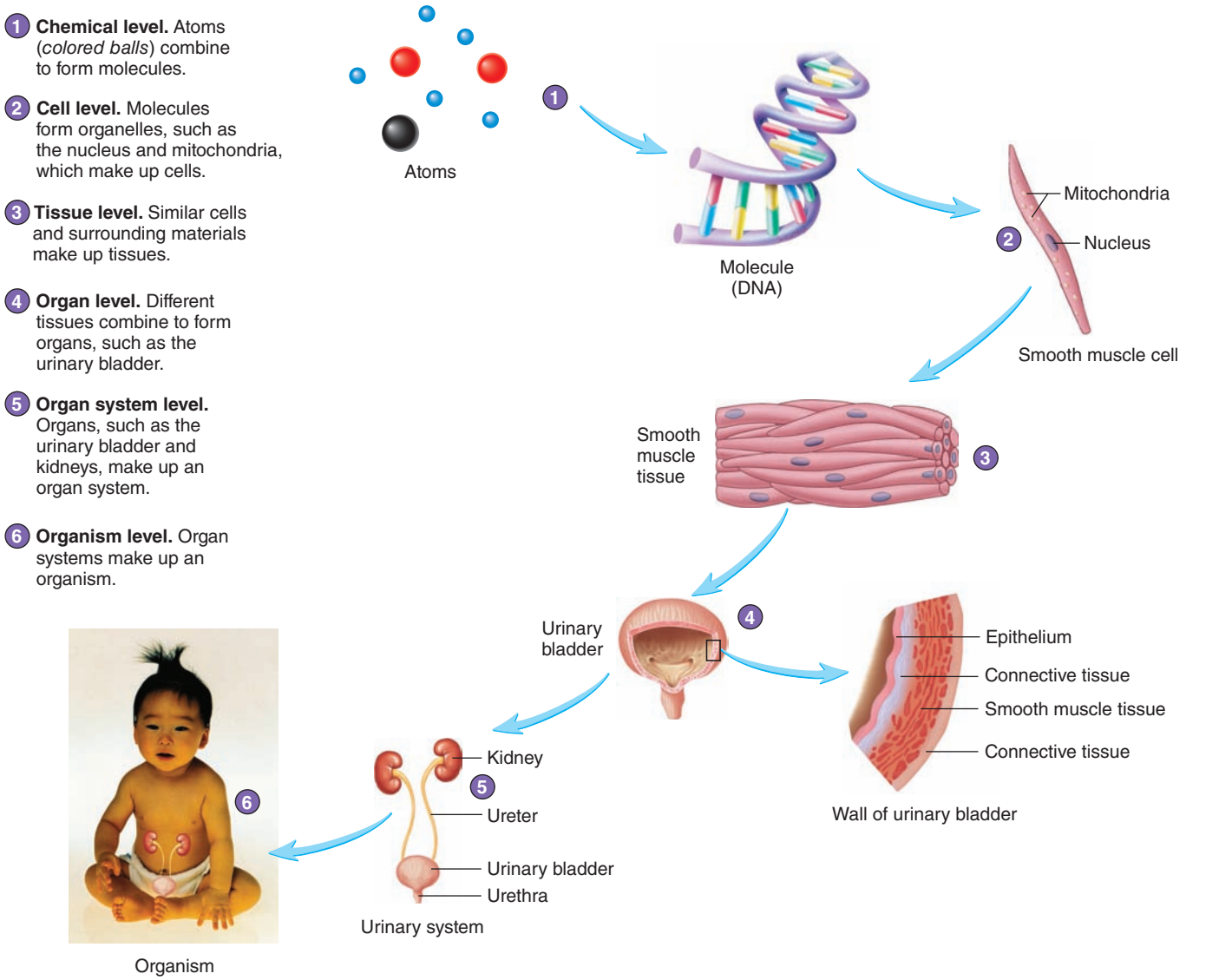
Studies of the human body must encompass both anatomy and physiology because structures, functions, and processes are interwoven. **Pathology** (pa-thol′ō-jē) is the medical science dealing with all aspects of disease, with an emphasis on the cause and development of abnormal conditions, as well as the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

ASSESS YOUR PROGRESS

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?*

TABLE 1.1 Anatomical Imaging

Imaging Technique	Image	Clinical Examples
X-ray		This extremely shortwave electromagnetic radiation (see chapter 2) moves through the body, exposing a photographic plate to form a **radiograph** (rā′dē-ō-graf). Bones and radiopaque dyes absorb the rays and create underexposed areas that appear white on the photographic film. Many of us have had an X-ray, either to visualize a broken bone or at the dentist. However, a major limitation of radiographs is that they give only flat, two-dimensional (2-D) images of the body.
Ultrasound		**Ultrasound,** the second oldest imaging technique, was first developed in the early 1950s from World War II sonar technology. It uses high-frequency sound waves, which are emitted from a transmitter-receiver placed on the skin over the area to be scanned. The sound waves strike internal organs and bounce back to a receiver on the skin. Even though the basic technology is fairly old, The most important advances in this field occurred only after it became possible to analyze the reflected sound waves by when a computer could be used to analyze the pattern of reflected sound waves and transfer. Once a computer analyzes the pattern of sound waves, the information is transferred to a monitor to be visualized as a **sonogram** (son′ō-gram) image. One of the more recent advances in ultrasound technology is the ability of more advanced computers to analyze changes in position through "real-time" movements. Among other medical applications, ultrasound is commonly used to evaluate the condition of the fetus during pregnancy.
Computed Tomography (CT)	 (a)  (b)	**Computed tomographic** (tō′mō-graf′ik) **(CT) scans,** developed in 1972 and originally called computerized axial tomographic (CAT) scans, are computer-analyzed x-ray images. A low-intensity x-ray tube is rotated through a 360-degree arc around the patient, and the images are fed into a computer. The computer then constructs the image of a "slice" through the body at the point where the x-ray beam was focused and rotated (*a*). Some computers are able to take several scans short distances apart and stack the slices to produce a 3-D image of a body part (*b*).
Digital Subtraction Angiography (DSA)		**Digital subtraction angiography** (an-jē-og′ră-fē) **(DSA)** is one step beyond CT scanning. A 3-D radiographic image of an organ, such as the brain, is made and stored in a computer. Then a radiopaque dye is injected into the blood, and a second radiographic computer image is made. The first image is subtracted from the second one, greatly enhancing the differences revealed by the injected dye. These dynamic computer images are the most common way angioplasty, is performed. Angioplasty uses a tiny balloon to unclog an artery.
Magnetic Resonance Imaging (MRI)		**Magnetic resonance imaging (MRI)** directs radio waves at a person lying inside a large electromagnetic field. The magnetic field causes the protons of various atoms to align (see chapter 2). Because of the large amounts of water in the body, the alignment of hydrogen atom protons is most important in this imaging system. Radio waves of certain frequencies, which change the alignment of the hydrogen atoms, then are directed at the patient. When the radio waves are turned off, the hydrogen atoms realign in accordance with the magnetic field. The time it takes the hydrogen atoms to realign is different for various body tissues. These differences can be analyzed by computer to produce very clear sections through the body. The technique is also very sensitive in detecting some forms of cancer far more readily than can a CT scan.
Positron Emission Tomography (PET)		**Positron emission tomographic (PET) scans** can identify the metabolic states of various tissues. This technique is particularly useful in analyzing the brain. When cells are active, they are using energy The energy they need is supplied by the break down of glucose (blood sugar). If radioactively treated ("labeled") glucose is given to a patient, the active cells take up the labeled glucose. As the radioactivity in the glucose decays, positively charged subatomic particles called positrons are emitted. When the positrons collide with electrons, the two particles annihilate each other and gamma rays are given off. The gamma rays can be detected, pinpointing the cells that are metabolically active.



PROCESS FIGURE 1.1 **Levels of Organization for the Human Body**

1.2 Structural and Functional Organization of the Human Body

LEARNING OUTCOMES

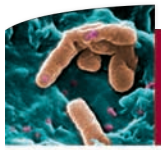
After reading this section, you should be able to

A. Name the six levels of organization of the body and describe the major characteristics of each level.

B. List the 11 organ systems, identify their components, and describe the major functions of each system.

The body can be studied at six levels of organization: the chemical, cell, tissue, organ, organ system, and whole organism levels (figure 1.1).

1. *Chemical level.* The chemical level involves interactions between atoms, which are tiny building blocks of matter. Atoms combine to form molecules, such as water, sugar, lipids, and proteins. The function of a molecule is intimately related to its structure. For example, collagen molecules are ropelike protein fibers that give skin structural strength and flexibility. With old age, the structure of collagen changes, and the skin becomes fragile and more easily torn. We present a brief overview of chemistry in chapter 2.
2. *Cell level.* **Cells** are the basic structural and functional units of plants and animals. Molecules combine to form **organelles** (or′gă-nelz; little organs), which are the small structures inside cells. For example, the nucleus is an organelle that contains the cell's hereditary information, and mitochondria are organelles that manufacture



MICROBES In Your Body

Getting to know your bacteria

Did you know that you have more microbial cells than human cells in your body? Astoundingly, for every cell in your body, there are 10 microbial cells. That's as many as 100 trillion microbial cells, which can collectively account for between 2 and 6 pounds of your body weight! A microbe is any living thing that cannot be seen with the naked eye (for example, bacteria, fungi, and protozoa). The total population of microbial cells on the human body is referred to as the microbiota, while the combination of these microbial cells and their 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, in October 2007 the National Institutes of Health (NIH) initiated the 5-year Human Microbiome Project, the largest study of its kind. 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. In fact, it seems that our microbiota are so completely intertwined with human cells that it has been suggested that humans are like corals. Corals are marine organisms that are collections of different life forms, all existing together. 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 lifespan, 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's 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 2

After reading this box and the section on homeostasis in this chapter, 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.* 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: epithelial, connective, muscle, and nervous. We discuss tissues in chapter 4.
4. *Organ level.* An **organ** is composed of two or more tissue types that perform one or more common functions. The urinary bladder, heart, stomach, and lung are examples of organs (figure 1.2).
5. *Organ system level.* 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, ureter, 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: the integumentary, skeletal, muscular, nervous, endocrine, cardiovascular, lymphatic, respiratory, digestive, urinary, and reproductive systems. Figure 1.3 presents a brief summary of these organ systems and their functions.
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 a network of organ systems, all mutually dependent on one another.

ASSESS YOUR PROGRESS

5. *From simplest to complex, list and define the body's six levels of organization.*
6. *What are the four basic types of tissues?*
7. *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?*

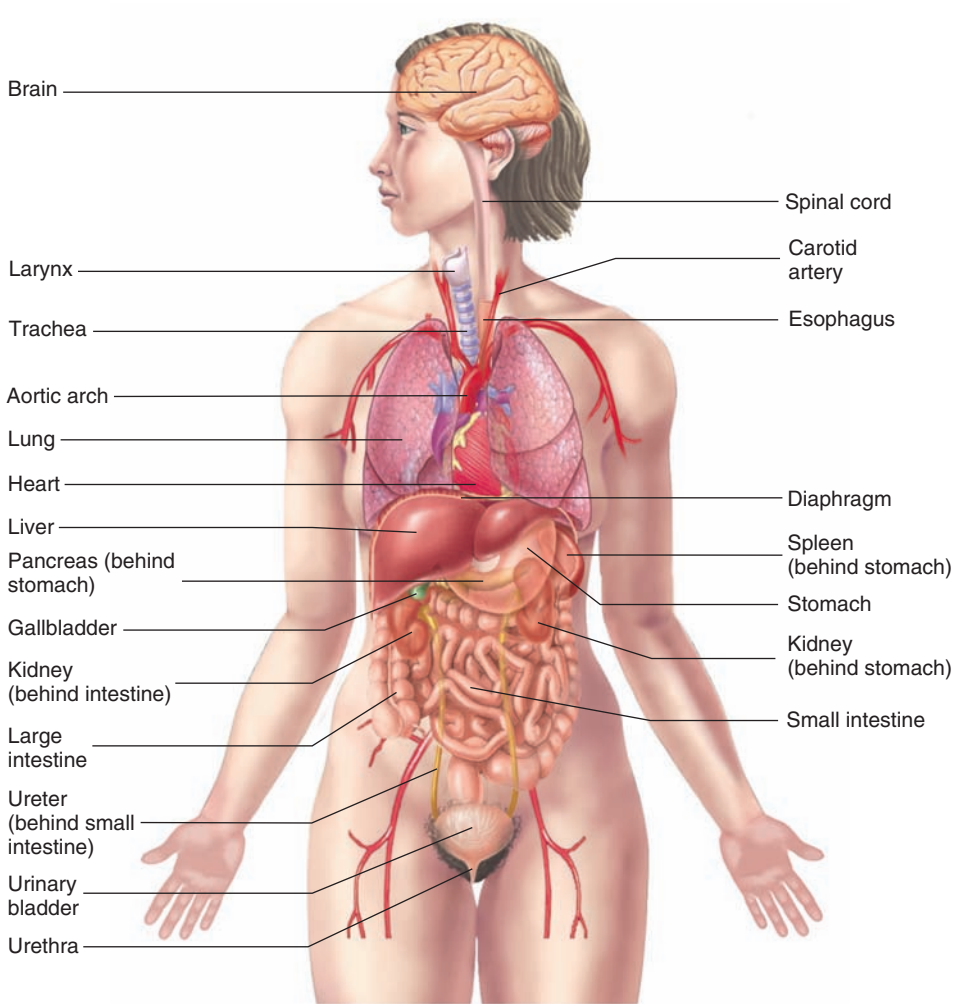


FIGURE 1.2 Major Organs of the Body AP|R

Predict 3

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.

1.3 Characteristics of Life

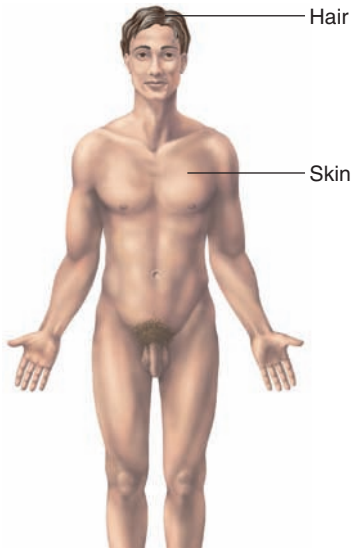
LEARNING OUTCOME

After reading this section, you should be able to

A. List and define the six characteristics of life.

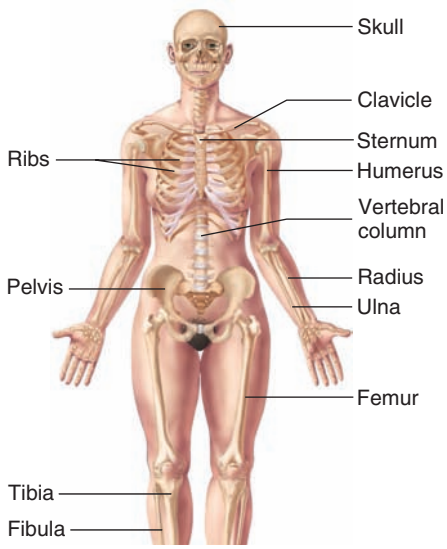
Humans are organisms, sharing characteristics with other organisms. The most important common feature of all organisms is life. This text recognizes six essential characteristics of life:

1. **Organization** refers to the specific interrelationships among the parts of an organism and how those parts interact to perform specific functions. Living things are highly organized. All organisms are composed of one or more cells. Some cells in turn are composed of highly specialized organelles, which depend on the precise organization of large molecules. Disruption of this organized state can result in loss of functions, or even death.
2. **Metabolism** (mĕ-tab′ō-lizm) refers to all of the chemical reactions taking place in the cells and internal environment of an organism. It includes an organism's ability to break down food molecules, which the organism uses as a source of energy and raw materials to synthesize its own molecules. Energy is also used when one part of a molecule moves relative to another part, changing the shape of the molecule. In single-celled organisms and certain human cells, this change in molecular shape can cause the whole cell to change shape. Sometimes this change in cell shape can allow the entire organism or cell to move to a different location. 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. Responses include actions such as moving toward



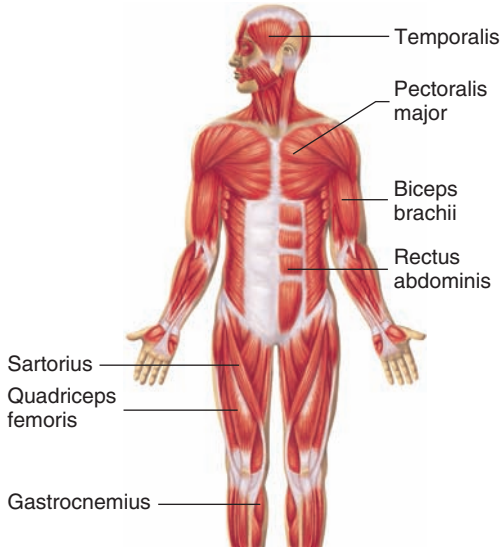
Integumentary System

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



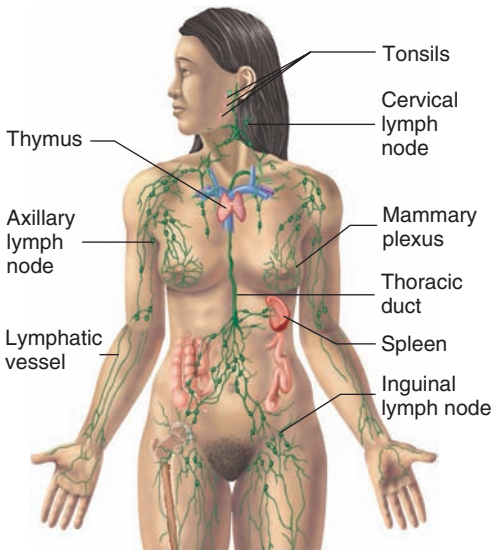
Skeletal System

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



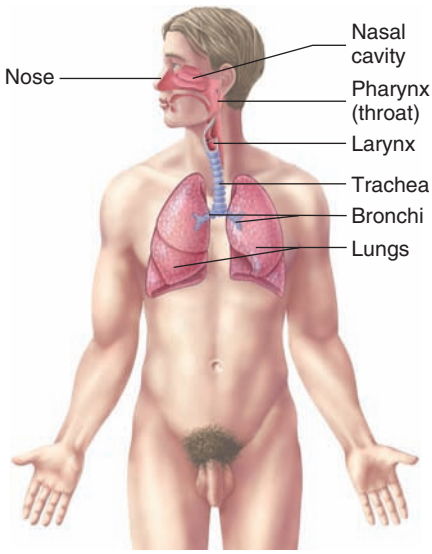
Muscular System

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



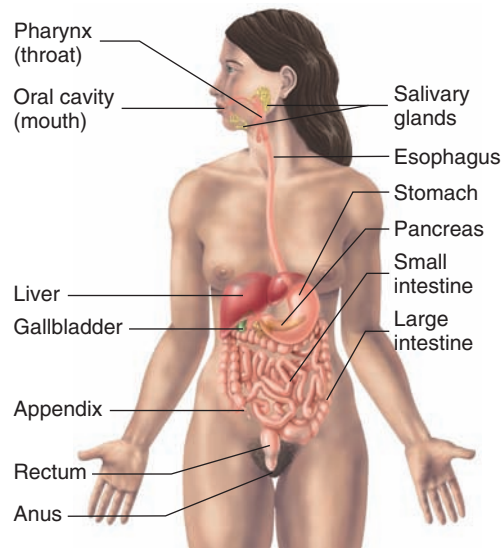
Lymphatic System

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.

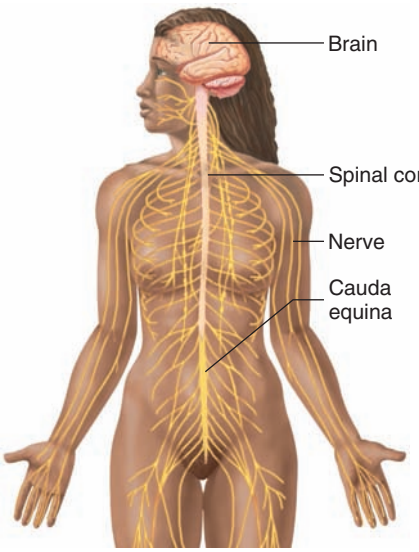


Digestive System

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.

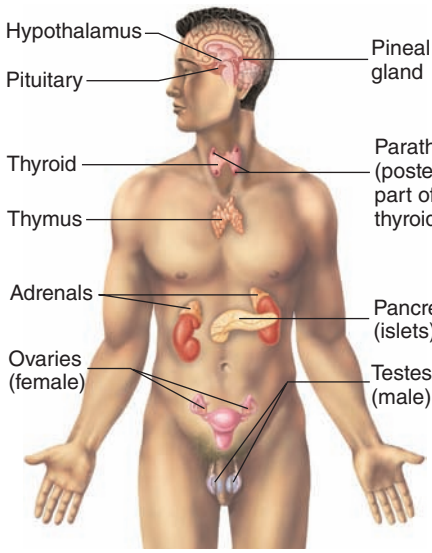
FIGURE 1.3 Organ Systems of the Body

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.



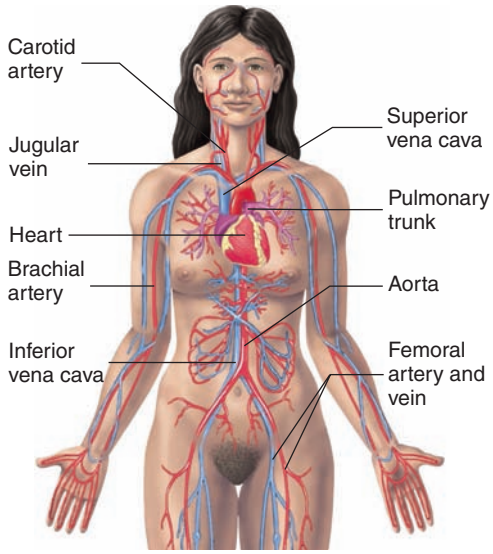
Nervous System

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.



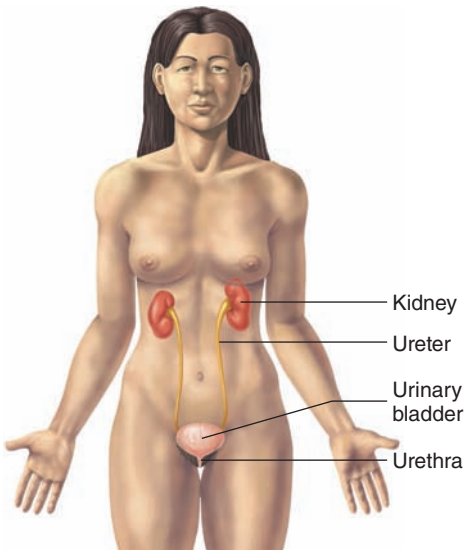
Endocrine System

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



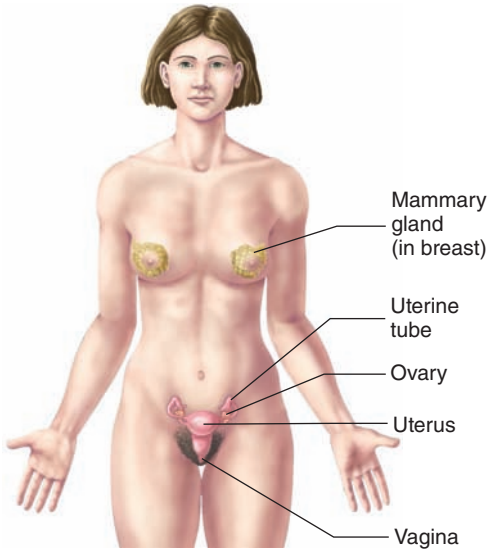
Cardiovascular System

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.



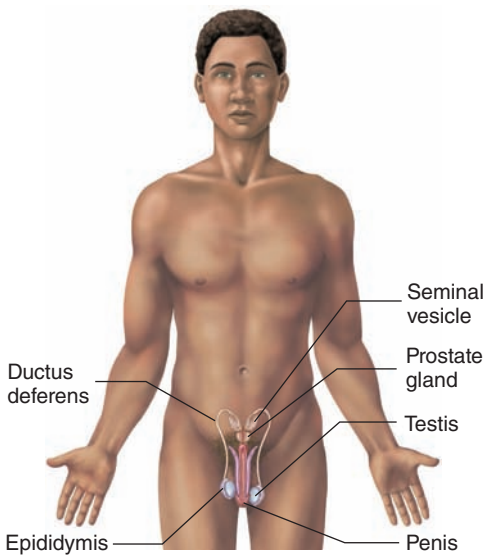
Urinary System

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)

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, bone grows because of an increase in cell number and the deposition of mineralized materials around the cells.
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** (mōr-fō-jen′ĕ-sis) is the change in shape of tissues, organs, and the entire organism.
6. **Reproduction** is the formation of new cells or new organisms. Without reproduction of cells, growth and development are not possible. Without reproduction of organisms, species become extinct.

ASSESS YOUR PROGRESS

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

9. *How does differentiation differ from morphogenesis?*

1.4 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.

Studying other organisms has increased our knowledge about humans because humans share many characteristics with other organisms. For example, studying single-celled bacteria provides much information about human cells. 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

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

1.5 Homeostasis

LEARNING OUTCOMES

After reading this section, you should be able to

A. Define *homeostasis* and explain why it is important for proper body function.

B. Describe a negative-feedback mechanism and give an example.

C. Describe a positive-feedback mechanism and give an example.

Homeostasis (hō′mē-ō-stā′sis) is the existence and maintenance of a relatively constant environment within the body. To achieve homeostasis, the body must actively regulate conditions that are constantly changing. As our bodies undergo their everyday processes, we are continuously exposed to new conditions. These conditions are called **variables** because their values can change. For example, a small amount of fluid surrounds each body cell; for cells to function normally, the volume, temperature, and chemical content of this fluid must be maintained within a narrow range.

One variable familiar to all of us is body temperature. Body temperature is a variable that can increase in a hot environment or decrease in a cold one. Homeostatic mechanisms, such as sweating or shivering, normally maintain body temperature near an ideal normal value, or **set point** (figure 1.4). Note that these mechanisms are not able to maintain body temperature *precisely* at the set point. Instead, body temperature increases and decreases slightly around the set point to produce a **normal range** of values. As long as body temperature remains within this normal range, homeostasis is maintained. Keep in mind that the fluctuations are minimal, however. Note in figure 1.4 that the normal body temperature range is no more than 1 degree Fahrenheit above or below normal. Our *average* body temperature is 98.6 degrees Fahrenheit.