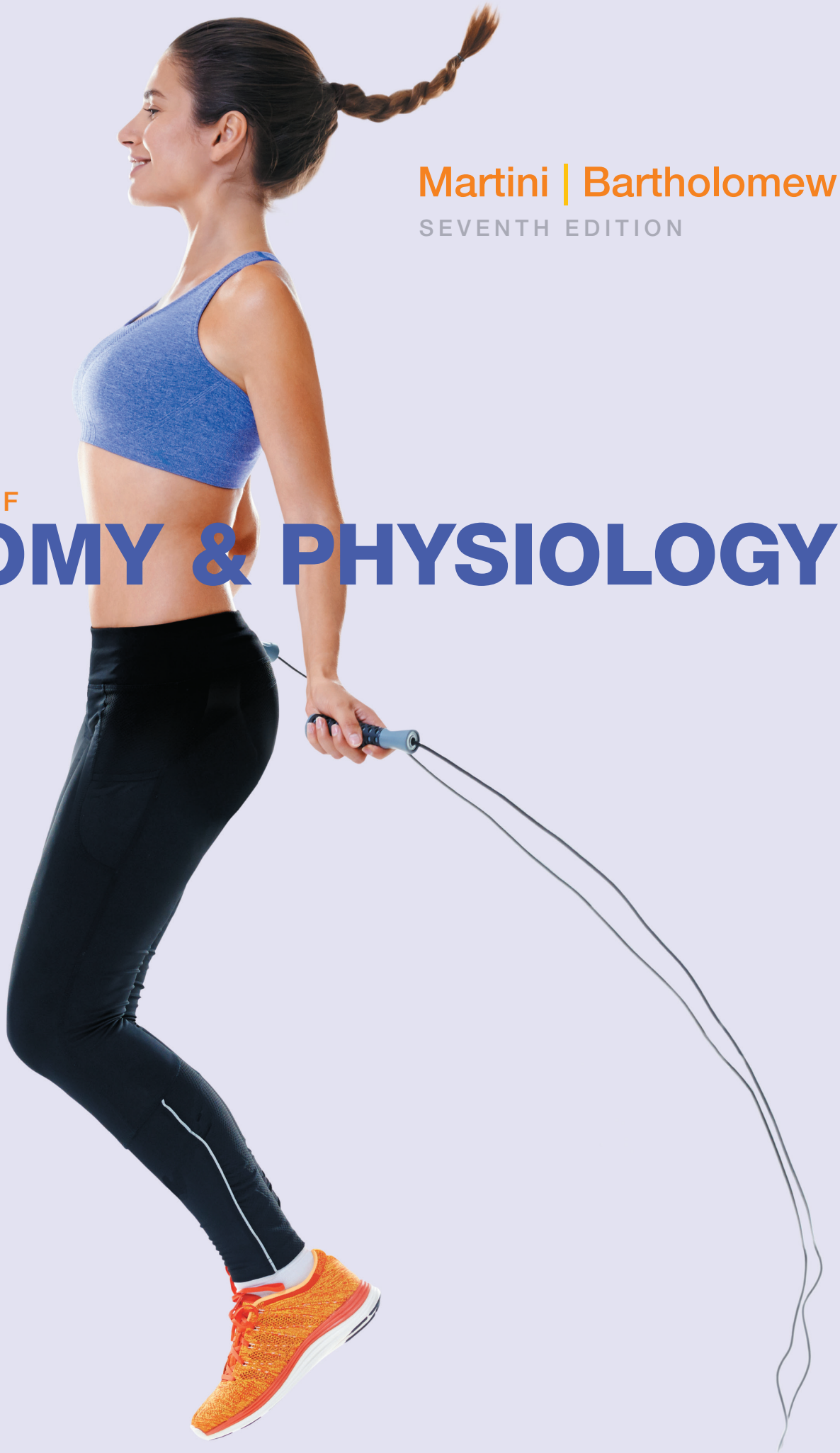


Martini | Bartholomew

SEVENTH EDITION

ESSENTIALS OF

ANATOMY & PHYSIOLOGY

Contents

NEW! Build Your Knowledge Helps

NEW! Build Your Knowledge Boxes coach students through the toughest part of A&P—physiology. These boxes refer to previously learned concepts to remind students of what they already know before introducing new information.

Build Your Knowledge

Recall that the endocrine system directs long-term changes in the activities of other organ systems (as you saw in **Chapter 1: An Introduction to Anatomy and Physiology**). Both the endocrine and nervous systems act to maintain homeostasis as environmental conditions change. The nervous system responds relatively quickly to stimuli. On the other hand, endocrine system responses develop more slowly but last much longer. ⮌ **p. 8**

in body fluids (interstitial fluid, blood plasma, and CSF). Adaptation usually takes place over a few seconds following stimulation. Except for the special senses of taste and smell, there are no well-defined chemosensory pathways in the brain or spinal cord. The chemoreceptors of the general senses send their information to brain stem centers that deal with the autonomic control of respiratory and cardiovascular functions.

The locations of important chemoreceptors are shown in Figure 9-5. Neurons within the respiratory centers of the brain respond to the concentrations of hydrogen ions (pH) and carbon dioxide molecules in the cerebrospinal fluid. Chemoreceptors are also found in the **carotid bodies,** near the origin of the internal carotid arteries on each side of the neck, and in the **aortic bodies,** between the major branches of the aortic arch. These receptors monitor the pH, carbon dioxide, and oxygen levels in arterial blood. The afferent fibers leaving the carotid and aortic bodies reach the respiratory centers by traveling within cranial nerves IX (glossopharyngeal) and X (vagus).

CHECKPOINT

4. List the four types of general sensory receptors, and identify the nature of the stimulus that excites each type.
5. Identify the three classes of mechanoreceptors.
6. What would happen if information from proprioceptors in your legs was blocked from reaching the CNS?

See the blue Answers tab at the back of the book.

Build Your Knowledge

Recall that there are separate pathways in the spinal cord that carry sensory information (as you saw in **Chapter 8: The Nervous System**). Examples of sensory pathways and the sensations they deliver to the brain include:

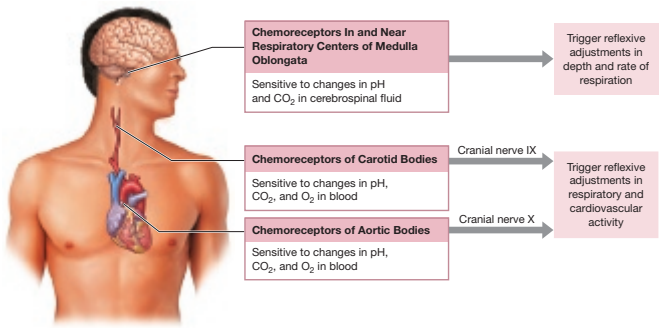
- the posterior column pathway (highly localized fine touch, pressure, vibration, and proprioception);
- the spinothalamic pathway (poorly localized touch, pressure, pain, and temperature);
- and the spinocerebellar pathway (proprioceptive information concerning the positions of muscles, bones, and joints). ⮌ **p. 286**

9-3 Olfaction, the sense of smell, involves olfactory receptors responding to chemical stimuli

Learning Outcome: Describe the sensory organs of smell, and discuss the processes involved in olfaction.

The sense of smell, or *olfaction,* is provided by paired **olfactory organs.** These organs are located in the nasal cavity on either side of the nasal septum (Figure 9-6a). Each olfactory organ

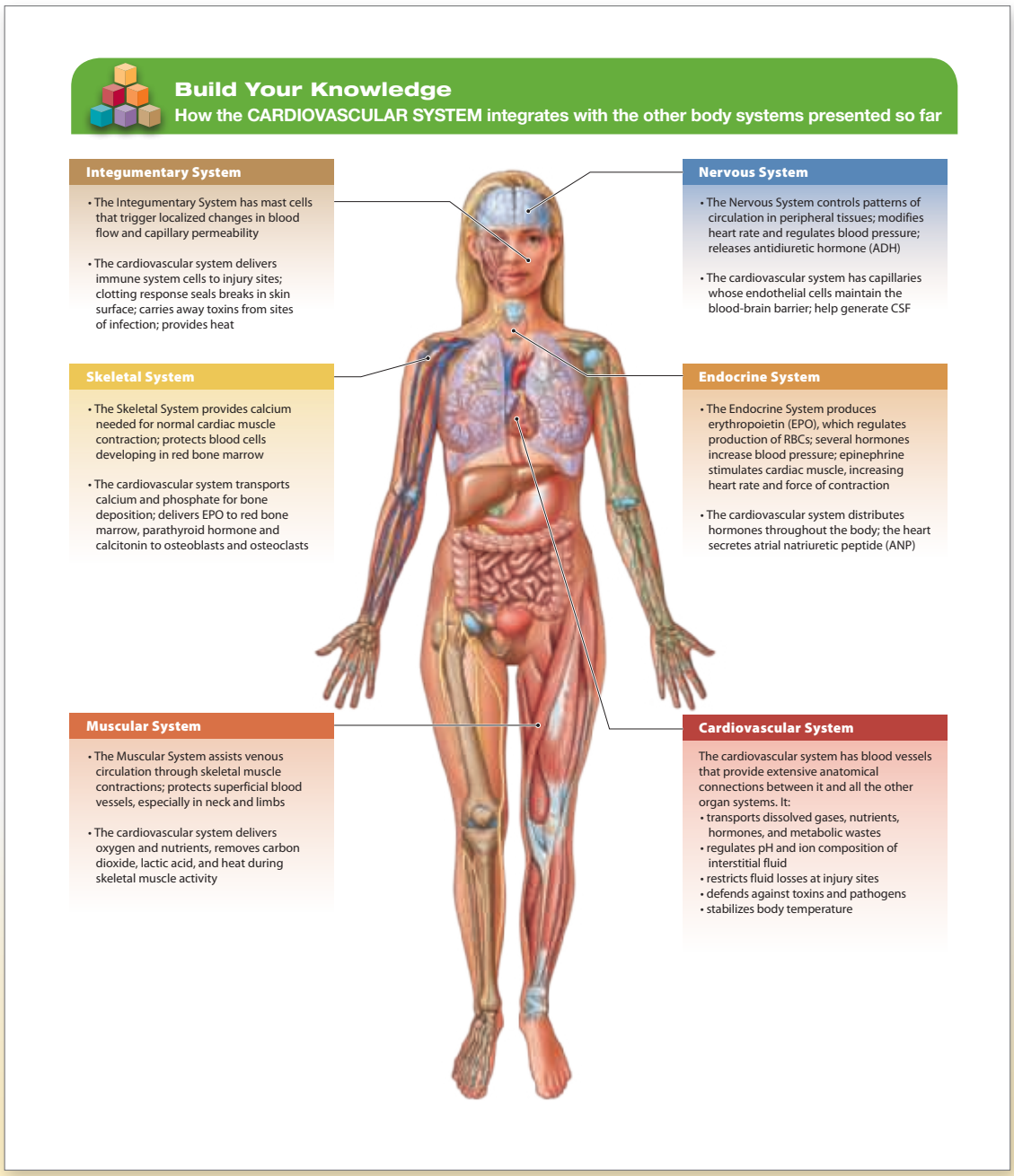
Figure 9-5 Locations and Functions of Chemoreceptors. Chemoreceptors are located in the CNS (on the ventrolateral surfaces of the medulla oblongata) and in the aortic and carotid bodies. These receptors are involved in the autonomic regulation of respiratory and cardiovascular function.



Build Your Knowledge Boxes appear throughout the chapter to remind students of key concepts. Corresponding questions are assignable in MasteringA&P®

Students Synthesize Information

At the end of each body system, a capstone Build Your Knowledge System Integrator helps students understand how body systems work together. Build Your Knowledge Concept Map Coaching Activities are assignable in MasteringA&P®



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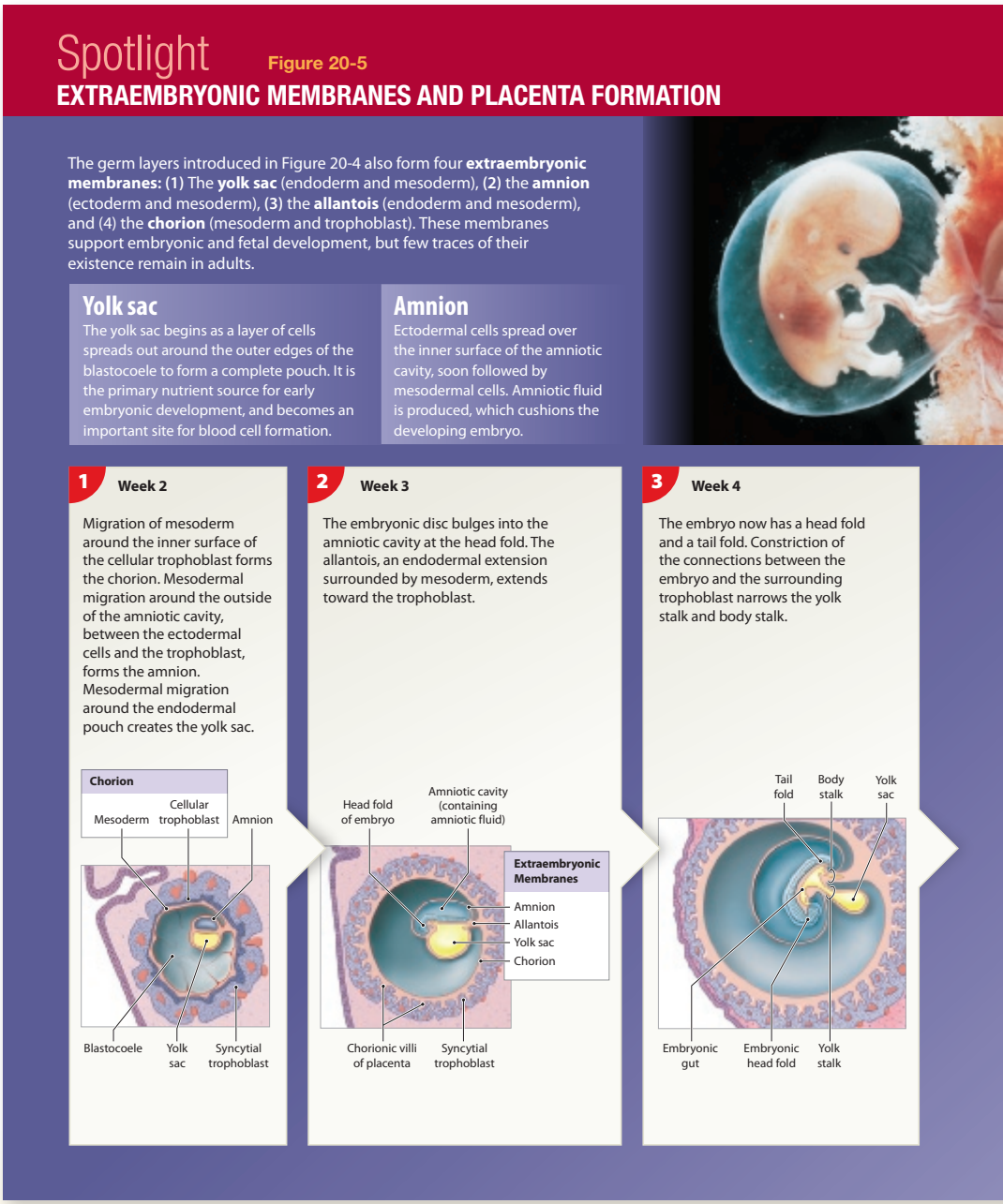
Spotlight Figures provide highly visual one- and two-page presentations of tough topics in the book. Brief text and related figures and photos communicate information in a visually effective and student-friendly format.

In the Seventh Edition, there is now at least one Spotlight Figure in every chapter along with a correlating new Coaching Activity in MasteringA&P®



NEW SPOTLIGHT FIGURES IN THE SEVENTH EDITION

Figure 1-1: Levels of Organization
Figure 4-16: Inflammation and Regeneration
Figure 5-2: The Epidermis
Figure 6-7: Types of Fractures and Steps in Repair
Figure 8-9: Propagation of an Action Potential
Figure 12-5: The Heart: Internal Anatomy and Blood Flow
Figure 13-13: Major Vessels of the System Circuit
Figure 14-4: Origin and Distribution of Lymphocytes
Figure 15-10: Pulmonary Ventilation
Figure 15-16: The Control of Respiration

Tough Topics

Allantois

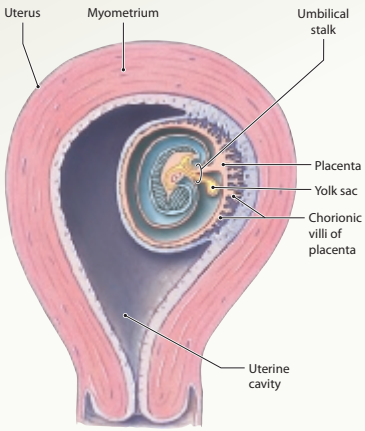
The allantois begins as an outpocket of the endoderm near the base of the yolk sac. The free endodermal tip then grows toward the wall of the blastocyst, surrounded by a mass of mesodermal cells. The base of the allantois eventually gives rise to the urinary bladder.

Chorion

The mesoderm associated with the allantois spreads around the entire blastocyst, separating the cellular trophoblast from the blastocoele. The appearance of blood vessels in the chorion is the first step in the creation of a functional placenta. By the third week of development, the mesoderm extends along the core of each trophoblastic villus, forming chorionic villi in contact with maternal tissues and blood vessels. These villi continue to enlarge and branch forming the placenta, the exchange platform between mother and fetus for nutrients, oxygen, and wastes.

4 **Week 5**

The developing embryo and extraembryonic membranes bulge into the uterine cavity. The trophoblast pushing out into the uterine cavity remains covered by endometrium but no longer participates in nutrient absorption and embryo support. The embryo moves away from the placenta, and the body stalk and yolk stalk fuse to form an umbilical stalk.



5 **Week 10**

The amnion has expanded greatly, filling the uterine cavity. The fetus is connected to the placenta by an elongated umbilical cord that contains a portion of the allantois, blood vessels, and the remnants of the yolk stalk.

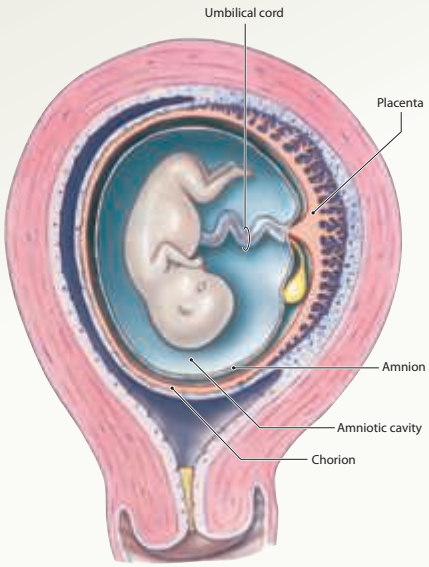
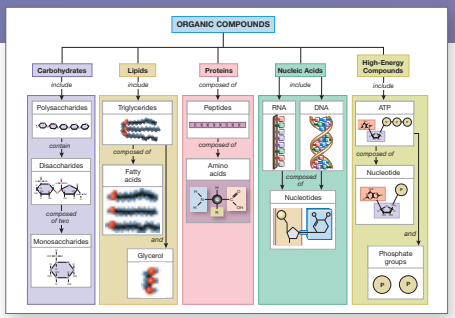
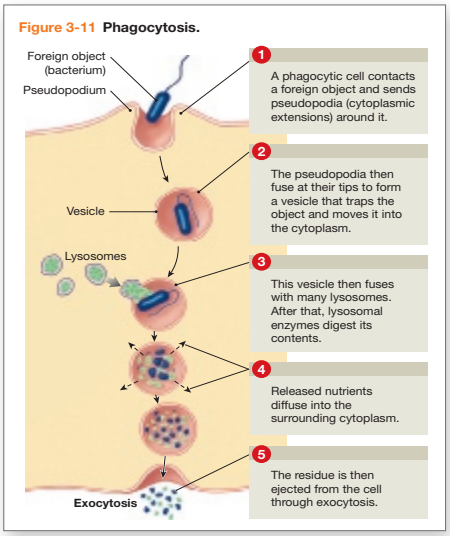


Figure 16-9: Regulation of Gastric Activity
Figure 16-18: Chemical Events in Digestion
Figure 17-5: Electron Transport System and ATP Formation
Figure 20-5: Extraembryonic Membranes and Placenta Formation

MORE!
Text/Art Integration



An Overview of the Structures of Organic Compounds in the Body, p. 49



Stepwise illustration of Phagocytosis, p. 68

Full-page Clinical Note on Diabetes Mellitus, p. 366

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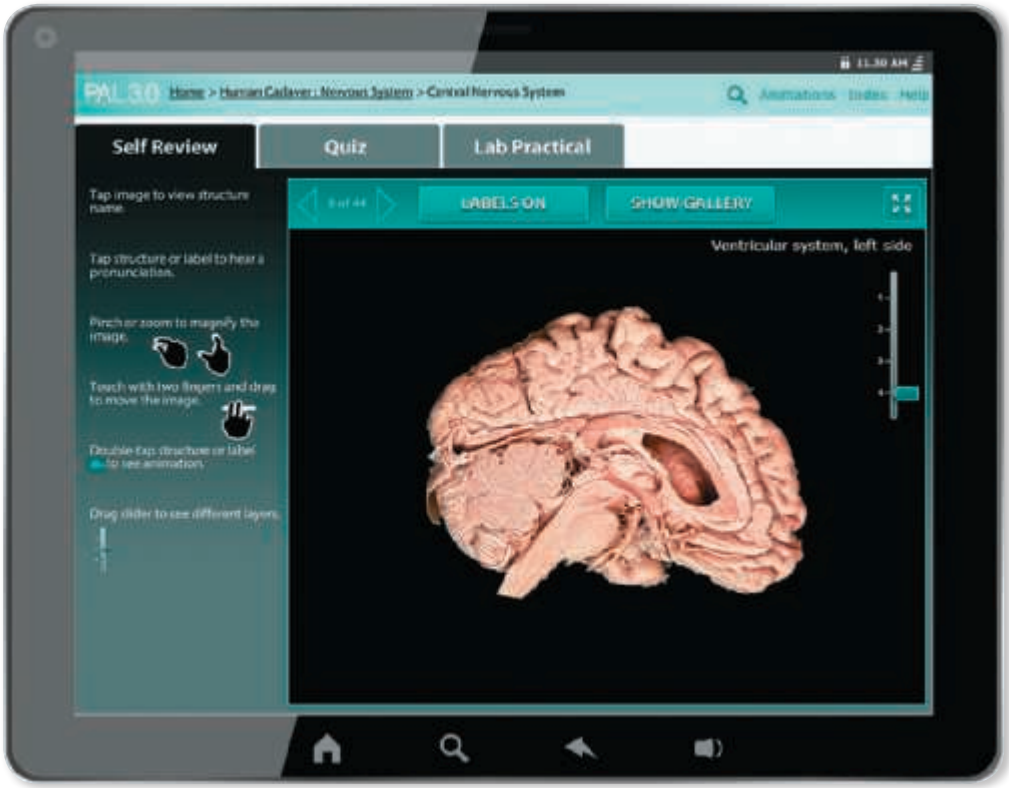

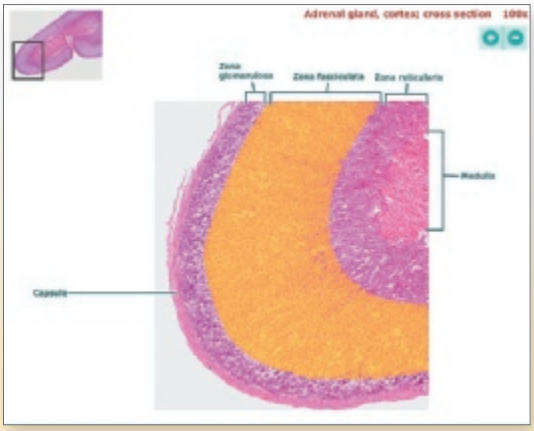

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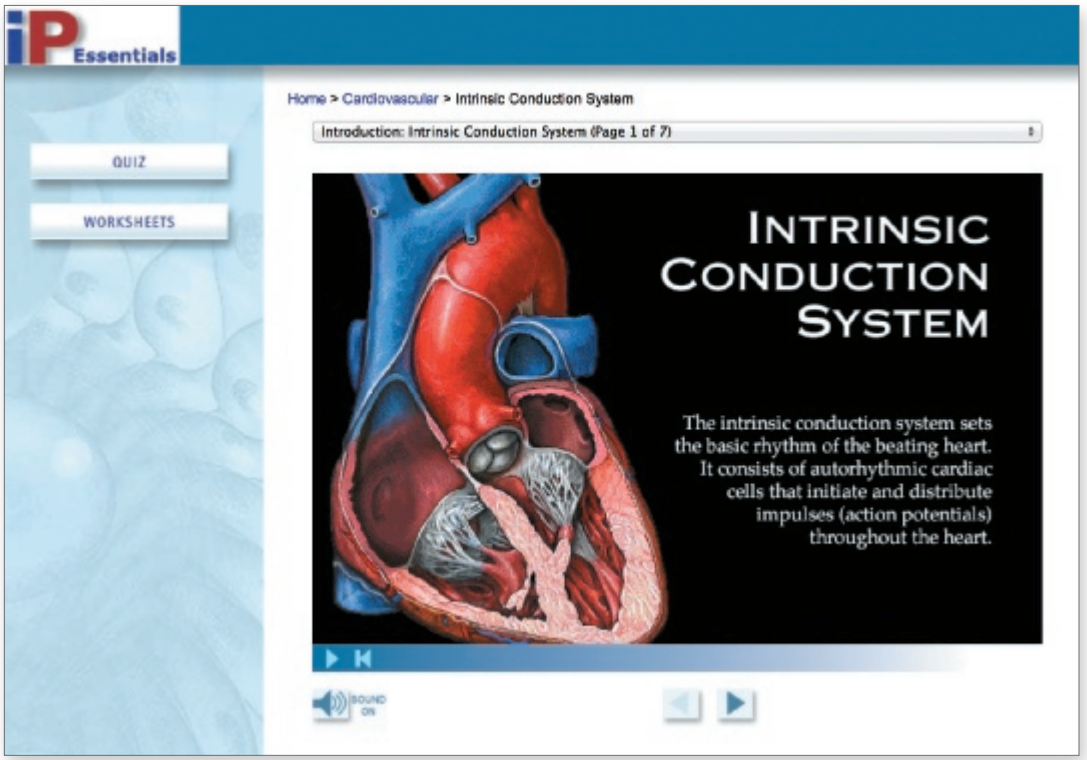

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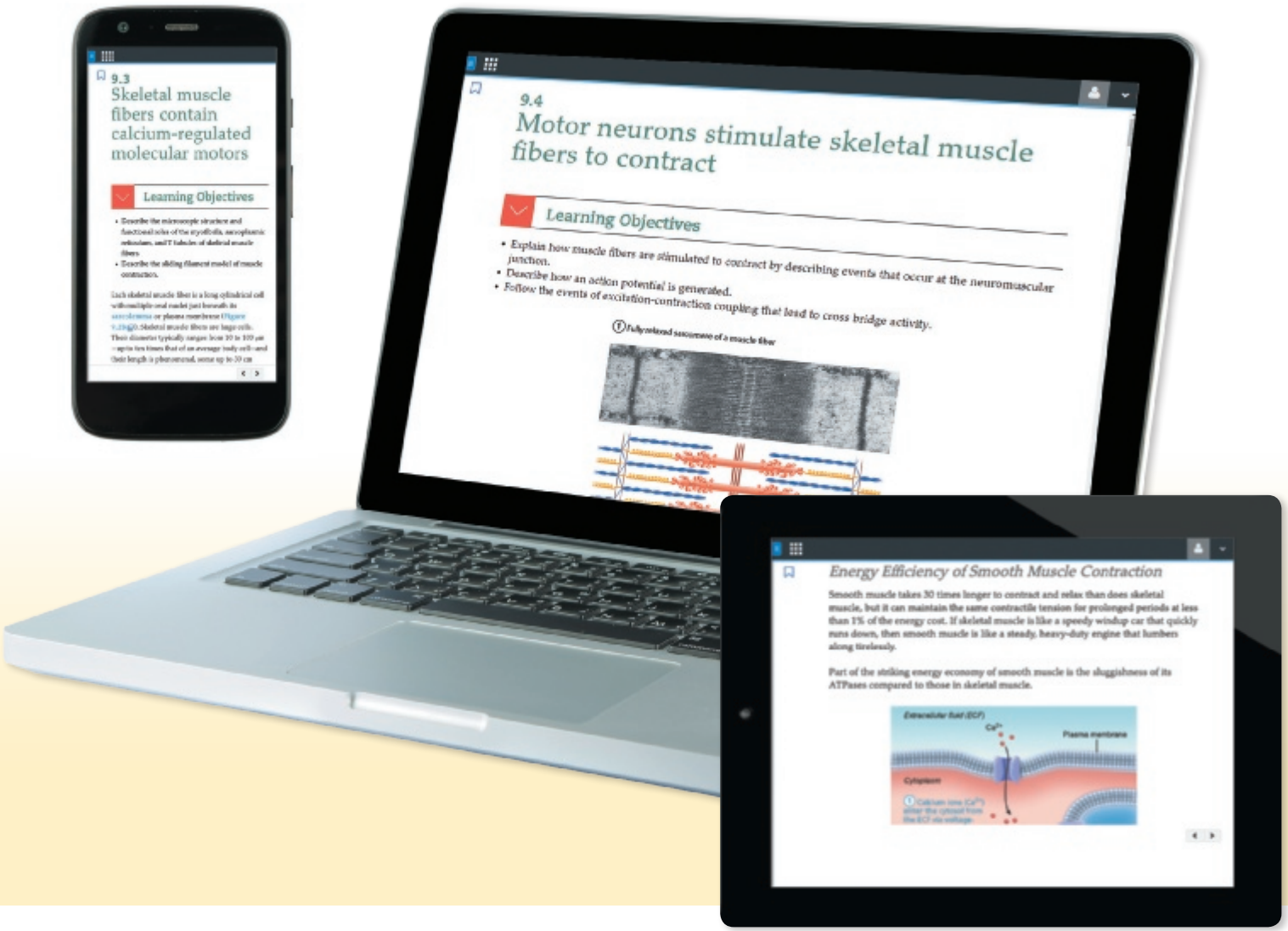

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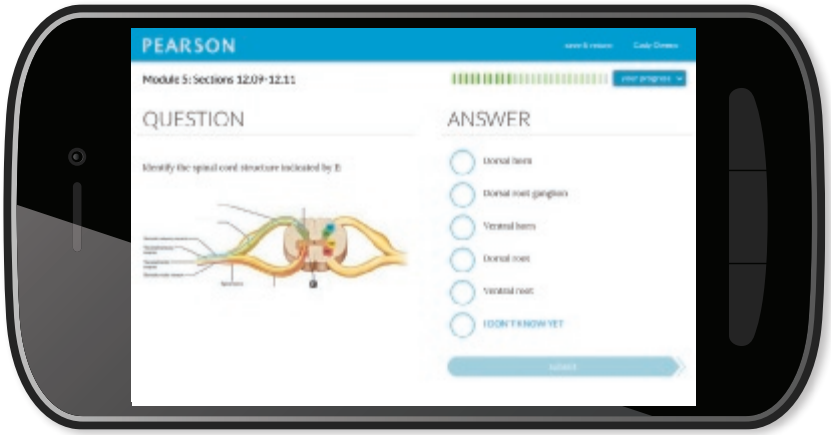

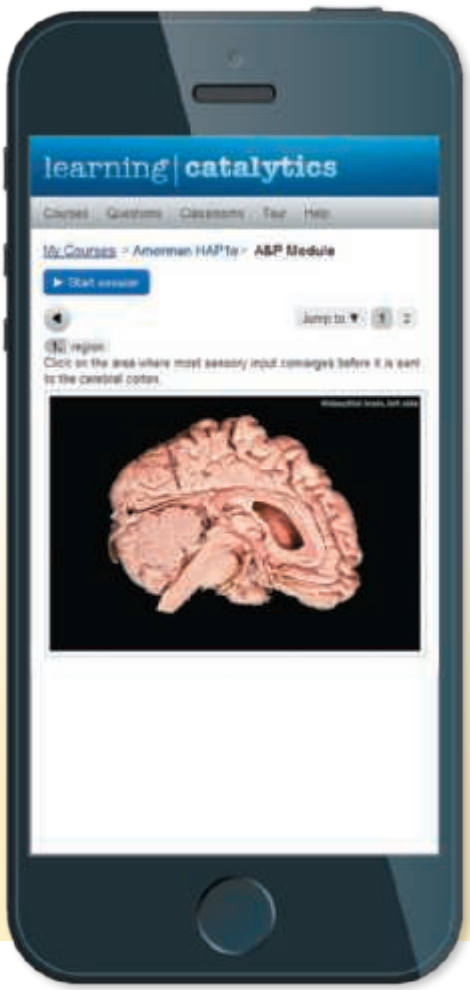

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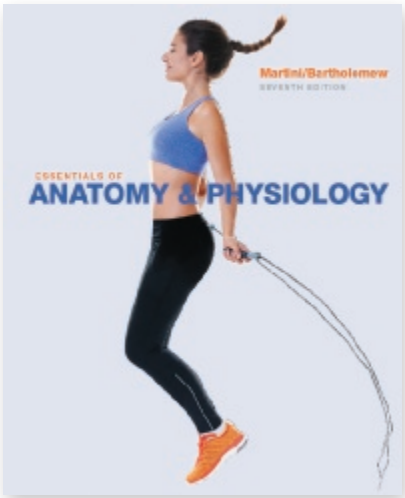

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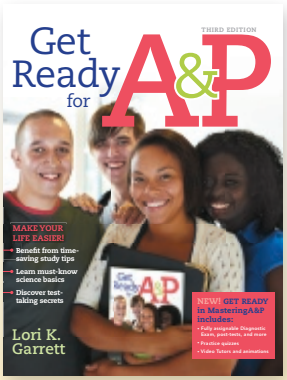

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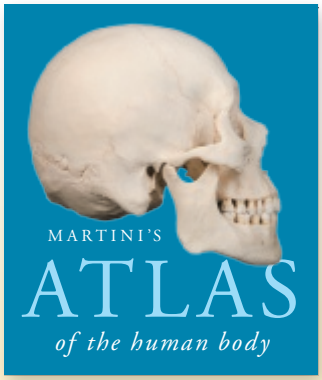

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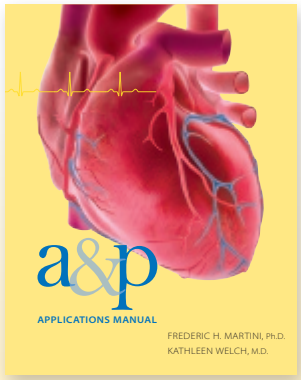

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SEVENTH EDITION

ESSENTIALS OF ANATOMY & PHYSIOLOGY

WITH

William C. Ober, M.D.
ART COORDINATOR AND ILLUSTRATOR

Claire E. Ober, R.N.
ILLUSTRATOR

Kathleen Welch, M.D.
CLINICAL CONSULTANT

Ralph T. Hutchings
BIOMEDICAL PHOTOGRAPHER

PEARSON

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Text and Illustration Team

FREDERIC (RIC) MARTINI, PH.D. (author) received his Ph.D. from Cornell University. In addition to his technical and journal publications, he has been the lead author of ten undergraduate texts on anatomy and physiology or anatomy. Dr. Martini is currently affiliated with the University of Hawaii at Manoa and has a long-standing bond with the Shoals Marine Laboratory, a joint venture between Cornell University and the University of New Hampshire. He has been active in the Human Anatomy and Physiology Society (HAPS) for 24 years and is now a President Emeritus of HAPS. He is also a member of the American Physiological Society, the American Association of Anatomists, the Society for Integrative and Comparative Biology, the Australia/New Zealand Association of Clinical Anatomists, the Hawaii Academy of Science, the American Association for the Advancement of Science, and the International Society of Vertebrate Morphologists.

EDWIN F. BARTHOLOMEW, M.S. (author) received his undergraduate degree from Bowling Green State University in Ohio and his M.S. from the University of Hawaii. His interests range widely, from human anatomy and physiology to the marine environment, "backyard" aquaculture, and art. Mr. Bartholomew has taught human anatomy and physiology at both the secondary and undergraduate levels. In addition, he has taught a range of other science courses (from botany to zoology) at Maui Community College (now the University of Hawaii Maui College). For many years, he taught at historic Lahainaluna High School, the oldest high school west of the Rockies, where he assisted in establishing an LHS Health Occupations Students of America (HOSA) chapter. He has written journal articles, a weekly newspaper column, and many magazine articles. Working with Dr. Martini, he coauthored *Structure & Function of the Human Body* and *The Human Body in Health and Disease* (Pearson). Along with Dr. Martini and Dr. Judi Nath, he coauthored *Fundamentals of Anatomy & Physiology, 10th edition*. He also coauthored *Visual Anatomy & Physiology, 2nd edition*, with Dr. Martini, Dr. William Ober, Dr. Judi Nath, and Dr. Kevin Petti. Mr. Bartholomew is a member of the Human Anatomy and Physiology Society, National Science Teacher's Association, and the American Association for the Advancement of Science.

WILLIAM C. OBER, M.D. (art coordinator and illustrator) received his undergraduate degree from Washington and Lee University and his M.D. from the University of Virginia. While in medical school, he also studied in the Department of Art as Applied to Medicine at Johns Hopkins University. After graduation, Dr. Ober completed a residency in Family Practice and later was on the faculty at the University of Virginia in the Department of Family Medicine. He was Chief of Medicine at Martha Jefferson Hospital and was an Instructor in the Division of Sports Medicine at UVA. He also was part of the Core Faculty at Shoals Marine Laboratory for 22 years, where he taught Biological Illustration every summer. He is currently a visiting professor of Biology at Washington and Lee University. The textbooks illustrated by his company Medical & Scientific Illustration have won numerous design and illustration awards.

CLAIRE E. OBER, R.N. (illustrator) practiced pediatric and obstetric nursing before turning to medical illustration as a full-time career. She received her degree at Mary Baldwin College with distinction in studio art. Following a five-year apprenticeship, she has worked as Dr. Ober's partner in Medical & Scientific Illustration since 1986. She was on the Core Faculty at Shoals Marine Laboratory and co-taught the Biological Illustration course.

KATHLEEN WELCH, M.D. (clinical consultant) received her M.D. from the University of Washington in Seattle and did her residency at the University of North Carolina in Chapel Hill. For two years, she served as Director of Maternal and Child Health at the LBJ Tropical Medical Center in American Samoa and subsequently was a member of the Department of Family Practice at the Kaiser Permanente Clinic in Lahaina, Hawaii. She was in private practice from 1987 until her retirement in 2012. Dr. Welch has been the Clinical Consultant for nine textbooks and the coauthor of one textbook and several clinical supplements. Dr. Welch is a Fellow of the American Academy of Family Practice and a member of the Hawaii Medical Association, the Maui County Medical Association, and the Human Anatomy and Physiology Society.

RALPH T. HUTCHINGS (biomedical photographer) was associated with the Royal College of Surgeons for 20 years. An engineer by training, he has focused for years on photographing the structure of the human body. The result has been a series of color atlases, including the *Color Atlas of Human Anatomy,* the *Color Atlas of Surface Anatomy,* and *The Human Skeleton* (all published by Mosby-Yearbook Publishing). For his anatomical portrayal of the human body, the International Photographers Association chose Mr. Hutchings as the best photographer of humans in the twentieth century. He lives in North London, where he tries to balance the demands of his photographic assignments with his hobbies of early motorcars and airplanes.

DEDICATION

To Kitty, P.K., Ivy, and Kate:
We couldn't have done this without you.
Thank you for your encouragement, patience,
and understanding.

Preface

Welcome to the Seventh Edition of *Essentials of Anatomy & Physiology*! This textbook introduces the essential concepts needed for an understanding of the human body and helps students place information in a meaningful context, develop their problem-solving skills, and prepare for a career in a medical or allied health field. In this edition, we continue to build on this text's hallmark quality: a clear, effective visual and narrative presentation of anatomy and physiology. During the revision process, the author and illustrator team drew upon their combined content knowledge, research skills, artistic talents, and 50-plus years of classroom experience to make this the best edition yet.

The broad changes to this edition are presented in the **New to the Seventh Edition** section below. Also below are the sections **Learning Outcomes** and **Chapter-by-Chapter Changes in the Seventh Edition**.

New to the Seventh Edition

In addition to the technical changes in this edition, such as updated statistics and anatomy and physiology descriptions, we have simplified the presentations to make the narrative easier to read. We have also focused on improving the integration of illustrations with the narrative. These are the key changes in this new edition:

- **Improved readability** uses simpler, shorter, more active sentences to make reading and studying easier for students. In all chapters, the Flesch/Kincaid reading levels have been decreased.
- **New Build Your Knowledge** feature within the narrative is an immediate reminder of earlier-presented material that will increase comprehension and integration of new information.
- **New Spotlight figures** have been added so that at least one is included in each chapter. Spotlight figures combine text and art to communicate key topics in visually effective single-page or two-page presentations.
- **New Design of Homeostasis figures** replace former 6th edition figures in various chapters.
- **Improved text-art integration** throughout the illustration program enhances the readability of figures. Tabular information is now integrated into the figures so that the relevant text is located immediately next to each part of a figure. Increased color saturation was also applied to the art throughout the text.
- **More Clinical Notes** contain visuals to draw students' attention to clinical information and scenarios they might encounter in their future careers.
- **New Build Your Knowledge Body System figures** for each body system chapter present representative portions of each body system. These figures continue to "build-a-body" as each new system is presented. System integration is again reinforced by the gradual increase in complexity.
- **Terminology** has been revised in selected cases to match the most common usage in medical specialties. We used *Terminologia Anatomica* and *Terminologia Histologica* as our reference for anatomical and tissue terms. We continue to use possessive forms of diseases when the proposed alternative has not been widely accepted, e.g., Parkinson disease is now Parkinson's disease.
- **MasteringA&P®**, Pearson's online learning and assessment system, contains new assignable activities tied to features in the book. Many Spotlight figures have Coaching Activities in Mastering. Build Your Knowledge sections are tied to multipart Mastering activities, and the Body System figures correspond to Concept Map Coaching Activities that will bring home the concept of body system integration. Instructors can assign homework from proven media programs such as Practice Anatomy Lab™ (PAL™) 3.0 and Essentials of Interactive Physiology®—all organized by chapter—and have assignments automatically graded. New Dynamic Study Module questions use mobile-ready technology to help students retain information efficiently. In the MasteringA&P® Study Area, students can access a full suite of self-study tools, including Bone and Dissection videos and A&P Flix.

Learning Outcomes

The chapters of the Seventh Edition are organized around specific Learning Outcomes that indicate what students should be able to do after studying the chapter.

- **Learning Outcomes** appear in chapter-opening numbered lists, as well as directly below each relevant chapter section heading.
- **Full-sentence chapter headings** do more than introduce new topics; they state the core fact or concept that will be presented in the section. There is a one-to-one

correspondence between the Learning Outcomes and the full-sentence section headings in every chapter.

- **Checkpoints** are located at the close of each section and ask students to pause and check their understanding of facts and concepts. The Checkpoints reinforce the Learning Outcomes presented on the chapter-opening page and below chapter section headings, resulting in a systematic integration of the Learning Outcomes over the course of the chapter. Answers are located in the blue Answers tab at the back of the book. All the Checkpoints have been reviewed, and questions were added or revised to reflect our improved readability.

All assessments in MasteringA&P are organized by the Learning Outcomes, making it easy for instructors to organize their courses and demonstrate results against goals for student achievement.

Chapter-by-Chapter Changes in the Seventh Edition

This annotated Table of Contents provides select examples of revision highlights in each chapter of the Seventh Edition.

Chapter 1 An Introduction to Anatomy and Physiology

- New Spotlight Figure 1-1 Levels of Organization
- Figure 1-2 The Organ Systems of the Human Body revised
- New Figure 1-3 The Control of Room Temperature
- New Figure 1-4 Negative Feedback in Thermoregulation
- New Figure 1-8 Directional References (incorporates former Table 1-1 Directional Terms)
- New Figure 1-9 Sectional Planes (incorporates former Table 1-2 Terms That Indicate Sectional Planes)
- Figure 1-10 Relationships among the Subdivisions of the Body Cavities of the Trunk revised
- New Clinical Note: Imaging Techniques (added PET scan of the brain; replaces Spotlight Figure 1-9 Imaging Techniques)

Chapter 2 The Chemical Level of Organization

- Figure 2-4 Ionic Bonding revised (new part c)
- Spotlight Figure 2-7 Chemical Notation revised ("reactants" and "product" labels added)
- Figure 2-11 The Structures of Glucose revised (new part c replaced former part c)
- Figure 2-17 Amino Acids and the Formation of Peptide Bonds revised
- New Figure 2-18 Protein Structure
- Figure 2-20 The Structure of Nucleic Acids revised

Chapter 3 Cell Structure and Function

- Figure 3-1 The Diversity of Cells in the Human Body revised
- Spotlight Figure 3-2 Anatomy of a Model Cell revised (distinguishes primary and motile cilia)
- Figure 3-4 Diffusion revised (Step art [1–4] added)
- New Figure 3-7 Osmotic Flow across a Plasma Membrane
- New Figure 3-11 Phagocytosis
- Figure 3-13 The Endoplasmic Reticulum revised
- New Figure 3-14 The Golgi Apparatus
- Spotlight Figure 3-15 Protein Synthesis, Processing, and Packaging revised
- Figure 3-16 Mitochondria revised (added ribosome label)
- New Figure 3-20 Translation
- Figure 3-23 Interphase, Mitosis, and Cytokinesis revised

Chapter 4 The Tissue Level of Organization

- New Figure 4-1 An Orientation to the Tissues of the Body
- Figure 4-2 Cell Junctions revised
- Figure 4-4 Simple Epithelia revised
- Figure 4-5 Stratified Epithelia revised
- Figure 4-6 Modes of Glandular Secretion revised
- New Figure 4-7 Major Types of Connective Tissue
- Figure 4-8 Cells and Fibers of Connective Tissue Proper revised (added Fibrocyte)
- Figure 4-9 Loose Connective Tissues revised
- Figure 4-10 Dense Connective Tissues revised
- Figure 4-11 Types of Cartilage revised
- Figure 4-13 Tissue Membranes revised (text in part b)
- Figure 4-14 Muscle Tissue revised
- Figure 4-15 Neural Tissue revised

Chapter 5 The Integumentary System

- New Terminology: added keratinocytes
- Figure 5-1 The General Structure of the Integumentary System revised (now includes papillary plexus)
- New Spotlight Figure 5-2 The Epidermis
- Figure 5-5 Hair Follicles and Hairs revised
- Figure 5-8 The Structure of a Nail revised (added cross-sectional view)
- New Figure 5-10 A Keloid
- New Clinical Note: Dermatitis
- Clinical Note: Hair Loss revised (new discussion of hair loss due to chemotherapy and radiation)
- New Clinical Note: Burns
- New Build Your Knowledge: How the INTEGUMENTARY SYSTEM integrates with the other body systems presented so far

Chapter 6 The Skeletal System

- Figure 6-2 The Structure of a Long Bone revised (added periosteum art)
- Figure 6-3 The Microscopic Structure of a Typical Bone revised (added Types of Bone Cells art)
- Figure 6-6 Appositional Bone Growth revised
- New Figure 6-7 An Introduction to Bone Markings
- Figure 6-10 The Adult Skull, Part I revised (added color-coded labels)
- Figure 6-11 The Adult Skull, Part II revised
- Figure 6-12 Sectional Anatomy of the Skull revised
- Figure 6-15 The Skull of an Infant revised
- Figure 6-16 The Vertebral Column revised (added text to labels)
- Figure 6-19 The Sacrum and Coccyx revised (added a lateral view)
- Figure 6-20 The Thoracic Cage revised
- Figure 6-25 The Bones of the Wrist and Hand revised
- Figure 6-26 The Hip Bones and the Pelvis revised (added a lateral view)
- Figure 6-30 The Bones of the Ankle and Foot revised (added arches and a lateral view)
- Figure 6-31 The Structure of a Synovial Joint revised
- Spotlight Figure 6-35 Synovial Joints revised (added descriptions of types of synovial joints)
- Figure 6-40 The Knee Joint revised (boxed ligament labels)
- New Clinical Note: Types of Fractures and Steps in Repair
- New Clinical Note: Osteoporosis
- New Build Your Knowledge: How the SKELETAL SYSTEM integrates with the other body systems presented so far

Chapter 7 The Muscular System

- Figure 7-2 The Organization of a Skeletal Muscle Fiber revised (added titin label)
- Spotlight Figure 7-4 Events at the Neuromuscular Junction revised
- New Figure 7-6 Steps Involved in Skeletal Muscle Contraction and Relaxation
- Figure 7-10 Muscle Metabolism revised
- New Figure 7-12 An Overview of the Major Skeletal Muscles
- Figure 7-14 Muscles of the Anterior Neck revised (added omohyoid muscle and boxed labels)
- Table 7-3 Muscles of the Head and Neck revised
- Figure 7-15 Muscles of the Spine revised
- Figure 7-16 Oblique and Rectus Muscles and the Diaphragm revised (parts b and c captions)
- Figure 7-19 Muscles That Move the Arm revised (added identification of rotator cuff muscles)
- New Figure 7-20 Muscles That Move the Forearm and Wrist
- Figure 7-22 Muscles That Move the Leg revised (added identification of hamstring muscles)
- Figure 7-23 Muscles That Move the Foot and Toes revised (added new anterior view and fibularis tertius muscle)
- Table 7-12 Muscles That Move the Foot and Toes revised (added fibularis tertius, brevis, and longus muscles)
- Clinical Note: Interference at the NMJ and Muscular Paralysis revised
- Clinical Note: Rigor Mortis revised
- Clinical Note: Tetanus revised
- Clinical Note: Intramuscular Injections revised
- New Build Your Knowledge: How the MUSCULAR SYSTEM integrates with the other body systems presented so far

Chapter 8 The Nervous System

- Figure 8-1 A Functional Overview of the Nervous System revised (new art is added and definitions are added for the CNS, PNS, Receptors, and Effectors)
- Figure 8-2 The Anatomy of a Representative Neuron revised (new three-dimensional neuron art)
- Figure 8-4 Neuroglia in the CNS revised (added descriptions of neuroglia to correlate the art with text)
- New Figure 8-7 The Resting Membrane Potential
- Spotlight Figure 8-8 The Generation of an Action Potential revised
- New Spotlight Figure 8-9 Propagation of an Action Potential
- Figure 8-11 The Events at a Cholinergic Synapse revised
- Figure 8-13 The Meninges of the Brain and Spinal Cord revised (art moved for label sharing and correlation between similar structures)
- New Figure 8-14 Gross Anatomy of the Spinal Cord
- Figure 8-16 The Brain revised (labels boxed to better correlate art and text)
- Figure 8-18 The Formation and Circulation of Cerebrospinal Fluid revised (added new art for part a and steps to improve correlation between art and text)
- Figure 8-19 Motor and Sensory Regions of the Cerebral Hemispheres revised (labels boxed to better correlate art and text)
- Figure 8-22 The Basal Nuclei revised (labels boxed to better correlate art and text)
- Figure 8-24 The Diencephalon and Brain Stem revised (labels boxed to better correlate art and text)
- Figure 8-25 The Cranial Nerves revised (incorporated table of cranial nerves to better correlate art and text)
- New Figure 8-26 Peripheral Nerves and Nerve Plexuses
- Figure 8-27 Dermatomes revised (added color-coded art and key to better correlate art and text)

- Figure 8-30 The Flexor Reflex, a Type of Withdrawal Reflex revised (step art added to better correlate art and text)
- Figure 8-31 The Posterior Column Pathway revised (step art added to better correlate art and text)
- Figure 8-32 The Corticospinal Pathway revised (step art added to better correlate art and text)
- Figure 8-34 The Sympathetic Division revised (shading added to spinal cord to better correlate art and text)
- Figure 8-35 The Parasympathetic Division revised (shading added to brain stem and spinal cord to better correlate art and text)
- Clinical Note: Epidural and Subdural Hemorrhages revised (added photograph)
- Clinical Note: Aphasia and Dyslexia revised
- Clinical Note: Alzheimer's Disease revised
- New Build Your Knowledge: How the NERVOUS SYSTEM integrates with the other body systems presented so far

Chapter 9 The General and Special Senses

- Figure 9-1 Receptors and Receptive Fields revised
- Figure 9-2 Referred Pain revised
- Figure 9-3 Tactile Receptors in the Skin revised (boxed text added to better correlate art and text)
- Figure 9-4 Baroreceptors and the Regulation of Autonomic Functions revised
- Figure 9-5 Locations and Functions of Chemoreceptors revised
- Figure 9-6 The Olfactory Organs revised (changed olfactory cilia label to olfactory dendrites)
- Figure 9-7 Gustatory Receptors revised (changed supporting cell label to transitional cell)
- Figure 9-10 The Sectional Anatomy of the Eye revised
- Figure 9-13 The Circulation of Aqueous Humor revised (enhanced color of arrow showing circulation route)
- Figure 9-14 Focal Point, Focal Distance, and Visual Accommodation revised
- Spotlight Figure 9-16 Refractive Problems revised (title corrected from Accommodation Problems)
- Figure 9-19 Bleaching and Regeneration of Visual Pigments revised (added step art and text to improve topic comprehension)
- Figure 9-22 The Middle Ear revised
- New Figure 9-23 The Internal Ear
- New Figure 9-24 The Semicircular Ducts
- New Figure 9-25 The Utricle and Saccule
- Figure 9-27 Sound and Hearing revised (added diagram to better correlate step art and text)
- Clinical Note: Cataracts revised (added photograph)

Chapter 10 The Endocrine System

- Figure 10-1 Organs and Tissues of the Endocrine System revised (new art)
- Figure 10-2 The Role of Target Cell Receptors in Hormone Action revised (added step art and text)
- Figure 10-3 Processes of Hormone Action revised (added step art and text to improve topic comprehension)
- Figure 10-5 The Location and Anatomy of the Pituitary Gland revised (new photomicrograph)
- Figure 10-6 The Hypophyseal Portal System and the Blood Supply to the Pituitary Gland revised (added boxed text to improve topic comprehension)
- Figure 10-9 The Thyroid Gland revised (added new diagram to clarify histological details in photomicrograph)
- New Figure 10-10 The Homeostatic Regulation of Calcium Ion Concentrations
- New Figure 10-12 The Adrenal Gland and Adrenal Hormones (added new photomicrograph and incorporated former Table 10-3 The Adrenal Hormones)
- New Figure 10-14 The Regulation of Blood Glucose Concentrations
- New Clinical Note: Diabetes Mellitus
- New Clinical Note: Endocrine Disorders
- New Build Your Knowledge: How the ENDOCRINE SYSTEM integrates with the other body systems presented so far

Chapter 11 The Cardiovascular System: Blood

- Spotlight Figure 11-1 The Composition of Whole Blood revised
- Figure 11-4 The Origins and Differentiation of RBCs, Platelets, and WBCs revised (replaced specific names of developing WBCs with "Developmental stages")
- New Figure 11-5 The Role of EPO in the Stimulation of Erythropoiesis
- Figure 11-7 Blood Type Testing revised (part of text, no longer within a Clinical Note)
- New Figure 11-9 The Vascular, Platelet, and Coagulation Phases of Hemostasis
- New Figure 11-10 The Structure of a Blood Clot
- Clinical Note: Hemolytic Disease of the Newborn revised (added new art)
- Clinical Note: Abnormal Hemostasis revised (added new thrombus art)

Chapter 12 The Cardiovascular System: The Heart

- New Figure 12-1 An Overview of the Cardiovascular System
- Figure 12-3 The Position and Surface Anatomy of the Heart revised (added new part b of cadaver dissection)

- Figure 12-4 The Heart Wall and Cardiac Muscle Tissue revised (improved correlation between parts a and c)
- New Spotlight Figure 12-5 The Heart: Internal Anatomy and Blood Flow
- Figure 12-8 Action Potentials and Muscle Cell Contraction in Skeletal and Cardiac Muscle revised
- Figure 12-9 The Conducting System of the Heart revised (new three-dimensional art in part b)
- Figure 12-10 An Electrocardiogram revised (new three-dimensional art in part b)
- Figure 12-11 The Cardiac Cycle revised (art enlarged)
- New Figure 12-12 Heart Sounds
- Figure 12-13 Autonomic Innervation of the Heart revised
- Clinical Note: Heart Valve Disorders revised (added photograph of bioprosthetic valve)

Chapter 13 The Cardiovascular System: Blood Vessels and Circulation

- Figure 13-1 A Comparison of a Typical Artery and a Typical Vein revised (clarified thickness of artery wall)
- New Figure 13-2 The Structure of the Various Types of Blood Vessels
- Figure 13-5 Pressures within the Systemic Circuit revised (clarified pulse pressure within the diagram)
- Figure 13-6 Forces Acting across Capillary Walls revised (added tissue cells to highlight capillary surroundings)
- New Figure 13-7 Short-Term and Long-Term Cardiovascular Responses
- New Figure 13-8 The Baroreceptor Reflexes of the Carotid and Aortic Sinuses
- New Figure 13-9 The Chemoreceptor Reflexes
- New Figure 13-10 The Hormonal Regulation of Blood Pressure and Blood Volume
- New Spotlight Figure 13-13 Major Vessels of the Systemic Circuit
- New Figure 13-14 Arteries of the Chest and Upper Limb (incorporates former art and flowchart)
- Figure 13-16 Major Arteries of the Trunk revised (added boxed labels to better correlate art and text)
- Figure 13-19 A Flowchart of the Tributaries of the Superior and Inferior Venae Cavae revised
- Figure 13-20 The Hepatic Portal System revised (added boxed labels to better correlate art and text)
- Clinical Note: Arteriosclerosis revised (added photomicrograph of a normal coronary artery for comparison)
- New Build Your Knowledge: How the CARDIOVASCULAR SYSTEM integrates with the other body systems presented so far

Chapter 14 The Lymphatic System and Immunity

- Figure 14-1 The Components of the Lymphatic System revised (added art depicting lymph and lymphocyte and red bone marrow)
- New Spotlight Figure 14-4 Origin and Distribution of Lymphocytes
- Figure 14-5 The Tonsils revised (added photomicrograph of pharyngeal tonsil)
- Figure 14-9 The Body's Innate Defenses revised
- Figure 14-11 Forms of Immunity revised
- Figure 14-13 Antigen Recognition and Activation of Cytotoxic T Cells revised (added costimulation to step 2 to correlate with text description)
- Figure 14-14 The B Cell Response to Antigen Exposure revised (added costimulation to step 2 art)
- Table 14-2 Cells That Participate in Tissue Defenses revised
- Figure 14-17 A Summary of the Immune Response and Its Relationship to Innate (Nonspecific) Defenses revised
- Clinical Note: "Swollen Glands" revised (added photograph)
- New Build Your Knowledge: How the LYMPHATIC SYSTEM integrates with the other body systems presented so far

Chapter 15 The Respiratory System

- New Figure 15-1 The Structures of the Respiratory System
- Figure 15-2 The Respiratory Mucosa revised (mucous gland added to part a to better correlate art and text)
- Figure 15-4 The Anatomy of the Larynx and Vocal Cords revised (corrected shared labeling between art in part d and photograph in part e)
- Figure 15-6 The Bronchi and Lobules of the Lung revised (improved clarity of pulmonary lobule anatomy in part b)
- Figure 15-7 Alveolar Organization revised (replaced part a art and part b SEM of lung tissue with photomicrograph)
- New Figure 15-8 The Gross Anatomy of the Lungs
- New Spotlight Figure 15-10 Pulmonary Ventilation
- Figure 15-12 An Overview of Respiratory Processes and Partial Pressures in Respiration revised
- Figure 15-14 A Summary of Gas Transport and Exchange revised (added partial pressures of oxygen and carbon dioxide to improve interpretation of the diagram)
- New Spotlight Figure 15-16 The Control of Respiration
- Clinical Note: Tracheal Blockage revised (added photograph of Heimlich maneuver)
- Clinical Note: Emphysema and Lung Cancer revised (added photographs of healthy lung and smoker's lung)
- New Build Your Knowledge: How the RESPIRATORY SYSTEM integrates with the other body systems presented so far

Chapter 16 The Digestive System

- Figure 16-1 The Components of the Digestive System revised (Teeth and Tongue moved to Accessory Organs of the Digestive System box)
- Figure 16-5 The Salivary Glands revised
- Figure 16-7 The Swallowing Process revised
- New Spotlight Figure 16-9 Regulation of Gastric Activity
- Figure 16-10 The Segments of the Small Intestine revised (new gross anatomy of the jejunum photograph)
- New Figure 16-12 The Activities of Major Digestive Tract Hormones
- Figure 16-13 The Pancreas revised (added a new part b diagram to improve interpretation of part c photomicrograph)
- Figure 16-15 Liver Histology revised
- Figure 16-17 The Large Intestine revised (added new part b cadaver photo of cecum and appendix)
- Clinical Note: Liver Disease revised (added cirrhosis of the liver art)
- New Build Your Knowledge: How the DIGESTIVE SYSTEM integrates with the other body systems presented so far

Chapter 17 Metabolism and Energetics

- Figure 17-3 Glycolysis revised (clarified text in Step 5)
- New Spotlight Figure 17-5 The Electron Transport System and ATP Formation
- Figure 17-6 A Summary of the Energy Yield of Aerobic Metabolism revised (clarified ATP gain per glucose molecule based on recently accepted lower conversion ratios of ATP per NADH and $FADH_2$)
- Figure 17-9 Lipoproteins and Lipid Transport revised
- Figure 17-10 A Summary of Catabolic and Anabolic Pathways for Lipids, Carbohydrates, and Proteins revised

Chapter 18 The Urinary System

- Figure 18-3 The Structure of the Kidney revised (changed renal lobe to kidney lobe in part a, added papillary duct label to part c)
- Figure 18-5 A Representative Nephron and the Collecting System revised (added boxed text into the art)
- Figure 18-6 The Renal Corpuscle revised (boxed labels added to better correlate art and text)
- Figure 18-8 The Effects of ADH on the DCT and Collecting Duct revised (added compulsory water reabsorption and variable water reabsorption)
- Spotlight Figure 18-9 A Summary of Kidney Function revised (added art showing urea transporter)
- New Figure 18-10 The Renin-Angiotensin-Aldosterone System and Regulation of GFR
- Figure 18-11 Organs for the Conduction and Storage of Urine revised (clarified center of trigone in part c)
- Table 18-4 Water Balance revised (added percentages)
- New Build Your Knowledge: How the URINARY SYSTEM integrates with the other body systems presented so far

Chapter 19 The Reproductive System

- Figure 19-1 The Male Reproductive System revised (boxed labels added to better correlate art and text)
- Figure 19-2 The Scrotum, Testes, and Seminiferous Tubules revised (boxed label added to better correlate art and text)
- Figure 19-5 The Ductus Deferens revised (added ampulla of ductus deferens label)
- Figure 19-6 The Penis revised (new terminology: changed glans to glans penis)
- Figure 19-8 The Female Reproductive System revised (boxed labels added to better correlate art and text)
- Figure 19-9 Oogenesis revised
- Figure 19-10 Follicle Development and the Ovarian Cycle revised (added new photomicrograph of secondary follicle and corrected image magnifications)
- Figure 19-11 The Uterus revised
- Figure 19-12 The Female External Genitalia revised (caption now clarifies that left labium minus has been removed to show erectile tissue)
- Spotlight Figure 19-14 Regulation of Female Reproduction revised (clarifies that tertiary follicles are involved in step 2 Follicular Phase of the Ovarian Cycle)
- Table 19-1 Hormones of the Reproductive System revised (new terminology: changed progestins to progesterone.)
- Clinical Note: Birth Control Strategies revised (new photograph of contraceptive devices)
- New Build Your Knowledge: How the REPRODUCTIVE SYSTEM integrates with the other body systems presented so far

Chapter 20 Development and Inheritance

- Figure 20-1 Fertilization revised (step 5 title)
- New Spotlight Figure 20-5 Extraembryonic Membranes and Placenta Formation
- Figure 20-7 Development during the First Trimester revised
- Figure 20-8 The Second and Third Trimesters revised (added new ultrasound photograph in part b)
- Table 20-2 An Overview of Prenatal and Early Postnatal Development revised (includes revised sizes and weights at different gestational ages)

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martini@pearson.com

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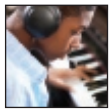

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1

An Introduction to Anatomy and Physiology

Learning Outcomes

These Learning Outcomes tell you what you should be able to do after completing the chapter. They correspond by number to this chapter's sections.

- **1-1** Describe the basic functions of living organisms.
- **1-2** Explain the relationship between anatomy and physiology, and describe various specialties of each discipline.
- **1-3** Identify the major levels of organization in organisms, from the simplest to the most complex.
- **1-4** Identify the 11 organ systems of the human body and contrast their major functions.
- **1-5** Explain the concept of homeostasis.
- **1-6** Describe how negative feedback and positive feedback are involved in homeostatic regulation.
- **1-7** Use anatomical terms to describe body regions, body sections, and relative positions.
- **1-8** Identify the major body cavities of the trunk and the subdivisions of each.

Clinical Notes
Homeostasis and Disease, p. 6
Imaging Techniques, pp. 20–21

Spotlight
Levels of Organization, p. 5

1

An Introduction to Studying the Human Body

In this textbook we will introduce you to the essential, inner workings of your body—giving information about its structure (anatomy) and function (physiology). As a human, you are most likely very curious, and few subjects arouse so much curiosity as our own bodies. You will discover how your body works under normal and abnormal conditions and how it maintains an internal state of balance. As we proceed, you will see how your body deals with injury, disease, or anything that threatens that crucial balance in a changing environment.

Build Your Knowledge

Throughout each chapter, you will find Build Your Knowledge boxes that will coach you through anatomy and physiology concepts. This feature will help you connect new material with what you already know. At the end of each chapter that closes a body system, you will see a "capstone" Build Your Knowledge page that will illustrate the integration of the body system with the other body systems presented up to that point in the book. Be sure to read every Build Your Knowledge box or page so that you can build your knowledge—and confidence!

1-1 All living things display responsiveness, growth, reproduction, movement, and metabolism

Learning Outcome Describe the basic functions of living organisms.

We live in a world containing an amazing diversity of living organisms that vary widely in appearance and lifestyle. One aim of **biology**—the study of life—is to discover the common patterns that underlie this diversity. Such discoveries show that all living things share these common functions:

- ***Responsiveness.*** Organisms respond to changes in their immediate environment. This property is also called *irritability*. You move your hand away from a hot stove, your dog barks at approaching strangers, fish are alarmed by loud noises, and tiny amoebas glide toward potential prey. Organisms also make longer-term changes as they adjust to their environments. For example, an animal may grow a heavier coat of fur as winter approaches, or it may migrate to a warmer climate. The capacity to make such adjustments is termed *adaptability*.
- ***Growth.*** Organisms increase in size through the growth or addition of **cells,** the simplest units of life. Single-celled creatures grow by getting larger. More complex organisms grow primarily by increasing the number of cells. Familiar organisms, such as dogs, cats, and humans, are made up of trillions of cells. As such multicellular organisms develop, individual cells become specialized to perform particular functions. This specialization is called *differentiation*.
- ***Reproduction.*** Organisms reproduce, creating new generations of similar, but not identical, organisms.
- ***Movement.*** Organisms can move. Their movement may be internal (transporting food, blood, or other materials within the body) or external (moving through the environment).
- ***Metabolism.*** Organisms rely on complex chemical reactions to provide the energy required for responsiveness, growth, reproduction, and movement. They also build complex chemicals, such as proteins. *Metabolism* refers to all the chemical operations in the body.

For normal metabolic operations, organisms must absorb materials from the environment. To generate energy efficiently, most cells require various nutrients they obtain in food, as well as oxygen, a gas. *Respiration* refers to the absorption, transport, and use of oxygen by cells. Metabolic operations often generate unneeded or potentially harmful waste products that must be eliminated through the process of *excretion*.

For very small organisms, absorption, respiration, and excretion involve the movement of materials across exposed surfaces. But creatures larger than a few millimeters across seldom absorb nutrients directly from their environment. For example, humans cannot absorb steaks, apples, or ice cream without processing them first. That processing, called

digestion, takes place in specialized structures in which complex foods are broken down into simpler components that can be transported and absorbed easily.

Respiration and excretion are also more complicated for large organisms. Humans have specialized structures for gas exchange (lungs) and excretion (kidneys). Digestion, respiration, and excretion occur in different parts of the body, but the cells of the body cannot travel to one place for nutrients, another for oxygen, and a third to get rid of waste products. Instead, individual cells remain where they are but communicate with other areas of the body through an internal transport system—the circulation. For example, the blood absorbs the waste products released by each of your cells and carries those wastes to the kidneys for excretion.

Biology includes many subspecialties. In this text we consider two biological subjects: anatomy (ah-NAT-o-mē) and physiology (fiz-ē-OL-o-jē). Over the course of this book, you will become familiar with the basic anatomy and physiology of the human body.

CHECKPOINT

1. How do vital functions such as responsiveness, growth, reproduction, and movement depend on metabolism?

See the blue Answers tab at the back of the book.

1-2 Anatomy is structure, and physiology is function

Learning Outcome Explain the relationship between anatomy and physiology, and describe various specialties of each discipline.

The word *anatomy* has Greek origins, as do many other anatomical terms and phrases. **Anatomy,** which means "a cutting open," is the study of internal and external structure and the physical relationships between body parts. **Physiology,** also derived from Greek, is the study of how living organisms carry out their vital functions. The two subjects are interrelated. Anatomical information provides clues about probable functions. Physiological processes can be explained only in terms of their underlying anatomy.

The link between structure and function is always present but not always understood. For example, the anatomy of the heart was clearly described in the fifteenth century, but almost 200 years passed before anyone realized that it pumped blood. This text will familiarize you with basic anatomy and give you an appreciation of the physiological processes that make human life possible. The information will help you to understand many diseases to make informed decisions about your own health.

Anatomy

We can divide anatomy into gross (macroscopic) anatomy or microscopic anatomy. We do so on the basis of the degree of structural detail under consideration. Other anatomical specialties focus on specific processes, such as respiration, or on medical applications, such as developing artificial limbs.

Gross Anatomy

Gross anatomy, or *macroscopic anatomy*, considers features visible with the unaided eye. We can approach gross anatomy in many ways. **Surface anatomy** is the study of general form and superficial markings. **Regional anatomy** considers all the superficial and internal features in a specific region of the body, such as the head, neck, or trunk. **Systemic anatomy** considers the structure of major *organ systems*, which are groups of organs that work together in a coordinated manner. For example, the heart, blood, and blood vessels form the *cardiovascular system*, which circulates oxygen and nutrients throughout the body.

Microscopic Anatomy

Microscopic anatomy concerns structures that we cannot see without magnification. The boundaries of microscopic anatomy are set by the limits of the equipment used. A light microscope reveals basic details about cell structure, but an electron microscope can visualize individual molecules only a few nanometers (nm, 1 millionth of a millimeter) across. In this text, we will consider details at all levels, from macroscopic to microscopic.

We can subdivide microscopic anatomy into specialties that consider features within a characteristic range of sizes. **Cytology** (sī-TOL-o-jē) analyzes the internal structure of individual *cells*. The trillions of living cells in our bodies are made up of chemical substances in various combinations. Our lives depend on the chemical processes taking place in those cells. For this reason we consider basic chemistry (Chapter 2: The Chemical Level of Organization) before looking at cell structure (Chapter 3: Cell Structure and Function).

Histology (his-TOL-o-jē) takes a broader perspective. It examines **tissues,** groups of specialized cells and cell products that work together to carry out specific functions (Chapter 4). Tissues combine to form **organs,** such as the heart, kidney, liver, and brain. We can examine many organs without a microscope, so at the organ level we cross the boundary into gross anatomy.

1

Physiology

Physiology is the study of function in living organisms. **Human physiology** is the study of the functions of the human body. These functions are complex and much more difficult to examine than most anatomical structures. As a result, the science of physiology includes even more specialties than does the science of anatomy.

The cornerstone of human physiology is **cell physiology,** the study of the functions of living cells. Cell physiology includes events at the chemical or molecular levels—chemical processes both within cells and between cells. **Special physiology** is the study of the physiology of specific organs. Examples include renal physiology (kidney function) and cardiac physiology (heart function). **Systemic physiology** considers all aspects of the function of specific organ systems. Respiratory physiology and reproductive physiology are examples. **Pathological physiology,** or **pathology** (pah-THOL-o-jē), is the study of the effects of diseases on organ or system functions. (The Greek word *pathos* means "disease.") Modern medicine depends on an understanding of both normal and pathological physiology, to know not only what has gone wrong but also how to correct it.

Special topics in physiology address specific functions of the human body as a whole. These specialties focus on functional relationships among multiple organ systems. Exercise physiology, for example, studies the physiological adjustments to exercise.

CHECKPOINT

2. Describe how anatomy and physiology are closely related.
3. Would a histologist more likely be considered a specialist in microscopic anatomy or in gross anatomy? Why?

See the blue Answers tab at the back of the book.

1-3 Levels of organization progress from atoms and molecules to a complete organism

Learning Outcome Identify the major levels of organization in organisms, from the simplest to the most complex.

To understand the human body, we must examine how it is organized at several different levels, from the submicroscopic to the macroscopic. Spotlight Figure 1-1 presents the relationships among the various levels of organization, using the cardiovascular system as an example.

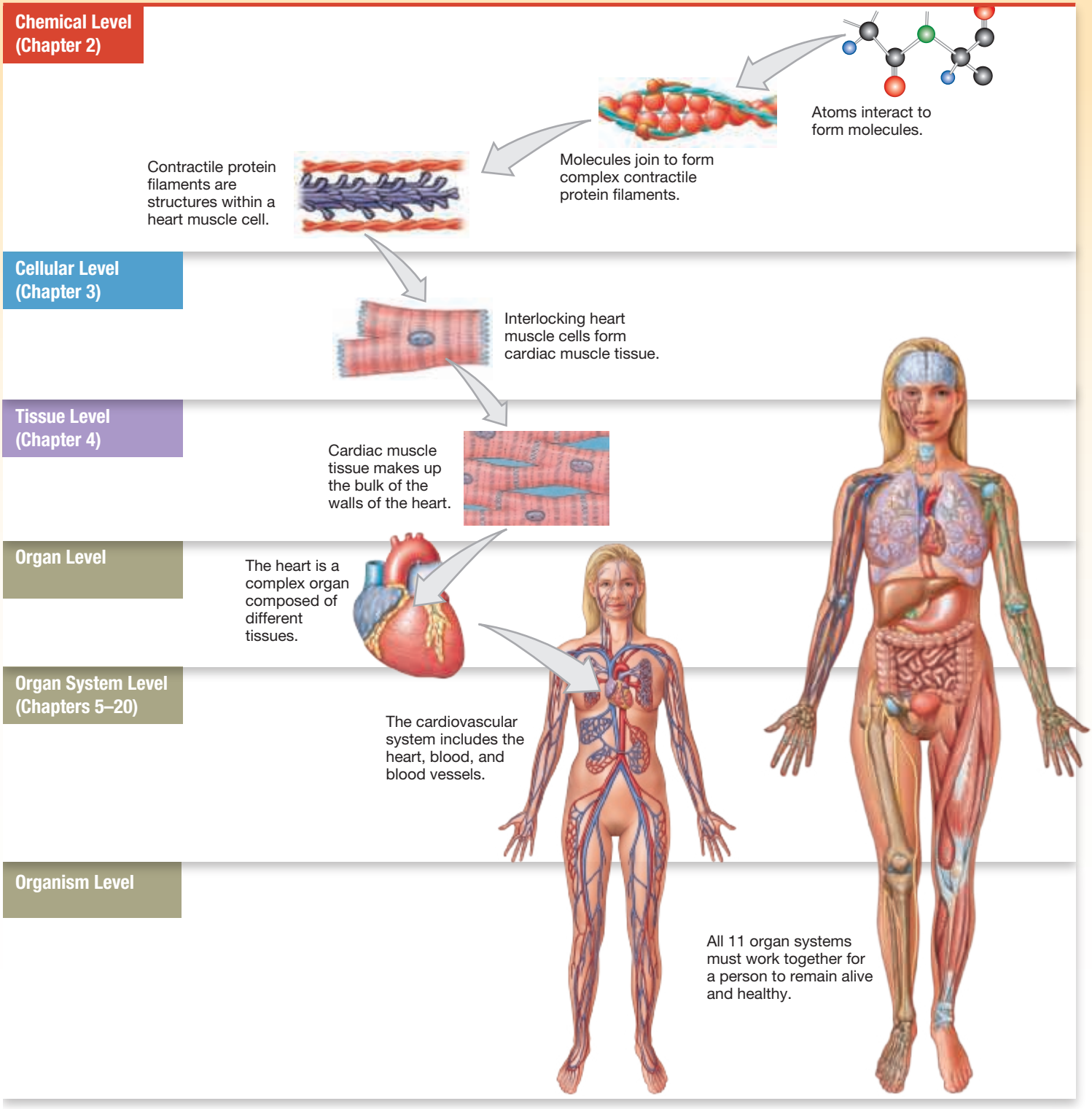
- ***Chemical level.*** *Atoms*, the smallest stable units of matter, combine to form *molecules* with complex shapes. Even at this simplest level, a molecule's specialized shape determines its function. This is the chemical level of organization.
- ***Cellular level.*** Different molecules can interact to form larger structures. Each type of structure has a specific function in a cell. For example, different types of protein filaments interact to produce the contractions of muscle cells in the heart. *Cells*, the smallest living units in the body, make up the cellular level of organization.
- ***Tissue level.*** A *tissue* is composed of similar cells working together to perform a specific function. Heart muscle cells form *cardiac muscle tissue*, an example of the tissue level of organization.
- ***Organ level.*** An *organ* consists of two or more different tissues working together to perform specific functions. An example of the organ level of organization is the *heart*, a hollow, three-dimensional organ with walls composed of layers of cardiac muscle and other tissues.
- ***Organ system level.*** Organs interact in *organ systems*. Each time it contracts, the heart pushes blood into a network of blood vessels. Together, the heart, blood, and blood vessels form the *cardiovascular system*, an example of the organ system level of organization.
- ***Organism level.*** All the organ systems of the body work together to maintain life and health. The highest level of organization is the *organism*—in this case, a human.

The organization at each level determines both the structural characteristics and the functions of higher levels. As Spotlight Figure 1-1 shows, the arrangement of atoms and molecules at the chemical level creates the protein filaments that, at the cellular level, give cardiac muscle cells the ability to contract. At the tissue level, these cells are linked, forming cardiac muscle tissue. The structure of the tissue ensures that the contractions are coordinated, producing a heartbeat. When that beat occurs, the internal anatomy of the heart, an organ, enables it to function as a pump. The heart is filled with blood and connected to the blood vessels, and the pumping action circulates blood through the vessels of the cardiovascular system. Through interactions with the respiratory, digestive, urinary, and other systems, the cardiovascular system performs a variety of functions essential to the survival of the organism.

Something that affects a system will ultimately affect each of the system's components. For example, the heart cannot pump blood effectively after massive blood loss. If the heart

SPOTLIGHT Figure 1-1
LEVELS OF ORGANIZATION

Our understanding of how the human body works is based on investigations of its different levels of organization. Interacting atoms form molecules that combine to form the protein filaments of a heart muscle cell. Such cells interlock, creating heart muscle tissue, which makes up most of the walls of the heart, a three-dimensional organ. The heart is only one component of the cardiovascular system, which also includes the blood and blood vessels. The various organ systems must work together to maintain life at the organism level.



cannot pump and blood cannot flow, oxygen and nutrients cannot be distributed. Very soon, the cardiac muscle tissue begins to break down as its individual muscle cells die from oxygen and nutrient starvation. These changes will also take place beyond the cardiovascular system: cells, tissues, and organs throughout the body will be damaged.

CHECKPOINT

4. Identify the major levels of organization of the human body from the simplest to the most complex.

See the blue Answers tab at the back of the book.

1-4 The human body consists of 11 organ systems

Learning Outcome Identify the 11 organ systems of the human body and contrast their major functions.

Figure 1-2 introduces the 11 organ systems in the human body and their major functions and components. The body's organ systems are (1) the integumentary system, (2) the skeletal system, (3) the muscular system, (4) the nervous system, (5) the endocrine system, (6) the cardiovascular system, (7) the lymphatic system, (8) the respiratory system, (9) the digestive system, (10) the urinary system, and (11) the reproductive system.

CHECKPOINT

5. Identify the organ systems of the body and list their major functions.
6. Which organ system includes the pituitary gland and directs long-term changes in the activities of the body's other systems?

See the blue Answers tab at the back of the book.

1-5 Homeostasis is the state of internal balance

Learning Outcome Explain the concept of homeostasis.

Organ systems are interdependent, interconnected, and take up a relatively small space. The cells, tissues, organs, and organ systems of the body function together in a shared environment. Just as the people in a large city breathe the same air and drink water from the local water company, the cells in the human body absorb oxygen and nutrients from the body fluids that surround them. All living cells are in contact with blood or some other body fluid. Any change in the composition of these fluids will affect the cells in some way. For example, changes in the temperature or salt content of the blood could cause anything from a minor adjustment (heart muscle tissue contracts more often, and the heart rate goes up) to a total disaster (the heart stops beating altogether).

Various physiological responses act to prevent potentially dangerous changes in the environment inside the body. **Homeostasis** (hō-mē-ō-STĀ-sis; *homeo*, unchanging + *stasis*, standing) refers to a stable internal environment. To survive, every living organism must maintain homeostasis. The term **homeostatic regulation** refers to the adjustments in physiological systems that preserve homeostasis.

Homeostatic regulation usually involves

1. a **receptor** that is sensitive to a particular environmental change or *stimulus*;
2. a **control center,** or *integration center*, which receives and processes information from the receptor; and
3. an **effector,** a cell or organ that responds to the commands of the control center and whose activity opposes or enhances the stimulus.

You are probably already familiar with several examples of homeostatic regulation, although not in those terms. As an example, think about the operation of the thermostat in a house or apartment (Figure 1-3).

CLINICAL NOTE

Homeostasis and Disease

The human body is amazingly effective in maintaining homeostasis. Nevertheless, an infection, an injury, or a genetic abnormality can sometimes have effects so severe that homeostatic responses can't fully compensate for them. One or more characteristics of the internal environment may then be pushed outside normal limits. When this happens, organ systems begin to malfunction, producing a state we know as illness or **disease.**

An understanding of normal homeostatic responses usually aids in thinking about what might be responsible for the signs and symptoms that are characteristic of many diseases. **Symptoms** are subjective—things that a person experiences and describes but that aren't otherwise detectable or measurable. Pain, nausea, and anxiety are examples. A **sign,** by contrast, is an objectively observable or measurable physical indication of a disease. Examples are a rash, a swelling, a fever, or sounds of abnormal breathing. Technology can reveal many additional signs that would not be evident to a physician's unaided senses: an unusual shape on an x-ray or MRI scan or an elevated concentration of a particular chemical in a blood test. We describe many aspects of human health, disease, and treatment in this textbook.

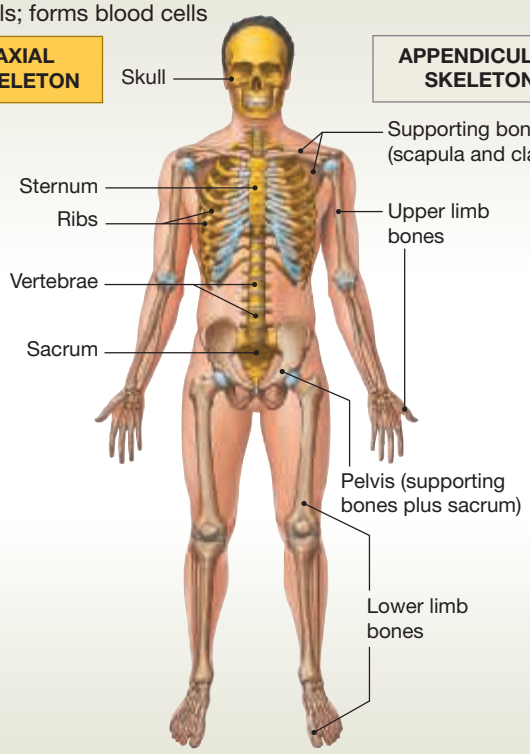
Figure 1-2 **The Organ Systems of the Human Body.**

The Integumentary System

Protects against environmental hazards; helps control body temperature; provides sensory information

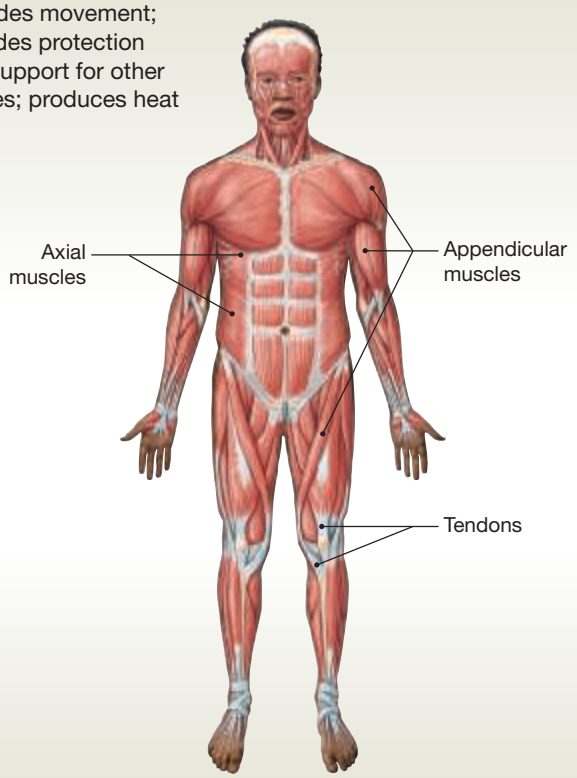
The Skeletal System

Provides support; protects tissues; stores minerals; forms blood cells



The Muscular System

Provides movement; provides protection and support for other tissues; produces heat



The Nervous System

Directs immediate responses to stimuli, usually by coordinating the activities of other organ systems; provides and interprets sensory information about internal and external conditions

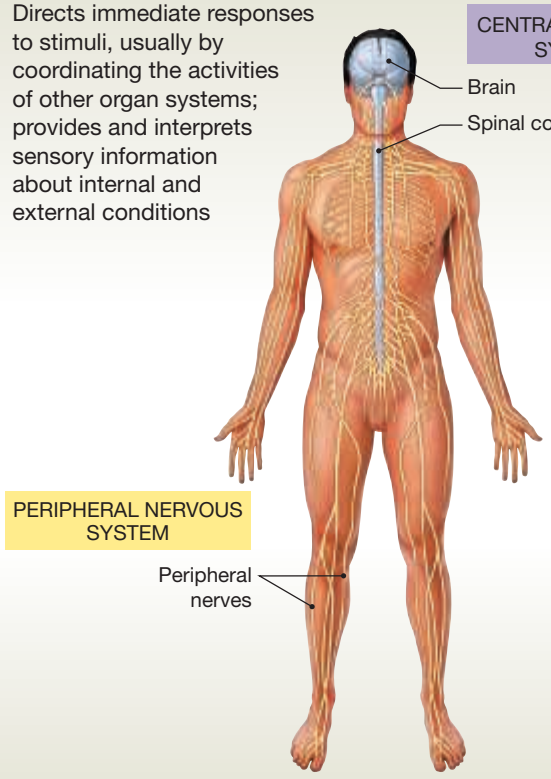
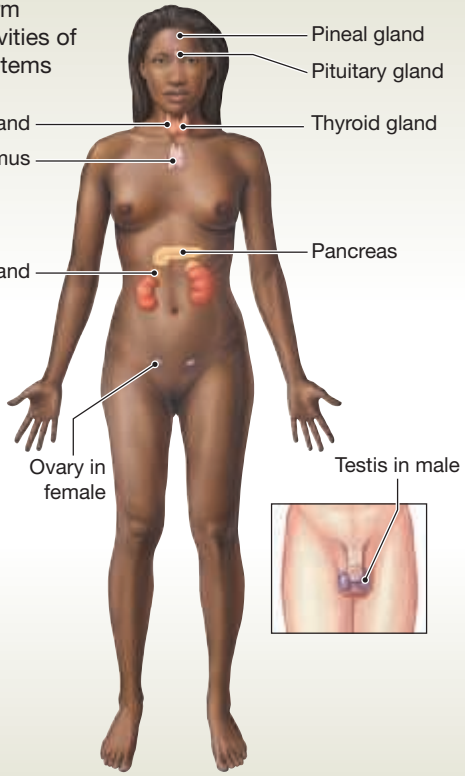


Figure 1-2 The Organ Systems of the Human Body. *(continued)*

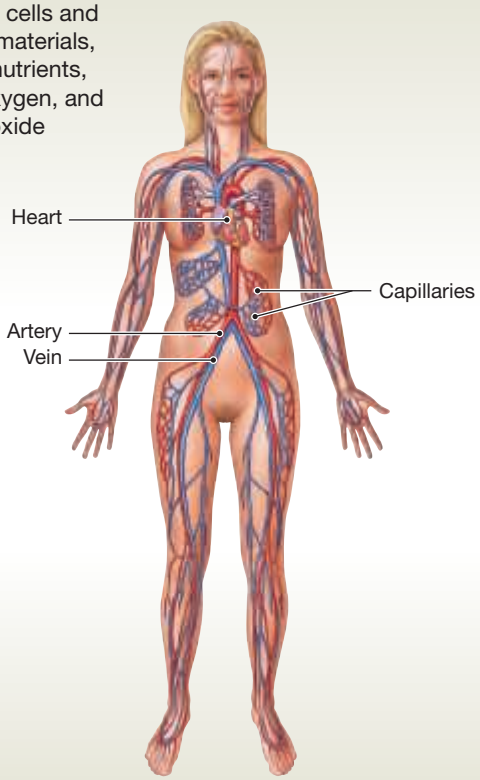
The Endocrine System

Directs long-term changes in activities of other organ systems



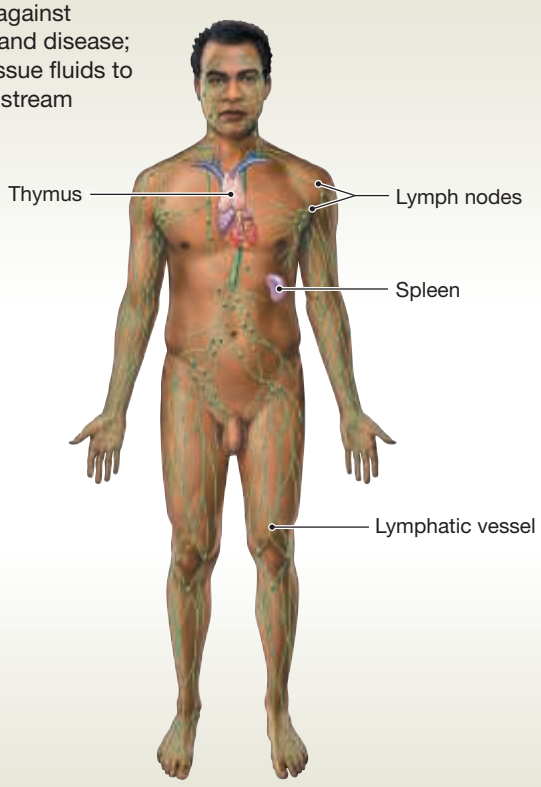
The Cardiovascular System

Transports cells and dissolved materials, including nutrients, wastes, oxygen, and carbon dioxide



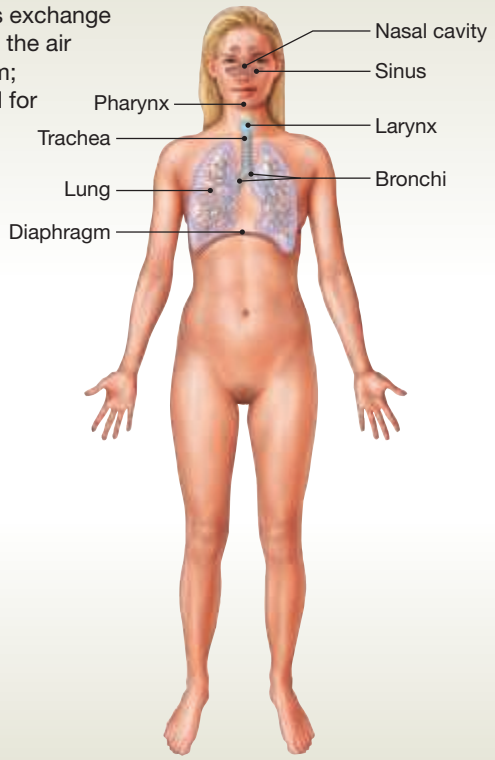
The Lymphatic System

Defends against infection and disease; returns tissue fluids to the bloodstream



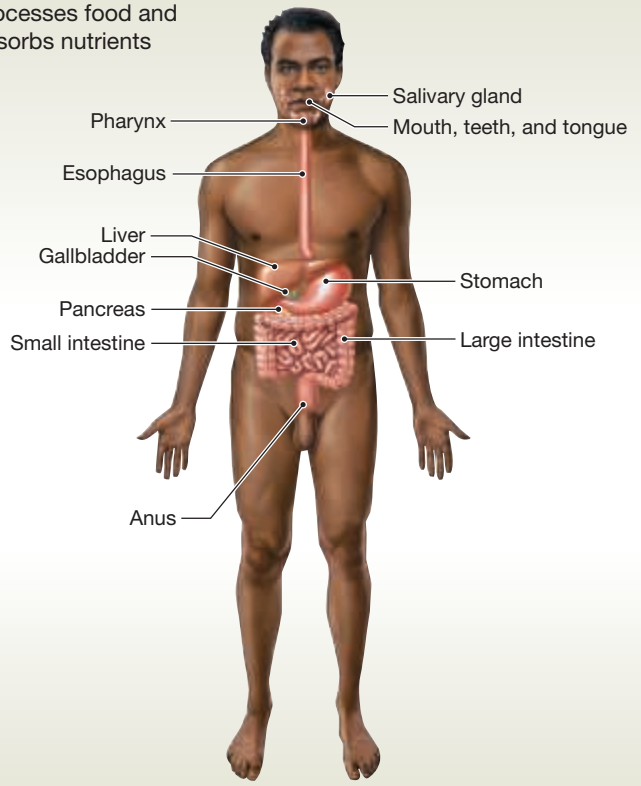
The Respiratory System

Delivers air to sites in the lungs where gas exchange occurs between the air and bloodstream; produces sound for communication



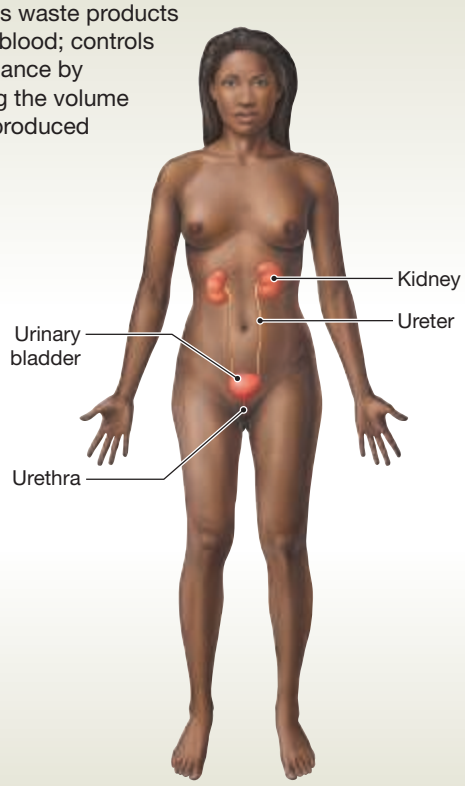
The Digestive System

Processes food and absorbs nutrients



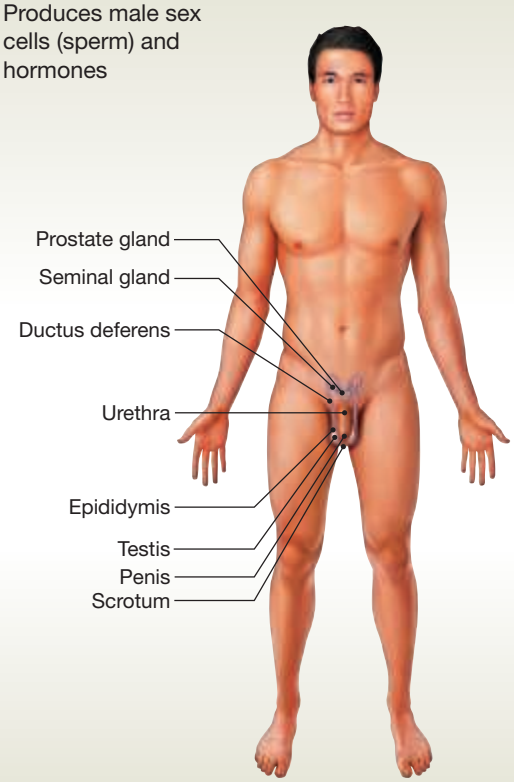
The Urinary System

Eliminates waste products from the blood; controls water balance by regulating the volume of urine produced



The Male Reproductive System

Produces male sex cells (sperm) and hormones



The Female Reproductive System

Produces female sex cells (oocytes, or immature eggs) and hormones; supports embryonic and fetal development from fertilization to birth