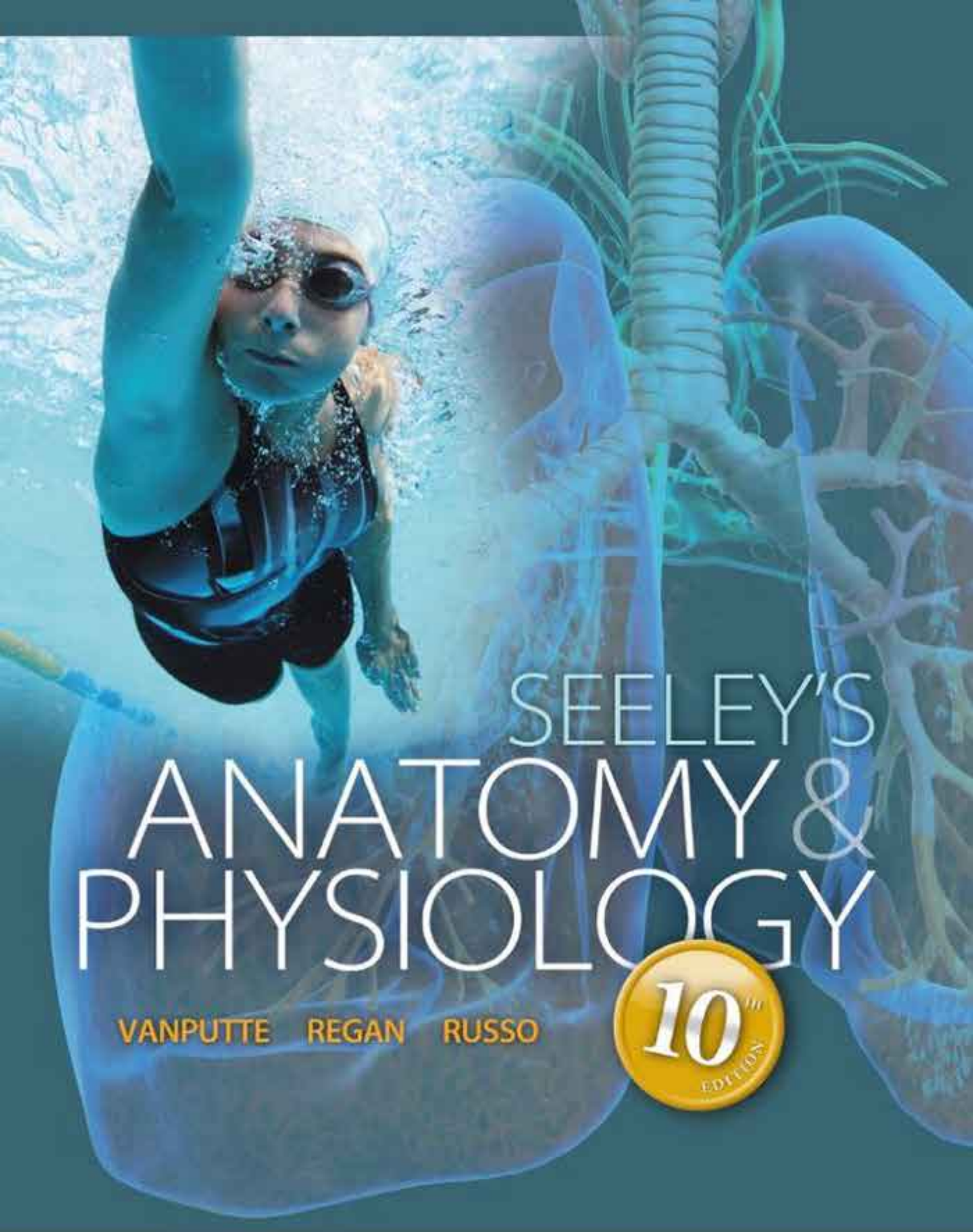

SEELEY'S
ANATOMY &
PHYSIOLOGY
VANPUTTE REGAN RUSSO
10TH EDITION

THE Seeley LEARNING SYSTEM

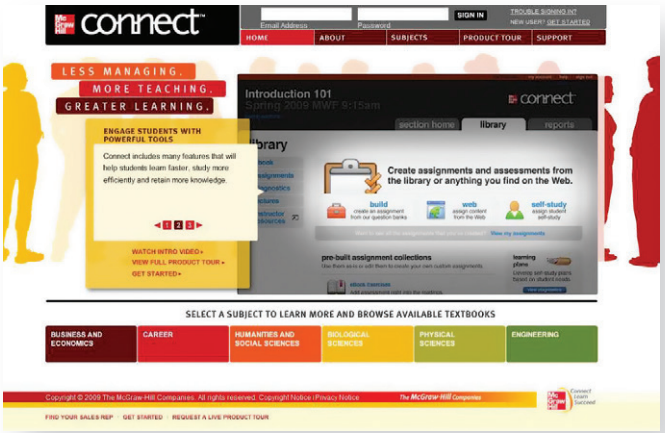
Teaching students HOW to think

connect® plus+

ANATOMY & PHYSIOLOGY

McGraw-Hill ConnectPlus® Anatomy & Physiology is an interactive learning platform that provides a customizable, assignable eBook, auto-graded assessments, an adaptive diagnostic tool, lecture capture, access to instructor resources, and powerful reporting—all in an easy-to-use interface.

Learn more at www.mcgrawhillconnect.com



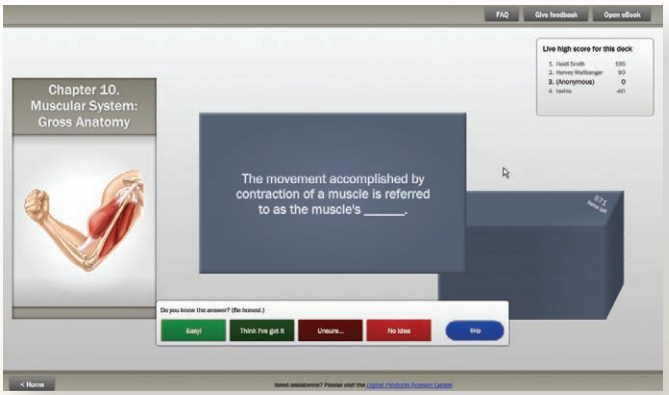
McGraw-Hill Higher Education and Blackboard® have teamed up!

What does this mean for you?

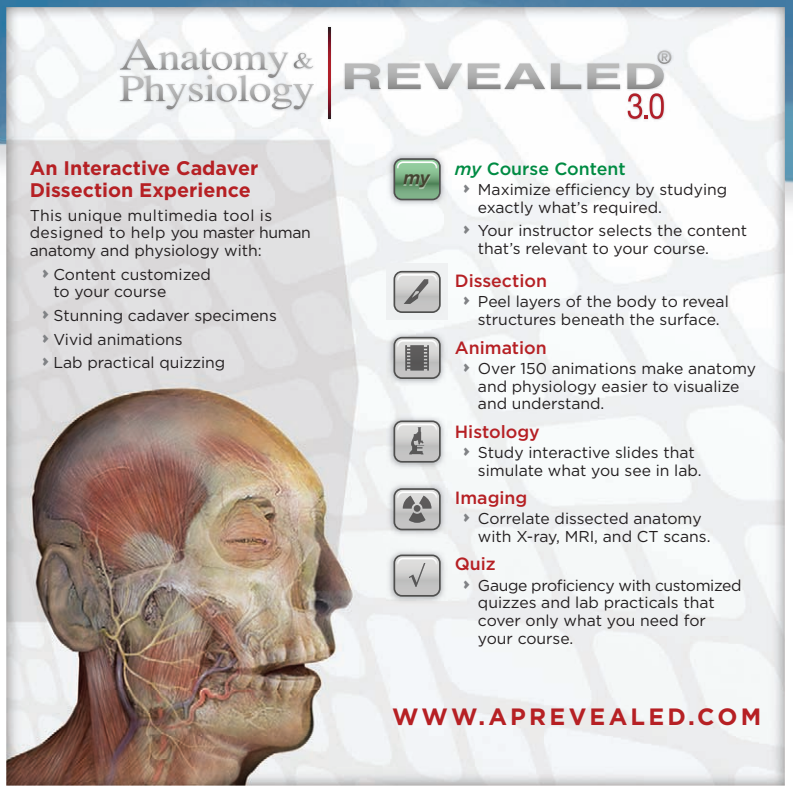
- **Life simplified.** Now, all McGraw-Hill content (text, tools, & homework) can be accessed directly from within your Blackboard course. All with one sign-on.
- **Deep integration.** McGraw-Hill's content and content engines are seamlessly woven within your Blackboard course.
- **No more manual synching!** Connect® assignments within Blackboard automatically (and instantly) feed grades directly to your Blackboard grade center. No more keeping track of two gradebooks!
- **A solution for everyone.** Even if your institution is not currently using Blackboard, we have a solution for you. Ask your McGraw-Hill representative for details.

Learn Fast. Learn Easy. Learn Smart.

McGraw-Hill LearnSmart™ is an adaptive diagnostic tool that constantly assesses student knowledge of course material. Sophisticated diagnostics adapt to each student's individual knowledge base, and vary the questions to determine what the student knows, doesn't know, knows but has forgotten, and how to best improve their knowledge level. Students actively learn required course concepts, and instructors can access specific LearnSmart reports to monitor progress. For more information, go to **www.mhlearnsmart.com**

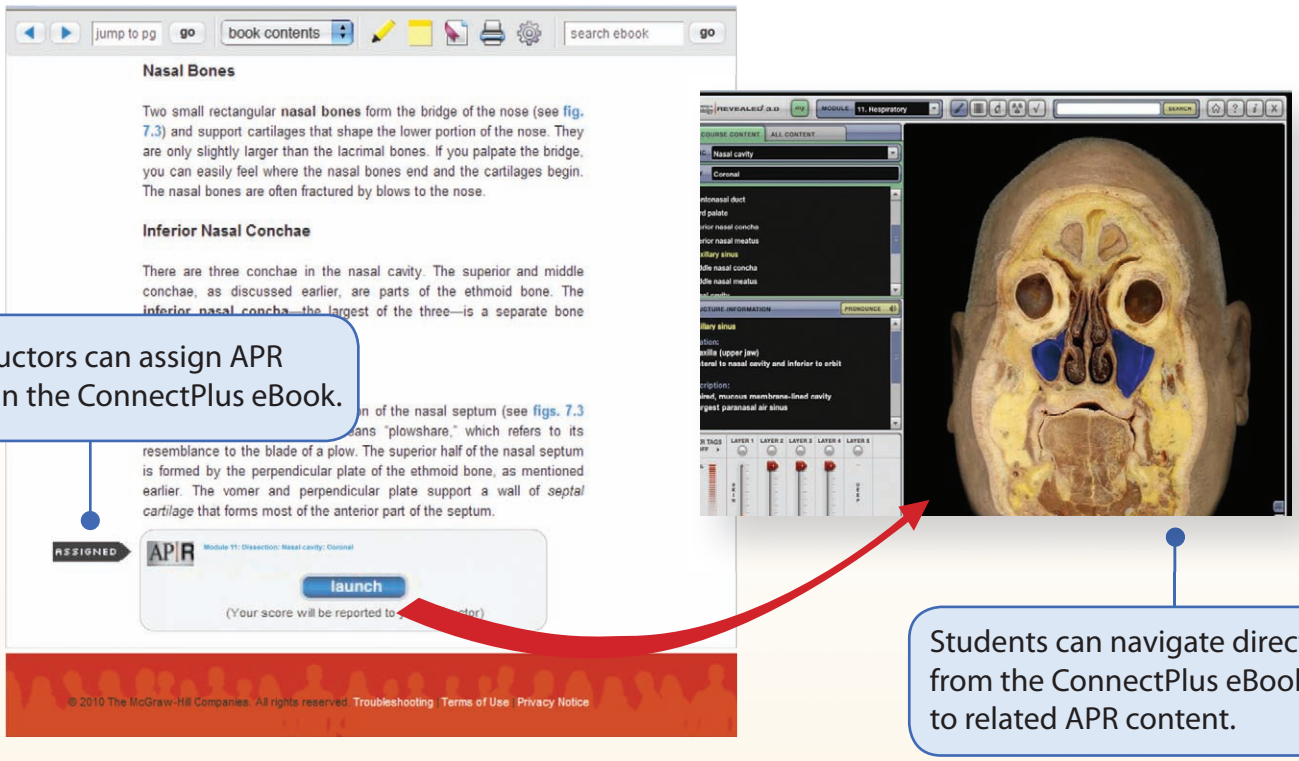


www.mhhe.com/seeley10

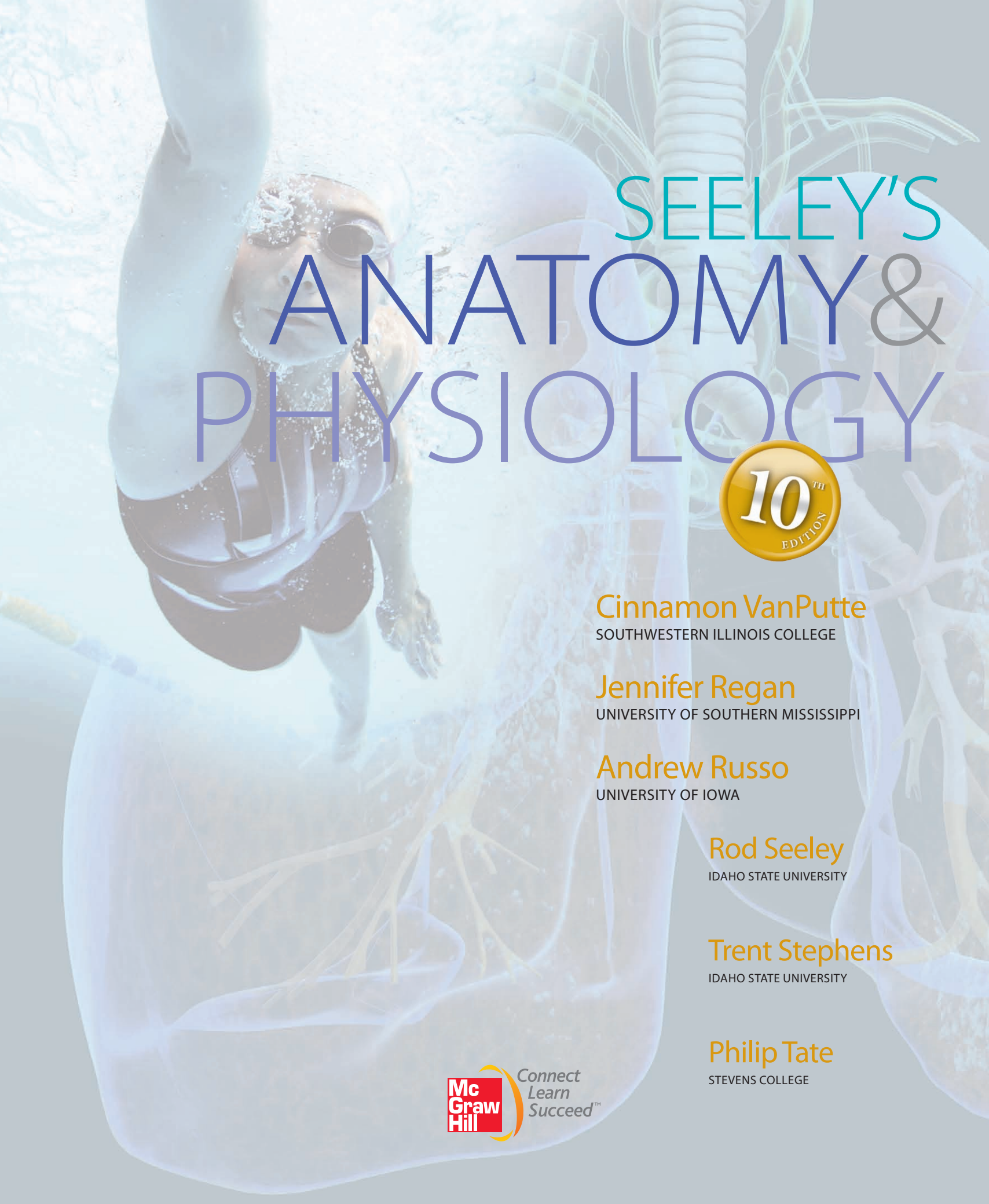


Full Textbook Integration! APR

Icons throughout the book indicate specific McGraw-Hill Anatomy & Physiology | REVEALED® content that corresponds to the text and figures.



Brief Contents



SEELEY'S ANATOMY & PHYSIOLOGY

10TH EDITION

Cinnamon VanPutte
SOUTHWESTERN ILLINOIS COLLEGE

Jennifer Regan
UNIVERSITY OF SOUTHERN MISSISSIPPI

Andrew Russo
UNIVERSITY OF IOWA

Rod Seeley
IDAHO STATE UNIVERSITY

Trent Stephens
IDAHO STATE UNIVERSITY

Philip Tate
STEVENS COLLEGE

Mc Graw Hill
Connect Learn Succeed™

SEELEY'S ANATOMY & PHYSIOLOGY, TENTH EDITION

This book is printed on acid-free paper.

1 2 3 4 5 6 7 8 9 0 QDB/QDB 1 0 9 8 7 6 5 4 3

ISBN 978–0–07–340363–2
MHID 0–07–340363–6

Senior Vice President, Products & Markets: *Kurt L. Strand*
Vice President, General Manager, Products & Markets: *Marty Lange*
Vice President, Content Production & Technology Services: *Kimberly Meriwether David*
Director of Development: *Rose Koos*
Managing Director: *Michael S. Hackett*
Director: *James F. Connely*
Developmental Editor: *Mandy C. Clark*
Senior Project Manager: *Jayne L. Klein*
Senior Buyer: *Laura Fuller*
Designer: *Tara McDermott*
Cover/Interior Design: *Elise Lansdon*
Cover Illustration: © *The McGraw-Hill Companies*
Cover Image: © *Koji Aoki/Corbis/RF*
Content Licensing Specialist: *John Leland*
Photo Research: *Jerry Marshall*
Senior Media Project Manager: *Tammy Juran*
Compositor: *ArtPlus Ltd.*
Typeface: *10/12 Minion*
Printer: *Quad/Graphics*

All credits appearing on page or at the end of the book are considered to be an extension of the copyright page.

Library of Congress Cataloging-in-Publication Data

Seeley, Rod R.
[Anatomy & physiology]
Seeley's anatomy & physiology. — 10th ed. / Rod Seeley, Cinnamon VanPutte, Jennifer Regan, Andrew Russo.
p. cm.
Includes index.
ISBN 978–0–07–340363–2 — ISBN 0–07–340363–6 (hard copy : alk. paper) 1. Human physiology. 2. Human anatomy.
I. VanPutte, Cinnamon L. II. Regan, Jennifer. III. Russo, Andrew. IV. Title. V. Title: Seeley's anatomy and physiology.
QP34.5.S4 2014
612–dc23

2012028548

www.mhhe.com

ABOUT THE **Authors**

Cinnamon L. VanPutte

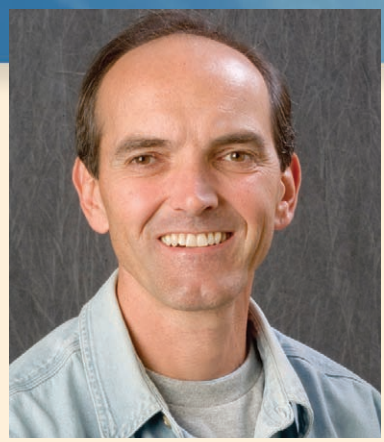
Associate Professor of Biology
Southwestern Illinois College

Cinnamon has been teaching biology and human anatomy and physiology for almost two decades. At Southwestern Illinois College she is a full-time faculty member and the coordinator for the anatomy and physiology courses. Cinnamon 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 *Seeley's Essentials of Human Anatomy & Physiology* epitomizes Cinnamon's passion for the field of human anatomy and physiology; she is committed to maintaining this tradition of excellence. Cinnamon and her husband, Robb, have two children: a daughter, Savannah, and a son, Ethan. Savannah is very creative and artistic; she loves to sing, write novels and do art projects. Robb and Ethan have their black belts in karate and Ethan is one of the youngest black belts at his martial arts school. Cinnamon is also active in martial arts and is a competitive Brazilian Jiu-Jitsu practitioner. She has competed at both the Pan Jiu-Jitsu Championship and the World Jiu-Jitsu Championship.

Jennifer L. Regan

Instructor
University of Southern Mississippi

For over ten 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

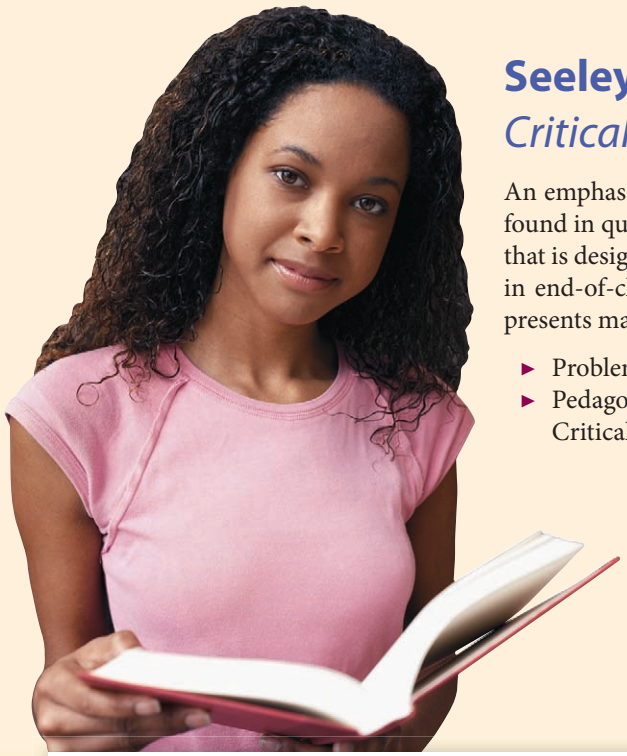
Andrew has over 20 years of classroom experience with human physiology, neurobiology, molecular biology, and cell biology courses at the University of Iowa. He is a recipient of the Collegiate Teaching Award and is currently the course director for Medical Cell Biology and Director of the Biosciences Graduate Program. He is also a member of several professional societies, including the American Physiological Society and 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 neurobiology of migraine. His decision to join the author team for *Seeley's Essentials of 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, now in college and graduate school. He enjoys all types of outdoor sports, especially bicycling, skiing, ultimate Frisbee and, before moving to Iowa, bodyboard surfing.

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.

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?

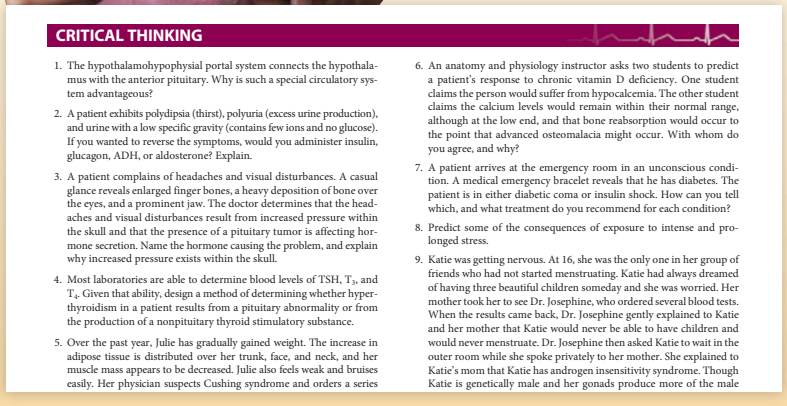


Seeley Learning System—*Emphasis on Critical Thinking*

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. The hypothalamohypophysial portal system connects the hypothalamus with the anterior pituitary. Why is such a special circulatory system advantageous?
2. A patient exhibits polydipsia (thirst), polyuria (excess urine production), and urine with a low specific gravity (contains few ions and no glucose). If you wanted to reverse the symptoms, would you administer insulin, glucagon, ADH, or aldosterone? Explain.
3. A patient complains of headaches and visual disturbances. A casual glance reveals enlarged finger bones, a heavy deposition of bone over the eyes, and a prominent jaw. The doctor determines that the headaches and visual disturbances result from increased pressure within the skull and that the presence of a pituitary tumor is affecting hormone secretion. Name the hormone causing the problem, and explain why increased pressure exists within the skull.
4. Most laboratories are able to determine blood levels of TSH, T_3, and T_4. Given that ability, design a method of determining whether hyperthyroidism in a patient results from a pituitary abnormality or from the production of a nonpituitary thyroid stimulatory substance.
5. Over the past year, Julie has gradually gained weight. The increase in adipose tissue is distributed over her trunk, face, and neck, and her muscle mass appears to be decreased. Julie also feels weak and bruises easily. Her physician suspects Cushing syndrome and orders a series
6. An anatomy and physiology instructor asks two students to predict a patient's response to chronic vitamin D deficiency. One student claims the person would suffer from hypocalcemia. The other student claims the calcium levels would remain within their normal range, although at the low end, and that bone reabsorption would occur to the point that advanced osteomalacia might occur. With whom do you agree, and why?
7. A patient arrives at the emergency room in an unconscious condition. A medical emergency bracelet reveals that he has diabetes. The patient is in either diabetic coma or insulin shock. How can you tell which, and what treatment do you recommend for each condition?
8. Predict some of the consequences of exposure to intense and prolonged stress.
9. Katie was getting nervous. At 16, she was the only one in her group of friends who had not started menstruating. Katie had always dreamed of having three beautiful children someday and she was worried. Her mother took her to see Dr. Josephine, who ordered several blood tests. When the results came back, Dr. Josephine gently explained to Katie and her mother that Katie would never be able to have children and would never menstruate. Dr. Josephine then asked Katie to wait in the outer room while she spoke privately to her mother. She explained to Katie's mom that Katie has androgen insensitivity syndrome. Though Katie is genetically male and her gonads produce more of the male

Predict 4

Explain the advantages of having elastic ligaments that extend from vertebra to vertebra in the vertebral column and why it would be a disadvantage if tendons, which connect skeletal muscles to bone, were elastic.

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 neuroglia 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-di'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 motor retardation, 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. In order for HIV to replicate, the viral RNA is used to make viral DNA, which is inserted into the host cell's DNA. The inserted viral DNA directs the production of new viral RNA and proteins, which are assembled to form new HIV. Key steps in the replication of HIV require viral enzymes. The enzyme **reverse transcriptase** promotes the formation of viral DNA from viral RNA, and **integrase** (in'te-grās) inserts the viral DNA into the host cell's DNA. A viral **protease** (prō'tē-ās) breaks large viral proteins into smaller proteins, which are incorporated into the new HIV.

Blocking the activity of HIV enzymes can inhibit the replication of HIV. The first effective treatment of AIDS was the drug azidothymidine (AZT; az'i-dō-thī'mi-dēn), also called zidovudine (zi-dō'voo-dēn). AZT is a **reverse transcriptase inhibitor,** which prevents HIV RNA from producing viral DNA. 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.

Protease inhibitors are drugs that interfere with viral proteases. The current treatment for suppressing HIV replication is **highly active antiretroviral therapy (HAART).** This therapy uses drugs from at least two classes of antivirals. Treatment may involve combining three drugs, such as two reverse transcriptase inhibitors and one protease inhibitor, because HIV is unlikely to develop resistance to all three drugs. This strategy has proven very effective in reducing the death rate from AIDS and partially restoring health in some individuals.

Still in the research stage are **integrase inhibitors,** which prevent the insertion of viral DNA into the host cell's DNA. Another advance in AIDS treatment is a test for measuring **viral load,** which measures the number of viral RNA molecules in a milliliter of blood. The actual level of HIV is one-half the RNA count because each HIV has two RNA strands. Viral load is a good predictor of how soon a person will develop AIDS. If viral load is high, the onset of AIDS is likely to occur sooner than if the viral load is low. It is also possible to detect developing viral resistance by an increase in viral load. In response, a change in drug dose or type may slow viral replication. Current treatment goals are to keep viral load below 500 RNA molecules per milliliter of blood.

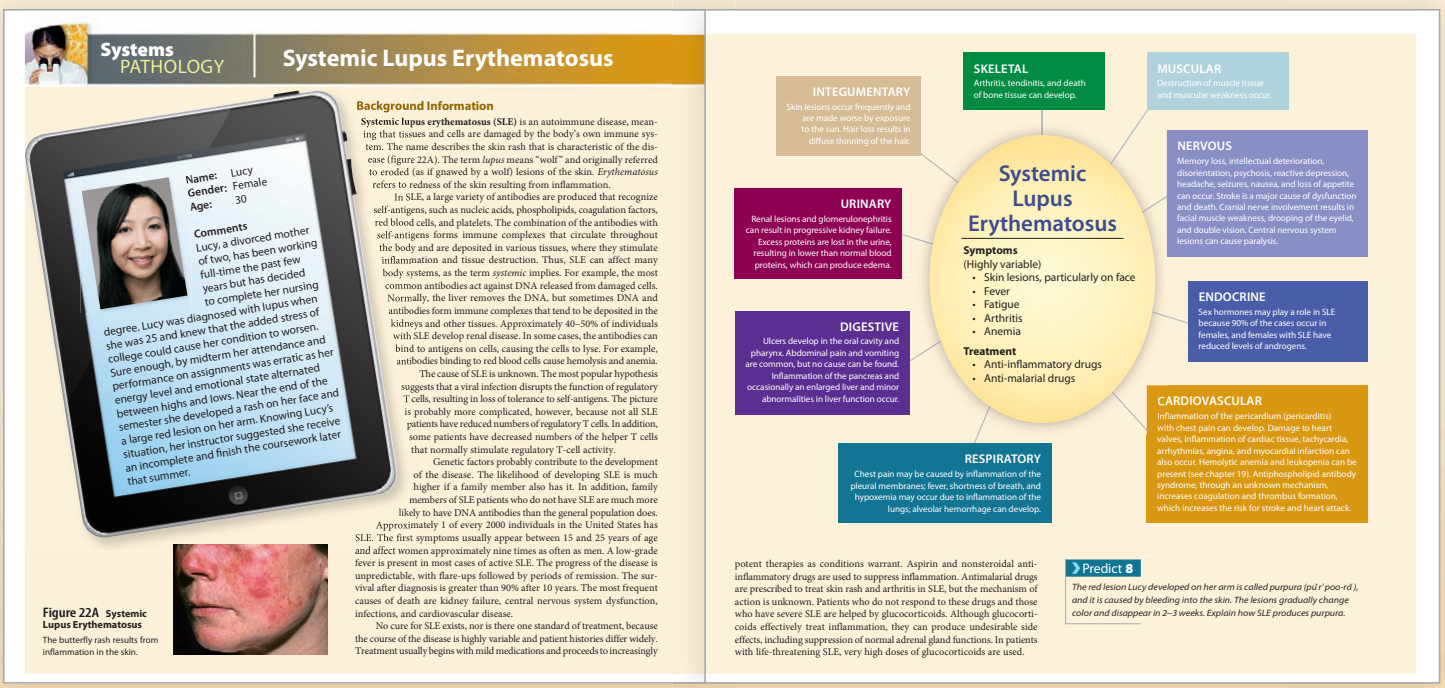
Effective treatment for AIDS is not the same as a cure. Even if viral load decreases to the point that the virus is undetected in the blood, the virus still remains in cells throughout the body. The virus may eventually mutate and escape drug suppression. The long-term goal for deterring AIDS is to develop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

- **NEW!** Chapter opening photos and scenarios have been correlated to provide a more complete story and begin critical thinking from the start of the chapter
- **UPDATED!** 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
- **UPDATED!** Clinical Genetics essays have been updated and streamlined for accuracy and impact
- **UPDATED!** Diseases and Disorders tables
- **UPDATED!** 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 was 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.

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
- Anti-malarial drugs

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.

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.

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

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 8
The red lesion Lucy developed on her arm is called purpura (pu'r'poo-rd), 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:

- **UPDATED!** Fundamental Figures teamed with special online support and now linked to APR
- **UPDATED!** 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
- **NEW!** 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
- **NEW!** Color saturation of art makes the art more engaging
- Macro-to-micro art

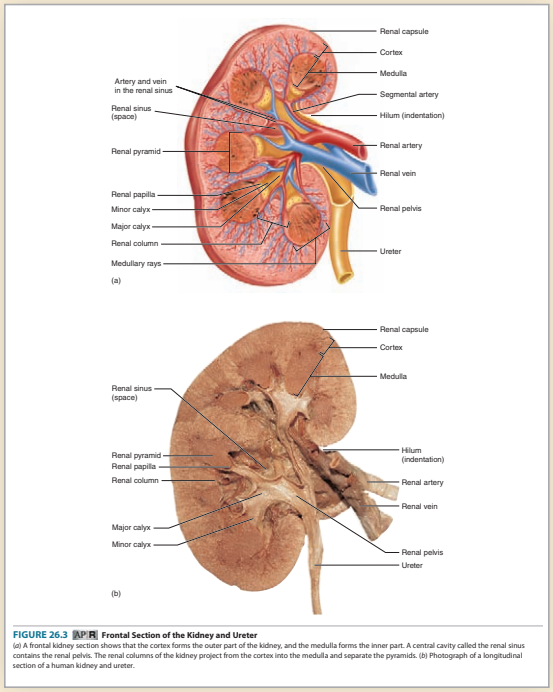


FIGURE 26.3 APR **Frontal Section of the Kidney and Ureter**
(a) A frontal kidney section shows that the cortex forms the outer part of the kidney, and the medulla forms the inner part. A central cavity called the renal sinus contains the renal pelvis. The renal columns of the kidney project from the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

FUNDAMENTAL **Figure**

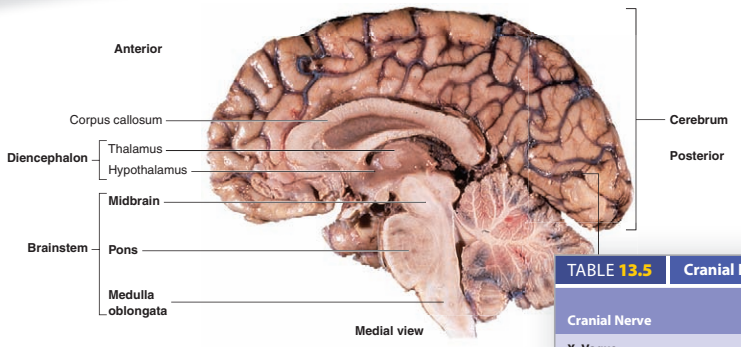
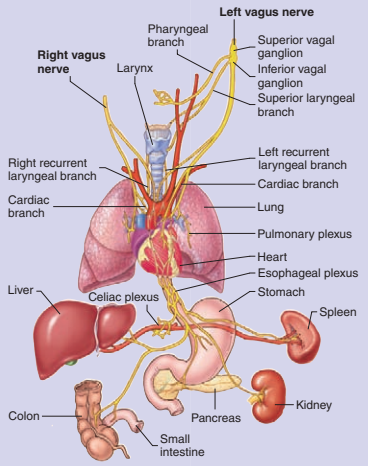


FIGURE 13.1 APR **Regions of the Brain**
Medial view of a mid-saggital section of the right half of the brain.

TABLE **13.5** **Cranial Nerves and Their Functions—Continued**

Cranial Nerve	Foramen or Fissure*	Function	Consequences of Lesions to Nerve
X. Vagus	Jugular foramen	Sensory, motor,† and parasympathetic Sensory from inferior pharynx, larynx, thoracic and abdominal organs; sense of taste from posterior tongue Motor to soft palate, pharynx, intrinsic laryngeal muscles (voice production), and an extrinsic tongue muscle (palatoglossus) Proprioceptive from those muscles Parasympathetic to thoracic and abdominal viscera	Difficulty swallowing and/or hoarseness; uvula deviates away from side of the dysfunction



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.

Incomparable Instructor and Student Resources—*Making teaching easier and learning smarter*

- **NEW!** Chapter opener rewritten with a focus on maintenance of homeostasis, a major underlying theme of the book
- **NEW!** In-text Learning Outcomes and Assessment Questions
- **NEW!** Learning Outcomes Correlation guide between Predict, Learn to Predict, Review and Comprehension, and Critical Thinking Questions
- Anatomy and Physiology | REVEALED® (APR) features "melt-away" dissection of real cadavers
- **NEW!** McGraw-Hill Anatomy & Physiology REVEALED® (APR) links to figures for eBook and is now also available for mobile devices
- Enhanced Lecture PowerPoints with APR cadaver images
- **NEW!** All figures are visually linked to create consistency throughout the text and art coloration has been saturated to help make the art more engaging
- Lecture PowerPoints with embedded animations
- **NEW!** Author Revised Testbank
- ConnectPlus® Course Management system
- **NEW!** Access to media-rich eBooks directly linked to APR
- **NEW!** LearnSmart™ tailors study time and identifies at-risk students and is now available for mobile devices
- Flex Art lets you take it apart and build it back during lecture
- **NEW!** Based on the same world-class super-adaptive technology as LearnSmart™, McGraw-Hill LabSmart™ is a must-see, outcomes-based lab simulation

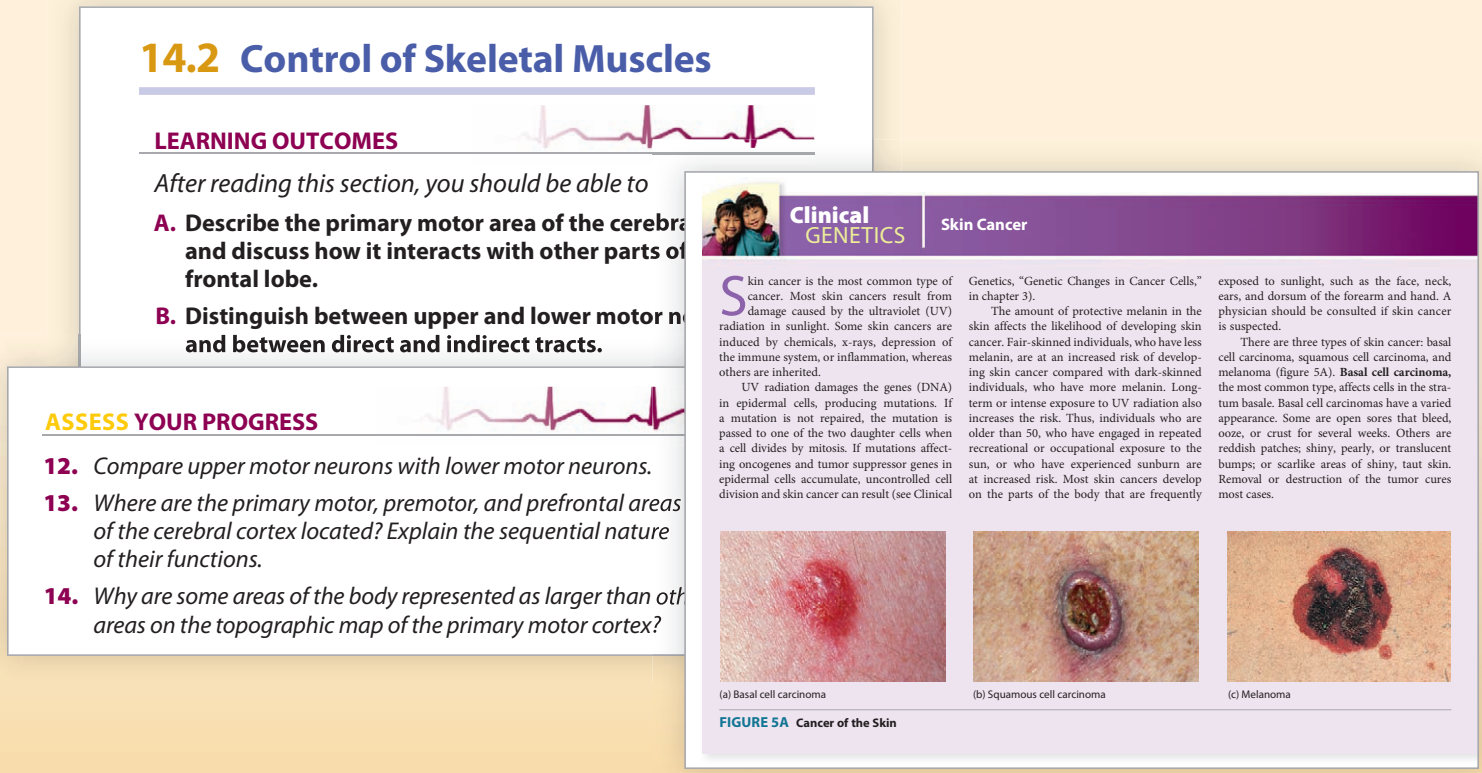
TENTH EDITION
Changes

What's New?

The tenth edition of *Seeley's Anatomy & Physiology* is the result of extensive analysis of the text and evaluation of input from instructors who have thoroughly reviewed chapters. The outcome is a retention of the beloved features which 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*

- **NEW!** Learning Outcomes are carefully written and labeled to outline expectations for each section
- **NEW!** Author Correlation of Review and Comprehension, Predict, and Critical Thinking Questions to Learning Outcomes are provided online to assist with linking course measuring standards and student comprehension
- **NEW!** Online student questions and test bank questions are correlated with Learning Outcomes to further scaffold and measure student progress and understanding
- The Clinical Genetics feature has been updated and streamlined to provide the newest and most accurate information available



14.2 Control of Skeletal Muscles

LEARNING OUTCOMES

After reading this section, you should be able to

A. Describe the primary motor area of the cerebra and discuss how it interacts with other parts of frontal lobe.

B. Distinguish between upper and lower motor n and between direct and indirect tracts.

ASSESS YOUR PROGRESS

12. *Compare upper motor neurons with lower motor neurons.*

13. *Where are the primary motor, premotor, and prefrontal areas of the cerebral cortex located? Explain the sequential nature of their functions.*

14. *Why are some areas of the body represented as larger than oth areas on the topographic map of the primary motor cortex?*

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.

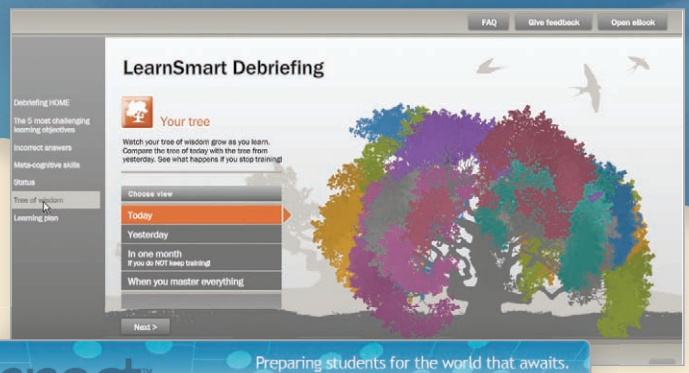
There are three types of skin cancer: basal cell carcinoma, squamous cell carcinoma, and melanoma (figure 5A). **Basal cell carcinoma,** the most common type, affects cells in the stratum basale. Basal cell carcinomas have a varied appearance. Some are open sores that bleed, ooze, or crust for several 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.

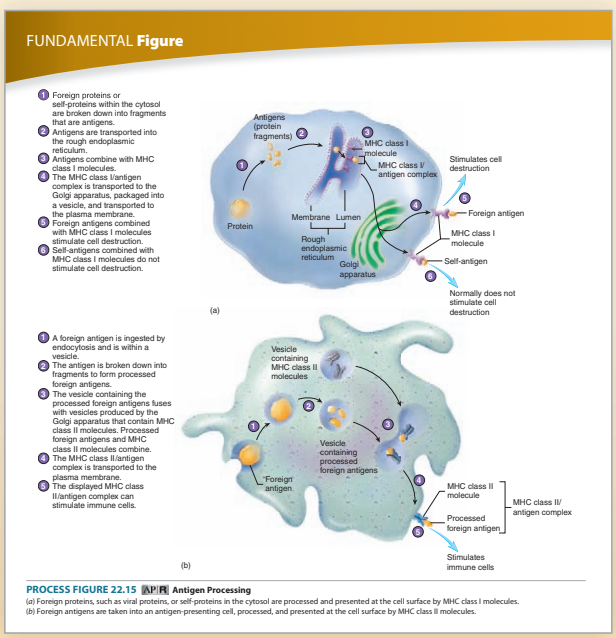
(a) Basal cell carcinoma (b) Squamous cell carcinoma (c) Melanoma

FIGURE 5A Cancer of the Skin

ConnectPlus® with LearnSmart™—
Making teaching easier and learning smarter

- A personalized cognitive mapping learning system, LearnSmart™, tailors study time and identifies at-risk students
- Deliver and track assignments, quizzes, and tests easily online
- Use various ready-to-go Lecture PowerPoints including embedded animations—or make your own using McGraw-Hill art
- "Flex" art—take it apart and build it back during lecture
- 24/7 eBook access with animations, videos, and practice quizzing





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.

Fundamental Figures—
Integrated with special ConnectPlus® assets!

- **NEW!** Special icons now link Fundamental Figures with corresponding modules within APR
- Additional online ConnectPlus® resources support these important figures
- Grouped together, the Fundamental Figures represent an excellent summary and study tool

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?

- 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 309

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.

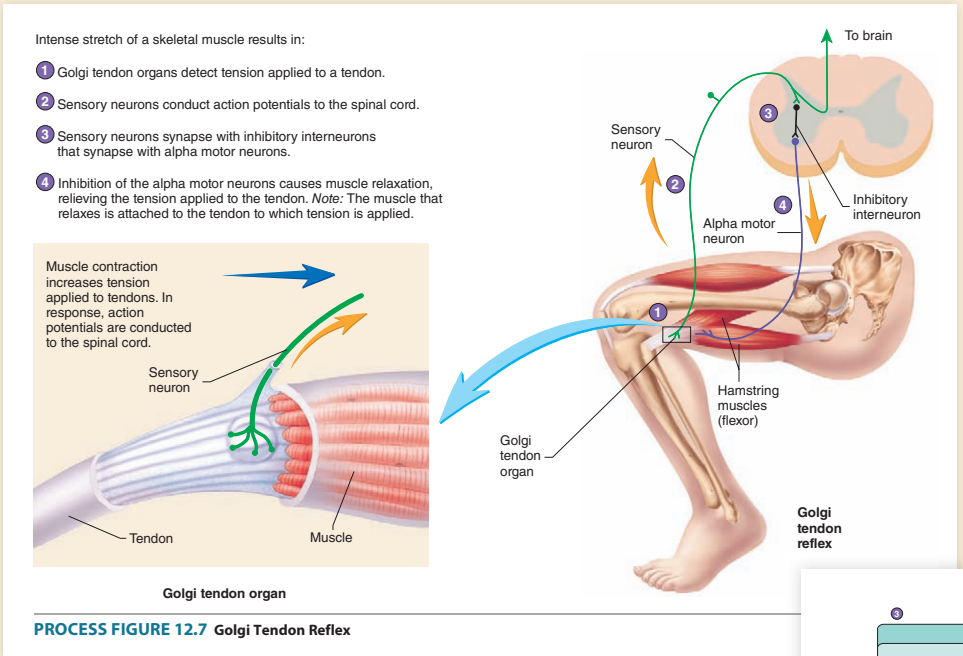
We read in chapter 10 that the muscles affected by Pedro's injury (psoas major, iliacus, pectineus, sartorius, vastus lateralis, vastus medius, vastus intermedius, and rectus femoris) are involved in flexing the hip, the knee, or both. Therefore, we can conclude that movements involving hip and knee 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.

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.



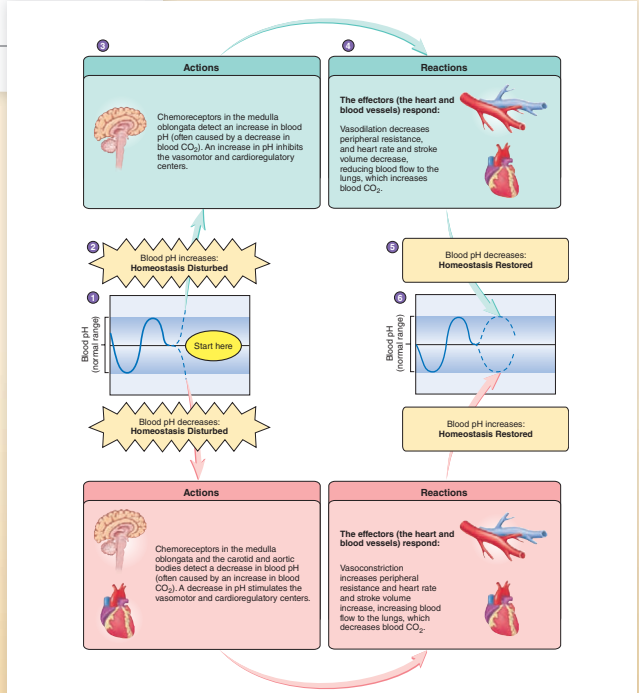
PROCESS FIGURE 12.7 **Golgi Tendon Reflex**

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 tenth 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.

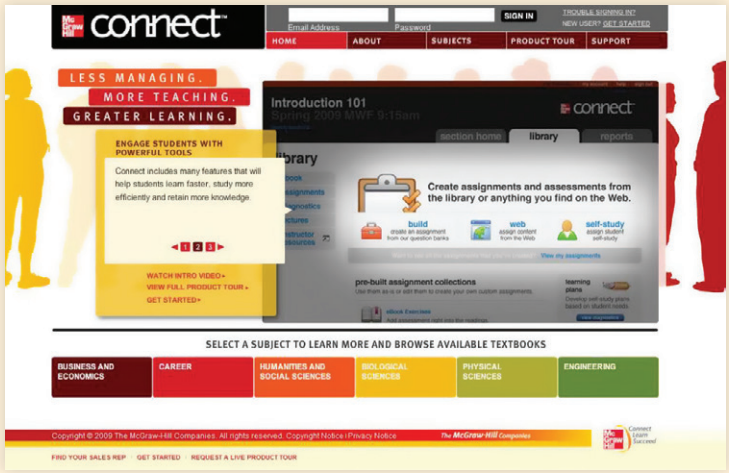


HOMEOSTASIS FIGURE 21.43 **Summary of the Effects of pH and Gases on Blood Pressure**
(1) Blood pH is within its normal range. (2) Blood pH increases outside the normal range, which causes homeostasis to be disturbed. (3) Chemoreceptors detect the increase in blood pH. The cardioregulatory and vasomotor centers in the brain are inhibited. (4) Nervous and hormonal changes alter the activity of cardiac muscle of the heart and smooth muscle of the blood vessels (effectors), causing heart rate and stroke volume to decrease and blood vessels to dilate, reducing blood flow to the lungs, which increases blood CO_2. (5) These changes cause blood pH to decrease. (6) Blood pH returns to its normal range, and homeostasis is restored. Observe the responses to a decrease in blood pH outside its normal range by following the *red arrows*. For more information on the chemoreceptor reflex, see figure 21.42; for the central nervous system ischemic response, see the text.

TEACHING AND Learning Supplements

McGraw-Hill Connect® Anatomy & Physiology—
www.mcgrawhillconnect.com

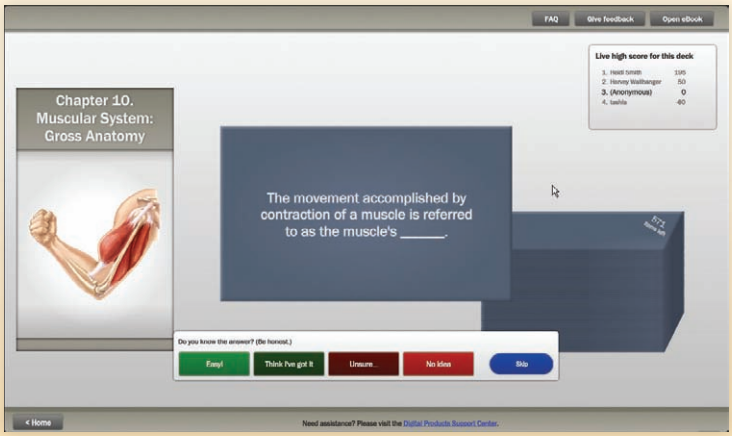
connect® plus+
ANATOMY & PHYSIOLOGY



McGraw-Hill Connect® Anatomy & Physiology provides online presentation, assignment, and assessment solutions. It connects your students with the tools and resources they'll need to achieve success.

With **Connect Anatomy & Physiology** you can deliver assignments, quizzes, and tests online. A robust set of questions and activities are presented and aligned with the textbook's learning outcomes. As an instructor, you can edit existing questions and author entirely new problems. Track individual student performance—by question, assignment, or in relation to the class overall—with detailed grade reports. Integrate grade reports easily with Learning Management Systems (LMS), such as WebCT and Blackboard.

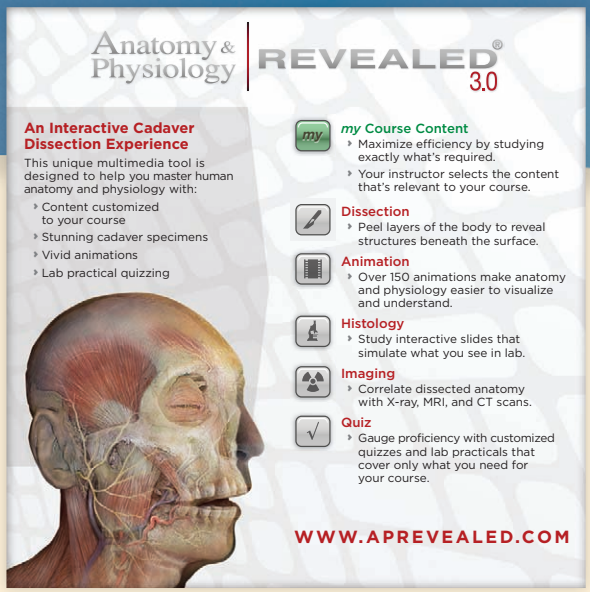
McGraw-Hill ConnectPlus® Anatomy & Physiology provides students with all the advantages of **Connect Anatomy & Physiology**, plus 24/7 online access to an eBook. This media-rich version of the book is available through the Connect platform and allows seamless integration of text, media, and assessments.
www.mcgrawhillconnect.com



LearnSmart™

www.mhlearnsmart.com

McGraw-Hill LearnSmart™ is available as an integrated feature of **McGraw-Hill Connect® Anatomy & Physiology**. It is an adaptive learning system designed to help students learn faster, study more efficiently, and retain more knowledge for greater success. LearnSmart assesses a student's knowledge of course content through a series of adaptive questions. It pinpoints concepts the student does not understand and maps out a personalized study plan for success. This innovative study tool also has features that allow instructors to see exactly what students have accomplished and a built-in assessment tool for graded assignments. Visit the following site for a demonstration.
www.mhlearnsmart.com



Complete Access

Anatomy & Physiology REVEALED® provides simple yet complete access to the entire human body. The app is organized into systems. For each, you will find dissection tools, histological and radiological imagery, videos, and a helpful quiz.

Additional Mobile Apps Available

COURSESMART LEARNSMART TEGRITY VITALSOURCE

Performance-Enhancing Study Tools and Low-Cost Textbook Alternatives

Electronic Books

If you or your students are ready for an alternative version of the traditional textbook, McGraw-Hill offers a cheaper and ecofriendly alternative to traditional textbooks. By purchasing eBooks from McGraw-Hill, students can save as much as 50% on selected titles delivered on the most advanced eBook platform available.

Contact your McGraw-Hill sales representative to discuss eBook packaging options.

McGraw-Hill Create™

With McGraw-Hill Create™, you can easily rearrange chapters, combine material from other content sources, and quickly upload content you have written, like your course syllabus or teaching notes. Find the content you need in Create by searching through thousands of leading McGraw-Hill textbooks. Arrange your book to fit your teaching style. Create even allows you to personalize your book's appearance by selecting the cover and adding your name, school, and course information. Order a Create book and you'll receive a complimentary print review copy in 3–5 business days or a complimentary electronic review copy (eComp) via e-mail in minutes. Go to www.mcgrawhillcreate.com today and register to experience how McGraw-Hill Create empowers you to teach your students your way. **www.mcgrawhillcreate.com**

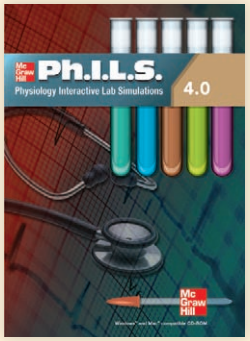
Other Resources Available

My Lectures–McGraw-Hill Tegrity

www.tegrity.com

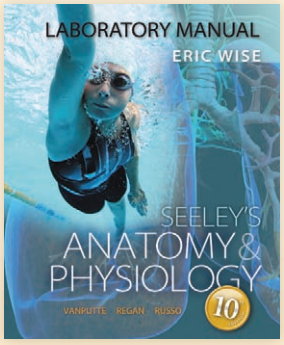
McGraw-Hill Tegrity® records and distributes your class lecture, with just a click of a button. Students can view anytime/anywhere via computer, iPod, or mobile device. It indexes as it records your PowerPoint® presentations and anything shown on your computer so students can use keywords to find exactly what they want to study. Tegrity is available as an integrated feature of McGraw-Hill Connect Anatomy & Physiology or as standalone.

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.

Correlated Website

The website that accompanies *Seeley's Essentials of Anatomy & Physiology* at **www.mhhe.com/seeley10** allows instructors to browse, select, and export files containing artwork from the text in multiple formats to create customized classroom presentations, visually based tests and quizzes, dynamic course website content, or printed support materials. The digital assets on the website are all available for teaching presentations:

- **Art** Full-color digital files of all the illustrations in the book and unlabeled versions of the same artwork can be readily incorporated into lecture presentations, exams, or custom-made classroom materials. In addition, all files are pre-inserted into blank PowerPoint slides for easy lecture presentations.
- **Photos** Digital files of instructionally significant photographs from the text can be reproduced for multiple classroom uses.
- **Tables** Every table that appears in the text is available to instructors in electronic form.
- **Animations** Numerous full-color animations illustrating physiological processes are provided. Harness the visual impact of processes in motion by importing these files into classroom presentations or online course materials.

Students will benefit from **practice quizzing, animation quizzing,** and other **study tools,** all correlated by chapter. Help with difficult concepts is only a click away!

McGraw-Hill LabSmart™

THE Virtual Lab Experience

Based on the same world-class super-adaptive technology as McGraw-Hill LearnSmart™, McGraw-Hill LabSmart™ is a must-see, outcomes-based lab simulation. It assesses a student's knowledge and adaptively corrects deficiencies, allowing the student to learn faster and retain more knowledge with greater success.

First, a student's knowledge is adaptively leveled on core learning outcomes: Questioning reveals knowledge deficiencies that are corrected by the delivery of content that is conditional on a student's response. Then, a simulated lab experience requires the student to think and act like a scientist: Recording, interpreting, and analyzing data using simulated equipment found in labs and clinics. The student is allowed to make mistakes—a powerful part of the learning experience! A virtual coach provides subtle hints when needed; asks questions about the student's choices; and allows the student to reflect upon and correct those mistakes. Whether your need is to overcome the logistical challenges of a traditional lab, provide better lab prep, improve student performance, or make your online experience one that rivals the real world, LabSmart accomplishes it all.

Learn more at www.mhlabsmart.com

Acknowledgments

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

Many hands besides our own have touched this text, guiding it through various stages of development and production. We wish to express our gratitude to the staff of McGraw-Hill for their help and encouragement. We appreciate the guidance and tutelage of Director James Connely. We are sincerely grateful to Developmental Editor Mandy Clark for her careful scrutiny of the manuscript, her creative ideas and suggestions, and her tremendous patience and encouragement. Special thanks are also offered to Copyeditor Deb DeBord for her attention to detail and for carefully polishing our words. A special acknowledgement of gratitude is owed to Project Manager Jayne Klein for her patience and detail-tracking abilities. Content Licensing Specialist John Leland, Production Supervisor Sandy Ludovissy, Designer Tara McDermott, and Media Project Manager Tammy Juran, we thank you for your time spent turning our manuscript into a book and its accompanying website. The McGraw-Hill employees with whom we have worked are excellent professionals. They have been consistently helpful and their efforts are truly appreciated. Their commitment to this project has clearly been more than a job to them.

Finally, we sincerely thank the reviewers and instructors who've provided us time and time again with remarkable feedback. We wish we could pay you what you're really worth to us! To conscientiously review a textbook requires a true commitment and dedication to excellence in teaching. Your helpful criticisms and suggestions for improvement were significant in revising the ninth edition. Our advisory board was a special group of exceptional reviewers to whom we could turn to at any time during the development of this text for almost immediate valuable input. To those of you who've participated in focus groups, we'd like to recognize the time you spent away from family and students in order to provide us with significant information about the future of anatomy and physiology at your institution. We gratefully acknowledge all of you who played a part in this edition by name in the next section.

Cinnamon VanPutte
Jennifer Regan
Andy Russo
Rod Seeley

Reviewers

Jerry M. Allen
KCTCS Somerset Community College

Timothy A. Ballard
University of North Carolina Wilmington

David M. Bastedo
San Bernadino Valley College

Mary L. Bonine
Northeast Iowa Community College–Peosta

Nishi Sood Bryska
University of North Carolina Charlotte

Ronald A. Canterbury
University of Cincinnati at Cincinnati

Claire Michelle Carpenter
Yakima Valley Community College

James Davis
University of Southern Maine

Kathryn A. Durham
Lorain County Community College

Clair B. Eckersell
Brigham Young University Idaho

Angela M. Edwards
Trident Technical College

Jeffrey G. Edwards
Brigham Young University

Maria Florez
Lone Start College–CyFair

Purti Gadkari
Wharton County Junior College

Ewa Gorski
Community College of Baltimore Cantonsville

Edwin Griff
University of Cincinnati at Cincinnati

Richard S. Groover
J. Sargeant Reynolds Community College

Robert F. Halliwell
TJL School of Pharmacy & Health Sciences

Clare Hays
Metro State College of Denver

Christopher W. Herman
Eastern Michigan University

William Huber
St. Louis Community College Forest Park

Jason Hunt
Brigham Young University Idaho

Susanne Kalup
Westmoreland County Community College

Kamal Kamal
Valencia Community College West

L. Henry Kermott
St. Olaf College

April Kilgore
KCTCS Somerset Community College

Tyjuanna R. S. LaBennett
North Carolina Central University

Steven D. Leidich
Cuyahoga Community College

Jerri K. Lindsey
Tarrant County College NE

Mary Katherine Lockwood
University of New Hampshire

Karen K. McLellan
Indiana University/Purdue University Fort Wayne

Kenneth Michalis
San Bernadino Valley College

Claire A. Miller
Community College of Denver

William R. Millington
Albany College of Pharmacy

Dan Miska
Wright State University

J. Jean Mitchell
Okaloosa–Walton College; University of Florida

Ramzi A. Ockaili
J. Sargeant Reynolds Community College

Sidney L. Palmer
Brigham Young University

Betsy Peitz
California State University, Los Angeles

Raffaelle Pernice
Hudson County Community College

Terri Pope
Cuyahoga Community College

Helen M. Rarick
Wilbur Wright College

Marilyn Shannon
Indiana University/Purdue University Fort Wayne

Jeff Simpson
Metropolitan State College of Denver

Jason Tasch
Cuyahoga Community College Metro

Janis G. Thompson
Lorain County Community College

Corinne Ulbright
Indiana University/Purdue University Indianapolis

Anthony J. Uzwiak
The College of New Jersey

Charles Wright III
Community College of Baltimore County–Essex

Accuracy Checkers

Nishi Bryska
UNC Charlotte

Lois Brewer Borek
Georgia State University

Ronald A. Canterbury
University of Cincinnati

Ethel Cornforth
San Jacinto College South

Emily Y. F. González
Northern Essex Community College

Clare Hays
Metropolitan State College of Denver

Chris Herman
Eastern Michigan University

Kristopher Kelley
University of Louisiana at Monroe

Allart Kok
Community College of Baltimore County

Cynthia Littlejohn
The University of Southern Mississippi

Karen McLellan
Indiana University/Purdue University Fort Wayne

Margaret Ott
Tyler Junior College

Josephine Rogers
University of Cincinnati

Tim Roye
San Jacinto College

Fadi N. Salloum
J. Sargeant Reynolds Community College

Marilyn M. Shannon
Indiana University/Purdue University Fort Wayne

Denise Slayback–Barry
Indiana University/Purdue University Indianapolis

Eric L. Sun
Macon State College

Corinne Ulbright
Indiana University/Purdue University Indianapolis

MaryJo A. Witz
Monroe Community College

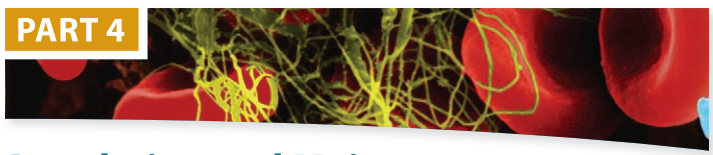
Dwight Wray
Brigham Young University–Idaho

Martin Zahn
Thomas Nelson Community College

Contents

Organization of the Human Body

Support and Movement



Chapter-by-Chapter Changes

Chapter 1

- Chapter opener rewritten with a focus on maintenance of homeostasis, a major underlying theme of the book.
- Chapter opener revised to link opening photo with Learn to Predict and chapter introduction. Provides a cohesive theme for better student learning and engagement.
- Learning outcomes goals at the beginning of the chapter were numbered to correlate with Predict questions and end-of-chapter questions.
- Clinical Impact "Anatomical Imaging" was converted to an illustrated table, table 1.1, which increases the perceived importance to students and makes the information easier to interpret.
- The homeostasis section was revised per reviewer feedback for a more accurate description of negative and positive feedback.

Chapter 2

- Redesigned and combined former figures 2.9 and 2.10 on synthesis and decomposition reactions into new figure 2.9. Eliminated redundant information and made information less daunting by showing simple schematics adjacent to more complex representations of protein and carbohydrate molecules.
- New figures 2.10 and 2.11 provide more intuitive presentations of energy in chemical reactions and concept of activation energy.
- New figure on buffers (figure 2.13) illustrates an important physiological concept previously described only with text.
- Hydrogen bonding and water sections have been rewritten to emphasize importance of H bonds in the structure and unique functions of water.
- Legend for covalent bonding figure 2.5 has been rewritten to increase clarity.
- Descriptions of both the conservation of energy and the release of energy during ATP hydrolysis have been rewritten to more clearly describe these fundamental points.
- Tertiary folding of proteins has been rewritten to clearly distinguish secondary from tertiary folding.
- New electron micrograph (figure 2.15c) has been added that better illustrates glycogen granules in a cell.
- Chapter opening material has been tied into the cover figure and the Learn to Predict question.
- Background coloring on several figures has been changed to make them more visually striking.

Chapter 3

- New chapter opener figure of aquaporin to tie in to Learn to Predict question.
- Clinical Impact "Microscopic Imaging" has been updated.
- Table 3.2 is now illustrated to better represent membrane protein function.
- Section 3.6 is reorganized into Passive Membrane Transport and Active Membrane Transport mechanisms.
- Table 3.3 has been reorganized to reflect revision of section 3.6.
- Section 3.12 Genetics has been moved to chapter 29.
- Clinical Genetics "Genetic Changes in Cancer Cells" updated.
- All figures illustrating the plasma membrane have been updated so that the cytoplasmic side is yellow. This provides consistency throughout the text and is more visually appealing.

Chapter 4

- Relationship between structure and function in A&P has been emphasized with a new paragraph and examples in section 4.1.
- Microscopy Clinical Impact has been moved to chapter 3. In the process, we removed extraneous technical information (such as fixation methods) and updated it with addition of atomic force microscopy (AFM). We have included new images of nuclear pores seen by light, TEM, SEM, and AFM to illustrate the different types of microscopy.
- Embryological terms in section 4.2 have been updated (epiblast and hypoblast).
- Figure 4.5 on matrix proteins has been greatly simplified. The figure had acquired too many unnecessary details, especially on collagen biosynthesis. The revised figure emphasizes the concepts that collagen, elastin, and proteoglycans have different properties. Corresponding changes in the text emphasizing the rope-like nature of collagen fibers and rubber-band like nature of elastin fibers have been made.

- Description of the basement membrane has been modified and now also included that its porous substance that allows diffusion of substances to and from the epithelium.
- Description of endocrine glands, including their different ontogenies, has been removed since this concept is not needed until later in the textbook.
- Ground substance of the matrix has been emphasized with a new heading.
- Based on increasing and solid evidence that brown fat plays important roles in the human adult, and not just infants, the statement that brown fat is primarily in infants has been removed.
- New cover image showing microvilli. This image matches the Learn to Predict question and the intense fluorescent signal will help grab student's attention.
- More vibrant color and contrast in several histology images to better display cell types in tissues (figures in tables 4.2, 4.3, 4.10c, 4.14).
- Eliminated neuroglia image since this topic is not emphasized in this chapter and glia are indicated in table 4.15 figure.
- Clinical Impact on Marfan syndrome has been streamlined by removing unimportant genetic details (chromosome number, types and number of allelic variants, protein name, etc).
- Clinical Impact on cancer has been updated and rewritten to focus on types of cancer arising from different tissues.
- Clinical Genetics on cancer has been moved to Chapter 3 and has been streamlined and updated. The relevant critical thinking question also moved to chapter 3.

Chapter 5

- Clinical Genetics "Skin Cancer" has been updated.
- New Systems Pathology presentation.

Chapter 6

- Chapter opener rewritten with a focus on maintenance of homeostasis, a major underlying theme of the book.
- Added osteoclast figure to fill in an important gap in information for bone growth and development and calcium homeostasis.
- Updated information on osteoclast function.
- Clinical Genetics box "Osteogenesis Imperfecta" updated for accuracy and currency.
- Figures 6.13 and 6.14 were combined so students can see the "big picture" and better correlate ideas.
- Added actual x-ray images to figure 6.20 for real world correlation.
- Figure 6.21 revised for better link between physiological process components.

Chapter 7

- Chapter opener rewritten with a focus on maintenance of homeostasis, a major underlying theme of the book.
- Clinical Impact "Herniated Discs" was revised and updated to include stem cell techniques for treatment and surgical methods.
- All figures were visually linked to create consistency throughout the chapter.

Chapter 8

- New Learn to Predict question that ties into the accompanying chapter opener figure of a knee MRI.
- Clarification that joints are where bones move in close contact with each other, but are not bone on bone.
- Clarification of difference between sutures and synostosis.
- Clarification of different fates of synchondrosis joints (convert to synostosis, synovial joints, or persist as synchondrosis joints).
- New presentation of types of synovial joints from six separate figures and one table into one figure (figure 8.8) to allow a more concise and organized presentation with better visualization and comparison between the different joints with respect to their structure, connecting bones, and movements.
- Revision of major knee ligament information. Text now emphasizes the two clinically important sets of ligaments (cruciate and collateral) and uses the more common terms of medial and lateral collateral ligaments. Role of the popliteal ligament has been deemphasized.
- New Predict question focused on PCL tears and posterior drawer test.
- Clinical Impact on joint changes in pregnancy has been updated and information added describing the importance and effectiveness of early diagnosis of congenital hip dislocation.
- Clinical Impact on TMJ disorders has been updated and rewritten to emphasize the symptoms of common chronic cases and successful treatment paradigms.
- Description of bunions has been corrected to indicate that they are deformations of the great toe that may have associated bursitis, but are distinct from bursitis.
- New Critical Thinking question brings information on inflammation and bones from chapter 7 with vertebral joints from chapter 8.
- Aging section has been clarified to describe how protein cross-linking causes loss of joint flexibility by changes in fibrous connective tissue of tendons and ligaments.
- Arrow colors in the figures that indicate movement have been changed to dark blue for consistency.

Chapter 9

- Figures 9.3, 9.4, 9.15, 9.17 and any other figure with myosin myofilaments were revised to more accurately reflect relative sizes of thick and thin filaments.
- Sections 9.4 and 9.5 were combined and reorganized to follow a more logical sequence; new information is built upon previous information.
- A new figure 9.16 was added per reviewer feedback to have information culminate in a "big picture" summary figure of skeletal muscle contraction.
- Figure 9.6 was revised so that a photomicrograph, which shows the actual process, was added.
- Throughout the chapter, the membrane potential figure scale was modified to more accurately reflect the level for skeletal muscle.
- Figure 9.21 was revised for clarity based on reviewer feedback.
- Based on reviewer feedback, new information on sarcopenia was added to the section on aging.
- Table 9.3 was revised for clarity and information on type of work supported by each path was added.
- Updated information on fiber types and distribution.

Chapter 10

- Added new table for muscle shapes (figures 10.2 and 10.3 were reorganized into an illustrated table) and the terminology was updated.
- Updated information on aging in Clinical Impact "Bodybuilding" per reviewer feedback.
- In all figures with a background screen, the color of the screen was changed to yellow, which looks more modern and increases student engagement.

Chapter 11

- Revised figure 11.2 into a flow chart so students may conceptually follow the organization of the nervous system.
- Reorganized glial cells into a single illustrated table to give a "big picture" among these cells.
- Section 11.5 was reorganized and revised for clarity.
- Combined old figures 11.12 and 11.13 into a new figure (11.7) to create a "big picture" figure to give students a greater connectivity.
- Revised figure 11.20 (new figure 11.14) for accuracy and clarity of concept.
- Revised figure 11.22 (new figure 11.16) for clarity.
- Revised section 11.7 to update terminology.
- Revised the Learn to Predict answer for accuracy.

Chapter 12

- Cervical rib syndrome case study has been renamed Thoracic Outlet Syndrome to reflect the more commonly used medical term and has been extensively modified and updated with new information, including treatments.
- Median nerve damage Clinical Impact has been rewritten and updated to include causes of carpal tunnel syndrome and that typing at a keyboard is no longer a recognized cause.
- Diseases and Disorders table has been updated and modified. Have added Marie-Charcot-Tooth syndrome, one of the most common inherited neurological disorders, and diabetic neuropathy, an increasingly common, but poorly understood disorder. Myotonic dystrophy has been removed since current research is still not clear whether this is a primary neuropathy. Grouping in infection categories has also been eliminated since the role of infection is not clear in some diseases.
- Multiple figures have been modified to improve presentation of information.
  - Consistent colors for sensory (green) and motor (purple) tracts in the spinal cord (figures 12.3, 12.11) and changed arrow colors in other figures for consistency.
  - Figure 12.9 process figure better describes the action of inhibitory neurons (dashed line) in the withdrawal reflex.
- The clinical connection of a lung tumor potentially compressing the phrenic nerve has been updated as the second most common and most lethal cancer among men.
- Minor wording changes to improve clarity—e.g. superficial and deep to describe white and gray matter of spinal cord instead of peripheral and central to avoid confusion with terms used to describe divisions of the nervous system (CNS, PNS). Consistent use of term motor when describing autonomic motor neurons to emphasize their motor functions. Revised coat/sleeve analogy to describe the dura and epineurium relationship.

Chapter 13

- New chapter opener photo (MRI) and introductory paragraph to better illustrate theme of chapter and match topic of the Learn to Predict question.
- Rewritten brainstem section to describe overall function, followed by anatomy.
- Revised reticular formation section to clarify that it is not an anatomical division of the brainstem, it spans all divisions of brainstem, and is involved in many functions in addition to the reticular activating system.
- Included description of the solitary nucleus and nucleus ambiguous serving as nuclei for multiple cranial nerves and clarified that several cranial nerves have more than one nucleus in the brainstem.
- Included general description of diencephalon in table 13.1.
- Thalamic nuclei have been highlighted with colors in figure 13.7 to allow better visualization.

- Added that the hypothalamus is the major coordinating center of the autonomic nervous system.
- Added prefrontal cortex and its functions to the description of the frontal lobe.
- Added that taste information is received and processed by the insula.
- Added arachnoid villi to the description of recirculation of cerebrospinal fluid by arachnoid granulations.
- Added general functions and comparison to spinal nerves to introduction of cranial nerves.
- Added that trigeminal sensory nerves also innervate meninges and their role in migraine. Description of migraine was also added to the Diseases and Disorders table.
- Added traumatic brain injury as the signature wound of the Iraq/Afghanistan wars.
- Rewritten facial palsy section of the Disease and Disorder table, including likely role of viral infections in Bell Palsy.
- Added the more commonly used clinical term torticollis for wry neck in Predict question.
- Removed Clinical Genetics box on neurofibromatosis since this is a rare disease and did not illustrate any pertinent contribution of genetics to A+P.
- More saturated colors in 5 figures, modified 4 other figures for better clarity.
- Added new schematic that better illustrates the layers and cell types in the cortex (figure 13.8c).

Chapter 14

- Evoked potentials have been added to the section on brain waves as a diagnostic tool for neurological disorders.
- Clarified the difference between sensation and perception, with sensation as the stimulus and perception as how our brain interprets the stimulus.
- The section on pain has been modified. Definition of pain receptors has been clarified and peripheral-acting analgesics have been included.
- Have clarified the origin of indirect motor pathways in the brainstem. Included the tectospinal tract as one of the major indirect pathways.
- Clinical Genetics material on Tay-Sachs has been shortened and rewritten to emphasize how this disorder exemplifies the application and power of genetic testing and counseling.
- Added that the reasoning behind clinical lesions of the corpus callosum is to treat intractable epilepsy.
- Added the sensation of tickle to table 14.2.
- Have removed statement that secondary receptor cells do not generate action potentials since taste receptor cells are exceptions that can generate both graded and action potentials.
- Figures 14.15 and 14.18 have been redrawn to include anatomical schematics of brain and other tissues to aid conceptualization of descending pathways and the cerebellar comparator function, respectively. In addition, the comparator pathways have been simplified with removal of the red nucleus.
- Updated image of an EEG net on a patient shown in figure 14.21.
- Direction of the action potential has been added to figure 14.23 to help students place LTP in the context of signal transmission.
- Updated and expanded Clinical Impact on headaches includes common triggers and a more complete description of symptoms.
- Updated Systems Pathology on stroke includes comparison of the two types of stroke with differences in diagnosis and treatments.
- New chapter opener figure shows a colorful and diverse image of labeled hippocampal neurons from transgenic mice.

Chapter 15

- New Learn to Predict question added.
- Function of conjunctiva has been added.
- Clinical Impact "Color Blindness" has been updated as a Clinical Genetics reading.
- In all figures with a background screen, the color of the screen was changed to yellow, which looks more modern and increases student engagement.

Chapter 16

- Overview of the Autonomic Nervous System added.
- Clarified differences between neural pathways presented in Sympathetic Division and Parasympathetic Division, and the means by which postganglionic fibers reach target organs in Autonomic Nerve Plexuses and Distribution of Autonomic Nerve Fibers.
- Dual innervation introduced at the beginning of the Physiology of the Autonomic Nervous System section.
- Comparison of sympathetic and parasympathetic activities moved to the beginning of the Physiology of the Autonomic Nervous System section.
- Definitions of agonist and antagonist drugs added to Neurotransmitter section.

Chapter 17

- Revised figure 17.3 for clarity.
- Revised figure 17.5 for clarity.
- Revised figure 17.9 for cohesion with other sections of the text.
- Revised figure 17.11 for accuracy.
- Revised figure 17.16 and 17.14 (combined two) and reordered for a more logical presentation of the information (old figures 17.14 and 17.16).
- Section 17.4 was reorganized for a more logical flow of information.

Chapter 18

- Figures 18.7, 18.9, 18.10, 18.12, 18.13 (hormone names added for each layer), and 18.17 revised for clarity.

- Figure 18.19 was revised into an illustrated table to help students make better connections.
- Added a new Critical Thinking question to enhance student learning and problem solving.

Chapter 19

- Production of Formed Elements revised to include intermediate stem cells: myeloid stem cell and lymphoid stem cell.
- Figure 19.2 revised to include myeloid stem cell and lymphoid stem cell.
- Figure 19.12 now includes a reference figure to illustrate the factors inside and outside the blood involved in coagulation.
- Figure 19.15 revised to better represent the interactions between maternal and fetal circulation.

Chapter 20

- Figure 20.2, revised making the inset figure larger and easier to see reference points for heart location.
- Section 20.7 Cardiac Cycle revised so that the discussion of the cardiac cycle begins with Atrial Systole. This correlates better with the discussion of EEG and the normal events associated with heart contraction and relaxation.
- Figure 20.18 and table 20.2 also revised to correlate with new organization of the cardiac cycle discussion.
- Systems Pathology "Myocardial Infarction" presented in new format.

Chapter 21

- Figure 21.6 revised moving the diagram of valves in veins to a separate figure.
- Figure 21.9 now illustrates the splenic and renal arteries more accurately.
- Figure 21.37 revised so blood flow is more obvious.

Chapter 22

- New chapter opener photo to correlate with Learn to Predict question.
- Figure 22.1 revised so components of lymphatic system are clear.
- Function of thymic corpuscles updated.
- Eosinophil function updated.
- Suppressor T cells are introduced as regulatory T cells.
- Genetic relationship of MHC molecules discussed to assist reader in understanding the need for genetic matches in tissue transplants.
- Systems Pathology "Systemic Lupus Erythematosus" presented in new format.

Chapter 23

- Reorganized the layout of section 23.2 on a functional basis to help students make connections between the anatomy and physiology.
- Corrected an error in section 23.3, "Airflow Into and Out of Alveoli" per reviewer feedback.
- Corrected figure 23.15 per reviewer feedback.
- Revised figure 23.21.

Chapter 24

- New chapter opener figure showing a gallstone in a colorful abdominal CT scan. Matches the Learn to Predict.
- Introduction revised to incorporate the points made by the Learn to Predict question.
- Clarified that ENS is a division of the ANS.
- Rewrote the section on stomach filling to clarify the rugae actions and regulation.
- New Predict question for the Case Study on spinal cord injury.
- Removed unnecessary information from the Clinical Genetics box.
- New Systems Pathology organization and new art to highlight the story.
- Reduced the number of learning outcomes for Oral Cavity section from six to three to better emphasize the important points.
- Corrected misstatements referring to Giardia and a bolus of food.
- Clarified summary statements on pancreatic secretions and regulation of pancreatic secretions.
- Added the kidney to the view of retroperitoneal organs in figure 24.5.
- Improved visualization of swallowing phases by highlighting movement of the larynx and epiglottis in figure 24.10.
- Changes in six figures to provide color consistency for arrows indicating functions, ion channels, and other molecules.

Chapter 25

- New Learn to Predict question.
- MyPlate replaces the MyPyramid discussion.
- Metabolism figures updated so that background color represents the cellular location (cytosol or mitochondrion) of each process.

Chapter 26

- Revised table 26.1 for accuracy.
- Added an introductory paragraph to Section 26.3—Urine Concentration Mechanism to help students make connections.
- Learning outcomes goals at the beginning of the chapter were numbered to correlate with Predict questions and end of chapter questions.

Chapter 27

- Moved table 27.3 to appear after the introductory text to make the information flow more logical.
- In all figures with a background screen, the color of the screen was changed to yellow, which looks more modern and increases student engagement.
- Chapter opener rewritten with a focus on maintenance of homeostasis, a major underlying theme of the book.

Chapter 28

- Estradiol introduced as a specific type of estrogen.
- Figures 28.8 and 28.18 revised so the hypothalamohypophysial portal system is more accurately represented.
- Atresia introduced in Oogenesis and Fertilization section.
- New figure 28.13 presents the process of oogenesis in context of ovarian follicle development.
- Clinical Impact—Cervical Cancer updated with new recommendations for HPV vaccination for males.
- Systems Pathology "Benign Uterine Tumors" presented in new format.

Chapter 29

- New chapter opener figure to correlate with Learn to Predict question.
- New chapter introduction discusses changes in perception of age over generations.
- Figure 29.21 revised so the hypothalamohypophysial portal system is more accurately represented.
- Genetics is now presented in this chapter instead of chapter 3.

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 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 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 structure—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 considered 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) examines the structural features of cells, and **histology** (his-tol′ō-jē) 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 from either a systemic or a regional perspective. In systemic anatomy, the body is studied system by system. A system is a group of structures that have one or more common functions, such as the cardiovascular, nervous, respiratory, skeletal, or muscular system. The systemic approach is taken in this and most other introductory textbooks. 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.

Surface anatomy is the study of the external form of the body and its relation to deeper structures. 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.

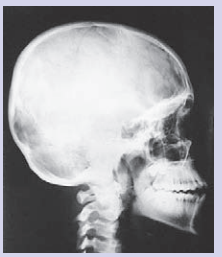
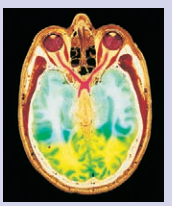
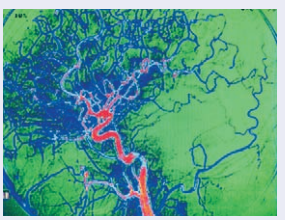
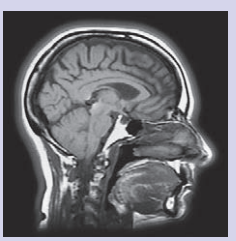
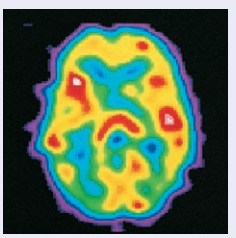
Like anatomy, physiology can be considered at many levels. **Cell physiology** examines the processes occurring in cells, and **systemic physiology** considers the functions of organ systems. **Neurophysiology** focuses on the nervous system, and **cardiovascular physiology** deals with the heart and 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. Almost everyone has had a radiograph taken, either to visualize a broken bone or to check for a cavity in a tooth. 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 as an extension of 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 the receiver on the skin. Even though the basic technology is fairly old, the most important advances in the field occurred only after it became possible to analyze the reflected sound waves by computer. Once a computer analyzes the pattern of sound waves, the information is transferred to a monitor and 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*).
Dynamic 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 can be used, for example, to guide a catheter into a carotid artery during angioplasty, a procedure by which a tiny balloon compresses the material clogging the 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 breakdown 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.

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, fats, 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 that make up cells. For example, the nucleus is an organelle that contains the cell's hereditary information, and mitochondria are organelles that manufacture 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 numerous tissues that make up the body are classified into four basic 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 complex 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?*

Predict 2

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

1.3 Characteristics of Life

LEARNING OUTCOME

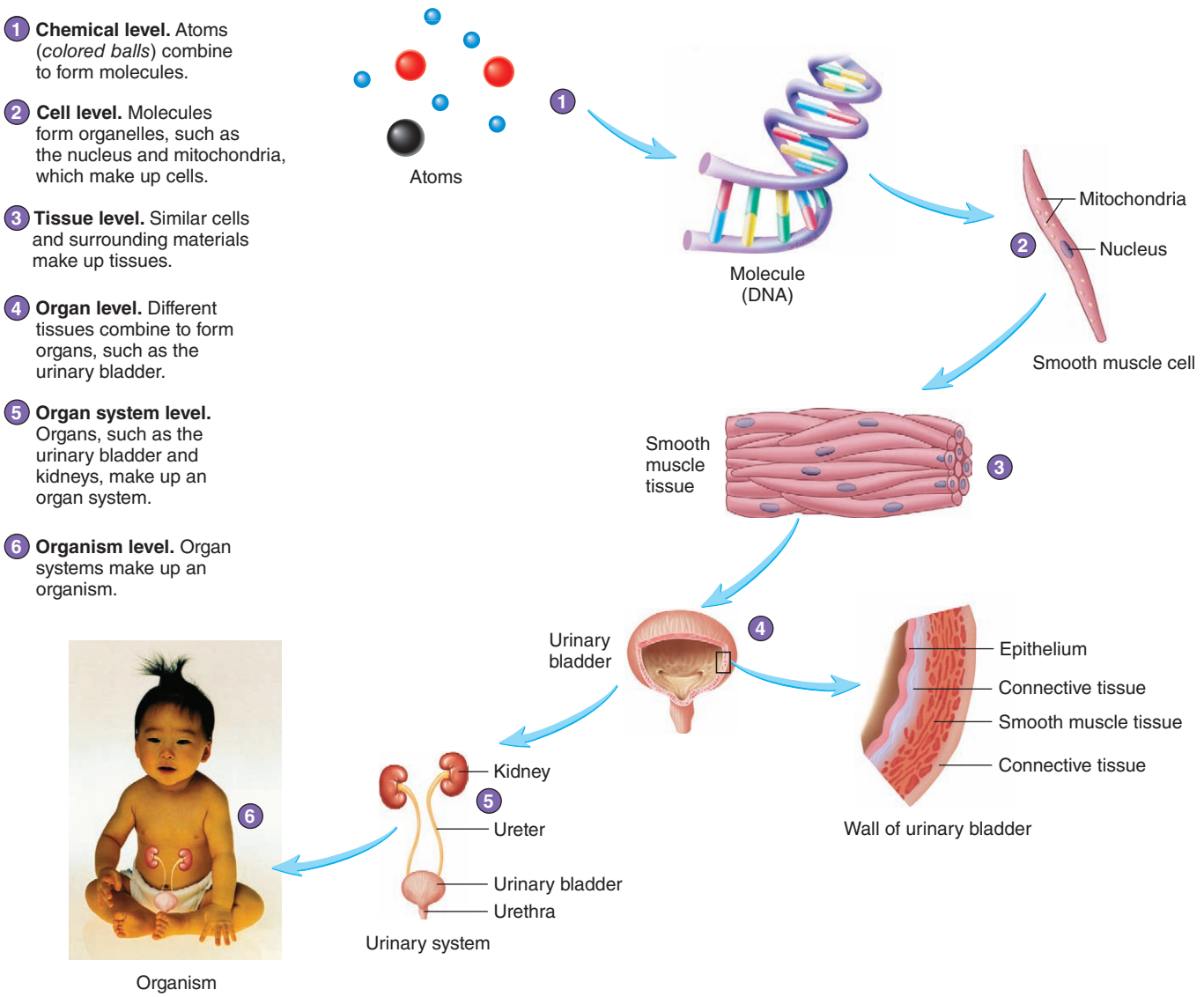
After reading this section, you should be able to

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. 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 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. Changes in molecular shape can lead to changes in cellular shape, which can produce movement of the organism. Metabolism is necessary for 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 such actions as moving toward food or water and moving away from danger or poor environmental conditions. Organisms can also make adjustments that maintain their internal environment. For example, if the

FUNDAMENTAL **Figure**



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

external environment causes the body temperature to rise, sweat glands produce sweat, which can lower body temperature back toward its normal range.

4. **Growth** refers to an increase in the size or number of cells, which produces an overall enlargement of all or part of an organism. For example, a muscle enlarged by exercise is composed of larger muscle cells than those of an untrained muscle, and the skin of an adult has more cells than the skin of an infant. An increase in the materials surrounding cells can also contribute to growth. For instance, 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** is change in cell structure and function from generalized to specialized, and **morphogenesis** (mōr-fō-jen′ĕ-sis) is change in the shape of tissues, organs, and the entire organism. For example, following fertilization, generalized cells specialize to become specific cell types, such as skin, bone, muscle, or nerve cells. These differentiated cells form the tissues and organs.
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.

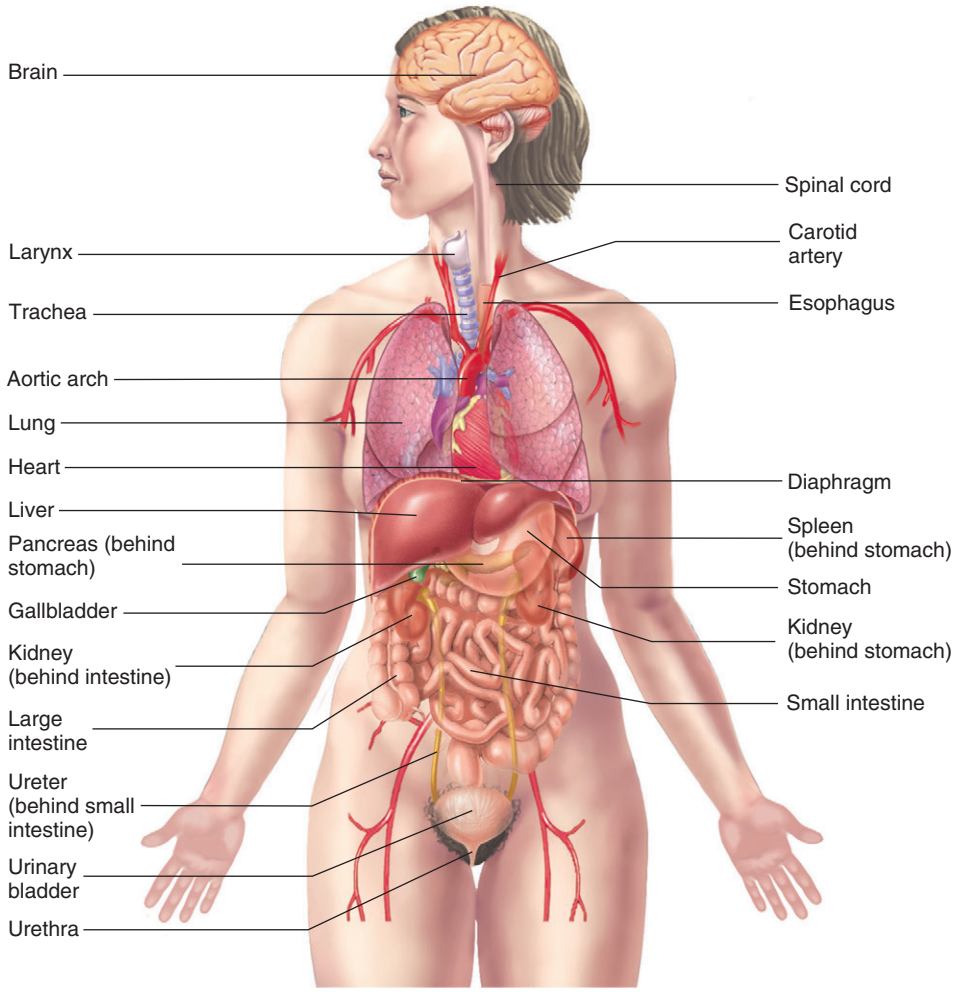


FIGURE 1.2 AP|R **Major Organs of the Body**

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

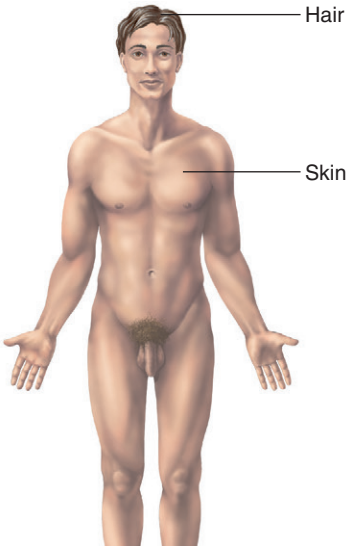
LEARNING OUTCOME

After reading this section, you should be able to

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

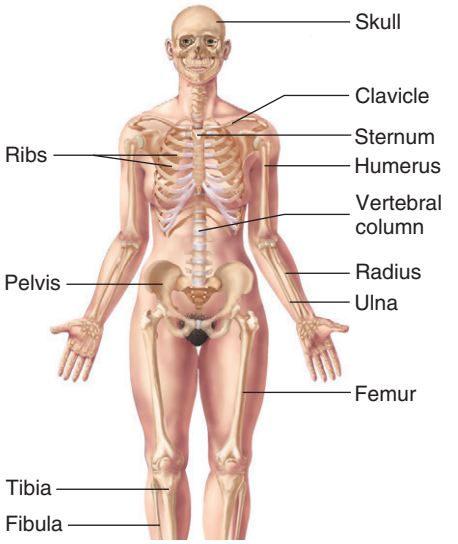
Studying other organisms has increased our knowledge about humans because humans share many characteristics with other organisms. For example, studying single-celled bacteria provides much information about human cells. However, some biomedical research cannot be accomplished using single-celled organisms 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



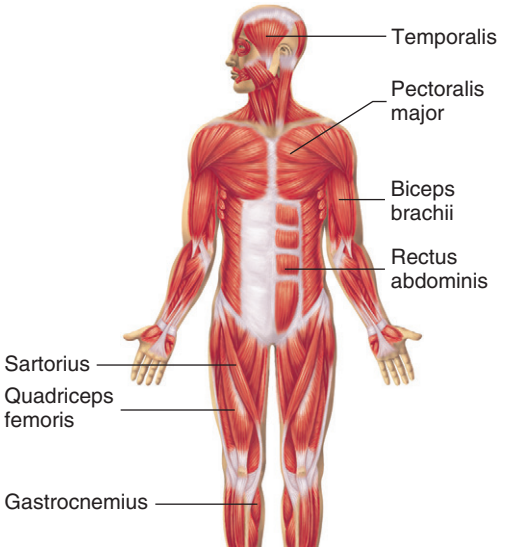
Integumentary System

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



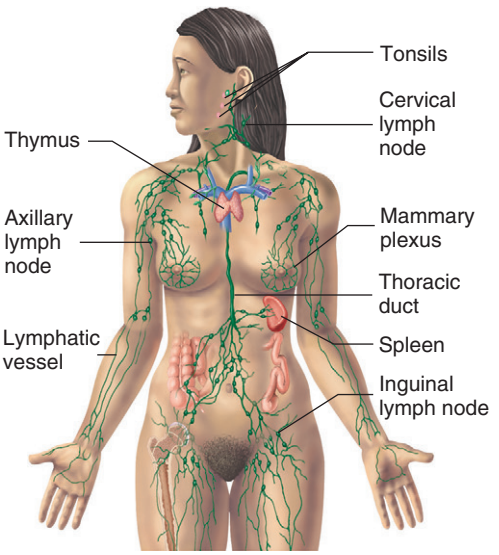
Skeletal System

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



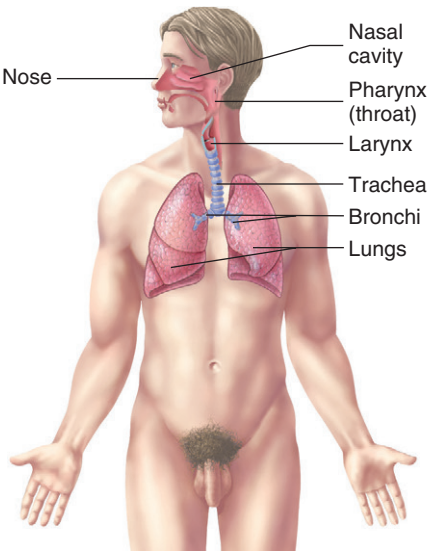
Muscular System

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



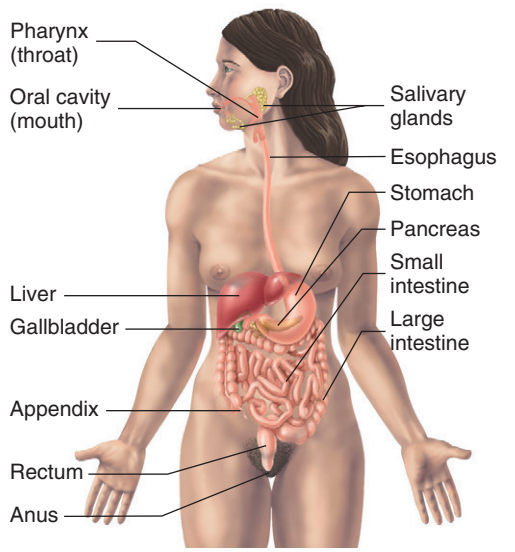
Lymphatic System

Removes foreign substances from the blood and lymph, combats disease, maintains tissue fluid balance, and absorbs 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

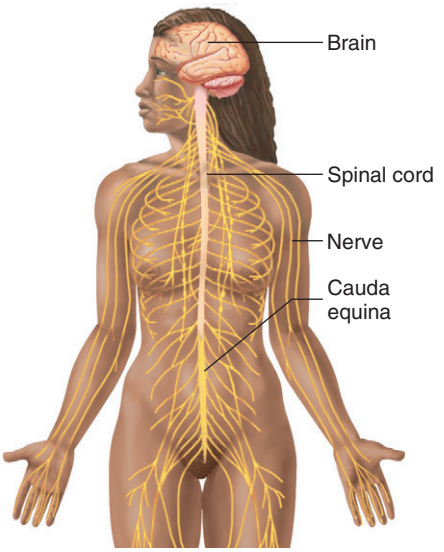
Performs the mechanical and chemical processes of digestion, absorption of nutrients, and elimination of wastes. Consists of the mouth, esophagus, stomach, intestines, and accessory organs.

FIGURE 1.3 Organ Systems of the Body

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.

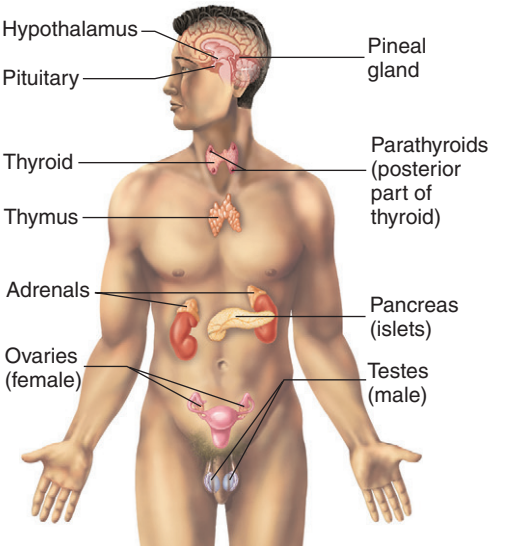
ASSESS YOUR PROGRESS

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



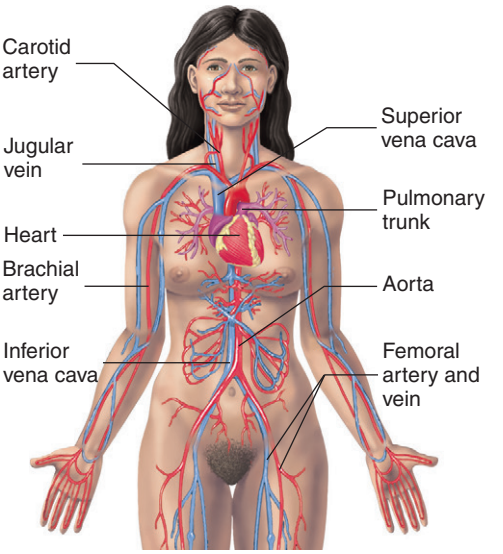
Nervous System

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.



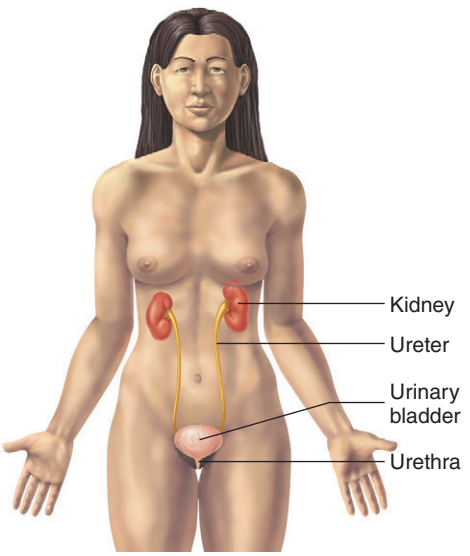
Endocrine System

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



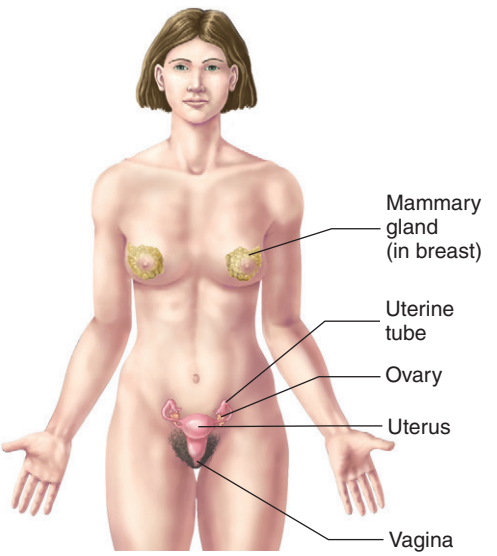
Cardiovascular System

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.



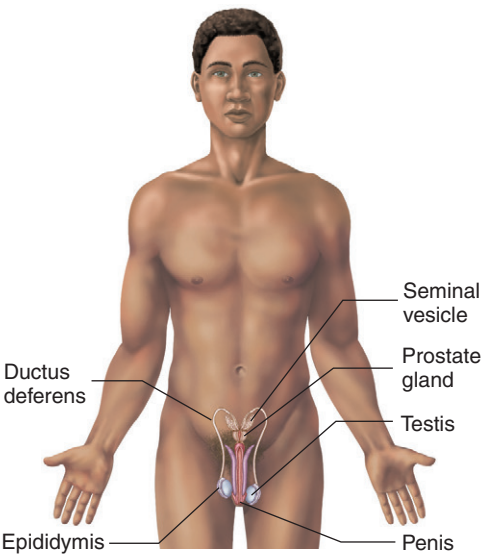
Urinary System

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, vagina, uterus, 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)**

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. A small amount of fluid surrounds each body cell. For cells to function normally, the volume, temperature, and chemical content of this fluid—conditions known as **variables** because their values can change—must remain within a narrow range. 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. Just as your home's thermostat does not keep the air temperature exactly at 75 degrees Fahrenheit at all times, your body's temperature does not stay perfectly stable.

The organ systems help keep the body's internal environment relatively constant. For example, the digestive, respiratory, cardiovascular, and urinary systems work together, so that each cell in the body receives adequate oxygen and nutrients and waste products do not accumulate to a toxic level. If body fluids deviate from homeostasis, body cells do not function normally and can even die. Disease disrupts homeostasis and sometimes results in death. Modern medicine attempts to understand disturbances in homeostasis and works to reestablish a normal range of values.

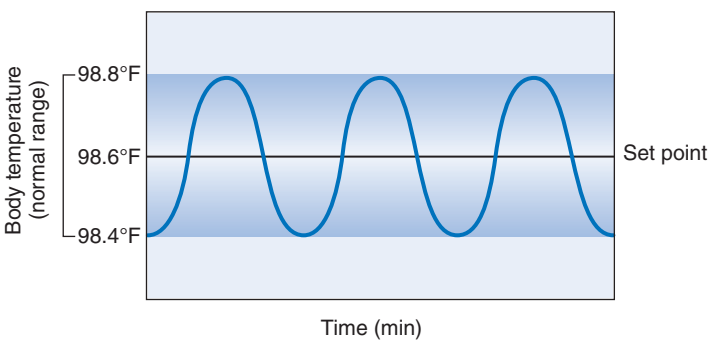


FIGURE 1.4 Homeostasis
Homeostasis is the maintenance of a variable around an ideal normal value, or set point. The value of the variable fluctuates around the set point to establish a normal range of values.

Negative Feedback

Most systems of the body are regulated by **negative-feedback** mechanisms, which maintain homeostasis. *Negative* means that any deviation from the set point is made smaller or is resisted; therefore, in a negative-feedback mechanism, the response to the original stimulus results in deviation from the set point, becoming smaller. An example of important negative-feedback mechanisms in the body are those maintaining normal blood pressure. Normal blood pressure is critical to our health because blood pressure helps move blood from the heart to tissues. The blood transports essential materials to and from the tissues. Because a disruption of normal blood pressure could result in a disease state, maintaining homeostasis through negative feedback is a critical activity. Most negative-feedback mechanisms have three components: (1) a **receptor,** which monitors the value of a variable; (2) a **control center,** which receives

Case STUDY — Orthostatic Hypotension

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

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

Predict 3

Although orthostatic hypotension has many causes, in the elderly it can be due to age-related decreases in neural and cardiovascular responses. Decreased fluid intake while feeling ill and sweating due to a fever can result in dehydration. Dehydration can decrease blood volume and lower blood pressure, increasing the likelihood of orthostatic hypotension. Use figure 1.6 to answer the following:

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

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

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