

MARTINI / BARTHOLOMEW



ESSENTIALS OF

Anatomy & Physiology

EIGHTH EDITION



Chapters

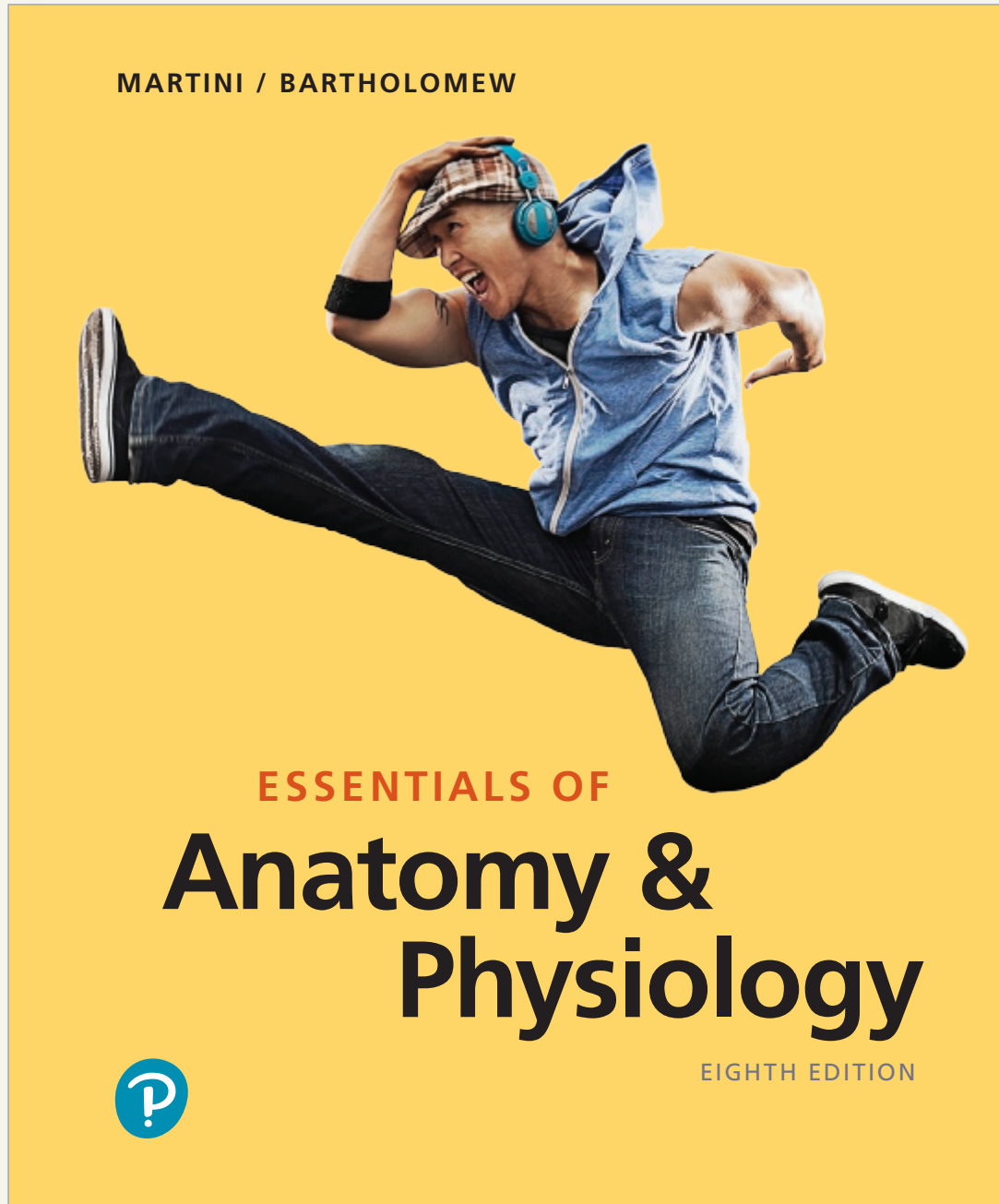
Spotlights

Build Your Knowledge

1	An Introduction to Anatomy and Physiology	1	1-1 Levels of Organization	
2	The Chemical Level of Organization	25	2-7 Chemical Notation	
3	Cell Structure and Function	55	3-2 Anatomy of a Model Cell 3-15 Protein Synthesis, Processing, and Packaging	
4	The Tissue Level of Organization	90	4-16 Inflammation and Regeneration *Spotlight Video	
5	The Integumentary System	121	5-2 The Epidermis	How the INTEGUMENTARY SYSTEM integrates with the other body systems presented so far
6	The Skeletal System	142	6-35 Synovial Joints *Spotlight Video	How the SKELETAL SYSTEM integrates with the other body systems presented so far
7	The Muscular System	191	7-4 Events at the Neuromuscular Junction 7-5 The Contraction Cycle *Spotlight Video	How the MUSCULAR SYSTEM integrates with the other body systems presented so far
8	The Nervous System	243	8-8 The Generation of an Action Potential 8-9 Propagation of an Action Potential	How the NERVOUS SYSTEM integrates with the other body systems presented so far
9	The General and Special Senses	305	9-16 Refractive Problems *Spotlight Video	
10	The Endocrine System	344	10-15 The General Adaptation Syndrome	How the ENDOCRINE SYSTEM integrates with the other body systems presented so far
11	The Cardiovascular System: Blood	379	11-1 The Composition of Whole Blood *Spotlight Video	
12	The Cardiovascular System: The Heart	404	12-5 The Heart: Internal Anatomy and Blood Flow *Spotlight Video	
13	The Cardiovascular System: Blood Vessels and Circulation	429	13-13 Major Vessels of the Systemic Circuit	How the CARDIOVASCULAR SYSTEM integrates with the other body systems presented so far
14	The Lymphatic System and Immunity	471	14-4 Origin and Distribution of Lymphocytes	How the LYMPHATIC SYSTEM integrates with the other body systems presented so far
15	The Respiratory System	505	15-10 Pulmonary Ventilation *Spotlight Video 15-16 The Control of Respiration	How the RESPIRATORY SYSTEM integrates with the other body systems presented so far
16	The Digestive System	538	16-9 Regulation of Gastric Activity 16-18 Chemical Events in Digestion *Spotlight Video	How the DIGESTIVE SYSTEM integrates with the other body systems presented so far
17	Metabolism and Energetics	577	17-5 Electron Transport Chain and ATP Formation	
18	The Urinary System	604	18-9 A Summary of Kidney Function *Spotlight Video	How the URINARY SYSTEM integrates with the other body systems presented so far
19	The Reproductive System	642	19-7 Regulation of Male Reproduction 19-14 Regulation of Female Reproduction *Spotlight Video	How the REPRODUCTIVE SYSTEM integrates with the other body systems presented so far
20	Development and Inheritance	675	20-5 Extra-Embryonic Membranes and Placenta Formation	

Martini's *Essentials of Anatomy and Physiology* 8e brings a legacy of superb illustration and text-art integration with a suite of new digital tools

The New Eighth edition takes the most popular features from the book and builds them out into effective interactives within the eText and Mastering A&P™



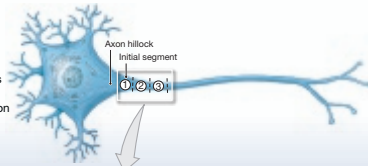
Spotlight Figures Visually Summarize Difficult Physiological Processes, Making Them Easier to Understand

These highly visual one- and two-page presentations of tough topics provide a bridge between readings and related figures and photos to communicate information in a student-friendly, visually effective format.

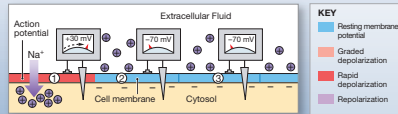
SPOTLIGHT Figure 8-9
PROPAGATION OF AN ACTION POTENTIAL

Continuous Propagation along an Unmyelinated Axon

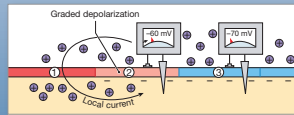
In an unmyelinated axon, an action potential moves along by continuous propagation. The action potential spreads by depolarizing the adjacent region of the axon membrane. This process continues to spread as a chain reaction down the axon.



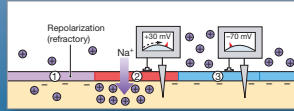
1 As an action potential develops at the initial segment (1), the membrane potential at this site depolarizes to +30 mV.



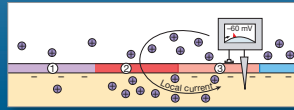
2 As the sodium ions entering at (1) spread away from the open voltage-gated channels, a graded depolarization quickly brings the membrane in segment (2) to threshold.



3 An action potential now occurs in segment (2) while segment (1) begins repolarization.

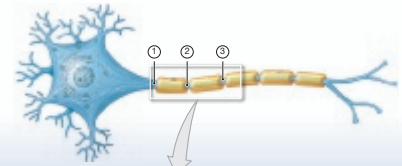


4 As the sodium ions entering at segment (2) spread laterally, a graded depolarization quickly brings the membrane in segment (3) to threshold, and the cycle is repeated.

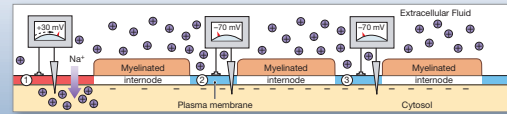


Saltatory Propagation along a Myelinated Axon

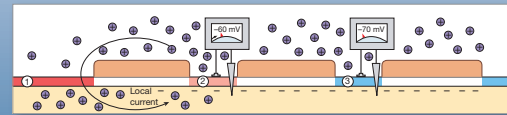
Because myelin limits the movement of ions across the axon membrane, the action potential must "jump" from node to node during propagation. This results in much faster propagation along the axon.



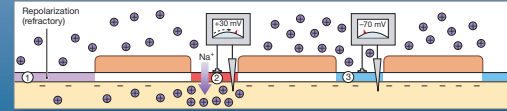
1 An action potential develops at the initial segment (1).



2 A local current produces a graded depolarization that brings the axon membrane at the next node to threshold.



3 An action potential develops at node (2).



4 A local current produces a graded depolarization that brings the axon membrane at node (3) to threshold.

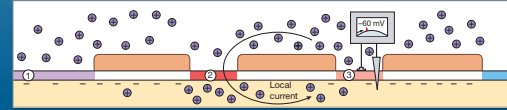
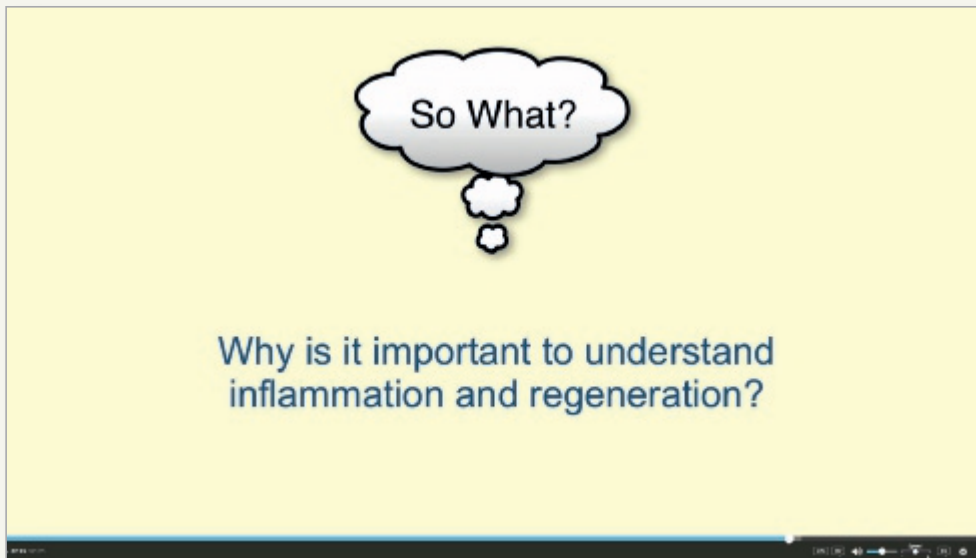


Figure 8-9 illustrates the propagation of an action potential. The left side shows continuous propagation along an unmyelinated axon, and the right side shows saltatory propagation along a myelinated axon. Both diagrams include a key for membrane potential changes: Resting membrane potential (blue), Graded depolarization (orange), Rapid depolarization (red), and Repolarization (purple).

NEW Spotlight Figure Videos Bring This Effective Text Feature to Life

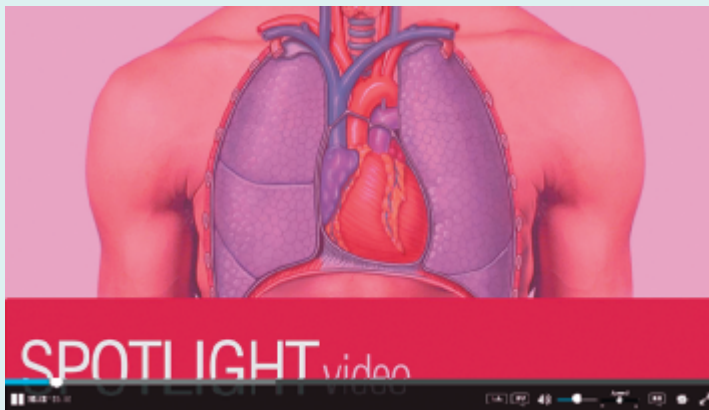


NEW! 10 Spotlight

Videos bring the popular in-text feature to life, with narrated, annotated guidance that walks students through some of the toughest topics in A&P. Spotlight Video topics include: Inflammation and Regeneration, Synovial Joints, The Contraction Cycle, Refractive Problems, The Composition of Whole Blood, The Heart: Internal Anatomy and Blood Flow, Pulmonary Ventilation, Chemical Events in Digestion, A Summary of Kidney Function, and Regulation of Female Reproduction.

SmartArt Video: Endochondral Ossification

Watch the [SmartArt Video for chapter 6](#), and then complete the question at right.



▼ Part A

A hard ossified bone in an adult actually begins within the embryo as a miniature version composed of _____.

- elastic cartilage
- hyaline cartilage
- dense regular connective tissue
- dense irregular connective tissue
- fibrocartilage


Submit

[Request Answer](#)

Coaching Activities in Mastering A&P™ allow instructors to assign the videos to ensure students view them.

Build Your Knowledge Integration Figures Emphasize That the Body Systems Work Together, Not in Isolation

Build Your Knowledge Integration features show students how body systems affect each other and work together to maintain homeostasis.



Build Your Knowledge

How the URINARY SYSTEM integrates with the other body systems presented so far

Integumentary System

- The Integumentary System prevents excessive fluid loss through skin surface; produces vitamin D₃, important for the renal production of calcitriol; sweat glands assist in elimination of water and solutes
- The urinary system eliminates nitrogenous wastes; maintains fluid, electrolyte, and acid-base balance of blood that nourishes the skin

Respiratory System

- The Respiratory System assists in the regulation of pH by eliminating carbon dioxide
- The urinary system assists in the elimination of carbon dioxide; provides bicarbonate buffers that assist in pH regulation

Cardiovascular System

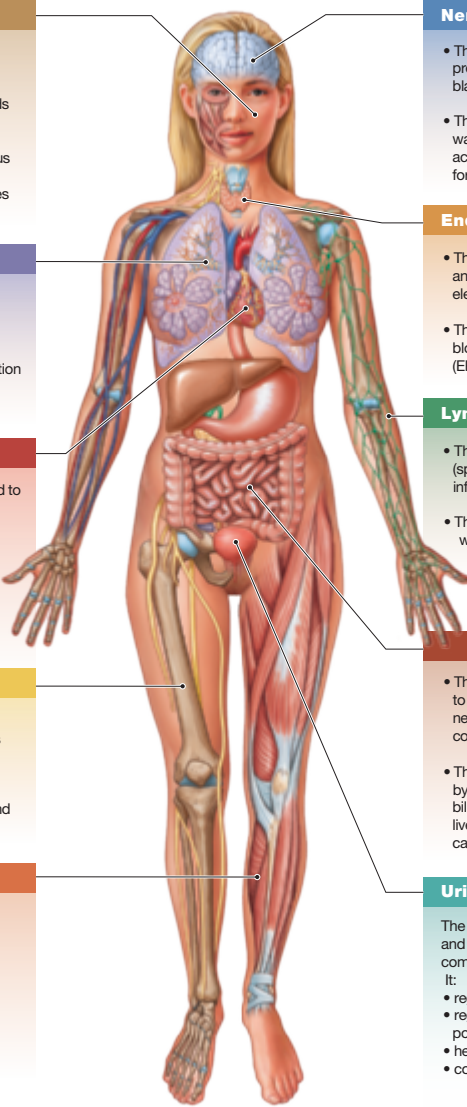
- The Cardiovascular System delivers blood to glomerular capillaries, where filtration occurs; accepts fluids and solutes reabsorbed during urine production
- The urinary system releases renin to elevate blood pressure and erythropoietin (EPO) to accelerate red blood cell production

Skeletal System

- The Skeletal System provides some protection for kidneys and ureters with its axial division; pelvis protects urinary bladder and proximal portion of urethra
- The urinary system conserves calcium and phosphate needed for bone growth

Muscular System

- The Muscular System controls urination by closing urethral sphincters. Muscle layers of trunk provide some protection for urinary organs
- The urinary system excretes waste products of muscle and protein metabolism; assists in regulation of calcium and phosphate concentrations



Nervous System

- The Nervous System adjusts renal blood pressure; monitors distension of urinary bladder and controls urination
- The urinary system eliminates nitrogenous wastes; maintains fluid, electrolyte, and acid-base balance of blood, which is critical for neural function

Endocrine System

- The Endocrine System produces aldosterone and ADH, which adjust rates of fluid and electrolyte reabsorption by kidneys
- The urinary system releases renin when local blood pressure drops and erythropoietin (EPO) when renal oxygen levels fall

Lymphatic System

- The Lymphatic System provides adaptive (specific) defense against urinary tract infections
- The urinary system eliminates toxins and wastes generated by cellular activities; acid pH of urine provides innate (nonspecific) defense against urinary tract infections

Digestive System

- The Digestive System absorbs water needed to excrete wastes at kidneys; absorbs ions needed to maintain normal body fluid concentrations; liver removes bilirubin
- The urinary system excretes toxins absorbed by the digestive epithelium; excretes bilirubin and nitrogenous wastes from the liver; calcitriol production by kidneys aids calcium and phosphate absorption

Urinary System

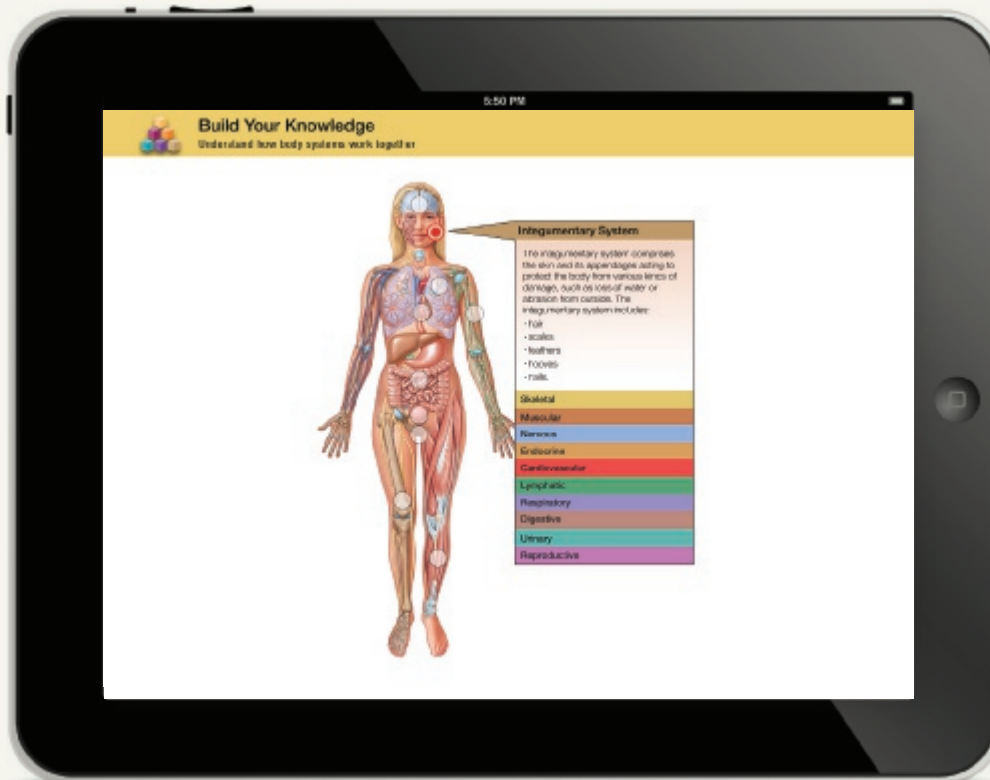
The urinary system excretes metabolic waste and maintains normal body fluid pH and ion composition.

It:

- regulates blood volume and blood pressure
- regulates plasma concentrations of sodium, potassium, chloride, and other ions
- helps to stabilize blood pH
- conserves valuable nutrients

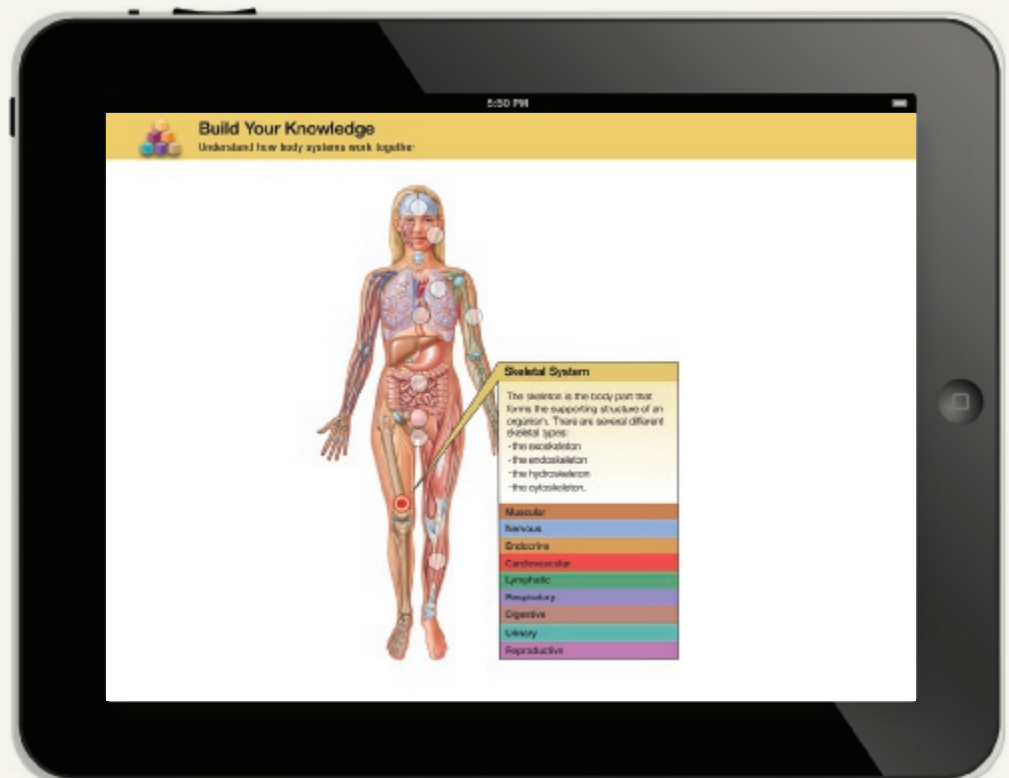
18

NEW Interactive Versions of These Figures Allow Students to Explore at Their Own Pace

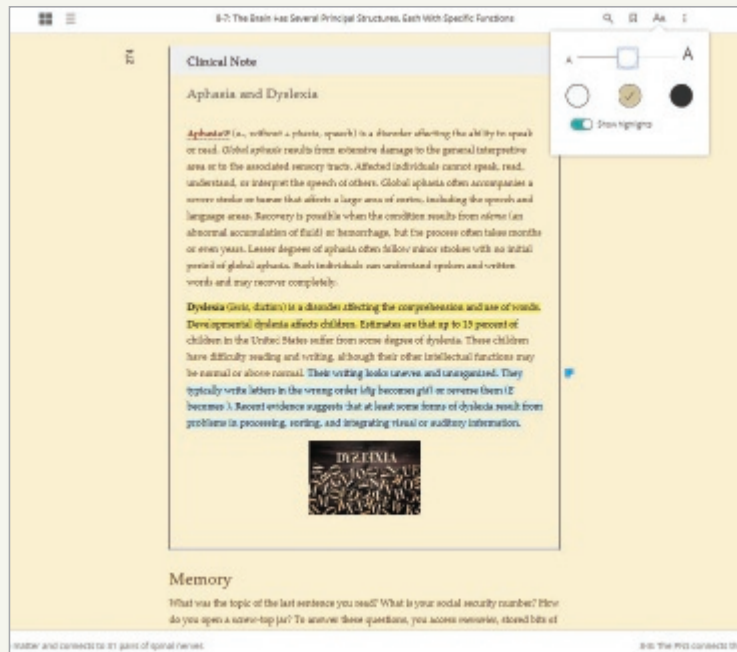


NEW! Build Your Knowledge Interactives give students the chance to navigate the inter-relationships among body systems within the eText.

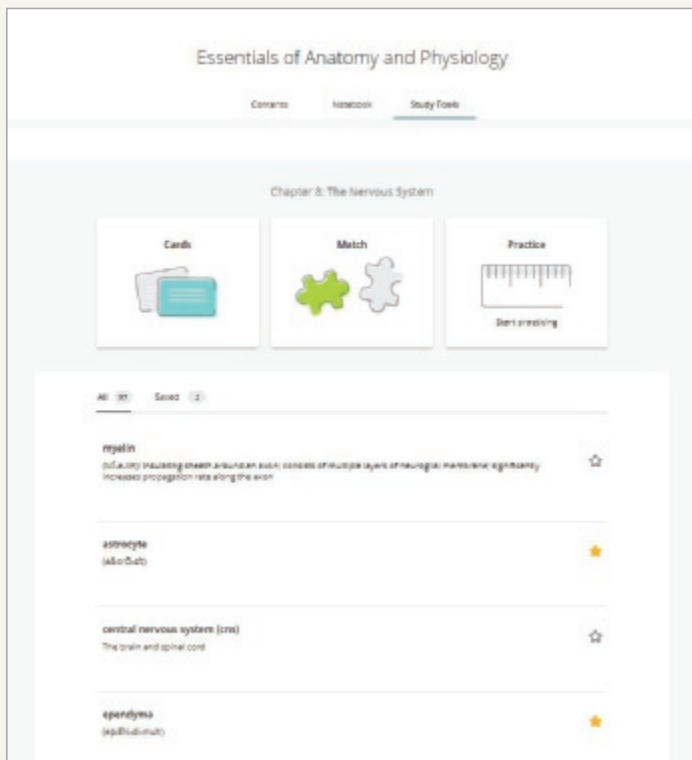
Build Your Knowledge Coaching Activities are assignable in Mastering A&P and provide hints and wrong answer-specific feedback to ensure mastery of the concepts.



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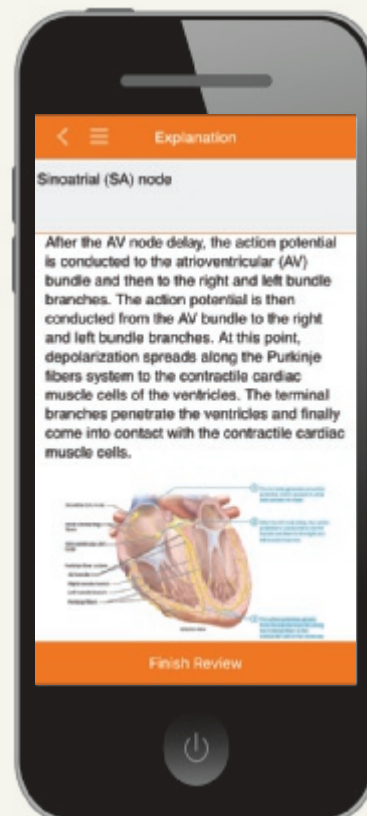
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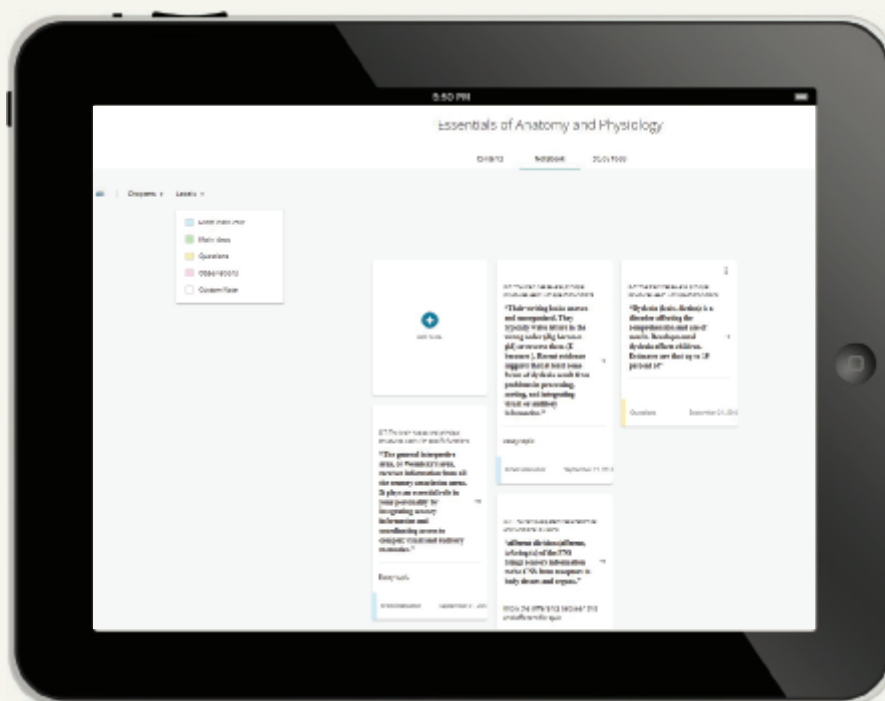


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MARTINI / BARTHOLOMEW



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ESSENTIALS OF
**Anatomy &
Physiology**



EIGHTH EDITION

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Library of Congress Cataloging-in-Publication Data

Names: Martini, Frederic, author. | Bartholomew, Edwin F., author.

Title: Essentials of anatomy & physiology / Martini, Bartholomew; with William C. Ober, art coordinator and illustrator; Claire E. Ober, illustrator; Kathleen Welch, clinical consultant; Kevin Petti, contributor.

Other titles: Essentials of anatomy and physiology

Description: Eighth edition. | Hoboken : Pearson Education, Inc., [2020] | Includes bibliographical references and index.

Identifiers: LCCN 2018049571 | ISBN 9780135203804 (student edition) | ISBN 0135203805 (student edition) | ISBN 9780135210758 (instructor's review copy) | ISBN 0135210755 (instructor's review copy)

Subjects: | MESH: Anatomy | Physiology

Classification: LCC QP36 | NLM QS 4 | DDC 612--dc23 LC record available at <https://lccn.loc.gov/2018049571>

ISBN 10: 0-13-520380-5
ISBN 13: 978-0-13-520380-4 (Student edition)
ISBN 10: 0-13-521075-5
ISBN 13: 978-0-13-521075-8 (Instructor's Review Copy)



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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 Eighth 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 Eighth Edition** section below. Also below are the sections **Learning Outcomes** and **Chapter-by-Chapter Changes in the Eighth Edition**.

New to the Eighth 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.
- **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.
- **Terminology** has been updated based on *Terminologia Anatomica* and *Terminologia Histologica*, our references 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's disease and Huntington's disease.
- **Mastering A&P**[®], Pearson's online learning and assessment system, contains new assignable activities tied to features in the book, including 10 narrated, annotated Spotlight

Videos that walk students through these popular features to explain core concepts, and a Build Your Knowledge interactive widget that allows them to see how body systems work together to maintain homeostasis. In addition, many Spotlight figures have Coaching Activities in Mastering, 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[™]) 3.1 and Interactive Physiology[®]—all organized by chapter—and have assignments automatically graded. Mobile friendly Dynamic Study Module questions help students study effectively and efficiently by allowing them to quiz themselves anytime, anywhere. In the Mastering A&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 Eighth 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 Mastering A&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 Eighth Edition

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

Chapter 1 An Introduction to Anatomy and Physiology

- Section 1-1 revised (*cellular differentiation* replaces *differentiation*; *the same kind of organisms* replaces *similar, but not identical, organisms*; *Organisms exhibit movement* replaces *Organisms can move*.)
- Figure 1-4 Negative Feedback: Control of Body Temperature revised (new title)
- Figure 1-10 Relationships among the Subdivisions of the Body Cavities of the Trunk revised (*visceral layer of serous pericardium* replaces *visceral pericardium*, *parietal layer of serous pericardium* replaces *parietal pericardium*)
- Review Questions: Level 1 revised (answer to question 21 corrected)
- Related Clinical Terms revised (*acute* and *chronic* terms added; *injury* added to definition of *radiology*)

Chapter 2 The Chemical Level of Organization

- Section 2-1 revised (clarified definition of *radiation*)
- Spotlight Figure 2-7 Chemical Notation revised (simplified introduction and replaced spelled out numbers with numerals to better integrate the Visual Representation and Chemical Notation columns)
- Section 2-8 revised (clarified that, in physiology, the term *electrolyte* applies to both the ionizable substance and its ions)
- New Clinical Note (*Too Sweet on Sugar* replaces *Fatty Acids and Health*)

Chapter 3 Cell Structure and Function

- Section 3-7 Learning Outcome revised (sequence of interphase and mitosis now correlates with section discussion)
- Table 3-1 revised (*propagation of nerve impulses* replaces *conduction of nerve impulses*)
- Figure 3-5 Diffusion Across the Plasma Membrane revised (color of water molecules now matches those in Chapter 2 figures)
- Figure 3-9 The Sodium-Potassium Exchange Pump revised (corrected relative sizes of sodium and potassium ions)
- Spotlight Figure 3-7 Protein Synthesis, Processing, and Packaging revised (added magnification of TEM illustrating exocytosis)
- Section 3-10 revised (*cellular differentiation* replaces *differentiation*)

Chapter 4 The Tissue Level of Organization

- Figure 4-1 An Orientation to the Body's Tissues revised (*nervous tissue* replaces *neural tissue*)
- Figure 4-2 Cell Junctions revised (*basal lamina* replaces *clear layer* and *reticular lamina* replaces *dense layer*)
- Figure 4-3 The Surfaces of Epithelial Cells (added *Lateral surfaces* and *Basal surface* labels)
- Figure 4-4 Simple Epithelia revised (moved part letters to highlight tissue types and enhance text-art integration)
- Figure 4-5 Stratified Epithelia revised (moved part letters to highlight tissue types and enhance text-art integration)
- Figure 4-6 Methods of Glandular Secretion revised (*Modes* changed to *Methods* in figure title and letters added to different parts of the figure to enhance text-art integration)
- Table 4-2 revised (*Method of Secretion* replaces *Mode of Secretion*)
- Clinical Note Marfan's Syndrome revised (*Marfan* replaces *Marfan's*)
- Figure 4-9 Loose Connective Tissue revised (moved part letters to highlight tissue types and enhance text-art integration)
- Figure 4-10 Dense Connective Tissue revised (moved part letters to highlight tissue types and enhance text-art integration)
- Figure 4-11 Types of Cartilage revised (moved part letters to highlight tissue types and enhance text-art integration)
- Figure 4-14 Muscle Tissue revised (moved part letters to highlight tissue types and enhance text-art integration)
- Figure 4-15 Nervous Tissue revised (new title *Nervous Tissue* replaces *Neural Tissue*)

Chapter 5 The Integumentary System

- The text now uses *subcutaneous layer* as the primary term and *hypodermis* as the secondary term.
- Figure 5-1 The General Structure of the Integumentary System revised (*Subcutaneous layer* replaces *Hypodermis*)
- Spotlight Figure 5-2 revised (part labels added to better align text and art)
- Section 5-2 heading revised (shortened to *Epidermal pigmentation and dermal circulation influence skin color*)
- Figure 5-5 Hair Follicles and Hairs revised (*Subcutaneous layer* replaces *Hypodermis* in part b)
- Figure 5-6 Sebaceous Glands and Their Relationship to Hair Follicles revised (*Subcutaneous layer* replaces *Hypodermis*)
- Figure 5-7 Sweat Glands revised (*Eccrine sweat gland* replaces *Merocrine sweat gland* as primary term, *Subcutaneous layer* replaces *Hypodermis*)

- Build Your Knowledge revised (added *in females, specialized integumentary glands secrete milk* to Integumentary System functions)
- Level 1: Reviewing Facts and Terms revised (answers to questions 5 and 9 corrected)

Chapter 6 The Skeletal System

- Figure 6-1 A Classification of Bones by Shape revised (bone art enlarged, added *Sectional view* label to part c)
- Clinical Note: Types of Fractures and Steps in Repair revised (replaced x-rays of *Displaced fracture* and *Spiral fracture*)
- Figure 6-8 The Skeleton revised (enlarged figure and increased color and contrast; added *Sternum* label)
- Figure 6-9 The Axial and Appendicular Divisions of the Skeleton revised (*Rib cage* replaced *Thoracic cage* to correlate with the *Axial Skeleton* bone count; *coxal bone* deleted from *Hip bone* box)
- Figure 6-10 The Adult Skull, Part I revised (added leader dots to leader lines of *Coronal suture*, *Squamous suture*, and *Lambdoid suture*)
- Figure 6-12 Sectional Anatomy of the Skull revised (added forked leader to *Frontal sinuses* label)
- Figure 6-13 The Paranasal Sinuses revised (*Ethmoidal cells* replaces *Ethmoidal sinuses*)
- Figure 6-16 The Vertebral Column revised (color coded Vertebral regions to match art in later chapters)
- Figure 6-17 Typical Vertebrae of the Cervical, Thoracic, and Lumbar Regions revised (changed color in icon art to match Figure 6-18 icon art)
- Figure 6-19 The Sacrum and Coccyx revised (adjusted position of *Lateral sacral crest* leader line in part b)
- Figure 6-20 The Thoracic Cage revised (added thoracic cage definition)
- Figure 6-24 The Right Radius and Ulna revised (*RADIUS* and *ULNA* labels changed to *Radius* and *Ulna* to match use in other figures in chapter)
- Figure 6-25 The Bones of the Wrist and Hand revised (rearranged terms in *Proximal Carpals* box to match sequence as discussed in the text)
- Section 6-10 revised (*Plane* movement replaces *Gliding* movement)
- Figure 6-26 The Hip Bones and the Pelvis revised (*Sacroiliac joint* replaces *Sacroiliac joint*)
- Figure 6-33 Rotational Movements revised (added a red dot to mark the location of the joint involved in rotational movements of the head)
- Section 6-11 heading and Learning Outcome revised (*joints* replaces *articulations*)

- Spotlight Figure 6-35 Synovial Joints revised (*Plane joint* replaces *Gliding joint*; *gliding* inserted into *Plane joint Movement* text)
- Figure 6-40 The Knee Joint revised (added *PCL* abbreviation after *Posterior cruciate ligament* and *ACL* abbreviation after *Anterior cruciate ligament* labels)

Chapter 7 The Muscular System

- Figure 7-1 The Organization of Skeletal Muscles revised (added part letters to enhance text–art integration)
- Figure 7-2 The Organization of a Skeletal Muscle Fiber revised (enhanced art)
- Figure 7-3 Changes in the Appearance of a Sarcomere during Contraction of a Skeletal Muscle Fiber (added *Relaxed myofibril* label in part a and *Relaxed myofibril* label in part b)
- Spotlight Figure 7-4 Events at the Neuromuscular Junction revised (updated ACh receptor membrane channel art and added text to step 5)
- Figure 7-6 Steps Involved in Skeletal Muscle Contraction and Relaxation revised (updated ACh receptor membrane channel and T tubule/Sarcoplasmic reticulum art)
- Figure 7-10 Muscle Metabolism revised (in part c, *the hydrolysis of ATP* replaces *pyruvate* as the source of hydrogen ions at peak activity)
- Table 7-12 Muscle Terminology revised (*Terms Indicating Specific Regions of the Body* moved to left column to better correlate with anatomical terminology introduced in Chapter 1)
- Figure 7-17 Muscles of the Pelvic Floor revised (in part b, *transverse perineal* replaces *transverse perineus*)

Chapter 8 The Nervous System

- Section 8-1 revised (recognized the *enteric nervous system (ENS)* as a third division of the *peripheral nervous system*)
- Figure 8-5 Schwann Cells and Peripheral Axons revised (added *neurolemmocytes* as a secondary term for Schwann cells; *neurolemma* replaces *neurilemma*)
- Figure 8-14 Gross Anatomy of the Spinal Cord revised (*lumbosacral enlargement* replaces *lumbar enlargement*; *ventral roots* replaces *anterior roots*; *dorsal roots* replaces *posterior roots*; *spinal ganglion* replaces *dorsal root ganglion*)
- Figure 8-15 Sectional Anatomy of the Spinal Cord revised (*spinal ganglion* replaces *dorsal root ganglion*)
- Figure 8-16c The Brain revised (*Medial view* replaces *Sagittal section*, *Brainstem* replaces *Brain stem*)
- Section 8-8 The PNS connects the CNS with the body's external and internal environments, Cranial Nerves revision (added sentence: *If the full name of the cranial nerve is*

given, then only the Roman numeral is needed, such as optic nerve (II)). This addition affects cranial nerves figure labels and text narrative.

- Figure 8-22 The Basal Nuclei revised (removed *amygdaloid body* from *Basal Nuclei* box since it is considered a component of the limbic system)
- Figure 8-25 The Cranial Nerves, parts a and b revised (*N* preceding Roman numeral of named optic nerves is deleted)
- Figure 8-26 Peripheral Nerves and Nerve Plexuses revised (leader line from *Femoral nerve* corrected)
- Figure 8-27 Dermatomes revised (*CN V* replaces *N V*)
- Figure 8-29 A Stretch Reflex revised (*quadriceps muscles* replaces *muscles* in second line of caption)
- Figure 8-31 The Posterior Column Pathway revised (*Primary Sensory Cortex* changed to *Primary Somatosensory Cortex*; *Dorsal root ganglion* changed to *Spinal ganglion*)
- Figure 8-32 The Corticospinal Pathway revised (*brainstem* replaces *brain stem*)
- Figure 8-35 The Parasympathetic Division revised (*N* changed to *CN*; added postganglionic neuron on rectum art)
- Table 8-2 The Effects of the Sympathetic and Parasympathetic Divisions of the ANS on Various Body Structures revised (EYE: Sympathetic Effects - *Focusing for distance vision* replaces *Focusing for near vision*; Parasympathetic Effects - *Focusing for close vision* replaces *Focusing for distance vision*)

Chapter 9 The General and Special Senses

- Figure 9-3 Tactile Receptors in the Skin revised (added myelin sheath to afferent nerve fiber in Tactile Discs box; *bulbous corpuscle* replaces *Ruffini corpuscle*; *lamellar [pacinian] corpuscle* replaces *lamellated [pacinian] corpuscle*)
- Figure 9-4 Baroreceptors and the Regulation of Autonomic Functions revised (changed *carotid sinus* to *carotid sinuses* and added a second leader; *aortic arch* replaces *aortic sinus* and corrected position of leader line)
- Figure 9-6 The Olfactory Organs revised (in part a, changed Olfactory nerve fibers (*N I*) to Olfactory nerve fibers (*I*); in part b, *dendritic bulb* replaces *knob*)
- Figure 9-7 Taste Buds and Gustatory Epithelial Cells revised (new title; in part a, eliminated line spacing between the four primary taste sensations to indicate that all portions of the tongue provide sweet, salty, sour, and bitter sensations; in part b, *gustatory epithelial cell* replaces *gustatory cell*)
- Figure 9-8 The Accessory Structures of the Eye revised (*lateral angle* replaces *lateral canthus* and *medial angle* replaces *medial canthus*)

- Figure 9-10 The Sectional Anatomy of the Eye revised (in parts a and c, *fovea centralis* replaces *fovea*; in part b, *neural layer* replaces *neural part* and *pigmented layer* replaces *pigmented part*; part c caption revised [*Superior view of dissection of the right eye* replaces *Horizontal dissection of the right eye*])
- Figure 9-11 Retinal Organization revised (*pigmented layer of retina* replaces *pigmented part of retina* and *neural layer of retina* replaces *neural part of retina*; *fovea centralis* replaces *fovea*)
- Figure 9-14 Focal Point, Focal Distance, and Visual Accommodation revised (in part a, text in art changed to "*Light rays from a distant source (object) are parallel*", and caption revised by adding "*the greater the angle of arriving light rays and*"; art in parts d and e exchanged to better match art in parts a, b, and c)
- Spotlight Figure 9-16 Refractive Problems revised (added "*a process called accommodation*" to the end of introductory paragraph)
- Figure 9-18 The Structure of Rods and Cones revised (*pigmented epithelium* replaces *pigment epithelium*)
- Figure 9-20 The Visual Pathways revised (*Optic nerves [III]* replaces *Optic nerves [N II]*)
- Figure 9-21 The Anatomy of the Ear revised (*Facial nerve [VII]* replaces *Facial nerve [N VII]* and *Vestibulocochlear nerve [N VIII]* replaces *Vestibulocochlear nerve [N VIII]*)
- Figure 9-23 The Internal Ear revised (*ampullary crests* replaces *cristae*)
- Figure 9-24 The Semicircular Ducts revised (*ampullary crest* replaces *crista ampullaris*; *ampullary cupula* replaces *cupula*; *Vestibular nerve* replaces *Vestibular branch*)
- Figure 9-25 The Utricle and Sacculae revised (*macula of utricle* replaces *macula*)
- Figure 9-27 Sound and Hearing revised (*Cochlear nerve* replaces *Cochlear branch of cranial nerve VIII*)
- Figure 9-28 Pathways for Auditory Sensations revised (*Vestibular nerve* replaces *Vestibular branch*; *Vestibulocochlear nerve [VIII]* replaces *Vestibulocochlear nerve [N VIII]*; in step 5, *auditory* replaces *acoustic*)

Chapter 10 The Endocrine System

- Figure 10-1 Organs and Tissues of the Endocrine System revised (deleted *Secretes* from the examples of Organs with Secondary Endocrine Functions)
- Figure 10-2 The Role of Target Cell Receptors in Hormone Action revised (*neurons* replaces *neural tissue*; *skeletal muscle fiber* replaces *skeletal muscle tissue*)
- Figure 10-4 Hypothalamic Control over Endocrine Function revised (added color coding to boxed text to enhance links between hypothalamic structures and functions)

- Figure 10-8 Pituitary Hormones and Their Targets revised (changed color of adrenal gland secretion oval to enhance link with revised boxed text color in Figure 10-4)
- Section 10-4 Title revised (*The thyroid gland synthesizes thyroid hormones that affect the rate of metabolism* replaces *The thyroid gland lies inferior to the larynx and requires iodine for hormone synthesis*)
- Table 10-1 The Pituitary Hormones revised (under Target column, *Interstitial endocrine cells of testes* replaces *Interstitial cells of testes*)
- Figure 10-10 The Homeostatic Regulation of the Blood Calcium Ion Concentration revised (clarified that figure discusses calcium ion concentration in *blood* and calcitonin's limited role in bone deposition)
- Table 10-2 Hormones of the Thyroid Gland and Parathyroid Glands revised (*principal cells* replaces *chief cells*)
- Figure 10-13 The Endocrine Pancreas revised (*bile duct* replaces *common bile duct*)
- Figure 10-14 The Homeostatic Regulation of the Blood Glucose Concentration revised (added Homeostatic to figure title and clarified normal blood glucose levels is a range)
- Clinical Note Diabetes Mellitus revised (updated estimated number of people in the U.S. with some form of diabetes)
- Clinical Note Endocrine Disorders revised (*congenital hypothyroidism* replaces *cretinism* and *infantile hypothyroidism*)
- Build Your Knowledge revised (clarified that vitamin D₃ is a *precursor to calcitriol production* in the Integumentary System box)

Chapter 11 The Cardiovascular System: Blood

- Spotlight Figure 11-1 The Composition of Whole Blood revised (clarified definition of hematocrit; updated *normal hematocrit range for adult males and adult females*)
- Section 11-3 Abundance of Red Blood Cells section revised (described the composition of the three layers observed after centrifugation of whole blood)
- Section 11-3 Structure of RBCs section revised (clarified that a *flexible cell membrane* accounts for ability of RBCs bend and squeeze through capillaries)
- Section 11-3 Sex and Iron Reserves revised (*Sex and Iron Reserves* replaces *Gender and Iron Reserves*)
- Figure 11-3 Recycling of Hemoglobin revised (clarified that Fe^{2+} is an *iron ion*; added label to large intestine)
- Clinical Note Abnormal Hemoglobin revised (*sickle cell disease [SCD]* replaces *sickle cell anemia [SCA]*)
- Figure 11-6 Blood Types and Cross-Reactions revised (corrected shapes of anti-A and anti-B antibodies)
- Figure 11-7 Blood Typing Testing revised (added “clumping” or “no clumping” under test results for clarification)

- Figure 11-9 The Vascular, Platelet, and Coagulation Phases of Hemostasis revised (added *Endothelium* label for clarification)

Chapter 12 The Cardiovascular System: The Heart

- Section 12-1 revised (clarified that *pericardium* includes an outer *fibrous pericardium* and an inner *serous pericardium*)
- Figure 12-1 The Location of the Heart in Thoracic Cavity revised (*parietal layer of serous pericardium* replaces *parietal pericardium*, *visceral layer of serous pericardium* replaces *visceral pericardium*)
- Figure 12-3 The Position and Anatomy of the Heart revised (parts are rearranged; part a art now shows the position of the heart)
- Figure 12-4 The Heart Wall and Cardiac Muscle Tissue revised (*parietal layer of serous pericardium* replaces *parietal pericardium*, *visceral layer of serous pericardium* replaces *visceral pericardium*)
- Spotlight Figure 12-5 The Heart: Internal Anatomy and Blood Flow revised (*tricuspid valve* replaces *right atrioventricular valve*, *mitral valve* replaces *left atrioventricular valve*)
- Figure 12-6 The Valves of the Heart revised (*tricuspid* replaces *right AV [tricuspid] valve*, *mitral valve* replaces *left AV [bicuspid] valve*)
- Figure 12-8 Action Potentials in Cardiac Contractile Cells and Skeletal Muscle Fibers revised (new figure title; *cardiac contractile cell* replaces *cardiac muscle cell*, *skeletal muscle fiber* replaces *skeletal muscle*)
- Figure 12-11 The Cardiac Cycle revised (Changed color of central *Cardiac cycle* to enhance text and art)
- Figure 12-12 Heart Sounds revised (new part a art avoids crossing of leader lines)
- Figure 12-13 Autonomic Innervation of the Heart revised (*Vagus nerve [X]* replaces *Vagus [NX]*)

Chapter 13 The Cardiovascular System: Blood Vessels and Circulation

- Figure 13-2 The Structure of the Various Types of Blood Vessels revised (clarified internal, or *lumen*, diameters of blood vessels)
- Figure 13-8 The Baroreceptor Reflexes of the Carotid Sinuses and Aortic Arch revised (new Figure title; *Baroreceptors in carotid sinuses and aortic arch* replaces *Baroreceptors in aortic and carotid sinuses*)
- Figure 13-18 The Venous Drainage of the Abdomen and Chest revised (*hemi-azygos* replaces *hemiazzygos*)
- Figure 13-19 A Flowchart of the Tributaries of the Superior and Inferior Venae Cavae revised (*Hemi-azygos* replaces *Hemiazzygos*)

- Figure 13-20 The Hepatic Portal System revised (clarified drainage of *left and right gastroepiploic veins*)
- BYK Integrator (*lactate* replaces *lactic acid*)
- Review Questions Level 1 Column B revised (*aortic arch and carotid sinuses* replaces *aortic and carotid sinuses*)

Chapter 14 The Lymphatic System and Immunity

- Definition of the term “immune response” revised from “a defense against specific antigens” to “the body’s reaction to infectious agents and abnormal substances”)
- Figure 14-1 The Components of the Lymphatic System revised (added CNS lymphatic vessels to the art; Other Lymphoid Tissues and Organs heading replaces Lymphoid Tissues and Organs heading because lymph nodes are organs)
- Spotlight Figure 14-4 Origin and Distribution of Lymphocytes revised (*hemocytoblasts* replaces *hematopoietic stem cells*)
- Figure 14-6 The Structure of a Lymph Node revised (*cortex* replaces *outer cortex*; *paracortex* replaces *deep cortex*)
- Figure 14-9 The Body’s Innate Defenses revised (clarifies the roles of *complement*)
- Figure 14-11 Forms of Immunity revised (*artificially acquired* replaces *artificially induced*)
- Figure 14-12 An Overview of Adaptive Immunity revised (former title “An Overview of the Immune Response”; new title emphasizes that adaptive immunity is part of the “immune response”)
- Figure 14-17 An Integrated Summary of the Immune Response (new title corresponds with broadened definition of the term “immune response”; *regulatory T cells* replaces *suppressor T cells*)

Chapter 15 The Respiratory System

- Figure 15-1 The Structures of the Respiratory System revised (*Respiratory bronchioles* replaces *Smallest bronchioles*)
- Figure 15-2 The Respiratory Mucosa revised (*mucus* replaces *mucus layer*)
- Figure 15-3 The Nose, Nasal Cavity, and Pharynx revised (*posterior internal apertures* replaces *internal nares*, and *nostrils* replaces *external nares*)
- Clinical Note Cystic Fibrosis revised (added text to clarify that cystic fibrosis affects not only the respiratory system, but also the digestive and reproductive systems)
- Figure 15-4 The Anatomy of the Larynx and Vocal Cords revised (*glottis in the open position* art and photomicrograph now positioned next to each other)
- Figure 15-5 The Anatomy of the Trachea revised (*main bronchi* replaces *primary bronchi* and *lobar bronchi* replaces *secondary bronchi*)
- Figure 15-6 Bronchial Branching and a Lobule of the Lung revised (new figure title; *segmental bronchi* replaces *tertiary bronchi*)

- Figure 15-7 Alveolar Organization revised (*pneumocyte type I* replaces *type I pneumocyte*, and *pneumocyte type II* replaces *type II pneumocyte*; *blood air barrier* replaces *respiratory membrane*)
- Figure 15-8 The Gross Anatomy of the Lungs revised (added caption “*The lobes are shown as though transparent to make the main branching of the bronchial tree visible*”)
- Spotlight Figure 15-10 Pulmonary Ventilation revised (clarified *rib cage* structures and that *accessory respiratory muscles* are only active in *forced breathing*)
- Figure 15-11 Pulmonary Volumes and Capacities revised (TV replaces V_T as abbreviation for tidal volume; clarified table describing sex differences)
- Spotlight Figure 15-16 The Control of Respiration revised (CN replaces N)
- BYK Integrator revised (deleted *nourish* from Integumentary System description)

Chapter 16 The Digestive System

- Section 16-1 revised under *Secretion*, added *salts* to the substances released into the digestive tract
- Section 16-1 revised (clarified that the *enteric nervous system [ENS]* consists of the *myenteric plexus* and *submucosal plexus*)
- Figure 16-1 The Components of the Digestive System revised (*mechanical digestion* replaces *mechanical processing*, *chemical digestion* replaces *chemical breakdown*)
- Figure 16-2 The Structure of the Digestive Tract revised (included *muscularis mucosae* within the Mucosa box, *muscular layer* replaces *muscularis externa*)
- Figure 16-4 The Oral Cavity revised (*frenulum of tongue* replaces *lingual frenulum*)
- Figure 16-6 Teeth: Structural Components and Dental Succession revised (*cement* replaces *cementum*, *alveolar process* replaces *bone of alveolus*, *deciduous teeth* replaces *primary teeth*, *permanent teeth* replaces *adult teeth*)
- Figure 16-8 The Anatomy of the Stomach revised (*muscular layer* replaces *muscularis externa*; added *gastrin-producing G cells* to part d caption)
- Spotlight Figure 16-9 Regulation of Gastric Activity revised (*muscular layer* replaces *muscularis externa*; *neural inhibition* and *hormonal inhibition* added to *Intestinal Phase KEY*)
- Figure 16-11 The Intestinal Wall revised (*muscular layer* replaces *muscularis externa*; *Goblet cells [intestinal mucous cells]* replaces *Mucous cells*)
- Figure 16-13 The Pancreas revised (*bile duct* replaces *common bile duct*)
- Figure 16-14 The Surface Anatomy of the Liver revised (*bile duct* replaces *common bile duct*)
- Figure 16-15 Liver Histology revised (*portal triad* replaces *portal area*; *interlobular bile duct* replaces *bile duct*, *interlobular artery* replaces *branch of the hepatic artery proper*,

interlobular vein replaces *branch of hepatic portal vein*; *stellate macrophages* replaces *Kupffer cells*)

- Figure 16-16 The Gallbladder revised (*bile duct* replaces *common bile duct*)
- Figure 16-17 The Large Intestine revised (*teniae coli* replaces *tenia coli* because there is no singular form to refer to one of the longitudinal smooth muscle bands)
- Spotlight Figure 16-18 Chemical Events in Digestion (clarified large organic molecules are *chemically* broken down before absorption)
- BYK Integrator revised (clarified mechanical and chemical digestion functions in Digestive System box)

Chapter 17 Metabolism and Energetics

- Figure 17-2 Nutrient Use in Cellular Metabolism revised (*electron transport chain* replaces *electron transport system*)
- Figure 17-4 The Citric Acid Cycle revised (*electron transport chain* replaces *electron transport system*)
- Spotlight Figure 17-5 Electron Transport Chain and ATP Formation revised (new figure title and clarified the role of *chemiosmosis* in ATP formation)
- Figure 17-6 A Summary of the Energy Yield of Aerobic Metabolism revised (*electron transport chain* replaces *electron transport system*)
- Figure 17-7 Carbohydrate Metabolism revised (clarified that gluconeogenesis only involves noncarbohydrates; deleted *Other carbohydrates* box from art)

Chapter 18 The Urinary System

- Section 18-1 revised (*metabolic wastes* replaces *organic wastes*)
- Figure 18-2 The Position of the Kidneys revised (clarified locations of *last thoracic* and *third lumbar vertebrae* to better correlate with text)
- Figure 18-4 The Blood Supply to the Kidneys revised (part a, added *segmental artery* label; part b, *renal pyramid* replaces *medulla*, and added *interlobar artery* and *interlobar vein* labels to better correlate with part a)
- Figure 18-5 A Representative Nephron and the Collecting System revised (highlighted general functions of *descending limb* and *ascending limb* in the Nephron Loop box with bullet points; *descending thin limb* replaces *thin descending limb*)
- Figure 18-6 The Renal Corpuscle revised (in part a, *capsular outer layer* replaces *parietal epithelium*, *visceral layer* replaces *visceral epithelium*; in part b, *fenestrated capillary endothelium* replaces *capillary epithelium*, *foot processes of podocytes* replaces *filtration slits*; in part c, *foot processes* replaces *pedicels*)
- Figure 18-10 The Renin-Angiotensin-Aldosterone System and Regulation of GFR revised (new figure title; *systemic veins* replaces *venous reservoirs*)

- Figure 18-11 Organs for Conducting and Storing Urine revised (new figure title; *ureteral orifices* replaces *ureteral openings*)
- NEW Figure 18-12 The Control of Urination
- Figure 18-14 Ions in Body Fluids revised (caption revised to emphasize electrical neutrality within each fluid compartment)
- BYK Integrator Urinary System revised (*excretes* replaces *removes*)

Chapter 19 The Reproductive System

- Section 19-1 revised (*sperm* replaces *spermatozoa/spermatozoon* as the primary term)
- Figure 19-2 The Scrotum, Testes, and Seminiferous Tubules revised (*sperm* replaces *spermatozoa*)
- Section 19-2 revised (*dartos muscle* replaces *dartos*; *sustenocytes* replaces *sustentacular cells*; *prostate* replaces *prostate gland*)
- Figure 19-3 Spermatogenesis revised (*sperm* replaces *spermatozoa/spermatozoon*)
- Figure 19-6 The Penis revised (*foreskin* replaces *prepuce*)
- Spotlight Figure 19-7 Regulation of Male Reproduction revised (*interstitial endocrine cells* replaces *interstitial cells*; *sperm* replaces *spermatozoa*)
- Figure 19-10 Ovarian Follicle Development and the Ovarian Cycle revised (*ovarian follicle* replaces *follicle*; in caption, clarified that ovarian follicles enter *the 28-day* ovarian cycle as tertiary ovarian follicles)
- Section 19-3 revised (*functional layer* of endometrium replaces *functional zone* of endometrium, and *basal layer* of endometrium replaces *basilar layer* of endometrium)
- Figure 19-12 The Female External Genitalia revised (*bulb of vestibule* replaces *vestibular bulb*)
- Spotlight Figure 19-14 Regulation of Female Reproduction revised (*ovarian follicle* replaces *follicle*; temperature ranges added for both Celsius and Fahrenheit scales; and Menses label changed to Menstrual Phase)
- BYK Integrator Reproductive System revised (kidneys *excrete* replaces *kidneys remove* in Urinary System box)

Chapter 20 Development and Inheritance

- Figure 20-1 Fertilization revised (in part b, changed step 2 title and text in steps 3 and 4; clarified when DNA synthesis occurs, *sperm* replaces *spermatozoon*)
- Figure 20-3 Events in Implantation revised (*cytotrophoblast* replaces *cellular trophoblast*, *syncytiotrophoblast* replaces *syncytial trophoblast*)
- Figure 20-4 The Inner Cell Mass revised (*extra-embryonic* replaces *extraembryonic*, changed *Gastrulation* from *day 12* to *day 15*)
- Spotlight Figure 20-5 Extra-Embryonic Membranes and Placenta Formation revised (added *mucus plug* to week 10/step 5 art)

- Figure 20-6 The Placenta and Placental Circulation revised (*Mucus plug* replaces *Cervical (mucous) plug*)
- Figure 20-7 Development during the First Trimester revised (new part a Week 3 art and new Week 4, 8, and fiberoptic photographs)
- Figure 20-8 Fetal Development in the Second and Third Trimesters revised (new photograph of 6-month-old fetus)
- Figure 20-16 The Milk Ejection Reflex (new title replaces *The Milk Let-Down Reflex*)
- Figure 20-16 A Map of Human Chromosomes revised (*Down Syndrome* replaces *Down's Syndrome*; *Marfan's Syndrome* replaces *Marfan Syndrome*; *Sickle Cell Disease* replaces *Sickle Cell Anemia*)
- Section 20-8 The Human Genome revised (new title; added description of gene-editing technique *CRISPR/Cas9*)

Acknowledgments

Every textbook represents a group effort. Foremost on the list are the faculty and reviewers whose advice, comments, and collective wisdom helped shape this edition. Their interest in the subject, their concern for the accuracy and method of presentation, and their experience with students of widely varying abilities and backgrounds made the review process an educational experience. To these individuals, who carefully recorded their comments, opinions, and sources, we express our sincere appreciation and best wishes.

We thank them for their participation and list their names and affiliations below.

Reviewers for the Eighth Edition

Meghan Andrikanich, *Lorain County Community College*

Jaysen Arno, *Pitt Community College*

Nick Butkevich, *Schoolcraft College*

Kristin Jacobson Flex, *Illinois Central College*

Deborah Furbish, *Wake Technical Community College*

Layla Khatib, *Moraine Valley Community College*

Brian Kipp, *Grand Valley State University*

Tara Leszczewicz, *College of DuPage*

Geralyne Lopez-de-Victoria, *Midlands Technical College*

Sudeep Majumdar, *Temple College*

Gary McIlvain, *Marshall University*

Angela Porta, *Kean University*

April Rottman, *Rock Valley College*

John Senter, *Austin Community College*

George Spiegel, *College of Southern Maryland*

Ashley Spring, *Eastern Florida State College*

Our gratitude is also extended to the many faculty and students at campuses across the United States (and out of the country) who made suggestions and comments that helped us improve this edition of *Essentials of Anatomy & Physiology*.

A textbook has two components: narrative and visual.

Virtually without exception, reviewers stressed the importance of accurate, integrated, and visually attractive illustrations in helping students understand essential material. The creative talents brought to this project by our artist team, William Ober, M.D. and Claire Ober, R.N., are inspiring and very much appreciated. Bill and Claire worked closely and tirelessly with us, imparting a unity of vision to the book as a whole while making it both clear and beautiful. The superb art program is also greatly enhanced by the incomparable bone and cadaver photographs of Ralph T. Hutchings, formerly of The Royal College of Surgeons in England.

We are deeply indebted to the Pearson staff and SPi Global, whose efforts were so vital to the creation of this edition. Special thanks are due to Norine Strang for her skillful management of the project through the entire production process. We appreciate the excellent design contributions of Jerilyn Bockorick, Design Manager, Mark Ong, cover designer, and Alisha Webber, interior text designer.

We must also express our appreciation to Lauren Chen and Kimberly Twardochleb for their work on the media supplements that accompany this title, and to our colleague Kevin Petti, for his outstanding efforts to script and record the new Spotlight Videos.

Thanks also to Wendy Mears, Product Marketing Manager, Derek Perrigo, Field Marketing Manager, and the entire Pearson Science sales team for keeping their fingers on the pulse of the market and helping us meet the needs of our users.

Above all, thanks to Jessica Picone for her patience in nurturing this project, and to Cheryl Cechvala, Senior Acquisitions Editor, for her dedication to the success of this book.

Finally, we would like to thank our families for their love and support during the revision process.

No two people could expect to produce a flawless textbook of this scope and complexity. Any errors or oversights are strictly our own rather than those of the reviewers, artists, or editors. In an effort to improve future editions, we ask that readers with pertinent information, suggestions, or comments concerning the organization or content of this textbook e-mail us directly at the e-mail address below. Any and all comments and suggestions will be deeply appreciated and carefully considered in the preparation of the next edition.

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Contents



1 An Introduction to Anatomy and Physiology 1

An Introduction to Studying the Human Body 2

- 1-1 All living things display responsiveness, growth, reproduction, movement, and metabolism 2
- 1-2 Anatomy is structure, and physiology is function 3
Anatomy • Physiology
- 1-3 Levels of organization progress from atoms and molecules to a complete organism 4
- 1-4 The human body consists of 11 organ systems 6
- 1-5 Homeostasis is the state of internal balance 6
- 1-6 Negative feedback opposes variations from normal, whereas positive feedback exaggerates them 10
Negative Feedback • Positive Feedback
- 1-7 Anatomical terms describe body regions, anatomical positions and directions, and body sections 13
Surface Anatomy • Sectional Anatomy
- 1-8 Body cavities of the trunk protect internal organs and allow them to change shape 15
The Thoracic Cavity • The Abdominopelvic Cavity

SPOTLIGHT

Levels of Organization 5

CLINICAL NOTES

Homeostasis and Disease 6

Imaging Techniques 20

Chapter Review 22



2 The Chemical Level of Organization 25

An Introduction to the Chemical Level of Organization 26

- 2-1 Atoms are the basic particles of matter 26
Atomic Structure • Isotopes • Atomic Weight • Electron Shells
- 2-2 Chemical bonds are forces formed by interactions between atoms 28
Ionic Bonds • Covalent Bonds • Hydrogen Bonds
- 2-3 Decomposition, synthesis, and exchange reactions are important chemical reactions in physiology 31
Basic Energy Concepts • Types of Reactions • Reversible Reactions

- 2-4 Enzymes catalyze specific biochemical reactions by lowering a reaction's activation energy 34
 - 2-5 Inorganic compounds usually lack carbon, and organic compounds always contain carbon 34
 - 2-6 Physiological systems depend on water 35
 - 2-7 Body fluid pH is vital for homeostasis 36
 - 2-8 Acids, bases, and salts have important physiological roles 37
Salts • Buffers and pH
 - 2-9 Carbohydrates contain carbon, hydrogen, and oxygen in a 1:2:1 ratio 38
Monosaccharides • Disaccharides and Polysaccharides
 - 2-10 Lipids contain a carbon-to-hydrogen ratio of 1:2 40
Fatty Acids • Fats • Steroids • Phospholipids
 - 2-11 Proteins contain carbon, hydrogen, oxygen, and nitrogen and are formed from amino acids 43
Protein Function • Protein Structure • Enzyme Function
 - 2-12 DNA and RNA are nucleic acids 46
Structure of Nucleic Acids
 - 2-13 ATP is a high-energy compound used by cells 48
 - 2-14 Chemicals form functional units called cells 50
- SPOTLIGHT**
Chemical Notation 32
- CLINICAL NOTE**
Too Sweet on Sugar? 41

Chapter Review 51



3 Cell Structure and Function 55

An Introduction to Cell Structure and Function 56

- 3-1 The study of cells provides the foundation for understanding human physiology 56
The Study of Cells • An Overview of Cell Anatomy
- 3-2 The plasma membrane separates the cell from its surrounding environment and performs various functions 57
Membrane Lipids • Membrane Proteins • Membrane Carbohydrates
- 3-3 Diffusion is a passive transport process that assists membrane passage 61
Diffusion

- 3-4 Carrier-mediated and vesicular transport processes assist membrane passage 65**
Carrier-Mediated Transport • Vesicular Transport
- 3-5 Organelles within the cytoplasm perform specific functions 69**
The Cytosol • The Organelles
- 3-6 The nucleus contains DNA and enzymes essential for controlling cellular activities 76**
Nuclear Structure and Contents • Information Storage in the Nucleus
- 3-7 DNA controls protein synthesis, cell structure, and cell function 78**
Transcription • Translation
- 3-8 Stages of a cell's life cycle include interphase, mitosis, and cytokinesis 81**
Interphase • Mitosis • Cytokinesis
- 3-9 Tumors and cancers are characterized by abnormal cell growth and division 84**
- 3-10 Cellular differentiation is cellular specialization as a result of gene activation or repression 85**

SPOTLIGHT

- Anatomy of a Model Cell 58
- Protein Synthesis, Processing, and Packaging 74

CLINICAL NOTES

- Inheritable Mitochondrial Disorders 73
- DNA Fingerprinting 78
- Mutations and Mosaicism 82

Chapter Review 86



4 The Tissue Level of Organization 90

An Introduction to the Tissue Level of Organization 91

- 4-1 The four tissue types are epithelial, connective, muscle, and nervous 91**
- 4-2 Epithelial tissue covers body surfaces, lines cavities and tubular structures, and serves essential functions 91**
Functions of Epithelia • Intercellular Connections • The Epithelial Surface • The Basement Membrane • Epithelial Renewal and Repair
- 4-3 Cell shape and number of layers determine the classification of epithelia 95**
Cell Layers • Cell Shapes • Classification of Epithelia • Glandular Epithelia
- 4-4 Connective tissue provides a protective structural framework for other tissue types 101**
Connective Tissue Proper • Types of Connective Tissue Proper • Fluid Connective Tissues • Supporting Connective Tissues

- 4-5 Tissue membranes are physical barriers of four types: mucous, serous, cutaneous, and synovial 110**
Mucous Membranes • Serous Membranes • The Cutaneous Membrane • Synovial Membranes
- 4-6 The three types of muscle tissue are skeletal, cardiac, and smooth 111**
Skeletal Muscle Tissue • Cardiac Muscle Tissue • Smooth Muscle Tissue
- 4-7 Nervous tissue responds to stimuli and propagates electrical impulses throughout the body 113**
- 4-8 The response to tissue injury involves inflammation and regeneration 114**
- 4-9 With advancing age, tissue repair declines and cancer rates increase 115**
Aging and Tissue Structure • Aging and Cancer Rates

SPOTLIGHT

- Inflammation and Regeneration 116

CLINICAL NOTES

- Exfoliative Cytology 101
- Marfan Syndrome 104
- Adipose Tissue and Weight Control 106
- Cartilages and Joint Injuries 107

Chapter Review 117



5 The Integumentary System 121

An Introduction to the Integumentary System 122

- 5-1 The epidermis is composed of strata (layers) with various functions 123**
Stratum Basale • Intermediate Strata • Stratum Corneum
- 5-2 Epidermal pigmentation and dermal circulation influence skin color 126**
The Role of Pigmentation • The Role of Dermal Circulation
- 5-3 Sunlight has beneficial and detrimental effects on the skin 127**
The Epidermis and Vitamin D₃ • Skin Cancers
- 5-4 The dermis is the tissue layer that supports the epidermis 128**
- 5-5 The subcutaneous layer connects the dermis to underlying tissues 129**
- 5-6 Hair is composed of dead, keratinized cells that have been pushed to the skin surface 129**
The Structure of Hair and Hair Follicles • Functions of Hair • Hair Color
- 5-7 Sebaceous glands and sweat glands are exocrine glands found in the skin 132**
Sebaceous (Oil) Glands • Sweat Glands

- 5-8** Nails are keratinized epidermal cells that protect the tips of fingers and toes 133
- 5-9** After an injury, the integument is repaired in several phases 134
Repair of Skin Injuries • Effects of Burns
- 5-10** Effects of aging include dermal thinning, wrinkling, and reduced melanocyte activity 137

SPOTLIGHT

The Epidermis 124

CLINICAL NOTES

Drug Administration through the Skin 125

Disorders of Keratin Production 126

Dermatitis 128

Hair Loss 131

Burns 136

Chapter Review 139

6 The Skeletal System 142

An Introduction to the Skeletal System 143

- 6-1** The skeletal system has five major functions 143
- 6-2** Bones are classified according to shape and structure 143
Macroscopic Features of Bone • Microscopic Features of Bone
- 6-3** Ossification and appositional growth are processes of bone formation and enlargement 146
Intramembranous Ossification • Endochondral Ossification • Bone Growth and Body Proportions • Requirements for Normal Bone Growth
- 6-4** Bone growth and development depend on a balance between bone formation and resorption, and on calcium availability 149
The Role of Remodeling in Support • The Skeleton as a Calcium Reserve • Repair of Fractures
- 6-5** Osteopenia has a widespread effect on aging skeletal tissue 152
- 6-6** The bones of the skeleton are distinguished by bone markings and grouped into two skeletal divisions 152
Bone Markings (Surface Features) • Skeletal Divisions
- 6-7** The bones of the skull, vertebral column, and thoracic cage make up the axial skeleton 156
The Skull • The Vertebral Column and Thoracic Cage
- 6-8** The pectoral girdles and upper limb bones, and the pelvic girdle and lower limb bones, make up the appendicular skeleton 166
The Pectoral Girdles • The Upper Limb • The Pelvic Girdle • The Lower Limb

- 6-9** Joints are categorized according to their range of motion or anatomical organization 174
Immovable Joints (Synarthroses) • Slightly Movable Joints (Amphiarthroses) • Freely Movable Joints (Diarthroses)

- 6-10** The structure and functions of synovial joints enable various skeletal movements 176
Types of Movements at Synovial Joints • Types of Synovial Joints

- 6-11** Intervertebral joints and appendicular joints demonstrate functional differences in support and mobility 179

Intervertebral Joints • Joints of the Upper Limb • Joints of the Lower Limb

- 6-12** The skeletal system supports and stores energy and minerals for other body systems 184

SPOTLIGHT

Synovial Joints 180

CLINICAL NOTES

Types of Fractures and Steps in Repair 150

Osteoporosis 152

Rheumatism and Arthritis 176

Hip Fractures 184

Chapter Review 186

7 The Muscular System 191

An Introduction to Muscle Tissue 192

- 7-1** Skeletal muscle performs five primary functions 192
- 7-2** A skeletal muscle contains muscle tissue, connective tissues, blood vessels, and nerves 192
Connective Tissue Organization • Blood Vessels and Nerves
- 7-3** Skeletal muscle fibers have distinctive features 194
The Sarcolemma and Transverse Tubules • Myofibrils • The Sarcoplasmic Reticulum • Sarcomeres
- 7-4** The nervous system and skeletal muscles communicate at neuromuscular junctions 197
The Neuromuscular Junction • The Contraction Cycle
- 7-5** Sarcomere shortening and muscle fiber stimulation produce tension 200
Frequency of Muscle Fiber Stimulation • Number of Muscle Fibers Activated • Isotonic and Isometric Contractions • Muscle Elongation Following Contraction
- 7-6** ATP is the energy source for muscle contraction 207
ATP and CP Reserves • ATP Generation • Energy Use and the Level of Muscle Activity • Muscle Fatigue • The Recovery Period

- 7-7 Muscle performance depends on muscle fiber type and physical conditioning** 210
Types of Skeletal Muscle Fibers • Physical Conditioning
- 7-8 Cardiac and smooth muscle tissues differ in structure and function from skeletal muscle tissue** 211
Cardiac Muscle Tissue • Smooth Muscle Tissue
- 7-9 Descriptive terms are used to name skeletal muscles** 213
Origins, Insertions, and Actions • Names of Skeletal Muscles
- 7-10 Axial muscles are muscles of the head and neck, vertebral column, trunk, and pelvic floor** 217
Muscles of the Head and Neck • Muscles of the Spine • The Axial Muscles of the Trunk • Muscles of the Pelvic Floor
- 7-11 Appendicular muscles are muscles of the shoulders, upper limbs, pelvic girdle, and lower limbs** 225
Muscles of the Shoulders and Upper Limbs • Muscles of the Pelvis and Lower Limbs
- 7-12 The size and power of muscle tissue decrease with advancing age** 236
- 7-13 Exercise produces responses in multiple body systems** 237
- SPOTLIGHTS**
- Events at the Neuromuscular Junction 198
- The Contraction Cycle 202
- CLINICAL NOTES**
- Interference at the NMJ and Muscular Paralysis 200
- Rigor Mortis 200
- Tetanus 201
- Hernias 220
- Intramuscular Injections 223

Chapter Review 239



8 The Nervous System 243

An Introduction to the Nervous System 244

- 8-1 The nervous system has anatomical and functional divisions** 244
- 8-2 Neurons are specialized for intercellular communication and are supported by cells called neuroglia** 245
Neurons • Neuroglia • Organization of Neurons in the Nervous System
- 8-3 In neurons, a change in the plasma membrane's electrical potential may result in an action potential (nerve impulse)** 251
The Membrane Potential • Propagation of an Action Potential

- 8-4 At synapses, communication takes place among neurons or between neurons and other cells** 258
Structure of a Synapse • Synaptic Function and Neurotransmitters • Neuronal Pools
- 8-5 The brain and spinal cord are surrounded by three layers of membranes called the meninges** 261
The Dura Mater • The Arachnoid • The Pia Mater
- 8-6 The spinal cord contains gray matter surrounded by white matter and connects to 31 pairs of spinal nerves** 262
Gross Anatomy • Sectional Anatomy
- 8-7 The brain has several principal structures, each with specific functions** 266
The Major Regions of the Brain • The Ventricles of the Brain • The Cerebrum • The Diencephalon • The Midbrain • The Pons • The Cerebellum • The Medulla Oblongata
- 8-8 The PNS connects the CNS with the body's external and internal environments** 278
The Cranial Nerves • The Spinal Nerves • Nerve Plexuses
- 8-9 Reflexes are rapid, automatic responses to stimuli** 283
Simple Reflexes • Complex Reflexes • Integration and Control of Spinal Reflexes
- 8-10 Separate pathways carry sensory information and motor commands** 286
Sensory Pathways • Motor Pathways
- 8-11 The autonomic nervous system, composed of the sympathetic and parasympathetic divisions, is involved in the unconscious regulation of body functions** 289
The Sympathetic Division • The Parasympathetic Division • Relationships between the Sympathetic and Parasympathetic Divisions
- 8-12 Aging produces various structural and functional changes in the nervous system** 294
- 8-13 The nervous system is closely integrated with other body systems** 296

SPOTLIGHTS

- The Generation of an Action Potential 254
- Propagation of an Action Potential 256

CLINICAL NOTES

- Demyelination Disorders 251
- Epidural and Subdural Hemorrhages 262
- Spinal Cord Injuries 264
- Aphasia and Dyslexia 274
- Seizures 275
- Cerebral Palsy 289
- Alzheimer's Disease 296

Chapter Review 298



9 The General and Special Senses 305

An Introduction to General and Special Senses 306

- 9-1** Sensory receptors connect our internal and external environments with the nervous system 306
- 9-2** General sensory receptors are classified by the type of stimulus that excites them 307
 - Pain • Temperature • Touch, Pressure, and Position • Chemical Detection
- 9-3** Olfaction, the sense of smell, involves olfactory receptors responding to chemical stimuli 311
 - The Olfactory Pathways
- 9-4** Gustation, the sense of taste, involves taste receptors responding to chemical stimuli 313
 - The Taste Pathways
- 9-5** Internal eye structures contribute to vision, while accessory eye structures provide protection 314
 - The Accessory Structures of the Eye • The Eye
- 9-6** Photoreceptors respond to light and change it into electrical signals essential to visual physiology 323
 - Rods and Cones • Photoreceptor Structure • Photoreception • The Visual Pathways
- 9-7** Equilibrium sensations originate within the internal ear, while hearing involves the detection and interpretation of sound waves 328
 - Anatomy of the Ear • Equilibrium • Hearing
- 9-8** Aging is accompanied by a noticeable decline in the special senses 338
 - Smell and Aging • Taste and Aging • Vision and Aging • Equilibrium and Aging • Hearing and Aging

SPOTLIGHT

Refractive Problems 324

CLINICAL NOTES

Cataracts 321
 Visual Acuity 326
 Night Blindness 327
 Hearing Deficits 336

Chapter Review 339



10 The Endocrine System 344

An Introduction to the Endocrine System 345

- 10-1** Homeostasis is preserved through intercellular communication 345

- 10-2** The endocrine system regulates physiological processes through the binding of hormones to receptors 346
 - The Structure of Hormones • Hormone Action • The Secretion and Distribution of Hormones • The Control of Endocrine Activity
- 10-3** The bilobed pituitary gland is an endocrine organ that releases nine peptide hormones 351
 - The Anterior Lobe of the Pituitary Gland • The Posterior Lobe of the Pituitary Gland
- 10-4** The thyroid gland synthesizes thyroid hormones that affect the rate of metabolism 356
 - Thyroid Follicles and Thyroid Hormones • The C Cells of the Thyroid Gland and Calcitonin
- 10-5** The four parathyroid glands, embedded in the posterior surfaces of the thyroid gland, secrete parathyroid hormone to elevate blood calcium levels 360
- 10-6** The adrenal glands, consisting of a cortex and a medulla, cap each kidney and secrete several hormones 360
 - The Adrenal Cortex • The Adrenal Medulla
- 10-7** The pineal gland, attached to the third ventricle, secretes melatonin 363
- 10-8** The endocrine pancreas produces insulin and glucagon, hormones that regulate blood glucose levels 363
 - Diabetes Mellitus
- 10-9** Many organs have secondary endocrine functions 365
 - The Intestines • The Kidneys • The Heart • The Thymus • The Gonads • Adipose Tissue
- 10-10** Hormones interact to produce coordinated physiological responses 368
 - Hormones and Growth • Hormones and Stress • Hormones and Behavior • Hormones and Aging
- 10-11** Extensive integration occurs between the endocrine system and other body systems 373
 - SPOTLIGHT**
The General Adaptation Syndrome 371
 - CLINICAL NOTES**
Diabetes Insipidus 355
Diabetes Mellitus 366
Hormones and Athletic Performance 369
Endocrine Disorders 372

Chapter Review 375



11 The Cardiovascular System: Blood 379

An Introduction to the Cardiovascular System 380

- 11-1** Blood has several important functions and unique physical characteristics 380
Composition of Blood • Blood Collection and Analysis
- 11-2** Plasma, the fluid portion of blood, contains significant quantities of plasma proteins 381
Plasma Proteins
- 11-3** Red blood cells, formed by erythropoiesis, contain hemoglobin that can be recycled 384
Abundance of Red Blood Cells • Structure of RBCs • Hemoglobin Structure and Function • RBC Life Span and Circulation • RBC Formation
- 11-4** The ABO blood types and Rh system are based on antigen–antibody responses 390
Cross-Reactions in Transfusions • Testing for Blood Compatibility
- 11-5** The various types of white blood cells contribute to the body's defenses 393
WBC Circulation and Movement • Types of WBCs • The Differential Count and Changes in WBC Abundance • WBC Formation
- 11-6** Platelets, disc-shaped structures formed from megakaryocytes, function in the clotting process 397
- 11-7** Hemostasis involves vascular spasm, platelet plug formation, and blood coagulation 397
Phases of Hemostasis • The Clotting Process • Clot Retraction and Removal

SPOTLIGHT

The Composition of Whole Blood 382

CLINICAL NOTES

Abnormal Hemoglobin 386
Hemolytic Disease of the Newborn 392
Abnormal Hemostasis 399

Chapter Review 401



12 The Cardiovascular System: The Heart 404

The Heart's Role in the Cardiovascular System 405

- 12-1** The heart is a four-chambered organ, supplied by coronary circulation, that pumps oxygen-poor blood to the lungs and oxygen-rich blood to the rest of the body 405
The Surface Anatomy of the Heart • The Heart Wall • Internal Anatomy and Organization

12-2 Contractile cells and the conducting system produce each heartbeat, and an electrocardiogram records the associated electrical events 415
Contractile Cells • The Conducting System • The Electrocardiogram

12-3 Events during a complete heartbeat make up a cardiac cycle 420
Phases of the Cardiac Cycle • Heart Sounds

12-4 Heart dynamics examines the factors that affect cardiac output 422
Blood Volume Reflexes • Autonomic Innervation • Hormones

SPOTLIGHT

The Heart: Internal Anatomy and Blood Flow 411

CLINICAL NOTES

Heart Valve Disorders 412
Abnormal Conditions Affecting Cardiac Output 423

Chapter Review 425



13 The Cardiovascular System: Blood Vessels and Circulation 429

An Introduction to Blood Vessels and Circulation 430

- 13-1** Arteries, arterioles, capillaries, venules, and veins differ in size, structure, and function 430
The Structure of Vessel Walls • Arteries • Capillaries • Veins
- 13-2** Pressure and resistance determine blood flow and affect rates of capillary exchange 435
Factors Affecting Blood Flow • Cardiovascular Pressures within the Systemic Circuit
- 13-3** Cardiovascular regulation involves autoregulation, neural processes, and endocrine responses 441
Autoregulation of Blood Flow within Tissues • Neural Control of Blood Pressure and Blood Flow • Hormones and Cardiovascular Regulation
- 13-4** The cardiovascular system adapts to physiological stress 447
Exercise and the Cardiovascular System • The Cardiovascular Response to Hemorrhage
- 13-5** The pulmonary and systemic circuits of the cardiovascular system exhibit three general functional patterns 449
- 13-6** In the pulmonary circuit, deoxygenated blood enters the lungs in arteries, and oxygenated blood leaves the lungs in veins 450

13-7 The systemic circuit carries oxygenated blood from the left ventricle to tissues other than the lungs' exchange surfaces, and returns deoxygenated blood to the right atrium 451
Systemic Arteries • Systemic Veins

13-8 Modifications of fetal and maternal cardiovascular systems promote the exchange of materials until birth 462
Placental Blood Supply • Fetal Circulation in the Heart and Great Vessels • Circulatory Changes at Birth

13-9 Aging affects the blood, heart, and blood vessels 463

13-10 The cardiovascular system is both structurally and functionally linked to all other systems 464

SPOTLIGHT

Major Vessels of the Systemic Circuit 452

CLINICAL NOTES

Arteriosclerosis 433

Capillary Dynamics and Blood Volume and Pressure 439

Checking the Pulse and Blood Pressure 440

Exercise, Cardiovascular Fitness, and Health 447

Shock 448

Chapter Review 466



14 The Lymphatic System and Immunity 471

An Introduction to the Lymphatic System and Immunity 472

14-1 Anatomical barriers and defense processes make up nonspecific defense, and lymphocytes provide specific defense 472

14-2 Lymphatic vessels, lymphocytes, lymphoid tissues, and lymphoid organs function in body defenses 473
Functions of the Lymphatic System • Lymphatic Vessels • Lymphocytes • Lymphoid Tissues • Lymphoid Organs

14-3 Innate (nonspecific) defenses respond in a characteristic way regardless of the potential threat 481
Physical Barriers • Phagocytes • Immune Surveillance • Interferons • The Complement System • Inflammation • Fever

14-4 Adaptive (specific) defenses respond to specific threats and are either cell mediated or antibody mediated 485
Forms of Immunity • An Overview of Adaptive Immunity

14-5 T cells play a role in starting and controlling adaptive immunity 487
Antigen Presentation • T Cell Activation

14-6 B cells respond to antigens by producing specific antibodies 489
B Cell Sensitization and Activation • Antibody Structure • Antibody Function • Primary and Secondary Responses to Antigen Exposure • Summary of the Immune Response • Hormones of the Immune System

14-7 Abnormal immune responses result in immune disorders 496
Autoimmune Disorders • Immunodeficiency Diseases • Allergies

14-8 The immune response diminishes as we age 497

14-9 For all body systems, the lymphatic system provides defenses against infection and returns tissue fluid to the circulation 498

SPOTLIGHT

Origin and Distribution of Lymphocytes 477

CLINICAL NOTES

“Swollen Glands” 479

Injury to the Spleen 481

AIDS 493

Stress and the Immune Response 497

Manipulating the Immune Response 498

Chapter Review 500



15 The Respiratory System 505

An Introduction to the Respiratory System 506

15-1 The respiratory system, composed of air-conducting and respiratory portions, has several basic functions 506
Functions of the Respiratory System • Structures of the Respiratory System

15-2 The nose, pharynx, larynx, trachea, bronchi, and larger bronchioles conduct air into the lungs 508
The Nose • The Pharynx • The Larynx • The Trachea • The Bronchi

15-3 The smallest bronchioles and the alveoli within the lungs make up the respiratory portion of the respiratory tract 514
The Bronchioles • The Blood Air Barrier • The Lungs • The Pleural Cavities

15-4 External respiration and internal respiration allow gas exchange within the body 518

- 15-5** Pulmonary ventilation—the exchange of air between the atmosphere and the lungs—involves pressure changes and muscle movement 519
Pressure and Airflow to the Lungs • Compliance • Modes of Breathing • Lung Volumes and Capacities
- 15-6** Gas exchange depends on the partial pressures of gases and the diffusion of molecules 522
Mixed Gases and Partial Pressures • Partial Pressures in the Pulmonary and Systemic Circuits
- 15-7** In gas transport, most oxygen is transported bound to hemoglobin, whereas carbon dioxide is transported in three ways 524
Oxygen Transport • Carbon Dioxide Transport
- 15-8** Neurons in the medulla oblongata and pons, along with respiratory reflexes, control respiration 527
The Local Control of Respiration • Control by the Respiratory Centers of the Brain • The Reflex Control of Respiration • Control by Higher Centers • Respiratory Changes at Birth
- 15-9** Respiratory performance declines with age 532
- 15-10** The respiratory system provides oxygen to, and removes carbon dioxide from, other organ systems 532

SPOTLIGHTS

- Pulmonary Ventilation 520
- The Control of Respiration 530

CLINICAL NOTES

- Cystic Fibrosis 509
- Tracheal Blockage 512
- Pneumonia 516
- Tuberculosis 517
- Decompression Sickness 523
- Carbon Monoxide Poisoning 525
- Emphysema and Lung Cancer 531

Chapter Review 534



16 The Digestive System 538

An Introduction to the Digestive System 539

- 16-1** The digestive system—the digestive tract and accessory organs—performs various food-processing functions 539
Functions of the Digestive System • Histological Organization of the Digestive Tract • The Movement of Digestive Materials
- 16-2** The oral cavity contains the tongue, salivary glands, and teeth, each with specific functions 543
The Tongue • Salivary Glands • Teeth

- 16-3** The pharynx is a passageway between the oral cavity and the esophagus 546
The Pharynx • The Esophagus • Swallowing
- 16-4** The J-shaped stomach receives food from the esophagus and aids in chemical and mechanical digestion 547
The Gastric Wall • The Regulation of Gastric Activity • Digestion in the Stomach
- 16-5** The small intestine chemically digests and absorbs nutrients 552
The Intestinal Wall • Intestinal Movements • Intestinal Secretions • Intestinal Hormones • Digestion in the Small Intestine
- 16-6** The pancreas, liver, and gallbladder are accessory organs that assist with chemical digestion in the small intestine 556
The Pancreas • The Liver • The Gallbladder
- 16-7** The large intestine is divided into three parts with regional specialization 562
The Cecum • The Colon • The Rectum • The Functions of the Large Intestine
- 16-8** Chemical digestion is the alteration of food that allows the absorption and use of nutrients 566
The Processing and Absorption of Nutrients • Water and Electrolyte Absorption • Absorption of Vitamins
- 16-9** Many age-related changes affect digestion and absorption 569
- 16-10** The digestive system is extensively integrated with other body systems 570

SPOTLIGHTS

- Regulation of Gastric Activity 550
- Chemical Events in Digestion 567

CLINICAL NOTES

- Gastritis and Peptic Ulcers 551
- Stomach Cancer 551
- Vomiting 555
- Pancreatitis 558
- Liver Disease 561
- Colorectal Cancer 564
- Diverticulosis 565
- Diarrhea and Constipation 565
- Lactose Intolerance 568

Chapter Review 572



17 Metabolism and Energetics 577

An Introduction to Nutrition and Metabolism 578

- 17-1** Metabolism refers to all the chemical reactions in the body, and energetics refers to the flow and transformation of energy 578

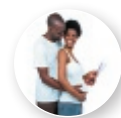
- 17-2 Carbohydrate metabolism involves glycolysis, ATP production, and gluconeogenesis** 580
Glycolysis • Energy Production Within Mitochondria • Energy Yield of Glycolysis and Cellular Respiration • Gluconeogenesis (Glucose Synthesis) • Alternate Catabolic Pathways
- 17-3 Lipid metabolism involves lipolysis, beta-oxidation, and the transport and distribution of lipids as lipoproteins and free fatty acids** 587
Lipid Catabolism • Lipids and Energy Production • Lipid Synthesis • Lipid Transport and Distribution
- 17-4 Protein catabolism involves transamination and deamination, and protein synthesis involves amination and transamination** 589
Amino Acid Catabolism • Amino Acids and Protein Synthesis
- 17-5 Nucleic acid catabolism involves RNA, but not DNA** 591
RNA Catabolism • Nucleic Acid Synthesis
- 17-6 Adequate nutrition is necessary to prevent deficiency disorders and maintain homeostasis** 592
Food Groups and a Balanced Diet • Minerals, Vitamins, and Water • Diet and Disease
- 17-7 Metabolic rate is the average caloric expenditure, and thermoregulation involves balancing heat-producing and heat-losing processes** 596
The Energy Content of Food • Energy Expenditure: Metabolic Rate • Thermoregulation
- 17-8 Caloric needs decline with advancing age** 599
- SPOTLIGHT**
Electron Transport Chain and ATP Formation 583
- CLINICAL NOTES**
Carbohydrate Loading 585
Dietary Fats and Cholesterol 587
Ketoacidosis 590
- 18-3 Different portions of the nephron form urine by filtration, reabsorption, and secretion** 613
Nephron Processes • Filtration at the Glomerulus • Reabsorption and Secretion along the Renal Tubule • Normal Urine
- 18-4 Normal kidney function depends on a stable GFR** 620
The Local Regulation of Kidney Function • The Hormonal Control of Kidney Function
- 18-5 Urine is transported by the ureters, stored in the bladder, and eliminated through the urethra, aided by urinary reflexes** 623
The Ureters • The Urinary Bladder • The Urethra • The Control of Urination
- 18-6 Fluid balance, electrolyte balance, and acid-base balance are interrelated and essential to homeostasis** 626
The ECF and the ICF
- 18-7 Blood pressure and osmosis are involved in maintaining fluid and electrolyte balance** 628
Fluid Balance • Electrolyte Balance
- 18-8 In acid-base balance, regulation of hydrogen ions in body fluids involves buffer systems and compensation by respiratory and renal processes** 630
Acids in the Body • Buffers and Buffer Systems • Maintaining Acid-Base Balance • Acid-Base Disorders
- 18-9 Age-related changes affect kidney function and the control of urination** 634
- 18-10 The urinary system is one of several body systems involved in waste excretion** 635
- SPOTLIGHT**
A Summary of Kidney Function 618
- CLINICAL NOTES**
Kidney Failure 622
Urinary Tract Infections 624
Incontinence 625
Disturbances of Acid-Base Balance 633

Chapter Review 600**Chapter Review 637**

18 The Urinary System 604

An Introduction to the Urinary System 605

- 18-1 The urinary system—made up of the kidneys, ureters, urinary bladder, and urethra—has three major functions** 605
- 18-2 The kidneys are highly vascular organs containing functional units called nephrons, which perform filtration, reabsorption, and secretion** 606
Superficial and Sectional Anatomy of the Kidneys • The Blood Supply to the Kidneys • The Nephron



19 The Reproductive System 642

An Introduction to the Reproductive System 643

- 19-1 Basic reproductive system structures are gonads, ducts, accessory glands and organs, and external genitalia** 643
- 19-2 Sperm formation (spermatogenesis) occurs in the testes, and hormones from the hypothalamus, pituitary gland, and testes control male reproductive functions** 644
The Testes • Spermatogenesis • The Male Reproductive Tract • The Accessory Glands • The External Genitalia • Hormones and Male Reproductive Function

- 19-3** Ovum production (oogenesis) occurs in the ovaries, and hormones from the pituitary gland and ovaries control female reproductive functions 653
The Ovaries • The Uterine Tubes • The Uterus • The Vagina • The External Genitalia • The Mammary Glands • Hormones and the Female Reproductive Cycle
- 19-4** The autonomic nervous system influences male and female sexual function 665
Male Sexual Function • Female Sexual Function
- 19-5** With age, decreasing levels of reproductive hormones cause functional changes 666
Menopause • The Male Climacteric
- 19-6** The reproductive system secretes hormones affecting growth and metabolism of all body systems 667

SPOTLIGHTS

- Regulation of Male Reproduction 652
- Regulation of Female Reproduction 662

CLINICAL NOTES

- Cryptorchidism 646
- Prostatitis 650
- Pelvic Inflammatory Disease (PID) 658
- Amenorrhea 659
- Breast Cancer 661
- Infertility 664
- Sexually Transmitted Diseases 665
- Birth Control Strategies 668

Chapter Review 671



20 Development and Inheritance 675

- An Introduction to Development and Inheritance 676**
- 20-1** Development is a continuous process that occurs from fertilization to maturity 676
- 20-2** Fertilization—the fusion of a secondary oocyte and a sperm—forms a zygote 677
An Overview of Fertilization • Ovulation and Oocyte Activation
- 20-3** Gestation consists of three stages of prenatal development: the first, second, and third trimesters 679

- 20-4** Critical events of the first trimester are cleavage, implantation, placentation, and embryogenesis 679
Cleavage and Blastocyst Formation • Implantation • Placentation • Embryogenesis
 - 20-5** During the second and third trimesters, maternal organ systems support the developing fetus, and the uterus undergoes structural and functional changes 687
The Effects of Pregnancy on Maternal Systems • Structural and Functional Changes in the Uterus
 - 20-6** Labor consists of the dilation, expulsion, and placental stages 694
The Stages of Labor • Premature Labor • Multiple Births
 - 20-7** Postnatal stages are the neonatal period, infancy, childhood, adolescence, and maturity, followed by senescence 696
The Neonatal Period, Infancy, and Childhood • Adolescence and Maturity
 - 20-8** Genes and chromosomes determine patterns of inheritance 698
Patterns of Inheritance • The Human Genome
- SPOTLIGHT**
Extra-Embryonic Membranes and Placenta Formation 684
- CLINICAL NOTES**
Abortion 698
Chromosomal Abnormalities and Genetic Analysis 704

Chapter Review 705

- Answers Answers to Checkpoints and Review Questions ANS-1
- Appendix Normal Physiological Values APP-1
- Glossary/Index G-1
- Credits CR-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 *cellular differentiation*.

- **Reproduction.** Organisms reproduce, creating new generations of the same kind of organisms.
- **Movement.** Organisms exhibit movement. The 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 details provide 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.

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

- Describe how anatomy and physiology are closely related.
- 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 heart-beat. 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

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.

