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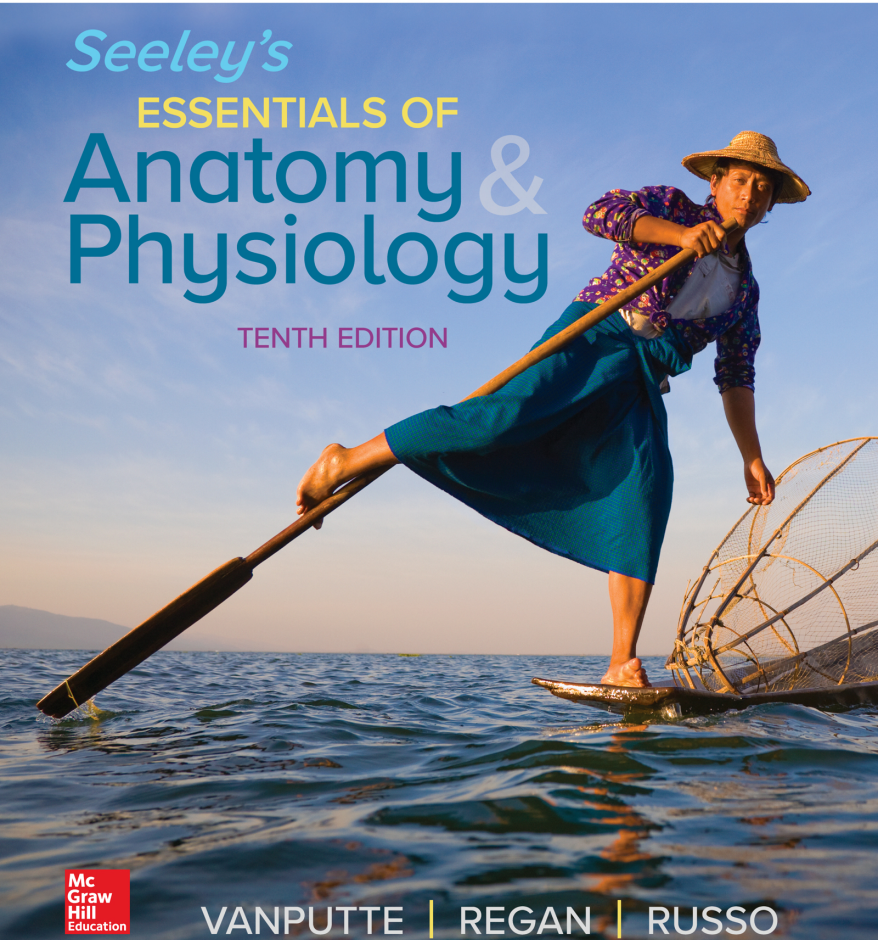
Seeley's ESSENTIALS OF Anatomy & Physiology

TENTH EDITION



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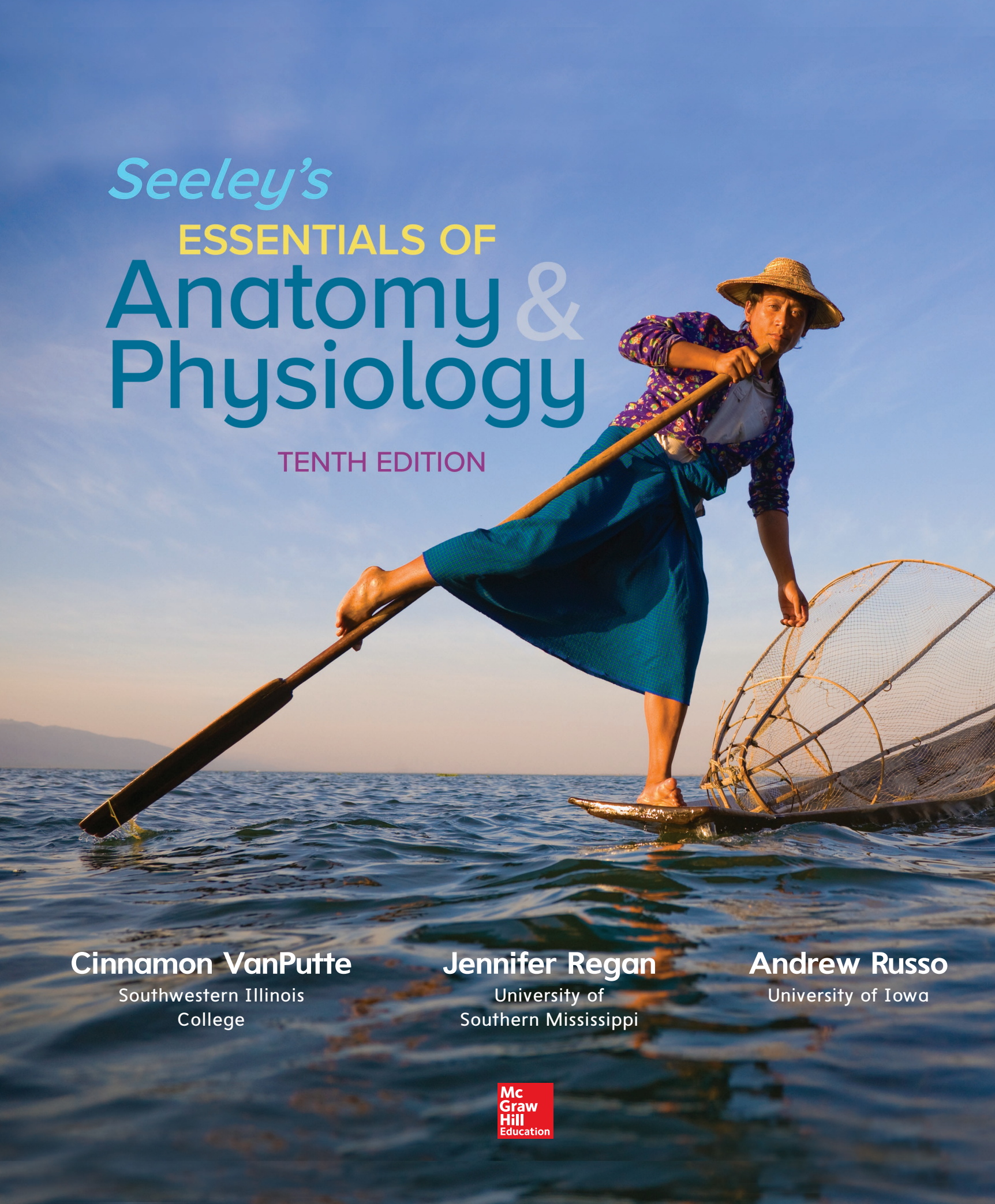

Seeley's ESSENTIALS OF Anatomy & Physiology

TENTH EDITION

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Southwestern Illinois College

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Mc Graw Hill Education

SEELEY'S ESSENTIALS OF ANATOMY & PHYSIOLOGY, TENTH 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

Courtesy of Leanna Rolla

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 (also a biology professor), have two children: a daughter, Savannah, and a son, Ethan. Savannah is pursuing her undergraduate education and hopes to one day become a pediatric occupational therapist. Ethan is involved in 4-H and shows steers and lambs. He is also a talented runner for both cross country and track.

Courtesy of Bridget Reeves

Jennifer L. Regan

Assistant Teaching Professor
University of Southern Mississippi

For over fifteen 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.

Courtesy of the University of Iowa

Andrew F. Russo

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Andrew has over 20 years of classroom experience with human physiology, neurobiology, molecular biology, and cell biology courses at the University of Iowa. He is a recipient of the Collegiate Teaching Award and the J. P. Long Teaching Award in Basic Sciences. He is currently the course director for a new medical school course called Mechanisms of Health and Disease that integrates physiology, histology, and genetics. He is a member of several professional societies, including the Society for Neuroscience. Andrew received his Ph.D. in biochemistry from the University of California at Berkeley. His research interests are focused on the molecular basis of migraine. His decision to join the author team for *Seeley's 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, and five grandchildren. He enjoys all types of outdoor sports, especially bicycling, skiing, running, and open water swimming.

Brief Contents

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Preface

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

Critical thinking skills help students build a knowledge base for solving problems. An emphasis on critical thinking is integrated throughout this textbook. This approach is found in questions at the beginning of 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 Process Figure questions that apply physiological processes to practical situations, to promote applied understanding; in end-of-chapter questions that go beyond rote memorization; and in a visual program that presents material in understandable, relevant images.

- Pedagogy builds student comprehension from knowledge to application (Apply It questions, Critical Thinking questions, and Learn to Apply It Answers)

Apply It 4

Why does your nose run when you cry?

Apply It 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. Given two series of neurons, explain why action potentials could be propagated along one series more rapidly than along the other series.
2. The left lung of a cancer patient was removed. To reduce the empty space left in the thorax after the lung was removed, the diaphragm on the left side was paralyzed so that the abdominal viscera would push the diaphragm upward into the space. What nerve should be cut to paralyze the left half of the diaphragm?
3. Name the nerve that, if damaged, produces the following symptoms:
   a. The elbow and wrist on one side are held in a flexed position and cannot be extended.
   b. The patient is unable to flex the right hip and extend the knee (as in kicking a ball).
4. A patient suffered brain damage in an automobile accident. Physicians suspected that the cerebellum was affected. On the basis of what you know about cerebellar function, how could you determine that the cerebellum was involved? What symptoms would you expect to see?
5. Landon was accidentally struck in the head with a baseball bat. He fell to the ground, unconscious. Later, when he had regained consciousness, he was unable to remember any of the events that happened during the 10 minutes before the accident. Explain.
6. Name the cranial nerve that, if damaged, produces the following symptoms:
   a. The patient is unable to move the tongue.
   b. The patient is unable to see out of one eye.
   c. The patient is unable to feel one side of the face.
   d. The patient is unable to move the facial muscles on one side.
   e. The pupil of one eye is dilated and does not constrict.
7. Why doesn't injury to the spinal cord at the level of C6 significantly interfere with nervous system control of the digestive system?

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.

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. Clinical Impact boxes provide a thorough clinical education that fully supports the surrounding textual material. Systems Pathology boxes provide a modern and systems interaction approach to clinical study of the materials presented.

- Clinical Impact essays (placed at key points in the text)
- Chapter-opening clinical scenarios/vignettes
- Learn to Apply It and chapter Apply It questions with unique Learn to Apply It Answers
- Systems Pathology Boxes

CLINICAL IMPACT Color Blindness

Color blindness is the absence of perception of one or more colors (figure 9.16). Color perception may be decreased or completely lost. The loss may involve perception of all three colors or of one or two colors. Most forms of color blindness occur more frequently in males and are X-linked genetic traits (see chapter 20). In Western Europe, about 8% of all males have some form of color blindness, whereas only about 1% of the females are color blind.

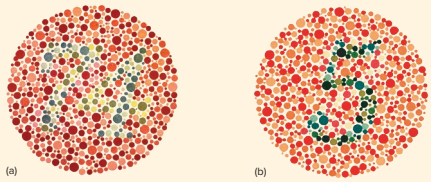
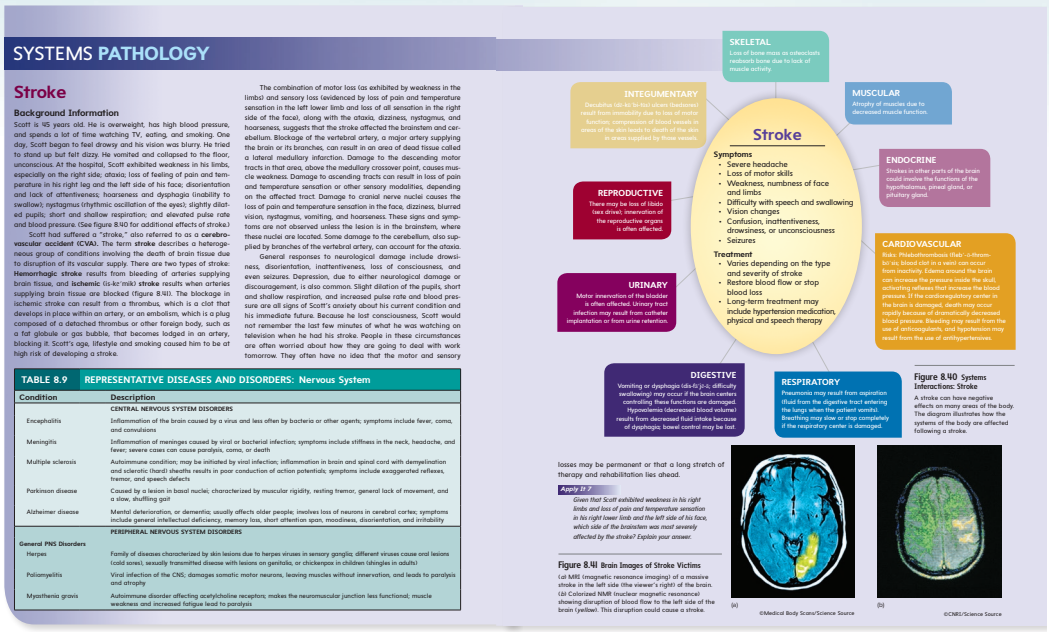


Figure 9.16

These color blindness charts demonstrate the differences in color perception associated with some forms of color blindness. (*a*) A person with normal vision can see the number 74, whereas a person with red-green color blindness sees the number 21. (*b*) A person with normal vision can see the number 5. A person with red-green color blindness sees the number 2. (a) ©Steve Allen/Getty Images RF; (b) ©Prisma Bildagentur AG/Alamy

Reproduced from *Ishihara's Tests for Colour Deficiency* published by Kanehara Trading, Inc., Tokyo, Japan. Tests for color deficiency cannot be conducted with this material. For accurate testing, the original plates should be used.

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.



SYSTEMS PATHOLOGY

Stroke

Background Information

Scott is 45 years old. He is overweight, has high blood pressure, and spends a lot of time watching TV, eating, and smoking. One day, Scott began to feel drowsy and his vision was blurry. He tried to stand up but felt dizzy. He vomited and collapsed to the floor, unconscious. At the hospital, Scott exhibited weakness in his limbs, especially on the right side; ataxia; loss of feeling of pain and temperature in his right leg and the left side of his face; disorientation and lack of attentiveness; hoarseness and dysphagia (inability to swallow); nystagmus (rhythmic oscillation of the eyes); slightly dilated pupils; short and shallow respiration; and elevated pulse rate and blood pressure. (See figure 8.40 for additional effects of stroke.)

Scott had suffered a "stroke," also referred to as a **cerebrovascular accident (CVA)**. The term **stroke** describes a heterogeneous group of conditions involving the death of brain tissue due to disruption of its vascular supply. There are two types of stroke: **Hemorrhagic stroke** results from bleeding of arteries supplying brain tissue, and **ischemic** (is-kē′ mik) **stroke** results when arteries supplying brain tissue are blocked (figure 8.41). The blockage in ischemic stroke can result from a thrombus, which is a clot that develops in place within an artery, or an embolism, which is a plug composed of a detached thrombus or other foreign body, such as a fat globule or gas bubble, that becomes lodged in an artery, blocking it. Scott's age, lifestyle and smoking caused him to be at high risk of developing a stroke.

The combination of motor loss (as exhibited by weakness in the limbs) and sensory loss (evidenced by loss of pain and temperature sensation in the left lower limb and loss of all sensation in the right side of the face), along with the ataxia, dizziness, nystagmus, and hoarseness, suggests that the stroke affected the brainstem and cerebellum. Blockage of the vertebral artery, a major artery supplying the brain or its branches, can result in an area of dead tissue called a lateral medullary infarction. Damage to the descending motor tracts in that area, above the medullary crossover point, causes muscle weakness. Damage to ascending tracts can result in loss of pain and temperature sensation or other sensory modalities, depending on the affected tract. Damage to cranial nerve nuclei causes the loss of pain and temperature sensation in the face, dizziness, blurred vision, nystagmus, vomiting, and hoarseness. These signs and symptoms are not observed unless the lesion is in the brainstem, where these nuclei are located. Some damage to the cerebellum, also supplied by branches of the vertebral artery, can account for the ataxia.

General responses to neurological damage include drowsiness, disorientation, inattentiveness, loss of consciousness, and even seizures. Depression, due to either neurological damage or discouragement, is also common. Slight dilation of the pupils, short and shallow respiration, and increased pulse rate and blood pressure are all signs of Scott's anxiety about his current condition and his immediate future. Because he lost consciousness, Scott would not remember the last few minutes of what he was watching on television when he had his stroke. People in these circumstances are often worried about how they are going to deal with work tomorrow. They often have no idea that the motor and sensory losses may be permanent or that a long stretch of therapy and rehabilitation lies ahead.

TABLE 8.9 REPRESENTATIVE DISEASES AND DISORDERS: Nervous System

Condition	Description
	CENTRAL NERVOUS SYSTEM DISORDERS
Encephalitis	Inflammation of the brain caused by a virus and less often by bacteria or other agents; symptoms include fever, coma, and convulsions
Meningitis	Inflammation of meninges caused by viral or bacterial infection; symptoms include stiffness in the neck, headache, and fever; severe cases can cause paralysis, coma, or death
Multiple sclerosis	Autoimmune condition; may be initiated by viral infection; inflammation in brain and spinal cord with demyelination and sclerotic (hard) sheaths results in poor conduction of action potentials; symptoms include exaggerated reflexes, tremor, and speech defects
Parkinson disease	Caused by a lesion in basal nuclei; characterized by muscular rigidity, resting tremor, general lack of movement, and a slow, shuffling gait
Alzheimer disease	Mental deterioration, or dementia; usually affects older people; involves loss of neurons in cerebral cortex; symptoms include general intellectual deficiency, memory loss, short attention span, moodiness, disorientation, and irritability
	PERIPHERAL NERVOUS SYSTEM DISORDERS
General PNS Disorders	
Herpes	Family of diseases characterized by skin lesions due to herpes viruses in sensory ganglia; different viruses cause oral lesions (cold sores), sexually transmitted disease with lesions on genitalia, or chickenpox in children (shingles in adults)
Poliomyelitis	Viral infection of the CNS; damages somatic motor neurons, leaving muscles without innervation, and leads to paralysis and atrophy
Myasthenia gravis	Autoimmune disorder affecting acetylcholine receptors; makes the neuromuscular junction less functional; muscle weakness and increased fatigue lead to paralysis

Apply It 7

Given that Scott exhibited weakness in his right limbs and loss of pain and temperature sensation in his right lower limb and the left side of his face, which side of the brainstem was most severely affected by the stroke? Explain your answer.

SKELETAL
Loss of bone mass as osteoclasts reabsorb bone due to lack of muscle activity.

INTEGUMENTARY
Decubitus (di-kū′ bi-tus) ulcers (bedsores) result from immobility due to loss of motor function; compression of blood vessels in areas of the skin leads to death of the skin in areas supplied by those vessels.

MUSCULAR
Atrophy of muscles due to decreased muscle function.

Stroke

Symptoms
- Severe headache
- Loss of motor skills
- Weakness, numbness of face and limbs
- Difficulty with speech and swallowing
- Vision changes
- Confusion, inattentiveness, drowsiness, or unconsciousness
- Seizures

Treatment
- Varies depending on the type and severity of stroke
- Restore blood flow or stop blood loss
- Long-term treatment may include hypertension medication, physical and speech therapy

ENDOCRINE
Strokes in other parts of the brain could involve the functions of the hypothalamus, pineal gland, or pituitary gland.

REPRODUCTIVE
There may be loss of libido (sex drive); innervation of the reproductive organs is often affected.

CARDIOVASCULAR
Risks: Phlebothrombosis (fleb′ -ō-throm-bō′ sis, blood clot in a vein) can occur from inactivity. Edema around the brain can increase the pressure inside the skull, activating reflexes that increase the blood pressure. If the cardioregulatory center in the brain is damaged, death may occur rapidly because of dramatically decreased blood pressure. Bleeding may result from the use of anticoagulants, and hypotension may result from the use of antihypertensives.

URINARY
Motor innervation of the bladder is often affected. Urinary tract infection may result from catheter implantation or from urine retention.

DIGESTIVE
Vomiting or dysphagia (dis-fā′ jē-ă; difficulty swallowing) may occur if the brain centers controlling these functions are damaged. Hypovolemia (decreased blood volume) results from decreased fluid intake because of dysphagia; bowel control may be lost.

RESPIRATORY
Pneumonia may result from aspiration (fluid from the digestive tract entering the lungs when the patient vomits). Breathing may slow or stop completely if the respiratory center is damaged.

Figure 8.40 Systems Interactions: Stroke
A stroke can have negative effects on many areas of the body. The diagram illustrates how the systems of the body are affected following a stroke.

Figure 8.41 Brain Images of Stroke Victims
(a) MRI (magnetic resonance imaging) of a massive stroke in the left side (the viewer's right) of the brain. (b) Colorized NMR (nuclear magnetic resonance) showing disruption of blood flow to the left side of the brain (yellow). This disruption could cause a stroke.

©Medical Body Scans/Science Source

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Systems Pathology Boxes

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

Microbes in Your Body helps students to understand the important role microbes play in helping various systems of the body to maintain homeostasis.

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; 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. 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.

However, could humans' gut microbiota be just as responsible (or even more responsible) for obesity? Comparisons between the gut microbiota of lean versus obese individuals seem to suggest the possibility of an important link between gut microbiota and our weight. The human gut, like other animals, is densely populated with microbiota. The majority (90%) of human gut bacteria fall into two groups: Firmicutes and Bacteroidetes. Lean people have more 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.

Changes in gut microbiota 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 autoimmune malfunction. Normal gut microbiota metabolism is critical for secretion of several anti-hunger hormones, and anti-depressive neurotransmitters and neurochemicals. Shifts in normal gut microbiota, as related to diet, may very well disrupt normal anti-hunger signals and gut permeability, leading to over-eating and inflammation related to obesity.

Can gut microbiota in obese people be manipulated to cause them to become lean? Several possibilities exist, including the distinct possibility that prescribing antibiotics against bacteria associated with obesity could shift the metabolism of an

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MICROBES IN YOUR BODY How Bacteria Affect Cardiac Muscle

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

Most people associate bacterial pneumonia with the lungs only. However,

community, it is well

umonia can cause serious

In fact, cardiac problems

the deaths in individu-

types of severe bacterial

t bacterial pneumonia is

bacterium *Streptococcus*

t until recently the mech-

this pathogen damages

ot been well understood.

hese bacteria induce the

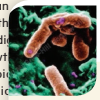
od vessels to endocytose

it them in cardiac muscle tissue. There, the bacteria release a toxin, called pneumolysin, which kills the cardiac muscle cells. These areas of dead cardiac muscle are called microlesions. In addition, during recovery from the infection, scars may form within the myocardium. Thus, the bacteria physically damage the heart, which interrupts the electrical signal necessary for cardiac muscle contraction. In addition, simply treating pneumonia with the traditional antibiotic, ampicillin, may actually worsen damage to the heart. Ampicillin causes the bacterial cell walls to burst, which releases a surge of pneumolysin, creating even more microlesions. Use of an antibiotic that does not destroy the bacterial cell walls will help reduce cardiac muscle death. Further, a vaccine against the bacterial molecule that induces the bacterial transport and against pneumolysin has shown great promise in minimizing the tissue damage caused by these bacteria.

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

Apply It 4

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



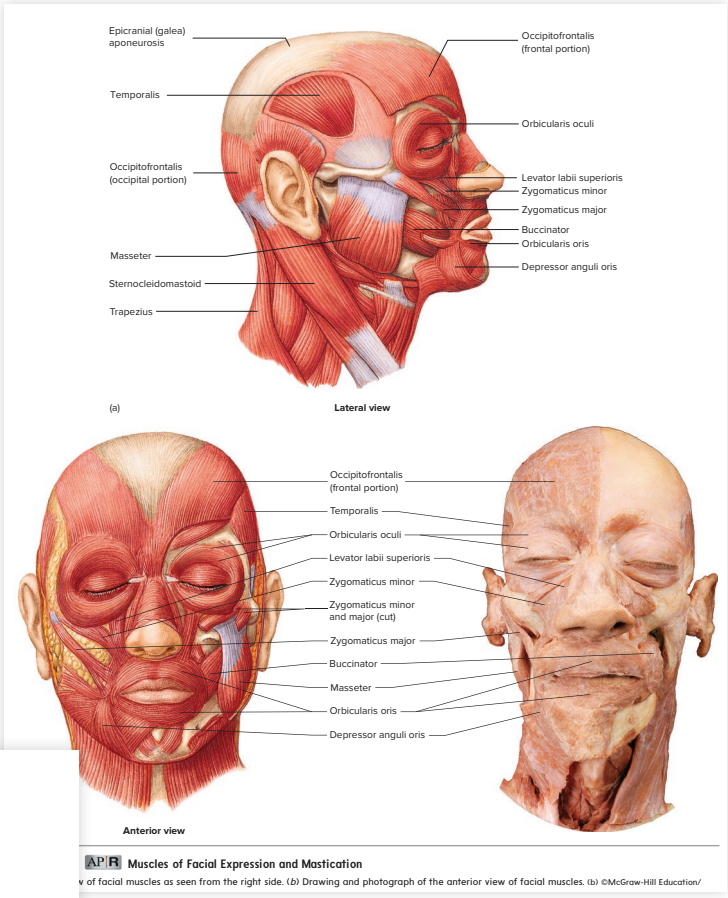
MICROBES IN YOUR BODY Using Bacteria to Fight Bacteria

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.

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**

v of facial muscles as seen from the right side. (*b*) Drawing and photograph of the anterior view of facial muscles. (b) ©McGraw-Hill Education/

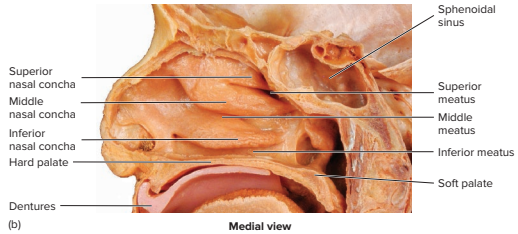


Figure 15.2 AP|R **Nasal Cavity and Pharynx**

(*a*) Sagittal section through the nasal cavity and pharynx. (*b*) Photograph of sagittal section of the nasal cavity. Note: This cadaver wore dentures during life. (b) ©R. T. Hutchings

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.

Multi-level Perspective Illustrations depicting complex structures or processes combine macroscopic and microscopic views to help students see the relationships between increasingly detailed drawings. Drawings are often paired with photographs to enhance the visualization of the structures.

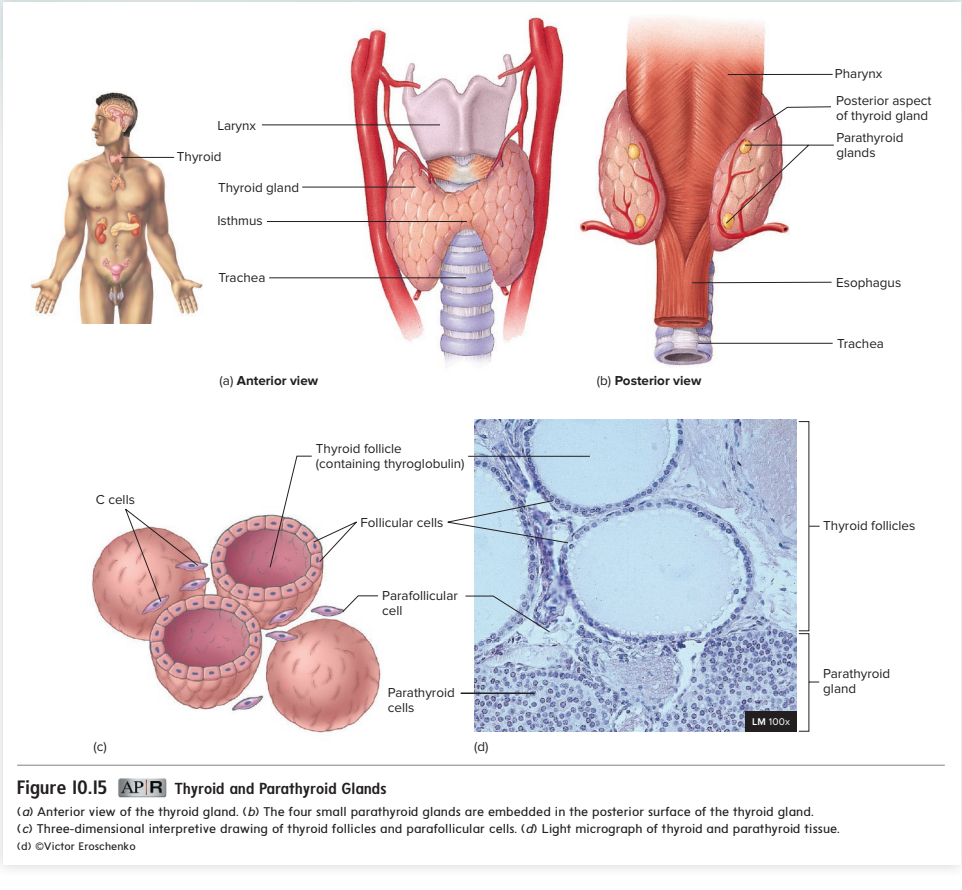
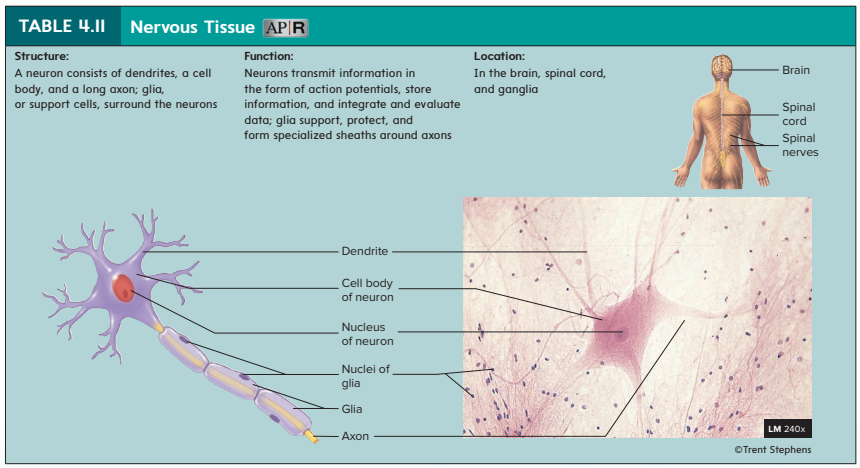


Figure 10.15 AP|R **Thyroid and Parathyroid Glands**

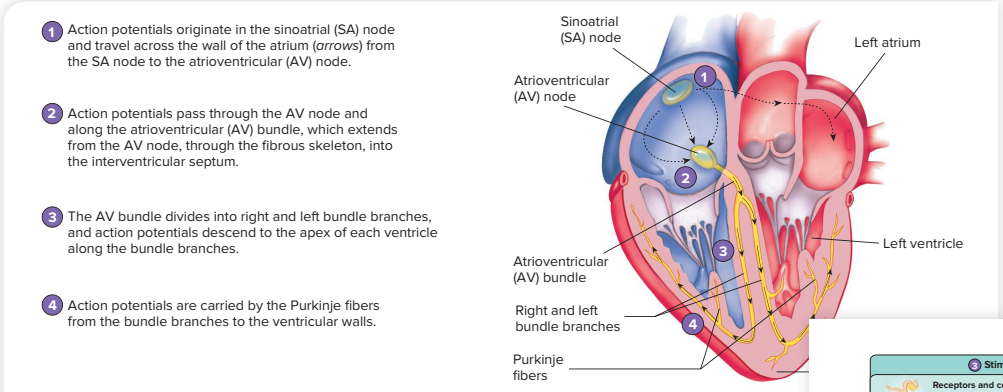
(*a*) Anterior view of the thyroid gland. (*b*) The four small parathyroid glands are embedded in the posterior surface of the thyroid gland. (*c*) Three-dimensional interpretive drawing of thyroid follicles and parafollicular cells. (*d*) Light micrograph of thyroid and parathyroid tissue.

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. Process Figure questions that follow each figure legend apply physiological processes to practical situations, to promote applied understanding. Homeostasis Figures summarize the mechanisms of homeostasis by diagramming how a given system regulates a parameter within a narrow range of values.



PROCESS Figure 12.15 AP|R **Conduction System of the Heart**

The conduction system of the heart is composed of specialized cardiac muscle cells that produce spontaneous action potentials. conduction system of the heart ensures the proper pattern of contractions of the atria and ventricle, ensuring blood flow.

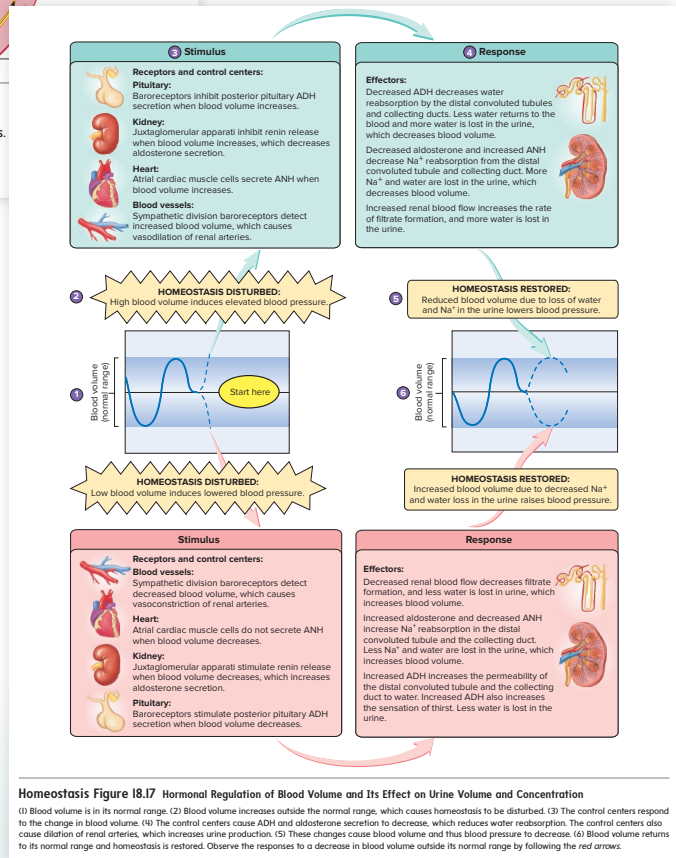
? Why is it important for stimulation of the ventricles to begin at the apex and spread toward the base?

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 18.17 Hormonal Regulation of Blood Volume and Its Effect on Urine Volume and Concentration

(1) Blood volume is in its normal range. (2) Blood volume increases outside the normal range, which causes homeostasis to be disturbed. (3) The control centers respond to the change in blood volume. (4) The control centers cause ADH and aldosterone secretion to decrease, which reduces water reabsorption. The control centers also cause dilation of renal arteries, which increases urine production. (5) These changes cause blood volume and thus blood pressure to decrease. (6) Blood volume returns to its normal range and homeostasis is restored. Observe the responses to a decrease in blood volume outside its normal range by following the *red arrows*.

Learn to Apply It and Learn to Apply It Answer—
Helping students learn how to think critically

- A *Learn to Apply It* question begins each chapter, which links the chapter opener scenario and photo to the topics covered within the chapter. *Apply It* questions appear throughout each chapter, to reinforce critical thinking.

▲ Kidney problems can result in dehydration and other negative effects.
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LEARN TO APPLY IT

Baby Maya was born early one morning. Not long after this picture was taken on her first day home from the hospital, Maya's parents noticed that her diapers were excessively wet hour after hour throughout the day and night. In addition, Maya was irritable, had a slight fever, and had vomited even though she had not eaten for several feedings. Her parents took her to the pediatrician, who ordered blood tests. The tests indicated that Maya had normal levels of antidiuretic hormone (ADH). **After reading this chapter, suggest the underlying mechanism for Maya's disorder.**

- A Learn to Apply It 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 APPLY IT

First we learn that Maya is unable to retain water and is urinating excessively. This helps us to narrow our focus to kidney function. Next we learn that Maya has normal levels of ADH. Excessive urination falls under the category of diabetes (derived from the Greek for "siphon"); however, diabetes insipidus is a condition involving ADH abnormality. There are two main causes of diabetes insipidus: The posterior pituitary fails to secrete ADH, or the kidney tubules have abnormal receptors for ADH and do not respond to the presence of ADH. In people suffering from diabetes insipidus, much of the filtrate entering both the proximal convoluted and the distal convoluted tubules becomes urine. People with this condition can produce as much as 20–30 L of urine each day. Because they lose so much water, they are continually in danger of severe dehydration. Even though their urine is dilute, producing such a large volume of urine leads to the loss of Na^+, Ca^{2+}, and other ions. The resulting ionic imbalances cause the nervous system and cardiac muscle to function abnormally. Because Maya's levels of ADH are normal, we can conclude that she has the type of diabetes insipidus involving abnormal receptors. Treatments for Maya include making sure she drinks plenty of water and giving her a sodium-sparing diuretic so that her kidneys retain sodium.

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

PEDAGOGICAL FEATURES ENSURE SUCCESS

Learning Outcomes are closely linked with in-chapter Apply It and Learn to Apply It 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.

14.1 FUNCTIONS OF THE LYMPHATIC SYSTEM

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

A. Describe the functions of the lymphatic system.
B. Explain how lymph is formed.

Studying Anatomy and Physiology does not have to be intimidating

SUMMARY

14.1 Functions of the Lymphatic System

The lymphatic system maintains fluid balance in tissues, absorbs lipids from the small intestine, and defends against pathogens.

14.2 Anatomy of the Lymphatic System

The lymphatic system consists of lymph, lymphocytes, lymphatic vessels, lymph nodes, tonsils, the spleen, and the thymus.

Lymphatic Capillaries and Vessels

1. Lymphatic vessels carry lymph away from tissues. Valves in the vessels ensure the one-way flow of lymph.
2. Skeletal muscle contraction, contraction of lymphatic vessel smooth muscle, and thoracic pressure changes move the lymph through the vessels.
3. Th
bl

Lymp

1. Ly su
2. Th an
3. Ly
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5. Th

3. Macrophages are large phagocytic cells that are active in the latter part of an infection. Macrophages are positioned at sites where pathogens may enter tissues.
4. Basophils and mast cells promote inflammation. Eosinophils also play a role in inflammation associated with allergic reactions.
5. Natural killer cells lyse tumor cells and virus-infected cells.

Inflammatory Response

1. Chemical mediators cause vasodilation and increase vascular permeability, allowing chemicals to enter damaged tissues. Chemicals also attract phagocytes.
2. The amount of chemical mediators and phagocytes increases until the cause of the inflammation is destroyed. Then the tissues undergo repair.
3. Local inflammation produces redness, heat, swelling, pain, and

REVIEW AND COMPREHENSION

1. List the parts of the lymphatic system, and describe the three main functions of the lymphatic system.
2. What is the function of the valves in lymphatic vessels? What causes lymph to move through lymphatic vessels?
3. Which parts of the body are drained by the right lymphatic duct and which by the thoracic duct?
4. Describe the cells and fibers of lymphatic tissue, and explain the functions of lymphatic tissue.
5. Name the three groups of tonsils. What is their function?
6. Where are lymph nodes found? What is the function of the germinal centers within lymph nodes?
7. Where is the spleen located? What are the functions of white pulp and red pulp within the spleen? What other function does the spleen perform?
8. Where is the thymus located, and what function does it perform?
9. What is the difference between innate immunity and adaptive

16. Which cells are responsible for antibody-mediated immunity and for cell-mediated immunity?
17. Describe the origin and development of B cells and T cells.
18. What is the function of antigen receptors and major histocompatibility proteins?
19. What is costimulation? Give an example.
20. Describe the process by which an antigen can cause an increase in helper T-cell numbers.
21. Describe the process by which helper T cells can stimulate B cells to divide, differentiate, and produce antibodies.
22. What are the functions of the variable and constant regions of an antibody?
23. Describe the direct and indirect ways that antibodies destroy antigens.
24. What are the functions of plasma cells and memory B cells?
25. Define primary and secondary responses. How do they differ

CRITICAL THINKING

1. A patient is suffering from edema in the right lower limb. Explain why elevation and massage of the limb help remove the excess fluid.
2. If the thymus of an experimental animal is removed immediately following birth, the animal exhibits the following characteristics:
   a. increased susceptibility to infections
   b. decreased numbers of lymphocytes
   c. greatly decreased ability to reject grafts
   Explain these observations.
3. Adjuvants are substances that slow, but do not stop, the release of an antigen from an injection site into the blood. Suppose injection A of a given amount of antigen is given without an adjuvant and injection B of the same amount of antigen is given with an adjuvant that caused the release of antigen over a period of 2 to 3 weeks. Does injection A or injection B result in the greater amount of antibody production? Explain.
4. Compare how long active immunity and passive immunity last. Explain the difference between the two types of immunity. In what situations is one type preferred over the other?
5. Tetanus is caused by bacteria (*Clostridium tetani*) that enter the body through wounds in the skin. The bacteria produce a toxin that causes spastic muscle contractions. Death often results from failure of the respiratory muscles. A patient goes to the emergency room after stepping on a nail. If the patient has been vaccinated against tetanus, he is given a tetanus booster shot, which consists of the toxin altered so that it is harmless. If the patient has never been vaccinated against tetanus, he is given an antiserum shot against tetanus. Explain the rationale for this treatment strategy. Sometimes both a booster and an antiserum shot are given, but at different locations on the body. Explain why this is done and why the shots are given in different locations.
6. A child appears healthy until approximately 9 months of age. Then the child develops severe bacterial infections, one after another. Fortunately, the infections are successfully treated with antibiotics. When infected with measles and other viral diseases, the child recovers without difficulty. Explain.
7. Samantha developed a poison ivy rash after a camping trip. Her doctor prescribed a cortisone ointment to relieve the inflammation. A few weeks later, Samantha scraped her elbow, which became inflamed. Because she had some leftover cortisone ointment, she applied it to the scrape. Was the ointment a good idea for the poison ivy? Was it an appropriate treatment for the scrape?

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.

Chapter-by-Chapter Changes

Chapter 1

- Figures 1.2, 1.6, 1.7, and 1.15 revised for clarity

Chapter 2

- Figure 2.2 now includes planetary models of atom structure
- Figure 2.3 revised to change atom models to planetary models for clarity
- Section 2.1— two new paragraphs explain electronegativity and its involvement in chemical bonding; also added, a discussion of the octet rule of chemical bonding
- Table 2.4 revised to include more functions of adipose tissue/lipids
- Section 2.5—a definition of R group added to the definition of amino acids; also added, a definition and explanation of saturated vs. unsaturated fatty acids
- Figure 2.17 revised to add a definition of E_a

Chapter 3

- Figure 3.23 revised for clarity of base pairing between DNA and RNA
- Table 3.1 updated to add peroxisome
- Revised description of concentration gradient
- Revised discussion of Golgi apparatus to include formation of lysosomes and transport of materials to the cell membrane

Chapter 4

- Section 4.2 Epithelial Tissue reorganized for clarity
- Section 4.2 Glands heavily revised for clarity
- Figure 4.2 updated to add adhesion belt
- Section 4.3 reorganized for clarity
- Table 4.5(a) updated for alignment of photomicrograph and illustration
- Table 4.9 revised to add platelets
- Section 4.6 Tissue Membranes revised for clarity

Chapter 5

- Figure 5.5 revised for accuracy

Chapter 6

- Section 6.2 updated for clarity
- Section 6.3 revised for accuracy; colloquial terminology updated to precise terminology
- Discussion of bone development revised to be more precise
- Clinical Impact: Bone Fractures revised to be more comprehensive
- Figure 6.10 revised for clarity
- Section 6.6 Axial Skeleton and subsection on Vertebral Column revised for accuracy and more precise terminology
- Figure 6.20 revised for clarity
- "Coxal bone" replaced with "hip bone" throughout
- Section 6.7, subsections on Ankle and Foot, updated for clarity; discussion of the function of the arch added
- Section 6.8 reorganized for clarity
- Section 6.8 updated to clarify the definitions of flexion and extension

Chapter 7

- New Section 7.2 General Properties of Muscle Tissue; subsequent sections renumbered
- Table 7.2 moved forward to be included with Section 7.1
- Figure 7.2 heavily revised to focus on the whole muscle and muscle cell anatomy
- Figure 7.3 revised to focus on the muscle fiber, and specifically the sarcomere
- Figure 7.4 revised
- Section 7.3, new paragraph added to the Skeletal Muscle Structure subsection
- Section 7.3, subsection Sarcomeres, revised and moved forward to fall before the subsection Actin and Myosin Myofilaments
- Section 7.3, heavy revision of a portion of the subsection Excitability of Muscle Fibers
- Tables 7.4, 7.5, 7.6, 7.8, and 7.13 revised to include more muscle actions

Chapter 8

- New Learn to Apply It question developed as chapter opener
- Figure 8.2 revised for clarity
- Discussion of glial cells revised to clearly delineate glial cells of the central nervous system and glial cells of the peripheral nervous system
- Table 8.1 revised, separating glial cells of the central nervous system from peripheral nervous system glial cells
- Discussion of the relationship between frequency of action potentials and strength of stimuli revised for clarity
- Spinal segment anatomy coverage revised for clarity
- Section 8.10 heading revised to "Somatic Motor Function" to more closely align with content

Chapter 9

- Section 9.4 Special Senses edited to introduce specific receptor types associated with specific senses
- Section 9.6, subsection on Neuronal Pathways for Taste, revised for clarity
- Section 9.7, subsection on Focusing Images on the Retina, revised to clearly describe the relationship between contraction and relaxation of ciliary muscles and shape of the lens

Chapter 10

- Section 10.8, new discussion of atrial natriuretic hormone

Chapter 11

- Section 11.1 revised for clarity
- Discussion of the breakdown of hemoglobin revised
- New figure 11.4 Hemoglobin

Chapter 12

- Section 12.3, subsection Heart Valves, revised to clearly identify each valve
- Coverage of coronary vessel compression during heart contraction revised for clarity
- New Microbes in Your Body box: How Bacteria Affect Cardiac Muscle
- Table 12.1 revised and retitled "Abnormal Heart Rhythms"

Chapter 13

- Section 13.2, discussion of precapillary sphincters revised for clarity
- Figure 13.6 revised for clarity
- Figure 13.10 updated for accuracy
- Figure 13.20 modified for clarity
- Section 13.6, revised subsection Capillary Exchange

Chapter 14

- Figure 14.1 revised to more accurately depict the thymus
- Discussion of proliferation of lymphocyte types revised for clarity

Chapter 15

- Section 15.3, Pleural Pressure, revised, including a more relatable analogy
- "Minute ventilation" changed to "minute volume"
- Table 15.2 edited to be more concise

Chapter 16

- Sections 16.1 and 16.2 revised

Chapter 17

- Brief discussion of the most recent updates to Dietary Guideline for Americans added
- Figure 17.2 updated with most recent food label design

Chapter 18

- Section 18.1 revised
- Section 18.2 reorganized for clarity; two new subheadings added to clarify discussion
- Section 18.3 filtration reorganized for clarity
- Section 18.4 heavily revised for clarity
- "Urinary sphincter" replaced with "urethral sphincter"
- Section 18.5, subsection Anatomy and Histology of the Ureters, Urinary Bladder, and Urethra, updated to reflect the most recent views on the existence of internal urethral sphincter in females

Chapter 19

- Section 19.3 revised to explain temperature requirements of sperm development
- Section 19.3 revised to clarify the functions and contents of testicular secretions, seminal vesicle secretions, and prostate gland secretions
- Clinical Impact: Control of Pregnancy now integrated into section 19.6

Chapter 20

- Boxed reading "Twins" incorporated into chapter text
- Section 20.3, subsection Respiratory and Circulatory Changes, revised for clarity
- Clinical Impact: Human Genome Project updated with most recent information on gene number estimates

List of Clinical Impact Essays

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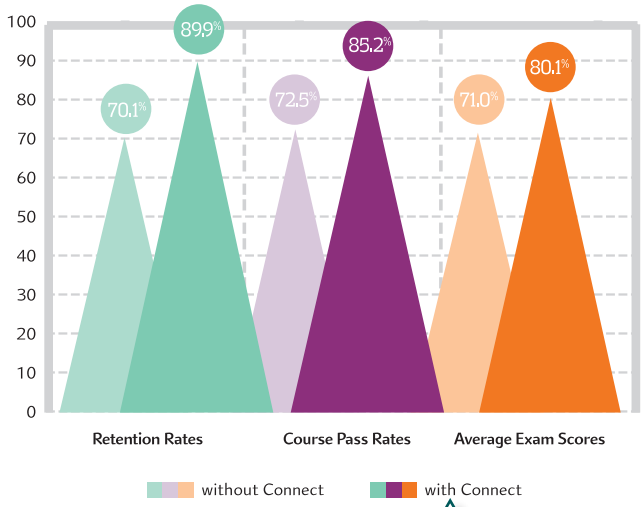

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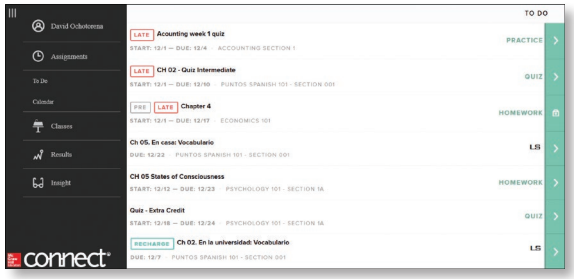

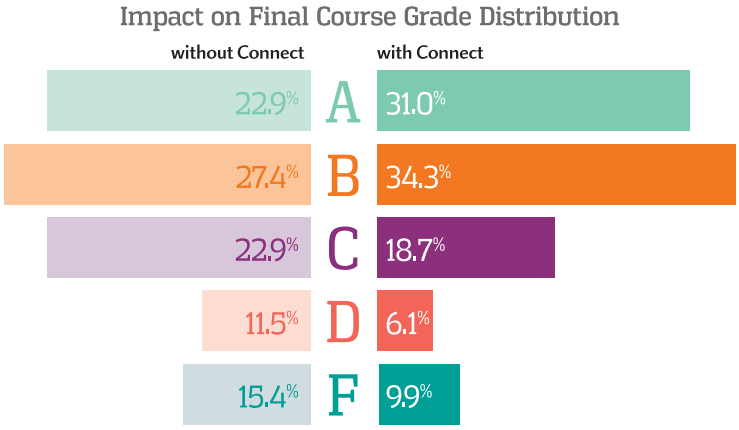

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Acknowledgments

In today's world, no textbook is brought to fruition through the work of the authors alone. Without the support of friends, family, and colleagues, it would not have been possible for us to complete our work on this text. The final product is truly a team effort. We want to express sincere gratitude to the staff of McGraw-Hill for their help and encouragement. We sincerely appreciate Executive Portfolio Manager Amy Reed and Senior Product Developer Donna Nemmers for their hours of work, suggestions, patience, and undying encouragement. We also thank Content Project Manager Jayne Klein, Content Licensing Specialist Lori Hancock, Buyer Laura Fuller, and Designer David Hash for their hours spent turning a manuscript into a book; Media Project Manager Danielle Clement for her assistance in building the various products that support our text; and Marketing Manager Jim Connely for his enthusiasm in promoting this book. The McGraw-Hill Education employees with whom we have worked are extremely professional, but more than that, they are completely dedicated to their role as part of the content team.

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Seeley's Essentials of

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CHAPTER

The Human Organism

LEARN TO APPLY IT

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.

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

▲ Just as the dancer in the photo works to balance his body's position, homeostasis works to balance the body's internal environment. ©Elnur/Shutterstock RF

I.1 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 interact with our surroundings by adjusting how the body responds to changes in environmental information. This information comes from inside and outside the body. These changes serve as **stimuli** (stimulus, *sing*.).

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 helps us to be well prepared to make a decision about our own health care or that of a loved one. It also can allow us to distinguish between useful medical treatments and those that may be harmful.

Anatomy (ă-nat′ŏ-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, such as when determining if a bone is broken or a ligament is torn. 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 for studying physiology are (1) to understand and predict the body's responses to stimuli and (2) to understand how the body maintains internal 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. This is important because a molecule's structure determines its function. 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 during everyday activities. 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.

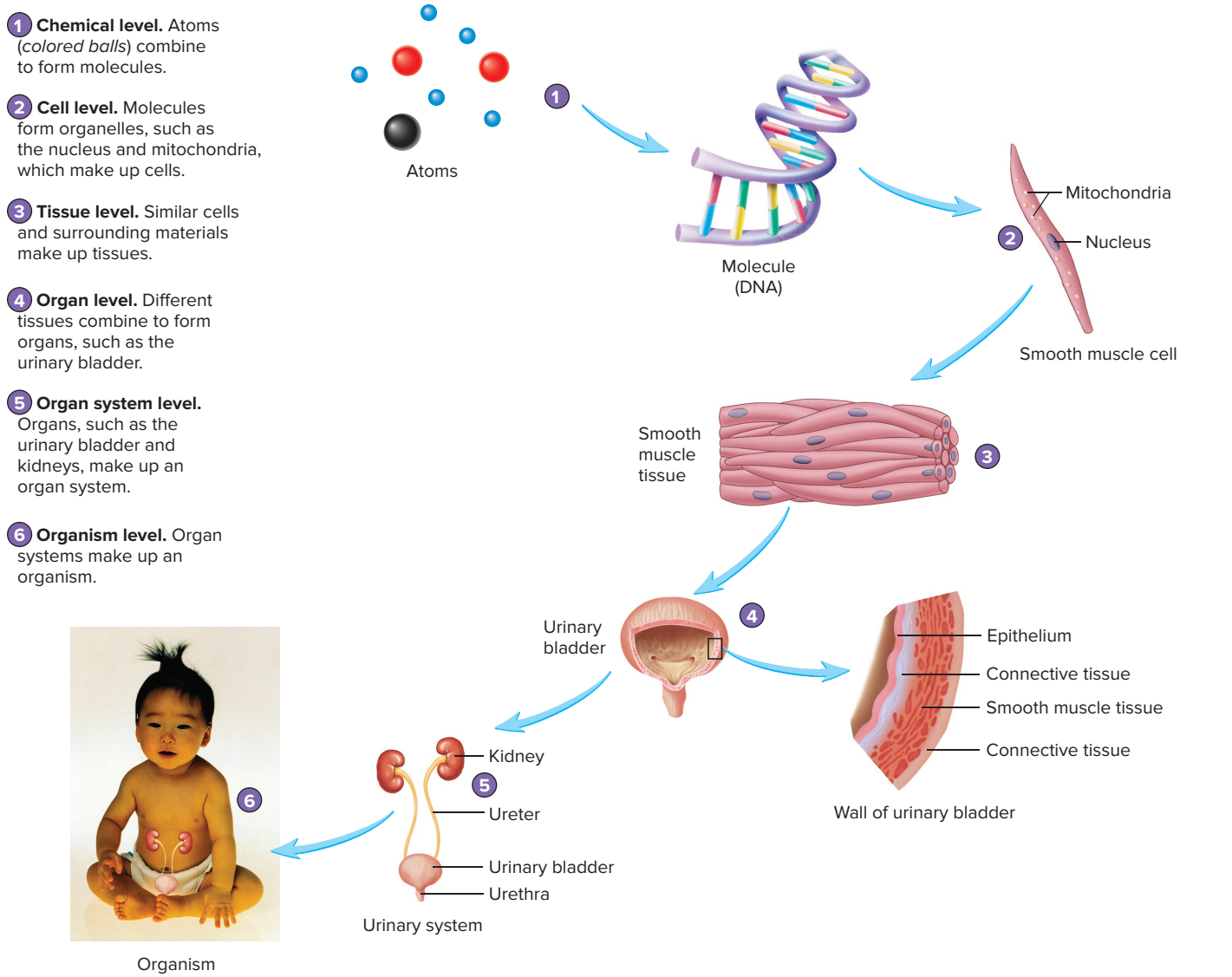
Organ Level

An **organ** (ōr′găn; a tool) is composed of two or more tissue types that together perform one or more common functions. Examples of some of our organs include the heart, stomach, liver, and urinary bladder (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, ureters, 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, nervous, endocrine, cardiovascular, lymphatic, respiratory, digestive, 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 food, processing it into nutrients that are carried by the blood of the cardiovascular system to the cells of the other systems. These cells use the nutrients 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.



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

The simplest level of organization in the human body is the atom. Atoms combine to form molecules. Molecules aggregate into cells. Cells form tissues, which combine with other tissues to form organs. Organs work in groups called organ systems. All organ systems work together to form an organism. I.I(6) ©Bart Harris/Getty Images

? Why is the skin considered an organ? What characterizes the integumentary system as an organ system?

Throughout this text, Systems Pathology essays consider the interactions of the organ systems.

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 upon 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 relationship of the many individual parts of an organism, from cell organelles to organs, interacting and working together. 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 to synthesize sugars (a process called photosynthesis), 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. Examples of responses are

MICROBES IN YOUR BODY Getting to Know Your Bacteria

Did you know that you have more microbial cells than human cells in your body? Microbial cells 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 "good" bacteria that do not cause disease and may even help us. It also includes pathogenic, or "bad" bacteria.

In October 2007 the National Institutes of Health (NIH) initiated the five-year Human Microbiome Project. This project identified over 5000 species and sequenced over 20 million unique microbial genes and demonstrated that Human health is dependent upon the health of our microbiota, especially the "good" bacteria. More specifically, the human microbiome is intimately involved in the development and maintenance of the immune system. And more evidence is mounting for a correlation between a host's microbiota, digestion, and metabolism. 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. 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.

movements toward food or water and away from danger or poor environmental conditions such as extreme cold or heat. 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.

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 grow when the number of bone cells increases and the bone cells become surrounded by bone matrix.
5. **Development** includes the changes an organism undergoes through time. Human development begins when the egg is fertilized by the sperm and ends with 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, cells start to specialize to become different 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; *-stasis*, to stop) 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. One familiar variable is body temperature, which can increase when the environment is hot or decrease when the environment is cold.

Homeostatic mechanisms, such as sweating or shivering, normally maintain body temperature near an average 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. These

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.

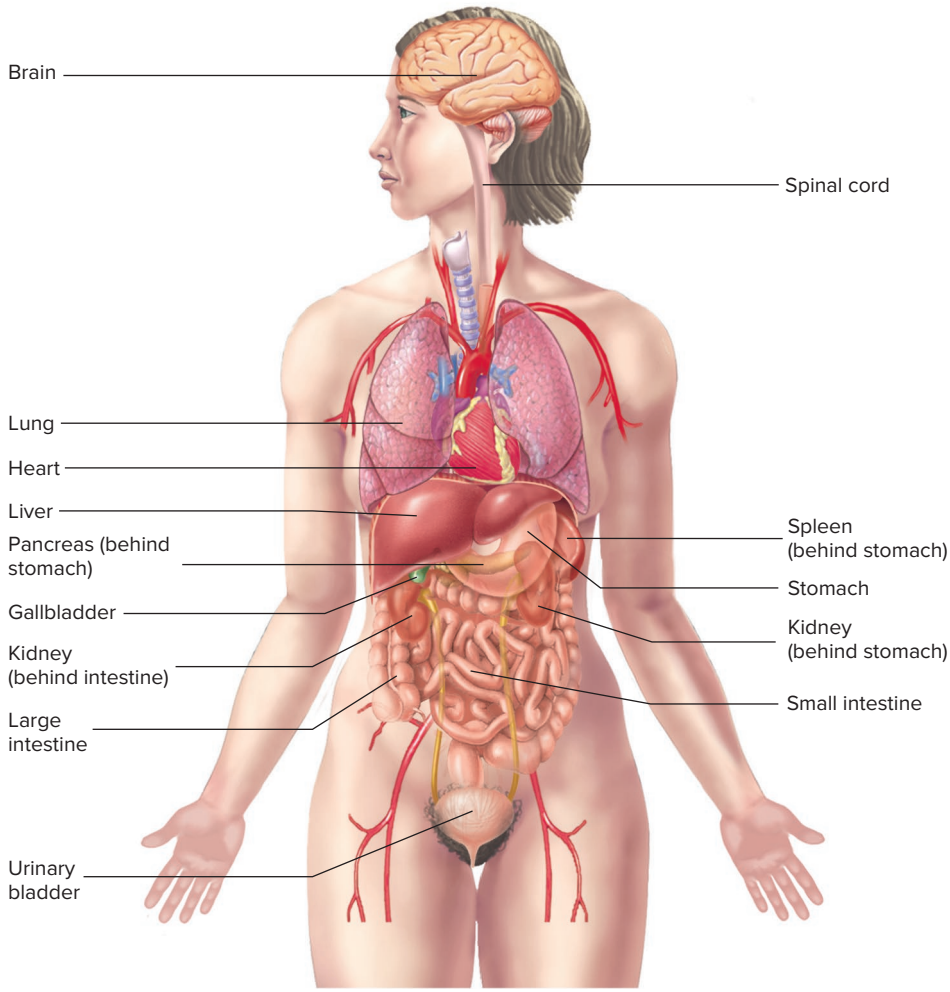
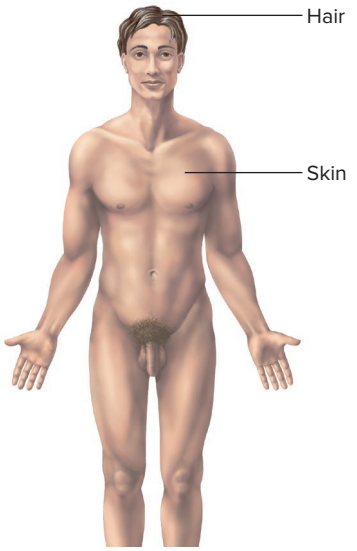


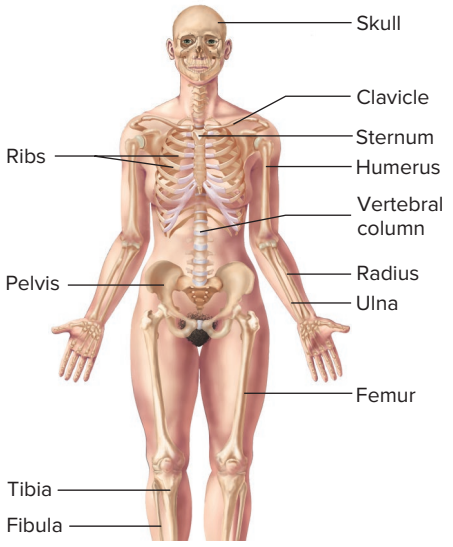
Figure I.2 Major Organs of the Body

The body's major organs include the brain, lungs, heart, liver, pancreas, spleen, stomach, gallbladder, kidneys, large intestine, small intestines, urinary bladder, and urethra.



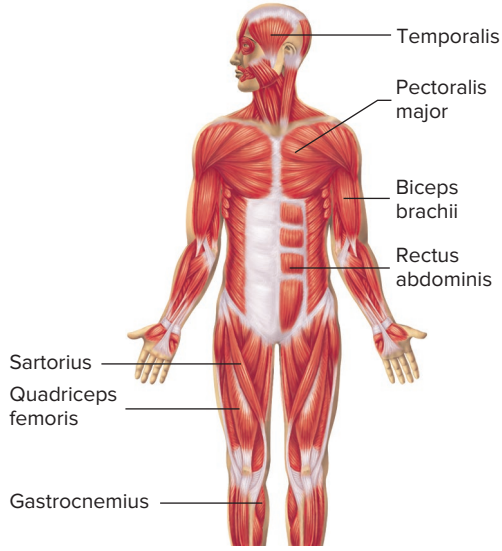
Integumentary System

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



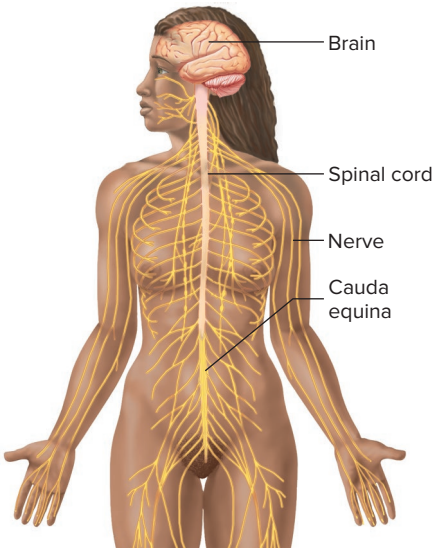
Skeletal System

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



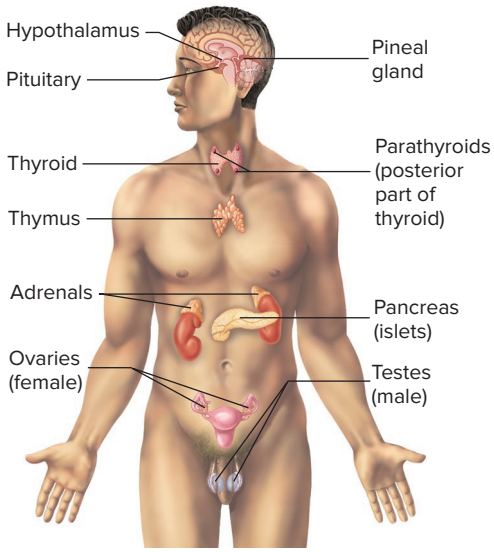
Muscular System

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



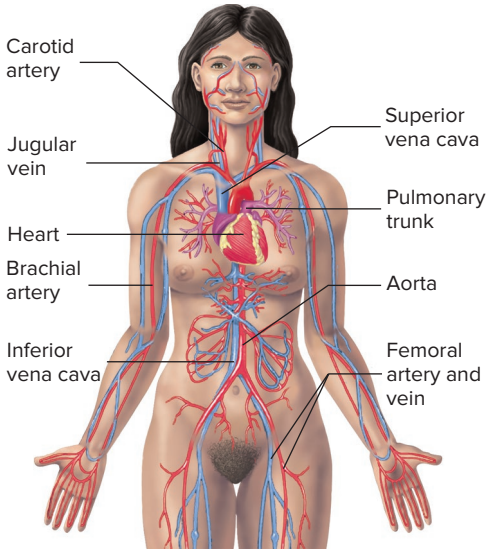
Nervous System

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

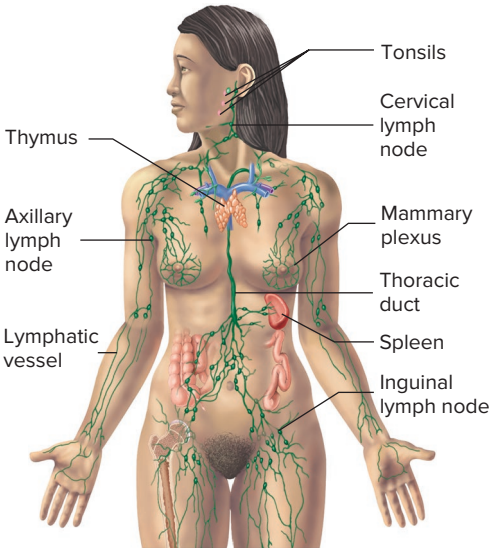
A major regulatory system that influences metabolism, growth, reproduction, and many other functions. Consists of endocrine glands, such as the pituitary, that secrete hormones.



Cardiovascular System

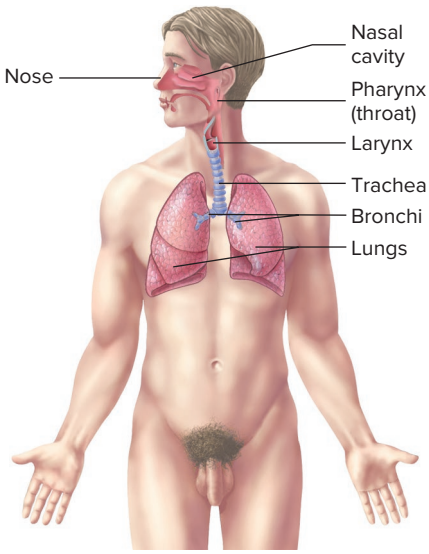
Transports nutrients, waste products, gases, and hormones throughout the body; plays a role in the immune response and the regulation of body temperature. Consists of the heart, blood vessels, and blood.

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



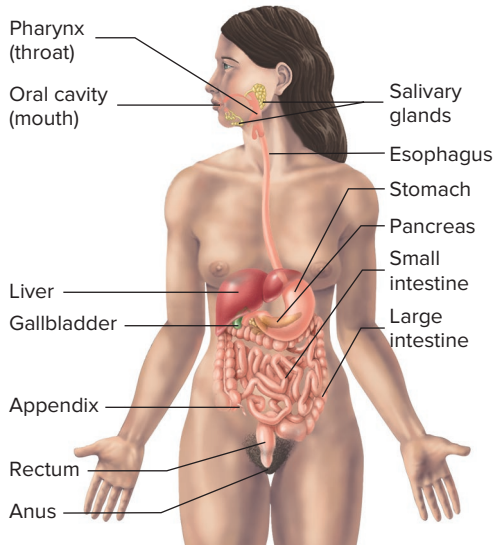
Lymphatic System

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



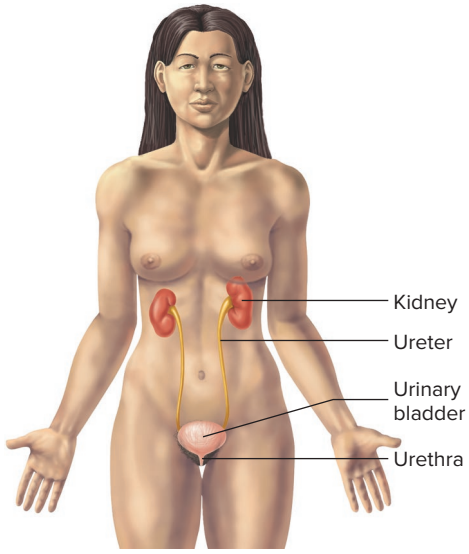
Respiratory System

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



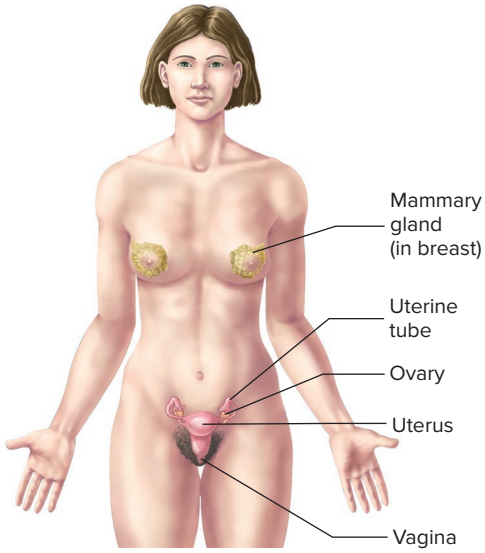
Digestive System

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



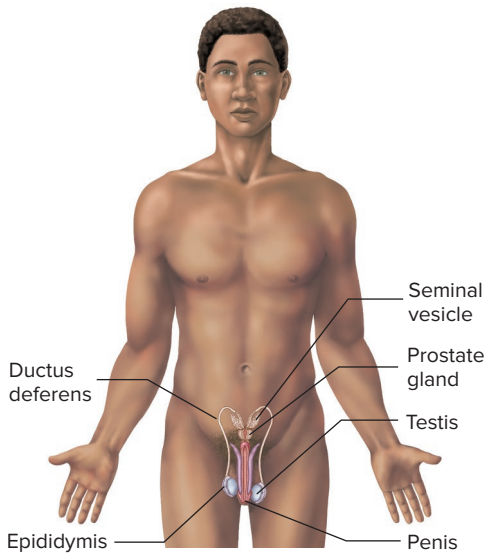
Urinary System

Removes waste products from the blood and regulates blood pH, ion balance, and water balance. Consists of the kidneys, urinary bladder, and ureters.



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)*

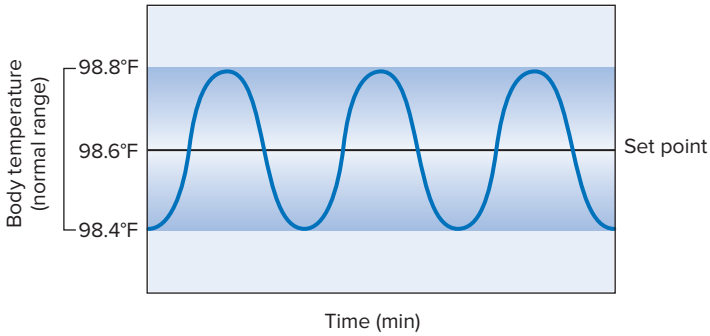


Figure 1.4 Homeostasis

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.

changes are actually fairly minimal. Note in figure 1.4 that the normal body temperature range is not more than 1°F above or below normal. Our *average* body temperature is 98.6°F.

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. In everyday terms, the word *negative* is used to mean "bad" or "undesirable." In this context, negative means "to decrease." *Negative feedback* is when 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.

Most 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, by detecting stimuli; (2) a **control center,** such as part of the brain, determines the set point for the variable and receives input from the receptor about the variable; and (3) an **effector** (ē-fek′tŏr), such as the sweat glands, can change the value of the variable when directed by the control center. 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).

Apply It 1

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, *positive* means that the deviation from the set point becomes even greater. In this case, the word "positive" indicates an increase. 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).

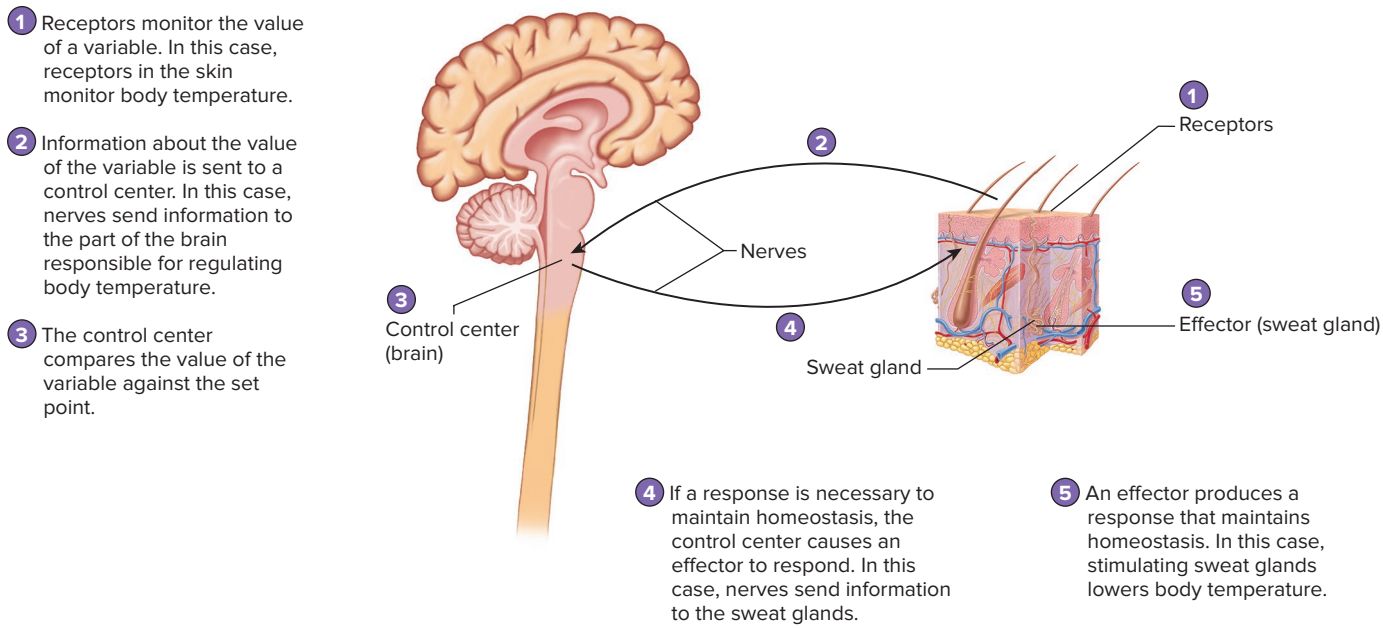
Birth is another example of a normally occurring positive-feedback mechanism. Near the end of pregnancy, the uterus is stretched by the baby's large size. This stretching, especially around the opening of the uterus, stimulates contractions of the uterine muscles. The uterine contractions push the baby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

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 fluids, or humors: blood, bile, mucus from the nose and lungs, and a black fluid in the pancreas. They also thought that an excess of any one humor caused disease. They believed the body healed itself by expelling the excess fluids, such as with a runny nose. This belief led to the practice of bloodletting to restore the body's normal balance of humors. Physicians would puncture larger, external vessels, or use leeches, blood-eating organisms.

Unfortunately, bloodletting went to extremes and 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 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 still more blood should be removed, undoubtedly causing many deaths. Eventually, 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.



PROCESS Figure 1.5 Negative-Feedback Mechanism: Body Temperature

Receptors detect changes in variables and communicate any changes to the control center, or brain in this case, which in turn controls the effectors, which are sweat glands in this example.

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

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 instead of helpful. One example of a detrimental positive-feedback mechanism is inadequate delivery of blood to cardiac (heart) muscle. Contraction of cardiac muscle generates blood pressure and 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 to cardiac muscle is inadequate.