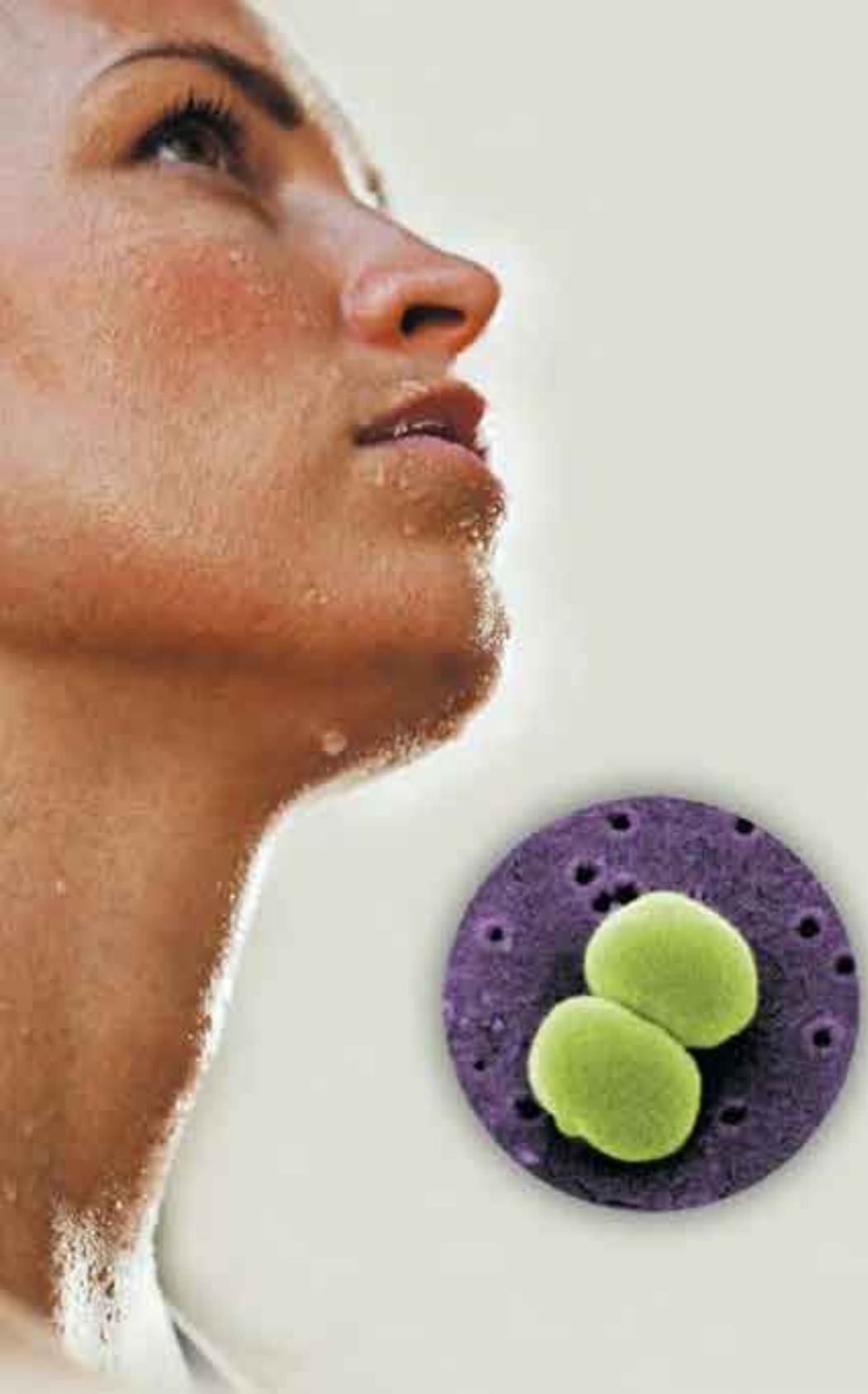

SEELEY'S ESSENTIALS OF ANATOMY & PHYSIOLOGY

NINTH EDITION

Cinnamon VanPutte
Southwestern Illinois College

Jennifer Regan
University of Southern Mississippi

Andrew Russo
University of Iowa

Mc Graw Hill Education

SEELEY'S ESSENTIALS OF ANATOMY & PHYSIOLOGY, NINTH EDITION

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DEDICATION

This text is dedicated to our families. Without their uncompromising support and love, this effort would not have been possible. Our spouses and children have been more than patient while we've spent many nights at the computer surrounded by mountains of books. We also want to acknowledge and dedicate this edition to the previous authors as we continue the standard of excellence that they have set for so many years. For each of us, authoring this text is a culmination of our passion for teaching and represents an opportunity to pass knowledge on to students beyond our own classrooms; this has all been made possible by the support and mentorship we in turn have received from our teachers, colleagues, friends, and family.

About the Authors

Cinnamon L. VanPutte

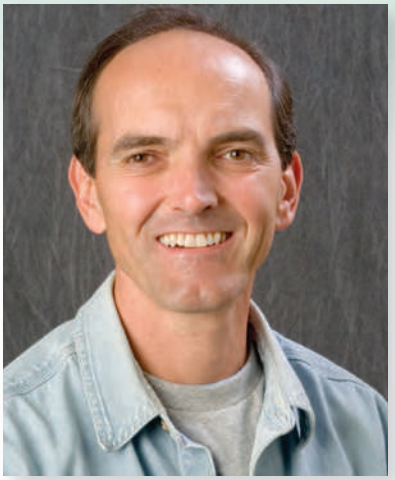
Professor of Biology
Southwestern Illinois College

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.

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Online Teaching and Learning Resources

Help Your Students Prepare for Class

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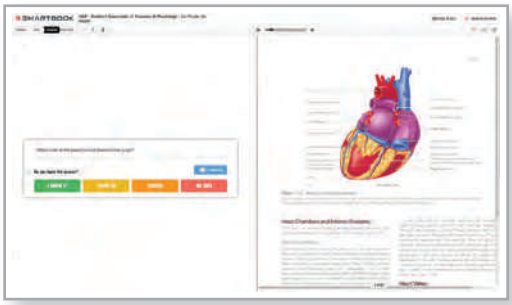


SMARTBOOK®

SmartBook is the first and only adaptive reading experience available for the higher education market. Powered by an intelligent diagnostic and adaptive engine, SmartBook facilitates the reading process by identifying what content a student knows and doesn't know through adaptive assessments. As the student reads, the reading material constantly adapts to ensure the student is focused on the content he or she needs the most to close any knowledge gaps.

LEARNSMART LABS®

LearnSmart Labs is a super adaptive simulated lab experience that brings meaningful scientific exploration to students. Through a series of adaptive questions, LearnSmart Labs identifies a student's knowledge gaps and provides resources to quickly and efficiently close those gaps. Once the student has mastered the necessary basic skills and concepts, they engage in a highly realistic simulated lab experience that allows for mistakes and the execution of the scientific method.

LEARNSMART®

LearnSmart is the only adaptive learning program proven to effectively assess a student's knowledge of basic course content and help them master it. By considering both confidence level and responses to actual content questions, LearnSmart identifies what an individual student knows and doesn't know and builds an optimal learning path, so that they spend less time on concepts they already know and more time on those they don't. LearnSmart also predicts when a student will forget concepts and introduces remedial content to prevent this. The result is that LearnSmart's adaptive learning path helps students learn faster, study more efficiently, and retain more knowledge, allowing instructors to focus valuable class time on higher-level concepts.

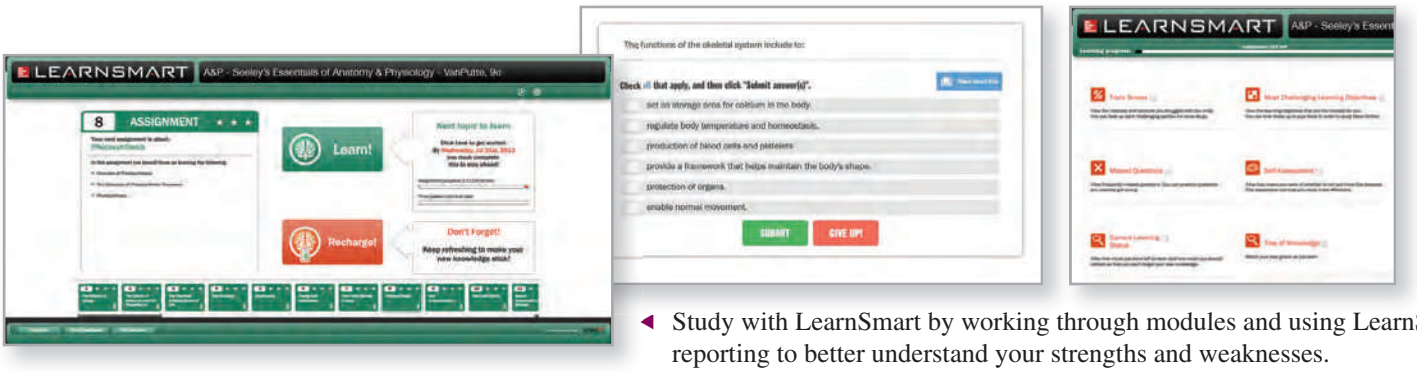
LEARNSMART PREP®

The primary goal of LearnSmart Prep is to help students who are unprepared to take college level courses. Using super adaptive technology, the program identifies what a student doesn't know, and then provides "teachable moments" designed to mimic the office hour experience. When combined with a personalized learning plan, an unprepared or struggling student has all the tools they need to quickly and effectively learn the foundational knowledge and skills necessary to be successful in a college level course.

LEARNSMART®

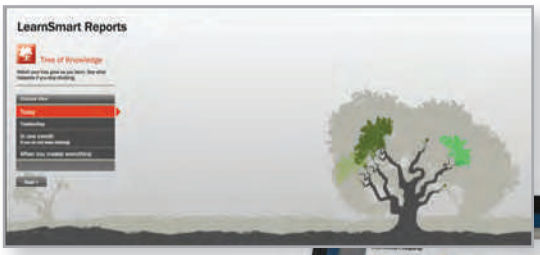
— A Diagnostic, Adaptive Learning System to help you learn—smarter

LearnSmart is the only adaptive learning program proven to effectively assess a student's knowledge of basic course content and help them master it. By considering both confidence level and responses to actual content questions, LearnSmart identifies what an individual student knows and doesn't know and builds an optimal learning path, so that they spend less time on concepts they already know and more time on those they don't. LearnSmart also predicts when a student will forget concepts and introduces remedial content to prevent this. The result is that LearnSmart's adaptive learning path helps students learn faster, study more efficiently, and retain more knowledge, allowing instructors to focus valuable class time on higher-level concepts.



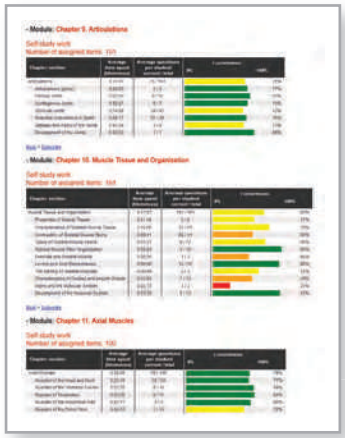
◀ Study with LearnSmart by working through modules and using LearnSmart's reporting to better understand your strengths and weaknesses.

Gauge your student's progress using reports in LearnSmart and Connect. Students can run these same reports in LearnSmart to track their own progress.



▲ The Tree of Knowledge tracks your progress, reporting on short-term successes and long-term retention.

▲ Download the LearnSmart app from iTunes or Google Play and work on LearnSmart from anywhere!



◀ Reports in Connect and LearnSmart help you monitor student assignments and performance, allowing for "just-in-time" teaching to clarify concepts that are more difficult for your students to understand.

McGraw-Hill Campus is an LMS integration service that offers instructors and students universal sign-on, automatic registration, and gradebook synchronization with our learning platforms and content. Gain seamless access to our full library of digital assets—1,500 e-texts and instructor resources that let you build richer courses from within your chosen LMS!

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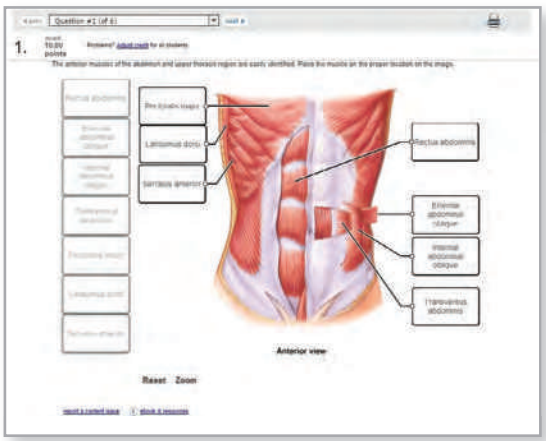
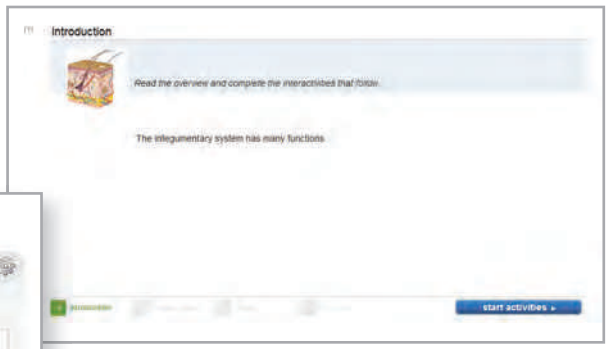
McGraw-Hill Connect® Anatomy & Physiology integrated learning platform provides auto-graded assessments, a customizable, assignable eBook, an adaptive diagnostic tool, and powerful reporting against learning outcomes and level of difficulty—all in an easy-to-use interface. Connect Anatomy & Physiology is specific to your book and can be completely customized to your course and specific learning outcomes, so you help your students connect to just the material they need to know.

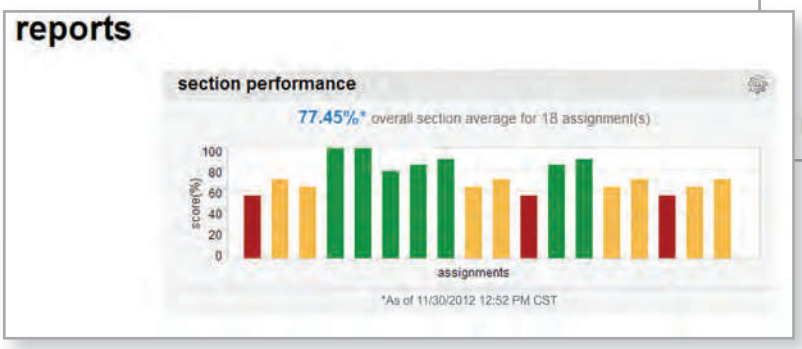
Save time with auto-graded assessments and tutorials

Fully editable, customizable, auto-graded interactive assignments using high quality art from the textbook, animations, and videos from a variety of sources take you way beyond multiple choice. Assignable content is available for every Learning Outcome in the book.



New! Clinical Question Types for Each Chapter!





Gather assessment information

Generate powerful data related to student performance against learning outcomes, specific topics, level of difficulty, and more.

All **Connect** content is pre-tagged to Learning Outcomes for each chapter as well as topic, section, Bloom's Level, and Human Anatomy and Physiology Society (HAPS) Learning Outcomes to assist you in both filtering out unneeded questions for ease of creating assignments and in reporting on your students' performance against these points. This will enhance your ability to effectively assess student learning in your courses by allowing you to align your learning activities to peer-reviewed standards from an international organization.

Presentation Tools Allow Instructors to Customize Lecture

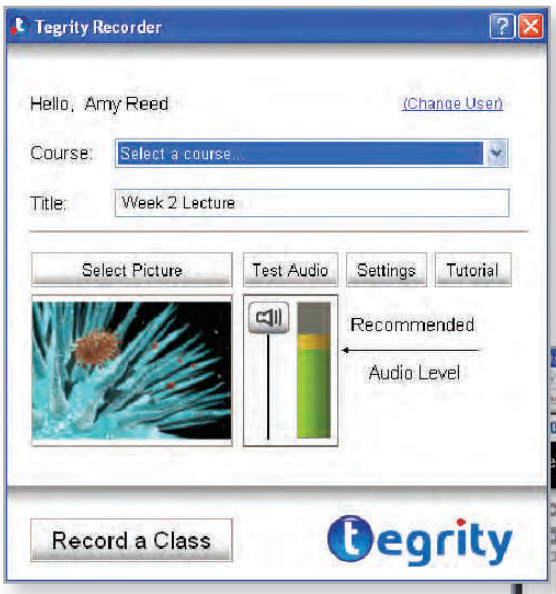
Everything you need, in one location

Enhanced Lecture Presentations contain lecture outlines, FlexArt, adjustable leader lines and labels, art, photos, tables, and animations embedded where appropriate. Fully customizable, but complete and ready to use, these presentations will enable you to spend less time preparing for lecture!

Animations—over 100 animations bringing key concepts to life, available for instructors and students.

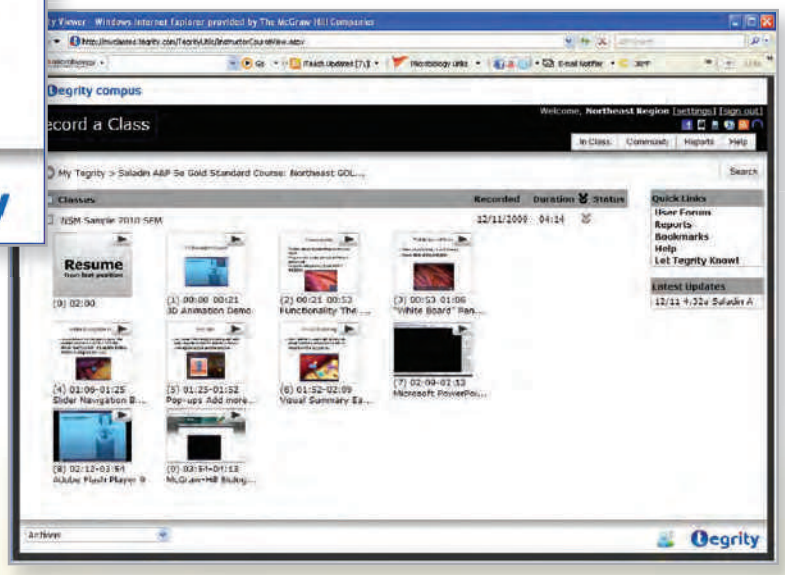
Animation PPTs—animations are truly embedded in PowerPoint for ultimate ease of use! Just copy and paste into your custom slideshow and you're done!

Chapter	Enhanced Lecture PPTs Complete with Lecture Outlines, Flex Art (Fully editable images from the text and key figures that can be manipulated), art, photos, tables and animations embedded where appropriate. Also available without animations embedded.	Animation PPTs Animations embedded into PowerPoint. Allows for easy presentation display and simple copying/pasting to your custom slide show.	Image PPTs All art, tables and photos from the text, optimized for presentation.	Art, Photos & Tables Art files, tables and photos as they appear in the text. Also provided as base art files without labels or leader lines.	Animations Animation files that can be easily downloaded and played.
All Chapters	Enhanced PPT Enhanced Keynote Enhanced PPT without animations	Enhanced PPT Enhanced Keynote	Image PPT	Labeled Images Unlabeled Images	Animations

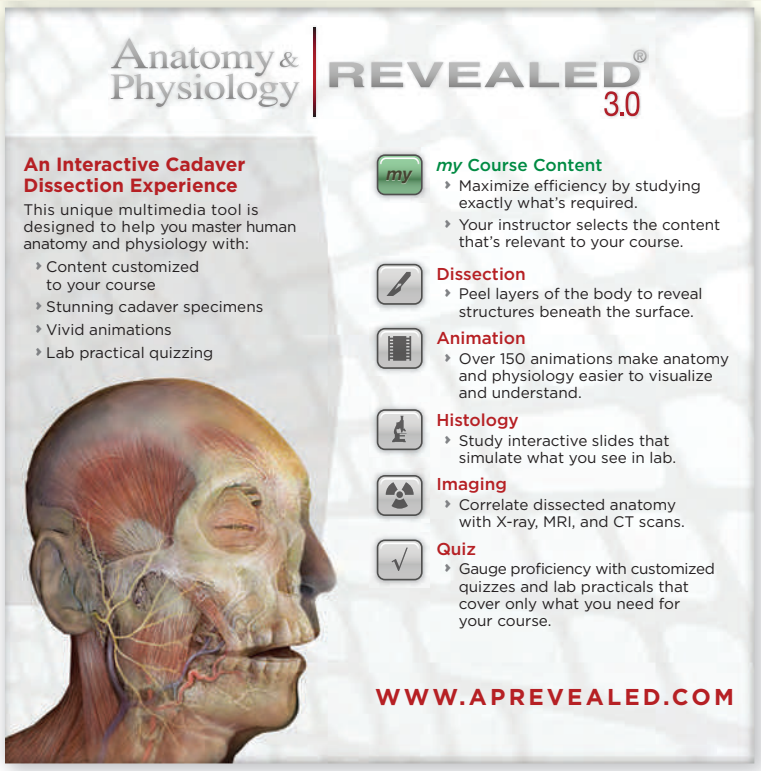


Take your course online—*easily*—with one-click Digital Lecture Capture

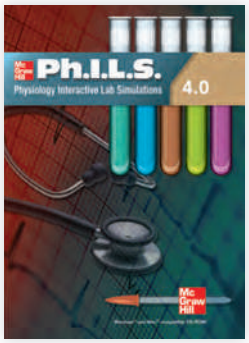
McGraw-Hill Tegrity Campus™ records and distributes your lecture with just a click of a button. Students can view them anytime/anywhere via computer, iPod, or mobile device. Tegrity Campus indexes as it records your slideshow presentations and anything shown on your computer so **students can see keywords to find exactly what they want to study.**



Teaching and Learning Supplements



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

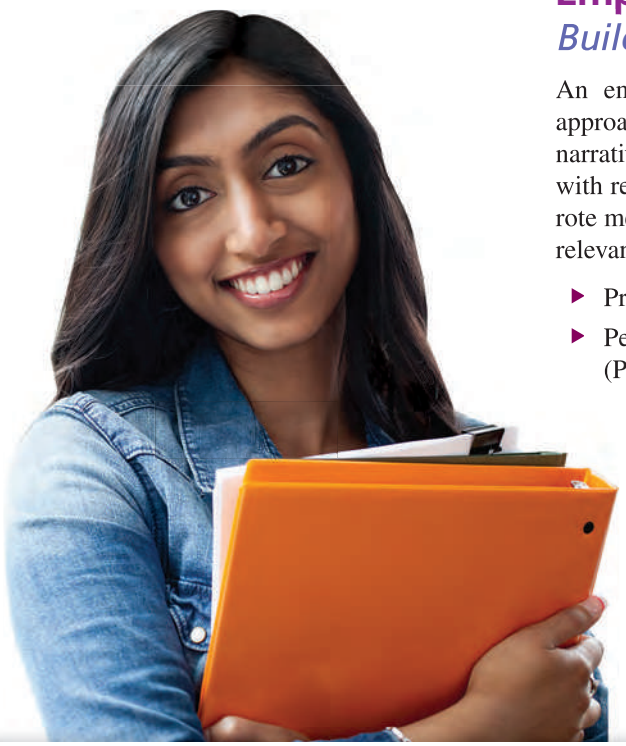


Physiology Interactive Lab Simulations (Ph.I.L.S.) 4.0

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

What Sets Seeley's Essentials Apart?

Seeley's Essentials of Anatomy & Physiology is designed to help students develop a solid, basic understanding of essential concepts in anatomy and physiology without an encyclopedic presentation of detail. Our goal as authors is to offer a textbook that provides enough information to allow students to understand basic concepts, and from that knowledge, make reasonable predictions and analyses. We have taken great care to select critically important information and present it in a way that maximizes understanding.



Emphasis on Critical Thinking—
Building a Knowledge Base for Solving Problems

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 5

What combination of movements at the shoulder and elbow joints allows a person to perform a crawl stroke in swimming?

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.

CRITICAL THINKING

1. A friend tells you that an ECG revealed that her son has a slight heart murmur. Should you be convinced that he has a heart murmur? Explain.
2. Predict the effect on Starling's law of the heart if the parasympathetic (vagus) nerves to the heart are cut.
3. Predict the effect on heart rate if the sensory nerve fibers from the baroreceptors are cut.
4. An experiment is performed on a dog in which the arterial blood pressure in the aorta is monitored before and after the common carotid arteries are clamped. Explain the change in arterial blood pressure that would occur. (*Hint:* Baroreceptors are located in the internal carotid arteries, which are superior to the site of clamping of the common carotid arteries.)
5. Predict the consequences on the heart if a person took a large dose of a drug that blocks calcium channels.
6. What happens to cardiac output following the ingestion of a large amount of fluid?
7. At rest, the cardiac output of athletes and nonathletes can be equal, but the heart rate of athletes is lower than that of nonathletes. At maximum exertion, the maximum heart rate of athletes and nonathletes can be equal, but the cardiac output of athletes is greater than that of nonathletes. Explain these differences.
8. Explain why it is useful that the walls of the ventricles are thicker than those of the atria.
9. Predict the effect of an incompetent aortic semilunar valve on ventricular and aortic pressure during ventricular systole and diastole.

Answers in Appendix D

Critical Thinking These innovative exercises encourage students to apply chapter concepts to solve a problem. Answering these questions helps students build a working knowledge of anatomy and physiology while developing reasoning skills. Answers are provided in Appendix D.

A CASE IN POINT

Injections

Howey Stickum, a student nurse, learns three ways to give injections. An **intradermal injection** is administered by drawing the skin taut and inserting a small needle at a shallow angle into the dermis; an example is the tuberculin skin test. A **subcutaneous injection** is achieved by pinching the skin to form a "tent" and inserting a short needle into the adipose tissue of the subcutaneous tissue; an example is an insulin injection. An **intramuscular injection** is accomplished by inserting a long needle at a 90-degree angle to the skin into a muscle deep to the subcutaneous tissue. Intramuscular injections are used for most vaccines and certain antibiotic

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

When problems in structure and/or function of the human body occur, this is often the best time to comprehend how the two are related. A Case in Point readings, untitled Clinical Asides, and Clinical Impact boxes all work to provide a thorough clinical education that fully supports the surrounding textual material. Systems Pathology and Systems Interactions vignettes provide a modern and system's interaction approach to clinical study of the materials presented.

A Case in Point
These case studies explore relevant issues of clinical interest and explain how material just presented in the text can be used to understand important anatomical and physiological concepts, particularly in a clinical setting.

CLINICAL IMPACT Bone Fractures

Bone fractures can be classified as **open** (or *compound*), if the bone protrudes through the skin, and **closed** (or *simple*), if the skin is not perforated. Figure 6A illustrates some of the different types of fractures. If the fracture totally separates the two bone fragments, it is called **complete;** if it doesn't, it is called **incomplete.** An incomplete fracture that occurs on the convex side of the curve of a bone is called a **greenstick fracture.** A **comminuted** (kom'i-nū-ted; broken into small pieces) fracture is one in which the bone breaks into more than two fragments. An **impacted** fracture occurs when one of the fragments of one part of the bone is driven into the spongy bone of another fragment.

Fractures can also be classified according to the direction of the fracture line as **linear** (parallel to the long axis); **transverse** (at right angles to the long axis); or **oblique** or **spiral** (at an angle other than a right angle to the long axis).

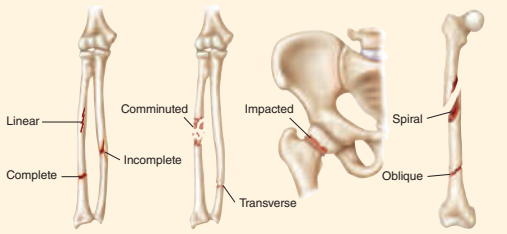
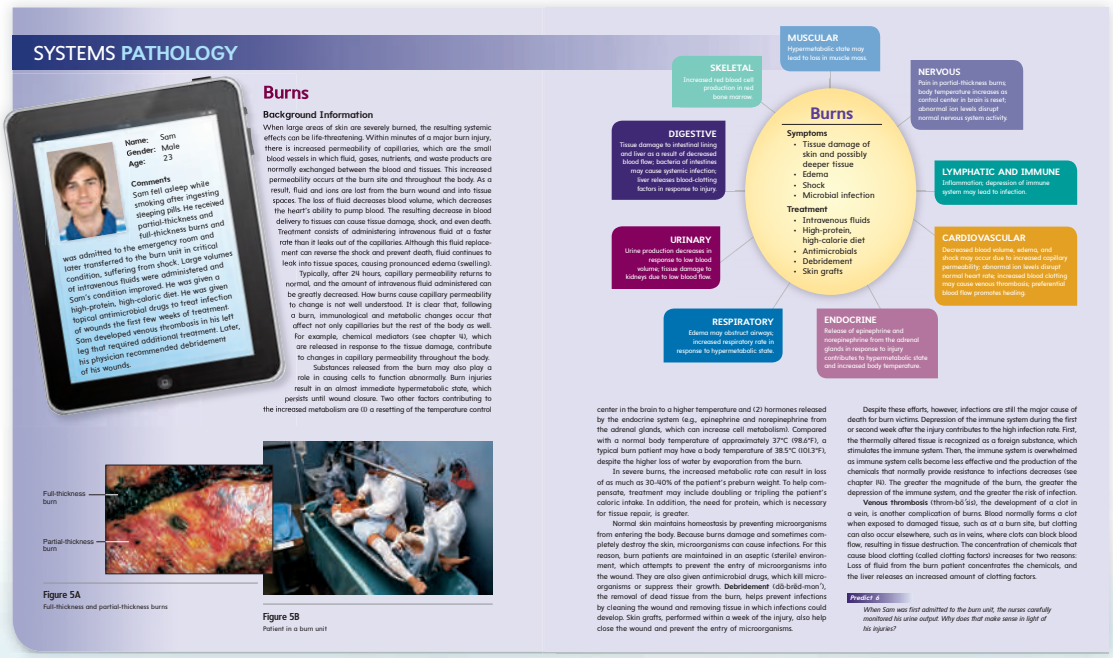


Figure 6A
Types of bone fractures.

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

- Clinical Impact boxes (placed at key points in the text)
- Chapter opening clinical scenarios/vignettes have been given a new look and many are revised
- Learn to Predict and chapter Predict questions with unique Learn to Predict Answers
- Clinical Asides
- Clinical Impact Essays
- Clinical Pathologies and Systems Interactions

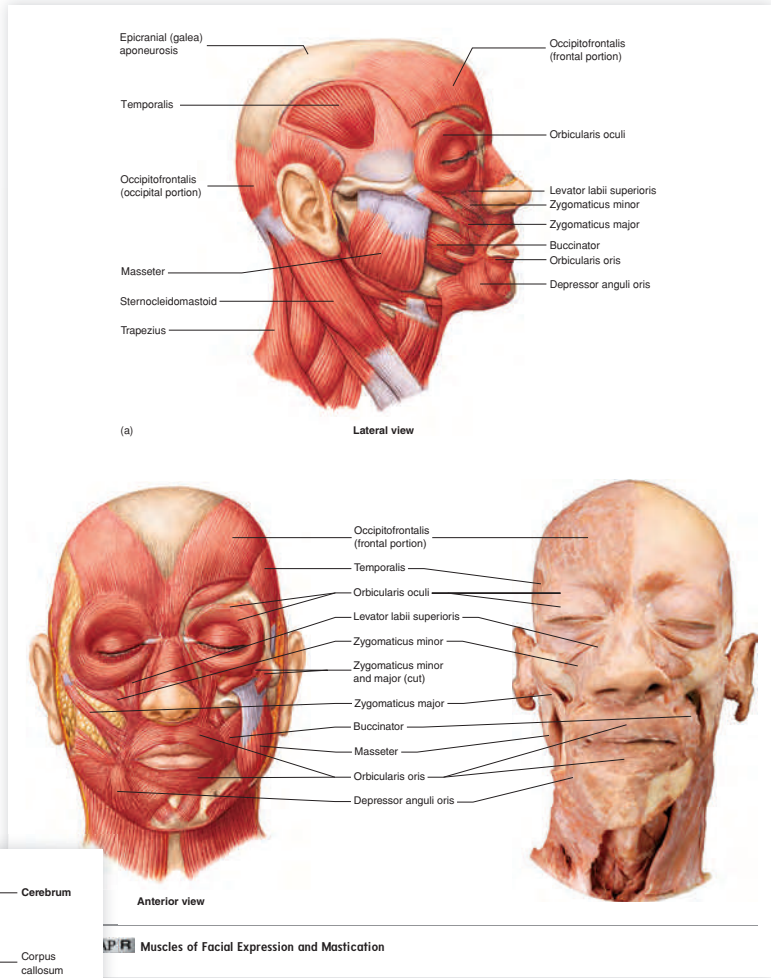


Systems Pathology Vignettes These spreads explore a specific condition or disorder related to a particular body system. Presented in a simplified case study format, each Systems Pathology vignette begins with a patient history followed by background information about the featured topic.

Exceptional Art—*Instructive Artwork Promotes Interest and Clarifies Ideas*

A picture is worth a thousand words—especially when you're learning anatomy and physiology. Brilliantly rendered and carefully reviewed for accuracy and consistency, the precisely labeled illustrations and photos provide concrete, visual reinforcement of important topics discussed throughout the text.

Realistic Anatomical Art The anatomical figures in *Seeley's Essentials of Anatomy & Physiology* have been carefully drawn to convey realistic, three-dimensional detail. Richly textured bones and artfully shaded muscles, organs, and vessels lend a sense of realism to the figures that helps students envision the appearance of actual structures within the body.



AP R Muscles of Facial Expression and Mastication

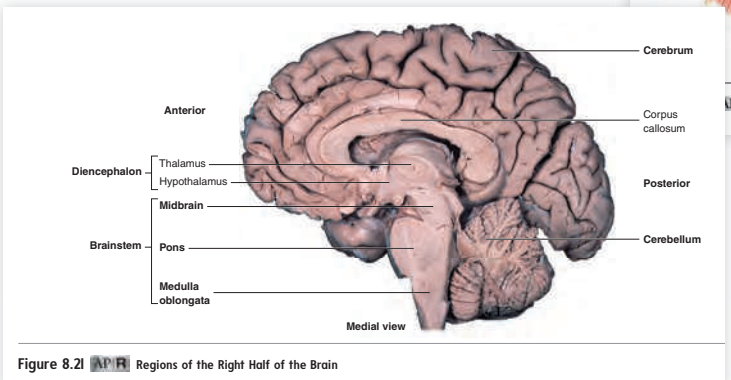
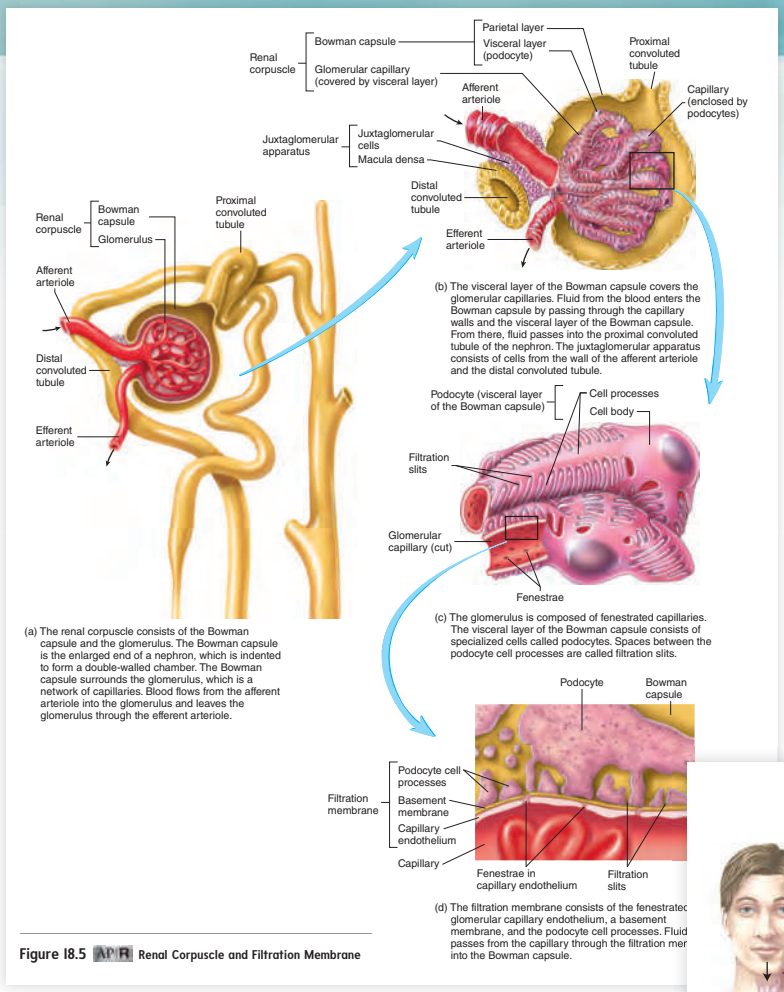


Figure 8.2l AP R Regions of the Right Half of the Brain

Atlas-quality cadaver images 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.



(a) The renal corpuscle consists of the Bowman capsule and the glomerulus. The Bowman capsule is the enlarged end of a nephron, which is indented to form a double-walled chamber. The Bowman capsule surrounds the glomerulus, which is a network of capillaries. Blood flows from the afferent arteriole into the glomerulus and leaves the glomerulus through the efferent arteriole.

(b) The visceral layer of the Bowman capsule covers the glomerular capillaries. Fluid from the blood enters the Bowman capsule by passing through the capillary walls and the visceral layer of the Bowman capsule. From there, fluid passes into the proximal convoluted tubule of the nephron. The juxtaglomerular apparatus consists of cells from the wall of the afferent arteriole and the distal convoluted tubule.

(c) The glomerulus is composed of fenestrated capillaries. The visceral layer of the Bowman capsule consists of specialized cells called podocytes. Spaces between the podocyte cell processes are called filtration slits.

(d) The filtration membrane consists of the fenestrated glomerular capillary endothelium, a basement membrane, and the podocyte cell processes. Fluid passes from the capillary through the filtration mem into the Bowman capsule.

Figure 18.5 A|P|R **Renal Corpuscle and Filtration Membrane**

Multi-level Perspective Illustrations depicting complex structures or processes combine macroscopic and microscopic views to help students see the relationships between increasingly detailed drawings.

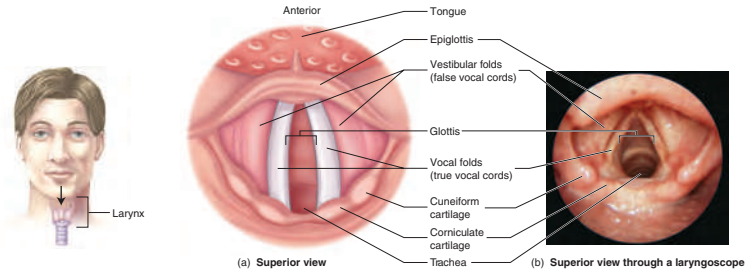


Figure 15.4 A|P|R **Vestibular and Vocal Folds**

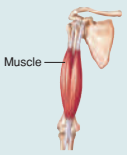
(*Far left*) The arrow shows the direction of viewing the vestibular and vocal folds. (*a*) The relationship of the vestibular folds to the vocal folds and the laryngeal cartilages. (*b*) Superior view of the vestibular and vocal folds as seen through a laryngoscope.

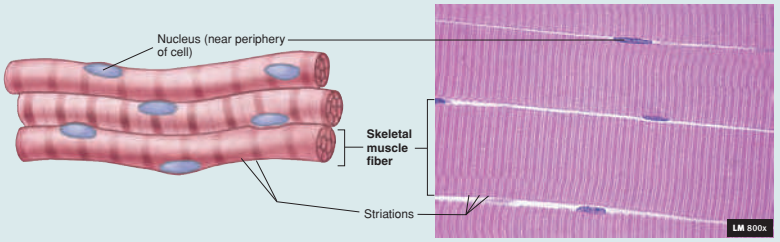
Combination Art Drawings are often paired with photographs to enhance the visualization of structures.

TABLE 4.10 Muscle Tissue

(a) Skeletal Muscle A|P|R

Structure:	Function:	Location:
Skeletal muscle cells or fibers appear striated (banded); cells are large, long, and cylindrical, with many nuclei	Movement of the body; under voluntary control	Attached to bone or other connective tissue

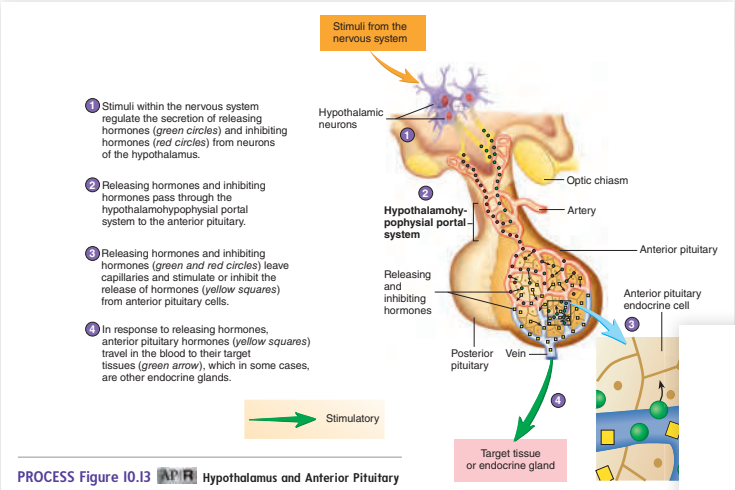




Histology Micrographs Light micrographs, as well as scanning and transmission electron micrographs, are used in conjunction with illustrations to present a true picture of anatomy and physiology from the cellular level.

Specialized Figures Clarify Tough Concepts

Studying anatomy and physiology does not have to be an intimidating task mired in memorization. *Seeley's Essentials of 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.



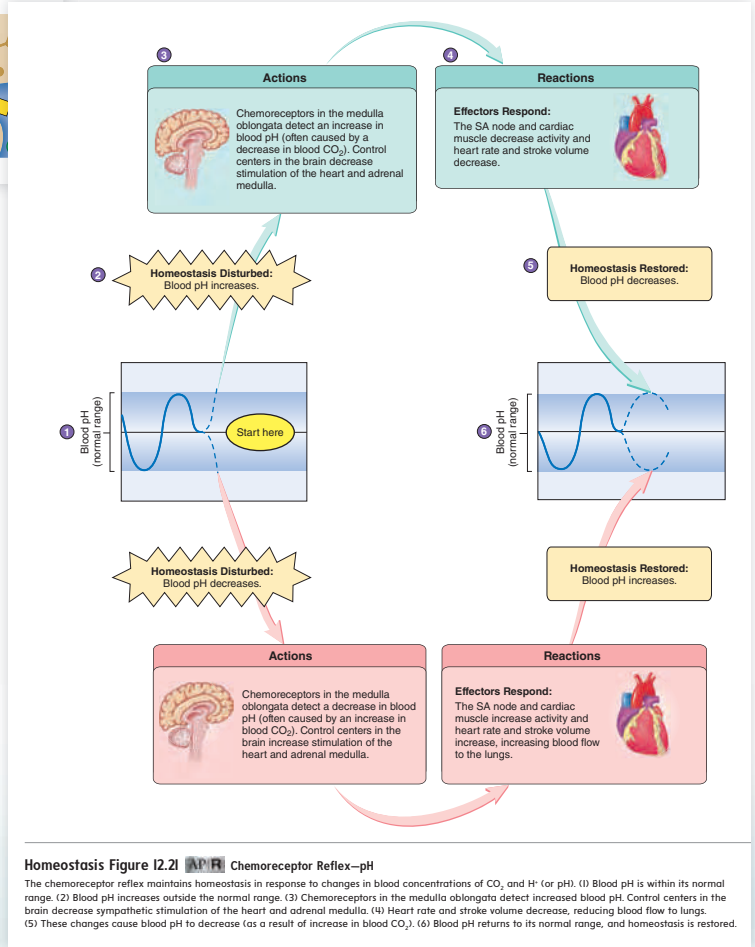
PROCESS Figure 10.13 APR Hypothalamus and Anterior Pituitary

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.

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 ninth edition.
- More succinct explanations
- Small icon illustrations included in boxes depict the organ or structure being discussed.

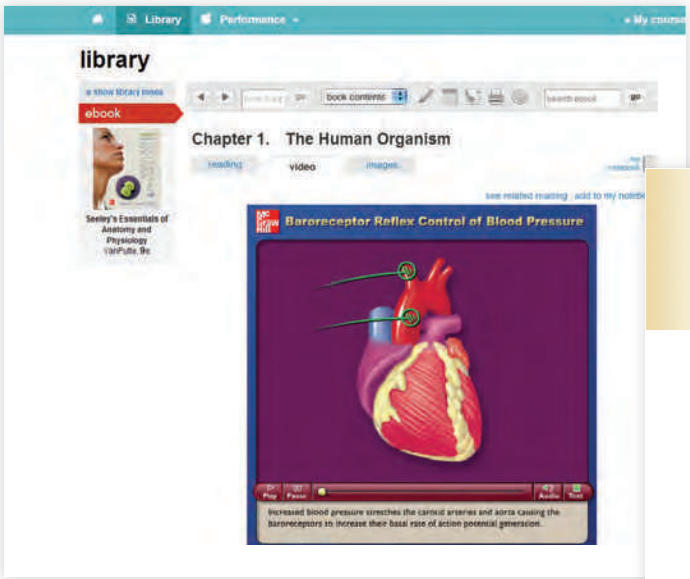


Homeostasis Figure 12.2l APR **Chemoreceptor Reflex—pH**

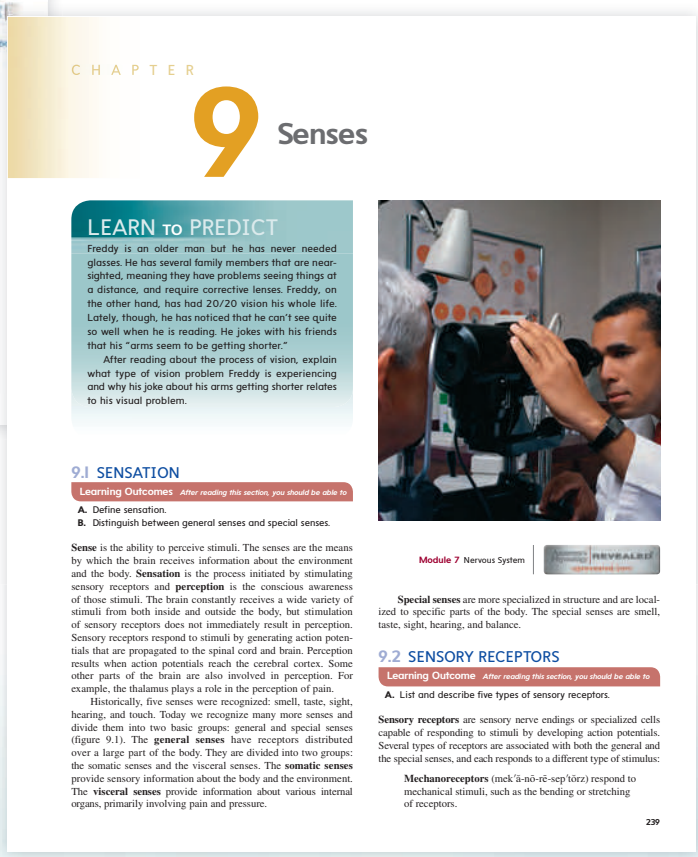
The chemoreceptor reflex maintains homeostasis in response to changes in blood concentrations of CO_2 and H^+ (or pH). (1) Blood pH is within its normal range. (2) Blood pH increases outside the normal range. (3) Chemoreceptors in the medulla oblongata detect increased blood pH. Control centers in the brain decrease sympathetic stimulation of the heart and adrenal medulla. (4) Heart rate and stroke volume decrease, reducing blood flow to lungs. (5) These changes cause blood pH to decrease (as a result of increase in blood CO_2). (6) Blood pH returns to its normal range, and homeostasis is restored.

Outstanding Instructor and Student Resources—
Focusing teaching and engaging students

- In-text Learning Outcomes are linked to section headers and Assessment Questions
- *McGraw-Hill Anatomy & Physiology REVEALED® (APR)* links to figures for eBook
- Learning Outcomes correlation guide between Predict, Learn to Predict, Review and Comprehension, and Critical Thinking Questions
- Correlation guide between APR and the textbook
- Enhanced Lecture PowerPoints with APR cadaver images
- Lecture PowerPoints with embedded animations
- McGraw-Hill Connect® Course Management system
- Access to media-rich eBooks
- McGraw-Hill LearnSmart® tailors study time and identifies at-risk students
- **NEW!** Clinical questions added to the Connect Question Bank based on the Clinical Features within each chapter



The interactive eBook takes the reading experience to a new level with links to animations and interactive exercises that supplement the text.


CHAPTER 9 Senses

LEARN TO PREDICT

Freddy is an older man but he has never needed glasses. He has several family members that are nearsighted, meaning they have problems seeing things at a distance, and require corrective lenses. Freddy, on the other hand, has had 20/20 vision his whole life. Lately, though, he has noticed that he can't see quite so well when he is reading. He jokes with his friends that his "arms seem to be getting shorter."

After reading about the process of vision, explain what type of vision problem Freddy is experiencing and why his joke about his arms getting shorter relates to his visual problem.

9.1 SENSATION

Learning Outcomes *After reading this section, you should be able to*

A. Define sensation.
B. Distinguish between general senses and special senses.

Sense is the ability to perceive stimuli. The senses are the means by which the brain receives information about the environment and the body. **Sensation** is the process initiated by stimulating sensory receptors and **perception** is the conscious awareness of those stimuli. The brain constantly receives a wide variety of stimuli from both inside and outside the body, but stimulation of sensory receptors does not immediately result in perception. Sensory receptors respond to stimuli by generating action potentials that are propagated to the spinal cord and brain. Perception results when action potentials reach the cerebral cortex. Some other parts of the brain are also involved in perception. For example, the thalamus plays a role in the perception of pain.

Historically, five senses were recognized: smell, taste, sight, hearing, and touch. Today we recognize many more senses and divide them into two basic groups: general and special senses (figure 9.1). The **general senses** have receptors distributed over a large part of the body. They are divided into two groups: the somatic senses and the visceral senses. The **somatic senses** provide sensory information about the body and the environment. The **visceral senses** provide information about various internal organs, primarily involving pain and pressure.

Module 7 Nervous System

Special senses are more specialized in structure and are localized to specific parts of the body. The special senses are smell, taste, sight, hearing, and balance.

9.2 SENSORY RECEPTORS

Learning Outcome *After reading this section, you should be able to*

A. List and describe five types of sensory receptors.

Sensory receptors are sensory nerve endings or specialized cells capable of responding to stimuli by developing action potentials. Several types of receptors are associated with both the general and the special senses, and each responds to a different type of stimulus:

Mechanoreceptors (mek'ă-nō-rĕ-sep'tŏrz) respond to mechanical stimuli, such as the bending or stretching of receptors.

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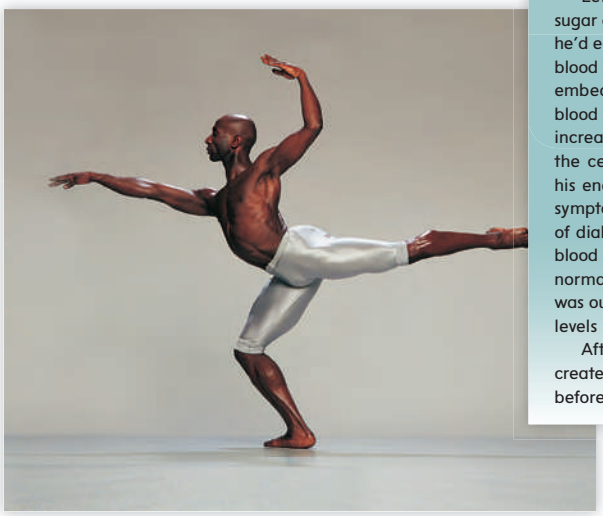
Functionality such as highlighting and post-it notes allow customizing for a personalized study guide.

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

- 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 links with the chapter opener photo and helps introduce the subject matter covered within the chapter.



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 the 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.

- A new 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.

ANSWER TO LEARN TO PREDICT

The first Predict feature in every chapter of this text is designed to help you develop the skills to successfully answer critical thinking questions. The first step in the process is always to analyze the question itself. In this case, the question asks you to evaluate the mechanisms governing Renzo's blood sugar levels, and it provides the clue that there's a homeostatic mechanism involved. In addition, the question describes a series of events that helps create an explanation: Renzo doesn't feel satisfied after eating, has elevated blood sugar, and then is prescribed an insulin pump.

In chapter I, we learn that homeostasis is the maintenance of a relatively constant internal environment. Renzo experienced hunger despite eating, and his blood sugar levels were higher than normal. In this situation, we see a disruption in homeostasis because his blood sugar stayed too high after eating. Normally, an increased blood sugar after a meal would return to the normal range by the activity of insulin secreted by the pancreas. When blood sugar returns to normal, insulin secretion stops. In Renzo's case, his pancreas has stopped making insulin. Thus, the doctor prescribed an insulin pump to take over for his pancreas. Now when Renzo eats, the insulin pump puts insulin into his blood and his blood sugar levels are maintained near the set point.

Answers to the rest of this chapter's Predict questions are in Appendix E.

PEDAGOGICAL FEATURES ENSURE SUCCESS

A major change you will notice in the ninth edition is the incorporation of Learning Outcomes that are closely linked with in-chapter Predict and Learn to Predict questions as well as the Summary, Critical Thinking, and Review and Comprehension questions. These carefully designed learning aids assist students in reviewing chapter content, evaluating their grasp of key concepts, and utilizing what they've learned.

3.4 MOVEMENT THROUGH THE CELL MEMBRANE

Learning Outcomes *After reading this section, you should be able to*

- **A.** Define diffusion and concentration gradient.
- **B.** Explain the role of osmosis and that of osmotic pressure in controlling the movement of water across the cell membrane. Compare hypotonic, isotonic, and hypertonic solutions.
- **C.** Define carrier-mediated transport, and compare the processes of facilitated diffusion, active transport, and secondary active transport.
- **D.** Describe endocytosis and exocytosis.

Studying Anatomy and Physiology does not have to be intimidating

SUMMARY

12.1 Functions of the Heart (p. 318)

1. The heart generates blood pressure.
2. The heart routes blood through the systemic and pulmonary circulations.
3. The ventricles are the main pumping chambers of the heart. The right ventricle pumps blood into the pulmonary trunk, and the left ventricle, which has a thicker wall, pumps blood into the aorta.
4. The ventricles are separated internally by the interventricular septum.

REVIEW AND COMPREHENSION

1. Describe the size and location of the heart, including its base and apex.
2. Describe the structure and function of the pericardium.
3. What chambers make up the left and right sides of the heart? What are their functions?
4. Describe the structure and location of the tricuspid, bicuspid, and

16. Define cardiac cycle, systole, and diastole.
17. Describe blood flow and the opening and closing of heart valves during the cardiac cycle.
18. Describe the pressure changes that occur in the left atrium, left ventricle, and aorta during ventricular systole and diastole

CRITICAL THINKING

1. A friend tells you that an ECG revealed that her son has a slight heart murmur. Should you be convinced that he has a heart murmur? Explain.
2. Predict the effect on Starling's law of the heart if the parasympathetic (vagus) nerves to the heart are cut.
3. Predict the effect on heart rate if the sensory nerve fibers from the baroreceptors are cut.
4. An experiment is performed on a dog in which the arterial blood pressure in the aorta is monitored before and after the common carotid arteries are clamped. Explain the change in arterial blood pressure that would occur. (*Hint:* Baroreceptors are located in the internal carotid arteries, which are superior to the site of clamping of the common carotid arteries.)
5. Predict the consequences on the heart if a person took a large dose of a drug that blocks calcium channels.
6. What happens to cardiac output following the ingestion of a large amount of fluid?
7. At rest, the cardiac output of athletes and nonathletes can be equal, but the heart rate of athletes is lower than that of nonathletes. At maximum exertion, the maximum heart rate of athletes and nonathletes can be equal, but the cardiac output of athletes is greater than that of nonathletes. Explain these differences.
8. Explain why it is useful that the walls of the ventricles are thicker than those of the atria.
9. Predict the effect of an incompetent aortic semilunar valve on ventricular and aortic pressure during ventricular systole and diastole.

Answers in Appendix D

Chapter Summary The summary is now conveniently linked by section and page number while it briefly states the important facts and concepts covered in each chapter.

Review and Comprehension These multiple-choice practice questions cover the main points presented in the chapter. Completing this self-test helps students gauge their mastery of the material.

Critical Thinking Questions These innovative exercises encourage students to apply chapter concepts to solve problems. Answering these questions helps build their working knowledge of anatomy and physiology while developing reasoning and critical thinking skills.

Answers to Predict Questions These innovative critical thinking questions encourage students to become active learners as they read. Predict Questions challenge the understanding of new concepts needed to solve a problem. The questions are answered in Appendix E, allowing students to evaluate their responses and understand the logic used to arrive at the correct answer.

Ninth Edition Changes

WHAT'S NEW AND IMPROVED?

The ninth edition of *Seeley's Essentials of Anatomy & Physiology* is the result of extensive analysis of the text and evaluation of input from anatomy and physiology instructors who have thoroughly reviewed chapters. The result 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. Updating of content, along with revision of Homeostasis Figures and the addition of a new feature entitled Microbes In Your Body, make this an exciting edition.

Learning Outcomes and Assessment—
Helping instructors track student progress

UPDATED! Learning Outcomes are carefully written to outline expectations for each section

NEW! Microbes In Your Body feature discussing the many important and sometimes, little known roles of microbes and the physiology of homeostasis

UPDATED! Online student questions and test bank questions are correlated with Learning Outcomes to further scaffold and measure student progress and understanding

NEW! Online clinical study questions are based from clinical features within the text including Microbes In Your Body and System Pathologies, and are correlated with Learning Outcomes and HAPS Learning Objectives to further develop and measure higher level thinking and application of learned content

6.8 JOINTS

Learning Outcomes *After reading this section, you should be able to*

- **A.** Describe the two systems for classifying joints.
- **B.** Explain the structure of a fibrous joint, list the three types, and give examples of each type.
- **C.** Give examples of cartilaginous joints.
- **D.** Illustrate the structure of a synovial joint and explain the roles of the components of a synovial joint.
- **E.** Classify synovial joints based on the shape of the bones in the joint and give an example of each type.
- **F.** Demonstrate the difference between the following pairs of movements: flexion and extension; plantar flexion and dorsiflexion; abduction and adduction; supination and pronation; elevation and depression; protraction and retraction; opposition and reposition; inversion and eversion.

MICROBES IN YOUR BODY Do our bacteria make us fat?

Obesity has increased at an alarming rate over the last three decades. It is estimated that over 150 billion adults worldwide are overweight or obese. In the United States, 1/3 of adults are obese. As obesity rates have increased, so have the rates of obesity-related health conditions such as insulin resistance, diabetes, and cardiovascular disease. Why this dramatic increase? There are two main reasons for obesity: diet/lifestyle and gut bacteria; and it seems these two may be related.

The most familiar cause of obesity is diet and lifestyle. The "typical" Western diet consists of frequent large meals high in refined grains, red meat, saturated fats, and sugary drinks. This is in sharp contrast to healthier diets rich in whole grains, vegetables, fruits, and nuts that help with weight control and prevention of chronic disease. From an evolutionary perspective, our bodies are adapted to conserve energy because food sources were scarce for ancient humans. Many of us now have easy access to energy-rich foods. Combined with a reduction in physical activity and less sleep for many Americans, the Western diet and lifestyle can lead to obesity and poor health.

Bacteroidetes than Firmicutes, while the opposite is true for obese people.

We now know that gut microbiota affect nutrient processing and absorption, hormonal regulation of nutrient use by body cells, and even our hunger level. In addition, our diet can influence the type of bacteria in our GI system. Studies of humans on carbohydrate-restricted or fat-restricted diets demonstrated that after weight loss, the number of Bacteroidetes ("lean person" bacteria) increased, while the number of Firmicutes ("obese person" bacteria) decreased. This makes sense in light of the fact that Firmicutes bacteria break down ingested food more completely than Bacterioidetes, which makes the food's energy easier to absorb by the human gut. Obese individuals store the absorbed energy in adipose tissue, which contributes to weight gain.

Furthermore, experiments with germ-free mice—mice lacking normal gut microbiota—have demonstrated just how important normal gut bacteria are for homeostasis. In the absence of normal gut microbiota, malfunctions in germ-free mice are widespread and significant. For example, when germ-free mice received gut microbiota transplants

pathogens. Finally, germ-free mice display an enhanced stress response, which is substantially reduced upon implantation of gut microbiota. Overall, these experiments demonstrate that there is a much greater correlation between bacteria, gut health, obesity, and anxiety than ever before realized.

Changes in gut microbiota also alter the hormonal regulation of nutrient use. Inflammation-promoting effects of an imbalanced gut microbiota is thought to induce obesity via promoting insulin resistance, a known autoimmu
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gery when pati
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well documented
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◀ This feature helps students to understand the important role microbes play in helping various systems of the body to maintain homeostasis.

MICROBES IN YOUR BODY Using Bacteria to Fight Bacteria

Acne (acne vulgaris) is the most common skin condition in the United States. Though 80% of all American adolescents develop acne, adults can also be affected by it. When considering all age groups, approximately 40 to 50 million Americans suffer from acne. Unfortunately, there is not a tried and true cure for acne; however, new research examining the skin microbiome may have found a natural and effective treatment to get healthy, clear skin. Unique species of bacteria, *Propionibacterium acnes (P. acnes),* are found in sebum-rich areas of the skin, such as the forehead, side of the nose, and back. Although it has been difficult to study these bacteria, the inception of the Human Microbiome Project (see "Getting to Know Your Bacteria" in chapter 1) allowed scientists to determine specific genetic traits of skin microbiome bacteria. Using this technique, scientists have identified three unique strains of *P. acnes*. Of the three strains, one strain is more dominant in people with acne-free skin. Research has shown that this strain of *P. acnes* does not adversely affect the host. However, the other two strains of *P. acnes* are pathogenic to humans. So, how does this information help scientists learn how to prevent acne? It seems that the "good" *P. acnes* prevents invasion of the skin by certain bacteria through a natural metabolic process. When *P. acnes* breaks down lipids, the skin pH is lowered to a level not tolerated by the invading bacteria. Scientists have proposed that the strain of *P. acnes* in healthy skin ("good" *P. acnes*) kills off the pathogenic strains of *P. acnes* ("bad" *P. acnes*) in a similar fashion. Since acne-affected people do not host the "good" strain, the "bad" strain can take over and cause the annoying skin eruptions of acne. Thus, perhaps in the future to prevent acne, affected people can apply the "good" *P. acnes* in a cream to prevent the "bad" *P. acnes* from taking over.

Chapter-by-Chapter Changes

Chapter 1

- Added figure legend to chapter opener photo to link photo more closely to the Learn to Predict for a complete story
- Throughout the entire textbook, dividing lines were added between the figures and the legends to help students clearly visualize the art concepts
- Systems figures were enhanced to increase clarity
- Homeostasis discussion was rewritten per reviewer feedback to: simplify, clarify, and make more accurate
- New predict #2 question and answer written to reflect changes in homeostasis discussion
- Figure 1.5 revised to match new homeostasis discussion
- Throughout the chapter and the entire textbook, adipose tissue replaces fat to be more accurate when referring to the material (adipose) where the chemical (fat) is stored
- Throughout the entire textbook, all homeostasis figures were revised for consistency and accuracy
- Figure 1.7 was updated to enhance students' comprehension of positive feedback, which is frequently misunderstood
- Figure 1.14 was updated by adding in organ art to help students relate the terms to actual organs
- New feature added: Microbes in Your Body, "Getting to Know your Bacteria." This helps the text to stay current in the field of biology where there is a greater focus on the microbiome and its importance in human health and homeostasis

Chapter 2

- Added a legend to the chapter opening photo to link better to the Learn to Predict
- Updated the discussion in section 2.1, "Ionic Bonding" for clarity
- Figure 2.2 was updated for better visibility and clarity
- Figure 2.3 was also updated for better visibility and clarity
- For consistency throughout the entire text, some symbols have replaced the words where appropriate (CO_2, O_2, and H_2O)
- Added table 2.3 to distinguish amongst chemical bond types
- Figure 2.13*b* was updated to represent unsaturated fatty acids in a more realistic way. Students need to see the molecule actually bent and not linear
- Figure 2.15 was updated to match other figures throughout the textbook
- Figure 2.17 was updated to match other graphs throughout the textbook
- A figure legend was added to figure 2.20 to explain why the bond between adjacent phosphates is represented differently than all the previous bonds shown in the chapter. Students without a chemistry background may be unfamiliar with this symbol

Chapter 3

- Increased size of figure 3.1 for better visual of organelles
- Image coloration changed for cytoplasm clarity
- Process figure 3.26 revised for clarity
- Osmosis discussion revised for clarity

Chapter 4

- Table 4.1 was updated to match the art in this chapter
- Table 4.2 was updated for consistency throughout the chapter
- In table 4.2*a,* the histology image was replaced with a clearer one of simple squamous epithelium
- In tables 4.4*a,* 4.6*a,* 4.7*c,* 4.9, and 4.10*c* a clearer histology image was used for clarity
- The terminology was changed from "respiratory passages" to "respiratory airways" for clarity
- The language in section 4.6, "Tissue Membranes" was clarified to indicate that the section describes tissue membranes and not cell membranes. "Fat" was changed to "adipose tissue" where appropriate

Chapter 5

- New Microbes in Your Body: Using Bacteria to Fight Bacteria

Chapter 6

- Throughout the chapter, the bone shading was lightened for realism
- A photo caption was added to the cover opener photo to link it to the Learn to Predict
- Figure 6.8 was updated to add an x-ray of a broken bone before and after callus formation
- In 6A, "greenstick fracture" was more clearly defined
- Throughout the chapter, the skull art's coloration was substantially brightened to help students more easily differentiate between the individual skull bones (figures 6.11 and 6.12*a*)
- In figure 6.12*a,* the nasal conchae drawings were clarified because in the former edition, the bones were not distinguishable from the background
- Figures 6.14, 6.15, 6.19*a,* 6.20, 6.25, 6.26, 6.31, 6.33 were revised to add photos of actual skulls, which share leader lines with the line art. This helps students conceptualize the anatomy more clearly
- Figures 6.24 and 6.28 were revised for accuracy of leader line placement
- The definition of flexion and extension was updated and corrected per reviewer feedback

Chapter 7

- Throughout the chapter, the actin and myosin myofilament line art was arranged so the myosin appears thicker than the actin
- A new Learn to Predict question was written that is more closely aligned with the chapter opening photo and muscle function
- A legend was added to the chapter opener photo to tie it in with the Learn to Predict

- The text for “Skeletal Muscle Structure” in section 7.2 was rewritten to flow logically from a macro view to a micro view
- Figure 7.2 was heavily revised so the art is oriented linearly and flows directly to the next, more magnified level of muscle structure
- Figure 7.3 was also heavily revised: Part a was added to show the logical flow from the macro to the micro; part b was cropped so the myofibrils are oriented linearly on the page and correlate more directly to part a; part c was added to provide a visual orientation of myofilament arrangement relative to each other
- Predict question #2 is new and covers muscle fiber electrical activity—a predict question topic that was missing in the previous edition
- Figure 7.11 was revised to better correlate a given response to its corresponding stimulus frequency
- Table 7.1 was added for clear distinction amongst fiber types
- The section on Energy Requirements for Muscle Contraction was updated to reflect the most up-to-date information about lactate fate. The definition of aerobic and anaerobic respiration in skeletal muscle was clarified
- The section on muscle fatigue was updated
- Figure 7.12 was heavily revised to visually differentiate between energy usage at rest vs. exercise
- A section on fiber type effect on activity level was added
- Table 7.3 on muscle nomenclature was added
- Figure 7.16 was updated to add a cadaver photo with shared leader lines with the line art. This helps students visualize the anatomy more clearly
- Table 7.13 was revised for consistent pronunciation of “teres”
- The Diseases and Disorders table was revised to accurately discuss ATP production and not lactic acid production

Chapter 8

- New figure 8.2 better represents the organization of the nervous system
- Revision of figure 8.11 more accurately represents saltatory conduction
- Dermatomal map added to figure 8.20

Chapter 9

- New figure 9.1 to present types of senses
- New section 9.2 describes types of receptors
- New figure 9.6 presents the pathways for the sense of taste
- Figure 9.16*a* revised for clarity
- New figure 9.20 presents the auditory pathway

Chapter 10

- Added a new Microbes in Your Body—“Do Our Bacteria Make Us Fat?” boxed reading
- Table 10.1 was updated to clarify the definition of autocrine chemical messengers
- The definition of paracrine chemical messengers in section 10.1 was updated
- Section 10.3 was updated to clarify hormones’ sources as groups of cells as well as glands
- Section 10.4 was updated for clarity and accuracy
- Updated section 10.5 “Inhibition of Hormone Release by Hormonal Stimuli” for clarity
- Section 10.6 “Classes of Receptors” was revised to reflect newer research on membrane-bound receptor action by lipid-soluble hormones
- Figures 10.7*a* and 10.8 were updated for consistency with others for style
- Figure 10.8 was updated to reflect the information about membrane-bound receptor actions
- Figures 10.9 and 10.10 were updated to match the style of others throughout the textbook
- Section 10.6—“Membrane-bound Receptors and Signal Amplification” was revised for clarity and to incorporate lipid-soluble hormones
- Section 10.7—“Hormones of the Posterior Pituitary” was revised for clarity
- Figure 10.17 was revised for consistency throughout the textbook
- The term “intracellular receptor” was changed to “nuclear receptor” throughout the chapter
- Figure 10.19 was updated for clarity
- Figures 10.20 and 10.21 were updated for consistency with other figures
- Section 10.7—“Pancreas, Insulin, and Diabetes” was revised for accuracy. It now includes a definition of somatostatin
- Figure 10.22 was revised to include somatostatin
- Table 10.3 was updated to use adipose not fat where appropriate
- Figure 10.23 was revised for consistency

Chapter 11

- Figure 11.1 updated to show blood as % body weight
- Figure 11.2 revised to introduce myeloid and lymphoid stem cells
- Revision of 11.6 clarifies the relationship between transfusion reactions and kidney failure
- Figure 11.13 revised to better represent the relationship between the maternal blood and fetal blood

Chapter 12

- Revisions to figure 12.13 allow for better visualization of cardiac muscle cell structure
- Figure 12.14 revised to contrast skeletal muscle and cardiac muscle refractory period and resultant tension production
- Discussion of cardiac cycle revised to correlate with the descriptions of blood flow and the ECG. Figure 12.17 also updated according to these revisions

Chapter 13

- Figure 13.24 revised to better represent influences of blood pressure and osmosis on capillary exchange
- Clinical Impact "Circulatory Shock" updated to distinguish between septic shock and blood poisoning

Chapter 14

- Figure 14.11 revised to include plasma cells producing antibodies
- New Microbes in Your Body feature: Do Our Gut Bacteria Drive Immune Development and Function?

Chapter 15

- The Learn to Predict was updated to include questions about a ventilator to link it to the photo
- The chapter opener photo was updated
- Section 15.1 was revised to incorporate the term pathogen
- Figure 15.2 was updated to better represent the pharyngeal tonsils
- Figure 15.7 was updated for accuracy
- Section 15.3—"Pressure Changes and Airflow" was updated for clarity; Pleural Pressure to direct students attention to the boxed reading
- The term "aerobic respiration" was converted to "cellular respiration" for consistency throughout the textbook
- Figure 15.14 was updated for clarity and accuracy of legend text
- Section 15.6—"Generation of Rhythmic Breathing" was revised for accuracy regarding somatic nervous system regulation of breathing
- Section 15.6—"Chemical Control of Breathing" was revised to distinguish between CO_2 levels during exercise and hyperventilation
- Figure 15.7 was updated for consistency
- Section 15.6—"Effect of Exercise on Breathing" was updated for accuracy regarding lactic acid production
- Figure 15B legend was revised for better distinction between the two images and magnifications were added to the photos
- The Diseases and Disorders table was updated to correctly place text with the "Thrombosis of the pulmonary arteries"

Chapter 16

- A new feature "Microbes in Your Body—Fecal Implants" was added
- Section 16.3—"Anatomy of the Oral Cavity" was updated to include the lingual tonsils
- Figure 16.5 was updated for consistency throughout the text
- Section 16.3—"Salivary Glands" was updated for accuracy; "Saliva" for clarity
- Section 16.3—"Esophagus" was updated for accuracy with skeletal: smooth muscle proportions
- Section 16.6—"Liver" was updated for accuracy with bile production and gallstone formation
- Section 16.6—"Functions of the Pancreas" were updated for clarity
- Figures 16.22, 16.23, 16.24, 16.25, and 16.27 was updated for consistency throughout the text

Chapter 17

- Recommended fiber intake added to the discussion of carbohydrates
- FDA proposed changes to food labels added to figure 17.2

Chapter 18

- The Learn to Predict was revised to link more closely to the chapter opener photo
- Throughout the chapter, the term "Bowman's" was changed to "The Bowman" capsule
- Figure 18.3 was updated for clarity and labels for Renal Column were added to parts a and b
- Section 18.3 was revised to indicate "Production," which is a more active regulation term and an analogy for kidney function was added to help students conceptualize the mechanisms more clearly
- Figure 18.5 was edited to reflect term changes
- Table 18.1 was updated to give normal values for pH and specific gravity
- Section 18.3 was updated to give better filtration definition
- Section 18.3—"Filtration" was revised for clarity and accuracy
- Figures 18.11, 18.13, 18.17, 18.19 and 18.22 were edited for clarity and consistency throughout the textbook

Chapter 19

- The Learn to Predict questions were updated to compare meiosis in males and females
- A caption was added to the chapter opener photo to link more closely to the Learn to Predict
- The box on "Descent of the Testes" was updated to include a discussion of treatments
- The language was changed from "Sex Hormones" to "Reproductive Hormones" to reflect the more current style
- Figures 19.7 and 19.14 were updated for consistency
- Figure 19A was updated to have more modern photos

Chapter 20

- Revision of Respiratory and Circulatory Changes in the newborn to better explain the changes of oxygenated blood and deoxygenated blood flow through vessels before and after birth
- Discussion of segregation errors revised for clarity

List of Clinical Impact Essays

Acknowledgments

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CHAPTER

The Human Organism

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 the 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.

I.I ANATOMY

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

Human anatomy and physiology is the study of the structure and function of the human body. The human body has many intricate parts with coordinated functions maintained by a complex system of checks and balances. The coordinated function of all the parts of the human body allows us to detect changes or stimuli, respond to stimuli, and perform many other actions.

Knowing human anatomy and physiology also provides 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.

Anatomy (ă-natʹŏ-mē) is the scientific discipline that investigates the structure of the body. The word *anatomy* means to dissect, or cut apart and separate, the parts of the body for study.

Anatomy covers a wide range of studies, including the structure of body parts, their microscopic organization, and the processes by which they develop. In addition, anatomy examines the relationship between the structure of a body part and its function. Just as the structure of a hammer makes it well suited for pounding nails, the structure of body parts allows them to perform specific functions effectively. For example, bones can provide strength and support because bone cells secrete a hard, mineralized substance. Understanding the relationship between structure and function makes it easier to understand and appreciate anatomy.

Two basic approaches to the study of anatomy are systemic anatomy and regional anatomy. **Systemic anatomy** is the study of the body by systems, such as the cardiovascular, nervous, skeletal, and muscular systems. It is the approach taken in this and most introductory textbooks. **Regional anatomy** is the study of the organization of the body by areas. Within each region, such as the head, abdomen, or arm, all systems are studied simultaneously. This is the approach taken in most medical and dental schools.

Anatomists have two general ways to examine the internal structures of a living person: surface anatomy and anatomical imaging. **Surface anatomy** is the study of external features, such as bony projections, which serve as landmarks for locating deeper structures (for examples, see chapters 6 and 7). **Anatomical imaging** involves the use of x-rays, ultrasound, magnetic resonance imaging (MRI), and other technologies to create pictures of internal structures. Both surface anatomy and anatomical imaging provide important information for diagnosing disease.

I.2 PHYSIOLOGY

Learning Outcomes *After reading this section, you should be able to*

A. Define physiology.
B. State two major goals of physiology.

Physiology (fiz-ē-ol′ō-jē; the study of nature) is the scientific discipline that deals with the processes or functions of living things. It is important in physiology to recognize structures as dynamic rather than fixed and unchanging. The major goals of physiology are (1) to understand and predict the body's responses to stimuli and (2) to understand how the body maintains conditions within a narrow range of values in the presence of continually changing internal and external environments. **Human physiology** is the study of a specific organism, the human, whereas **cellular physiology** and **systemic physiology** are subdivisions that emphasize specific organizational levels.

I.3 STRUCTURAL AND FUNCTIONAL ORGANIZATION OF THE HUMAN BODY

Learning Outcomes *After reading this section, you should be able to*

A. Describe the six levels of organization of the body, and describe the major characteristics of each level.
B. List the eleven organ systems, identify their components, and describe the major functions of each system.

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

Chemical Level

The structural and functional characteristics of all organisms are determined by their chemical makeup. The **chemical** level of organization involves how atoms, such as hydrogen and carbon, interact and combine into molecules. The function of a molecule is intimately related to its structure. For example, collagen molecules are strong, ropelike 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. A brief overview of chemistry is presented in chapter 2.

Cell Level

Cells are the basic structural and functional units of organisms, such as plants and animals. Molecules can combine to form **organelles** (or′gă-nelz; little organs), which are the small structures that make up some cells. For example, the nucleus contains the cell's hereditary information, and mitochondria manufacture adenosine triphosphate (ATP), a molecule cells use for a source of energy. Although cell types differ in their structure and function, they have many characteristics in common. Knowledge of these characteristics and their variations is essential to a basic understanding of anatomy and physiology. The cell is discussed in chapter 3.

Tissue Level

A **tissue** (tish′ū) is 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 many tissues that make up the body are classified into four primary types: epithelial, connective, muscle, and nervous. Tissues are discussed in chapter 4.

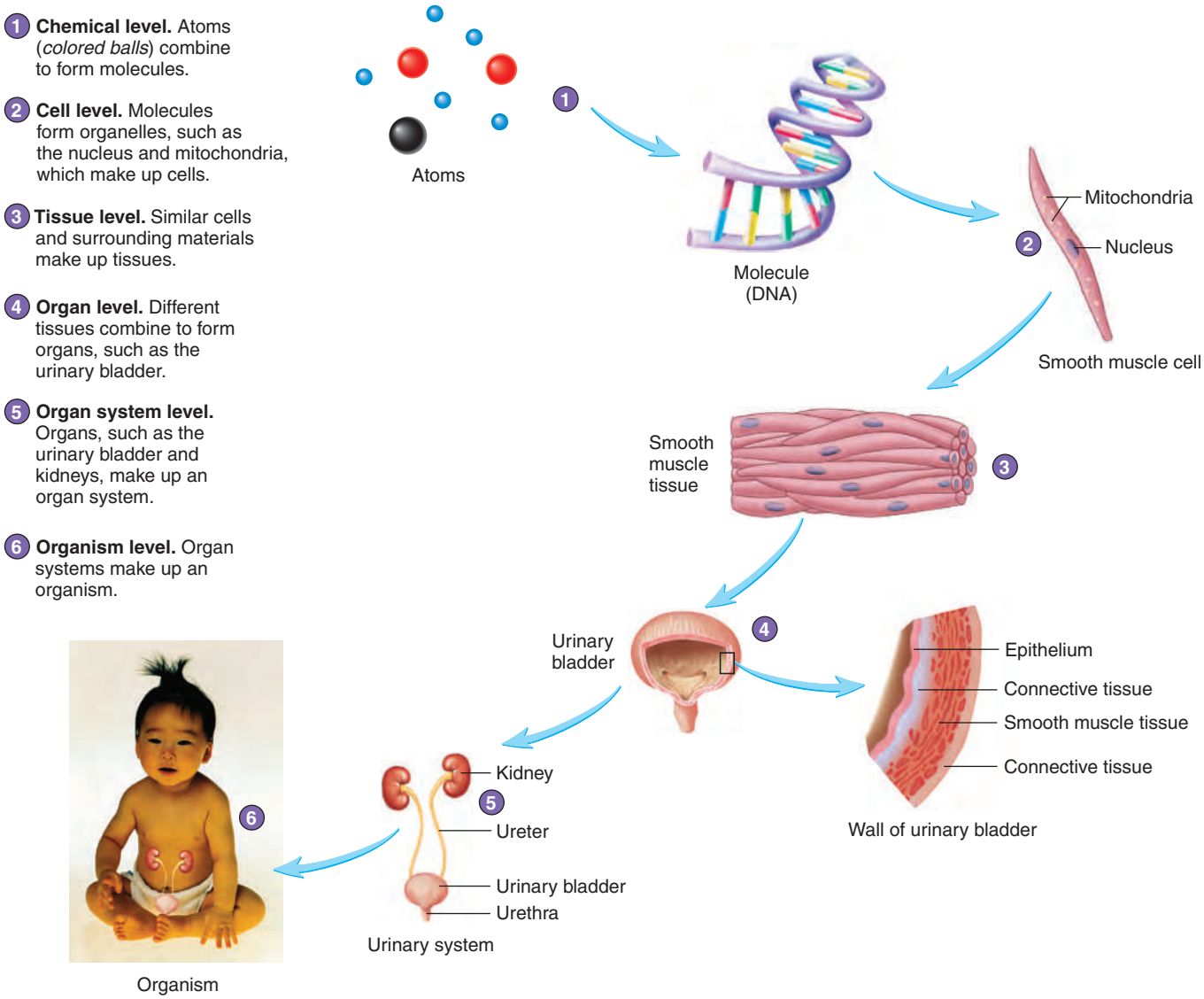
Organ Level

An **organ** (ōr′găn; a tool) is composed of two or more tissue types that together perform one or more common functions. The urinary bladder, skin, stomach, and heart are examples of organs (figure 1.2).

Organ System Level

An **organ system** is a group of organs classified as a unit because of a common function or set of functions. For example, the urinary system consists of the kidneys, ureter, urinary bladder, and urethra. The kidneys produce urine, which is transported by the ureters to the urinary bladder, where it is stored until eliminated from the body by passing through the urethra. In this text, we consider eleven major organ systems: integumentary, skeletal, muscular, lymphatic, respiratory, digestive, nervous, endocrine, cardiovascular, urinary, and reproductive (figure 1.3).

The coordinated activity of the organ systems is necessary for normal function. For example, the digestive system takes in and processes food, which is carried by the blood of the cardiovascular system to the cells of the other systems. These cells use the food and produce waste products that are carried by the blood to the kidneys of the urinary system, which removes waste products from the blood. Because the organ systems are so interrelated, dysfunction in one organ system can have profound effects on other systems. For example, a heart attack can result in inadequate circulation of blood. Consequently, the organs of other systems, such as the brain and kidneys, can malfunction. Throughout this text, Systems Pathology essays consider the interactions of the organ systems.



PROCESS Figure I.1 Levels of Organization for the Human Body

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 that are mutually dependent on one another (figure 1.3).

I.4 CHARACTERISTICS OF LIFE

Learning Outcome *After reading this section, you should be able to*

A. List and define six characteristics of life.

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

1. **Organization** refers to the specific interrelationships among the parts of an organism and how those parts interact to perform specific functions. Living things are highly organized. All organisms are composed of one or more cells. Some cells, in turn, are composed of highly specialized organelles, which depend on the precise functions of large molecules. Disruption of this organized state can result in loss of function and death.
2. **Metabolism** (mĕ-tab′ō-lizm) is the ability to use energy to perform vital functions, such as growth, movement, and reproduction. Plants capture energy from sunlight, and humans obtain energy from food.
3. **Responsiveness** is the ability of an organism to sense changes in the environment and make the adjustments that help maintain its life. Responses include movement toward food or water and away from danger or poor environmental conditions. Organisms can also make adjustments that maintain their internal environment. For example, if body temperature increases in a hot environment, sweat glands produce sweat, which can lower body temperature down to the normal level.

MICROBES IN YOUR BODY Getting to Know Your Bacteria

Did you know that you have more microbial cells than human cells in your body? Astoundingly, for every cell in your body, there are ten microbial cells. That's as many as 100 trillion microbial cells, which can collectively account for anywhere between 2 and 6 pounds of your body weight! A microbe is any living thing that cannot be seen with the naked eye (for example, bacteria, viruses, fungi, and protozoa). The total population of microbial cells on the human body is referred to as the microbiota, while the combination of these microbial cells and their genes is known as the microbiome. The microbiota includes so-called "good" bacteria that do not cause disease and may even help us. It also includes pathogenic, or "bad" bacteria.

With that many microbes in and on our bodies, you might wonder how they affect our health. To answer that question, in October 2007 the National Institute of Health (NIH) initiated the 5-year Human Microbiome Project, the largest study of its kind. Five significant regions of the human body were examined: airway, skin, mouth, gastrointestinal tract, and vagina. This project identified over 5000 species and sequenced over 20 million unique microbial genes.

What did scientists learn from the Human Microbiome Project? Human health is dependent upon the health of our microbiota, especially the "good" bacteria. In fact, it seems that our microbiota are so completely intertwined with human cells that in a 2013 *New York Times* article, Dr. David Relman of Stanford University suggested that humans are like corals. Corals are marine organisms that are collections of different life forms all existing together. More specifically, the human microbiome is intimately involved in the development and maintenance of the immune system. And more evidence is mounting for a correlation between a host's microbiota, digestion, and metabolism. Researchers have suggested that microbial genes are more responsible for our survival than human genes. There are even a few consistent pathogens that are present without causing disease, suggesting that their presence may be good for us. However, there does not seem to be a universal healthy human microbiome. Rather, the human microbiome varies across lifespan, ethnicity, nationality, culture, and geographical location. Instead of being a detriment, this variation may actually be very useful for at least one major reason. There seems to be a correlation between certain diseases and a "characteristic microbiome community," especially for autoimmune and inflammatory diseases (Crohn's, asthma, multiple sclerosis), which have become more prevalent. Scientists are beginning to believe that any significant change in the profile of the microbiome of the human gut may increase a person's susceptibility to autoimmune diseases. It has been proposed that these changes may be associated with exposure to antibiotics, particularly in infancy. Fortunately, newer studies of microbial transplantations have shown that the protective and other functions of bacteria can be transferred from one person to the next. However, this work is all very new and much research remains to be done.

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

4. **Growth** refers to an increase in size of all or part of the organism. It can result from an increase in cell number, cell size, or the amount of substance surrounding cells. For example, bones become larger as the number of bone cells increases and they become surrounded by bone matrix.
5. **Development** includes the changes an organism undergoes through time; it begins with fertilization and ends at death. The greatest developmental changes occur before birth, but many changes continue after birth, and some continue throughout life. Development usually involves growth, but it also involves differentiation. **Differentiation** is change in cell structure and function from generalized to specialized. For example, following fertilization, generalized cells specialize to become specific cell types, such as skin, bone, muscle, or nerve cells. These differentiated cells form tissues and organs.
6. **Reproduction** is the formation of new cells or new organisms. Without reproduction of cells, growth and tissue repair are impossible. Without reproduction of the organism, the species becomes extinct.

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; *homeo-*, the same) is the existence and maintenance of a relatively constant environment within the body despite fluctuations in either the external environment or the internal environment. Most body cells are surrounded by a small amount of fluid, and normal cell functions depend on the maintenance of the cells' fluid environment within a narrow range of conditions, including temperature, volume, and chemical content. These conditions are called **variables** because their values can change. For example, body temperature is a variable that can increase in a hot environment or decrease in a cold environment.

CLINICAL IMPACT Cadavers and the Law

The study of human bodies is the foundation of medical education, and for much of history, anatomists have used the bodies of people who have died, called cadavers, for these studies. However, public sentiment has often made it difficult for anatomists to obtain human bodies for dissection. In the early 1800s, the benefits of human dissection for training physicians had become very apparent, and the need for cadavers increased beyond the ability to acquire them legally. Thus arose the resurrectionists, or body snatchers. For a fee and no questions asked, they removed bodies from graves and provided them to medical schools. Because the bodies were not easy to obtain and were not always in the best condition, two enterprising men named William Burke and William Hare went one step further. Over a period of time, they murdered seventeen people in Scotland and sold their bodies to a medical school. When discovered, Hare testified against Burke and went free. Burke was convicted, hanged, and publicly dissected. Discovery of Burke's activities so outraged the public that sensible laws regulating the acquisition of cadavers were soon passed, and this dark chapter in the history of anatomy was closed.

Today, in the United States, it is quite simple to donate your body for scientific study. The Uniform Anatomical Gift Act allows individuals to donate their organs or entire cadaver by putting a notation on their driver's license. You need only to contact a medical school or private agency to file the forms that give them the rights to your cadaver. Once the donor dies, the family of the deceased usually pays only the transportation costs for the remains. After dissection, the body is cremated, and the cremains can be returned to the family.

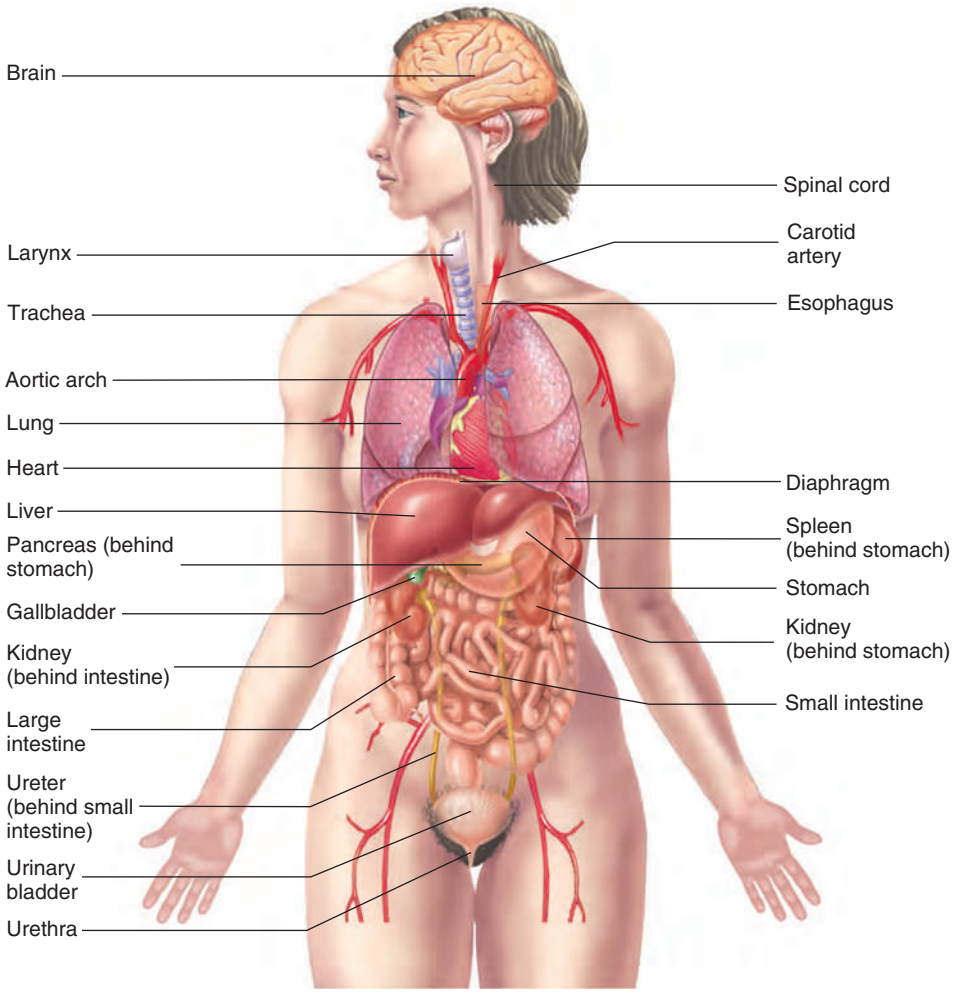
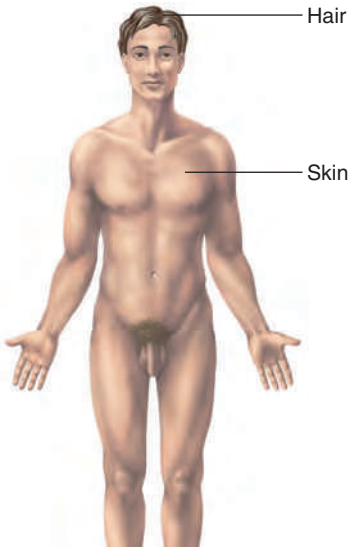
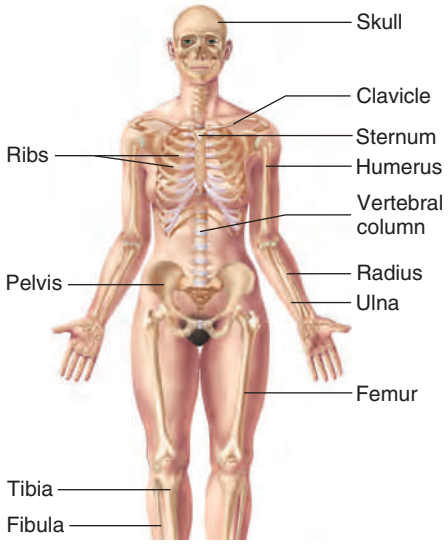


Figure I.2 Major Organs of the Body



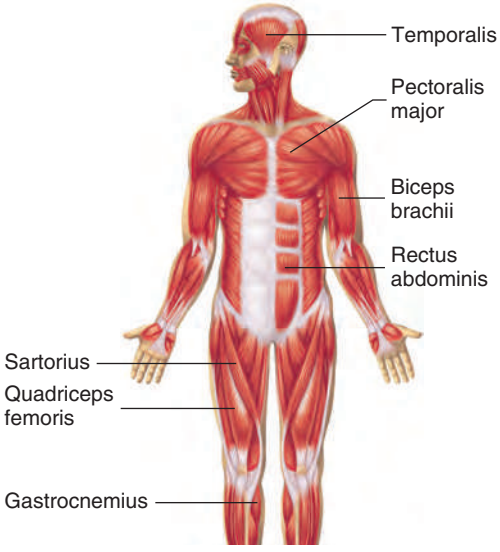
Integumentary System

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



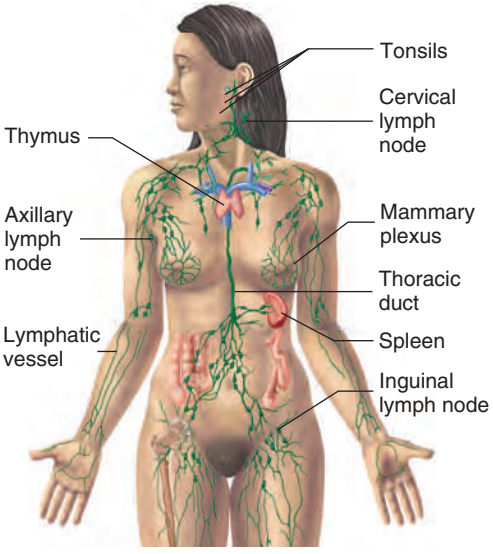
Skeletal System

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



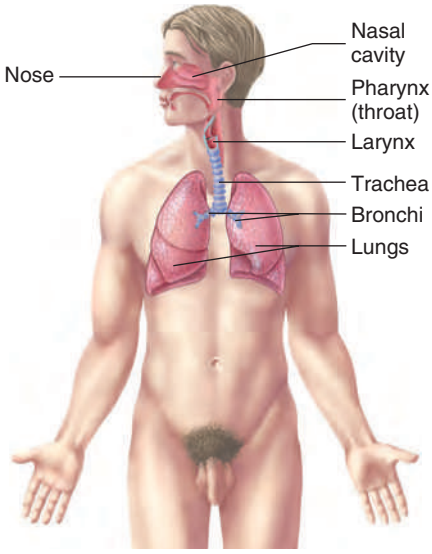
Muscular System

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



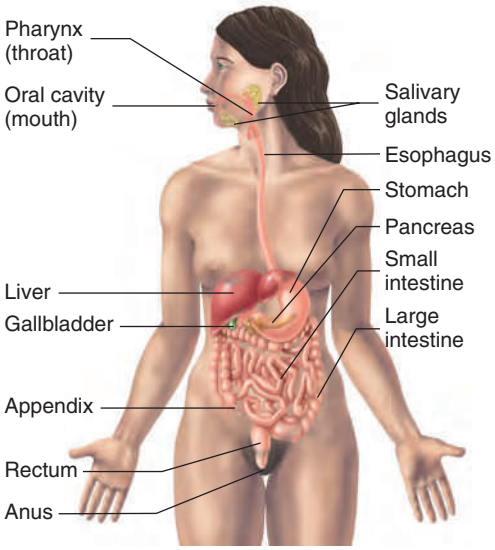
Lymphatic System

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



Respiratory System

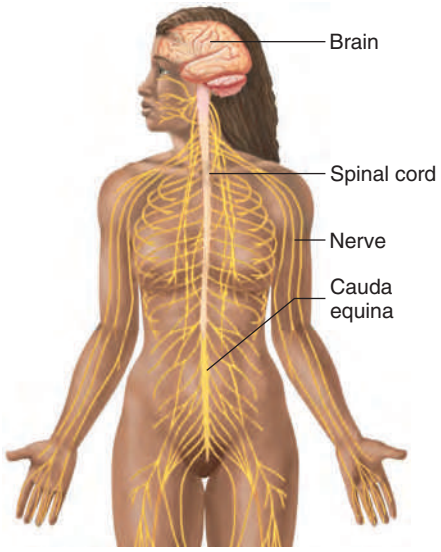
Exchanges oxygen and carbon dioxide between the blood and air and regulates blood pH. Consists of the lungs and respiratory passages.



Digestive System

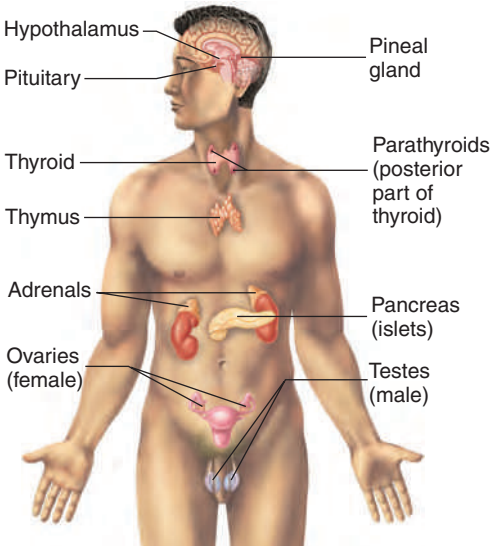
Performs the mechanical and chemical processes of digestion, absorption of nutrients, and elimination of wastes. Consists of the mouth, esophagus, stomach, intestines, and accessory organs.

Figure 1.3 AP|R **Organ Systems of the Body**



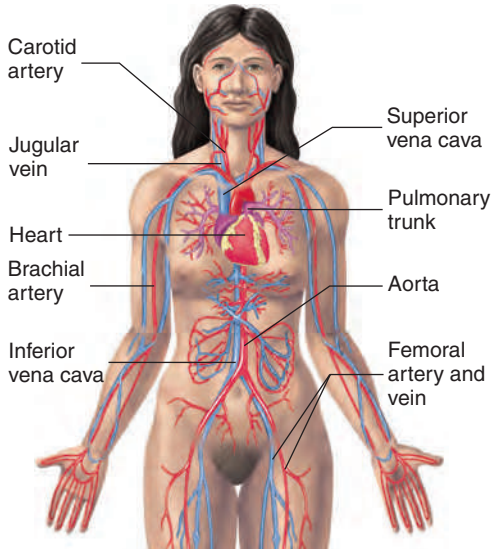
Nervous System

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



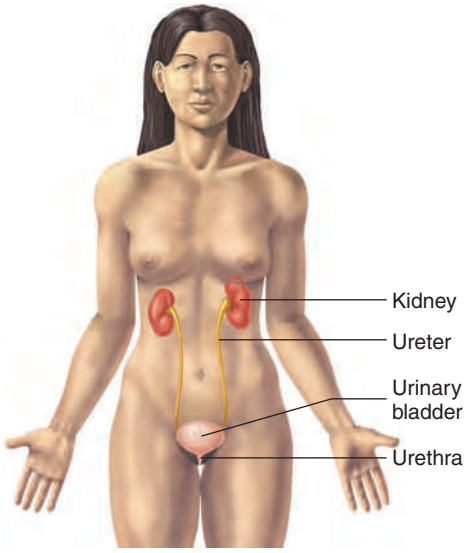
Endocrine System

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



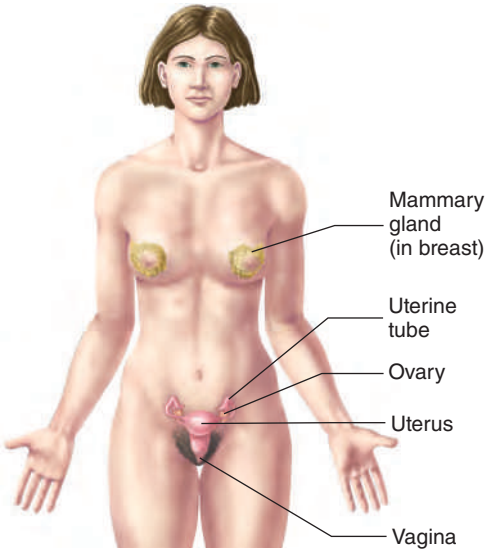
Cardiovascular System

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



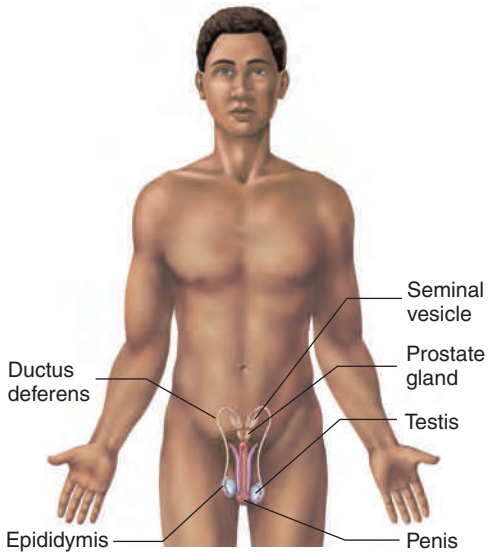
Urinary System

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



Female Reproductive System

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



Male Reproductive System

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

Figure I.3 AP|R **Organ Systems of the Body** *(continued)*

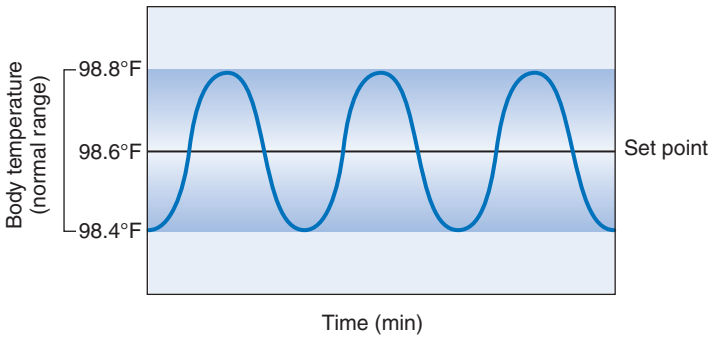


Figure 1.4 Homeostasis

Homeostasis is the maintenance of a variable, such as body temperature, 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.

Homeostatic mechanisms, such as sweating or shivering, normally maintain body temperature near an ideal normal value, or **set point** (figure 1.4). Most homeostatic mechanisms are governed by the nervous system or the endocrine system. Note that homeostatic mechanisms are not able to maintain body temperature *precisely* at the set point. Instead, body temperature increases and decreases slightly around the set point, producing a **normal range** of values. As long as body temperatures remain within this normal range, homeostasis is maintained.

The organ systems help control the internal environment so that it remains relatively constant. For example, the digestive, respiratory, cardiovascular, and urinary systems function together so that each cell in the body receives adequate oxygen and nutrients and so that waste products do not accumulate to a toxic level. If the fluid surrounding cells deviates from homeostasis, the cells do not function normally and may 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.

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. Negative feedback does not prevent variation but maintains variation within a normal range.

The maintenance of normal body temperature is an example of a negative-feedback mechanism. Normal body temperature is important because it allows molecules and enzymes to keep their normal shape so they can function optimally. An optimal body temperature prevents molecules from being permanently destroyed. Picture the change in appearance of egg whites as they are cooked; a similar phenomenon can happen to molecules in our body if the temperature becomes too high. Thus, normal body temperature is required to ensure that tissue homeostasis is maintained.

Many negative-feedback mechanisms, such as the one that maintains normal body temperature, have three components: (1) A **receptor** (rē-sep′tŏr, rē-sep′tōr) monitors the value of a variable, such as body temperature; (2) a **control center,** such as part of the brain, establishes the set point around which the variable is maintained; and (3) an **effector** (ē-fek′tŏr), such as the sweat glands, can change the value of the variable. A changed variable is a **stimulus** because it initiates a homeostatic mechanism.

Normal body temperature depends on the coordination of multiple structures, which are regulated by the control center, or hypothalamus, in the brain. If body temperature rises, sweat glands (the effectors) produce sweat and the body cools. If body temperature falls, sweat glands do not produce sweat (figure 1.5). The stepwise process that regulates body temperature involves the interaction of receptors, the control center, and effectors. Often, there is more than one effector and the control center must integrate them. In the case of elevated body temperature, thermoreceptors in the skin and hypothalamus detect the increase in temperature and send the information to the hypothalamus control center. In turn, the hypothalamus stimulates blood vessels in the skin to relax and sweat glands to produce sweat, which sends more blood to the body's surface for radiation of heat away from the body. The sweat glands and skin blood vessels are the effectors in this scenario. Once body temperature returns to normal, the control center signals the sweat glands to reduce sweat production and the blood vessels constrict to their normal diameter. On the other hand, if body temperature drops, the control center does not stimulate the sweat glands. Instead, the skin blood vessels constrict more than normal and blood is directed to deeper regions of the body, conserving heat in the interior of the body. In addition, the hypothalamus stimulates shivering, quick cycles of skeletal muscle contractions, which generates a great amount of heat. Again, once the body temperature returns to normal, the effectors stop. In both cases, the effectors do not produce their responses indefinitely and are controlled by negative feedback. Negative feedback acts to return the variable to its normal range (figure 1.6).

Predict 2

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

Positive Feedback

Positive-feedback mechanisms occur when the initial stimulus further stimulates the response. In other words, the deviation from the set point becomes even greater. At times, this type of response is required to re-achieve homeostasis. For example, during blood loss, a chemical responsible for clot formation stimulates production of itself. In this way, a disruption in homeostasis is resolved through a positive-feedback mechanism. What prevents the entire vascular system from clotting? The clot formation process is self-limiting. Eventually, the components needed to form a clot will be depleted in the damaged area and more clot material cannot be formed (figure 1.7).

Birth is another example of a normally occurring positive-feedback mechanism. Near the end of pregnancy, the uterus is stretched by the baby's large size. This stretching, especially around the opening of the uterus, stimulates contractions of the

CLINICAL IMPACT Humors and Homeostasis

The idea that the body maintains a balance (homeostasis) can be traced back to ancient Greece. Early physicians believed that the body supported four juices, or humors: the red juice of blood, the yellow juice of bile, the white juice secreted from the nose and lungs, and a black juice in the pancreas. They also thought that health resulted from a proper balance of these juices and that an excess of any one of them caused disease. Normally, they believed, the body would attempt to heal itself by expelling the excess juice, as when mucus runs from the nose of a person with a cold. This belief led to the practice of bloodletting to restore the body's normal balance of juices. Typically, physicians used sharp instruments to puncture the larger, external vessels, but sometimes they applied leeches, blood-eating organisms, to the skin.

Tragically, in the eighteenth and nineteenth centuries, bloodletting went to extremes. During this period, a physician might recommend bloodletting, but barbers conducted the actual procedure. In fact, the traditional red-and-white-striped barber pole originated as a symbol for bloodletting. The brass basin on top of the pole represented the bowl for leeches, and the bowl on the bottom represented the basin for collecting blood. The stripes represented the bandages used as tourniquets, and the pole itself stood for the wooden staff patients gripped during the procedure. The fact that bloodletting did not improve the patient's condition was taken as evidence that not enough blood had been removed to restore a healthy balance of the body's juices. Thus, the obvious solution was to let still more blood, undoubtedly causing many deaths. Eventually, the failure of this approach became obvious, and the practice was abandoned.

The modern term for bloodletting is **phlebotomy** (fle-bot′ō-mē), but it is practiced in a controlled setting and removes only small volumes of blood, usually for laboratory testing. There are some diseases in which bloodletting is still useful—for example, **polycythemia** (pol′ē-sī-thē′mē-ă), an overabundance of red blood cells. However, bloodletting in these patients does not continue until the patient faints or dies. Fortunately, we now understand more about how the body maintains homeostasis.

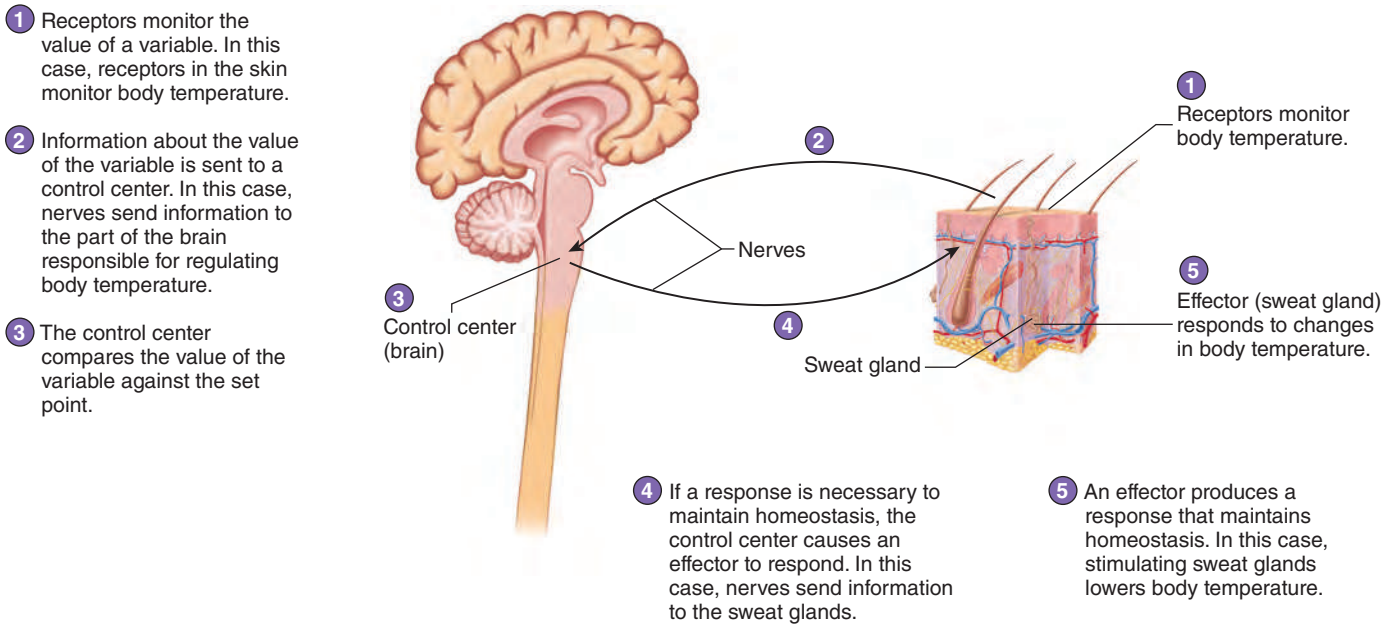


Figure I.5 Negative-Feedback Mechanism: Body Temperature

uterine muscles. The uterine contractions push the baby against the opening of the uterus, stretching it further. This stimulates additional contractions, which result in additional stretching. This positive-feedback sequence ends when the baby is delivered from the uterus and the stretching stimulus is eliminated.

On the other hand, occasionally a positive-feedback mechanism can be detrimental. One example of a detrimental positive-feedback mechanism is inadequate delivery of blood to cardiac (heart) muscle. Contraction of cardiac muscle generates blood pressure and moves blood through the blood vessels to the tissues. A system of blood vessels on the outside of the heart provides cardiac muscle with a blood supply sufficient to allow normal contractions to occur. In effect, the heart pumps blood to itself. Just as with other tissues, blood pressure must be maintained to ensure adequate delivery of blood to the cardiac muscle. Following extreme blood loss, blood pressure decreases to the point that the delivery of blood