MARTINI / BARTHOLOMEW

ESSENTIALS OF

Anatomy & Physiology

EIGHTH EDITION

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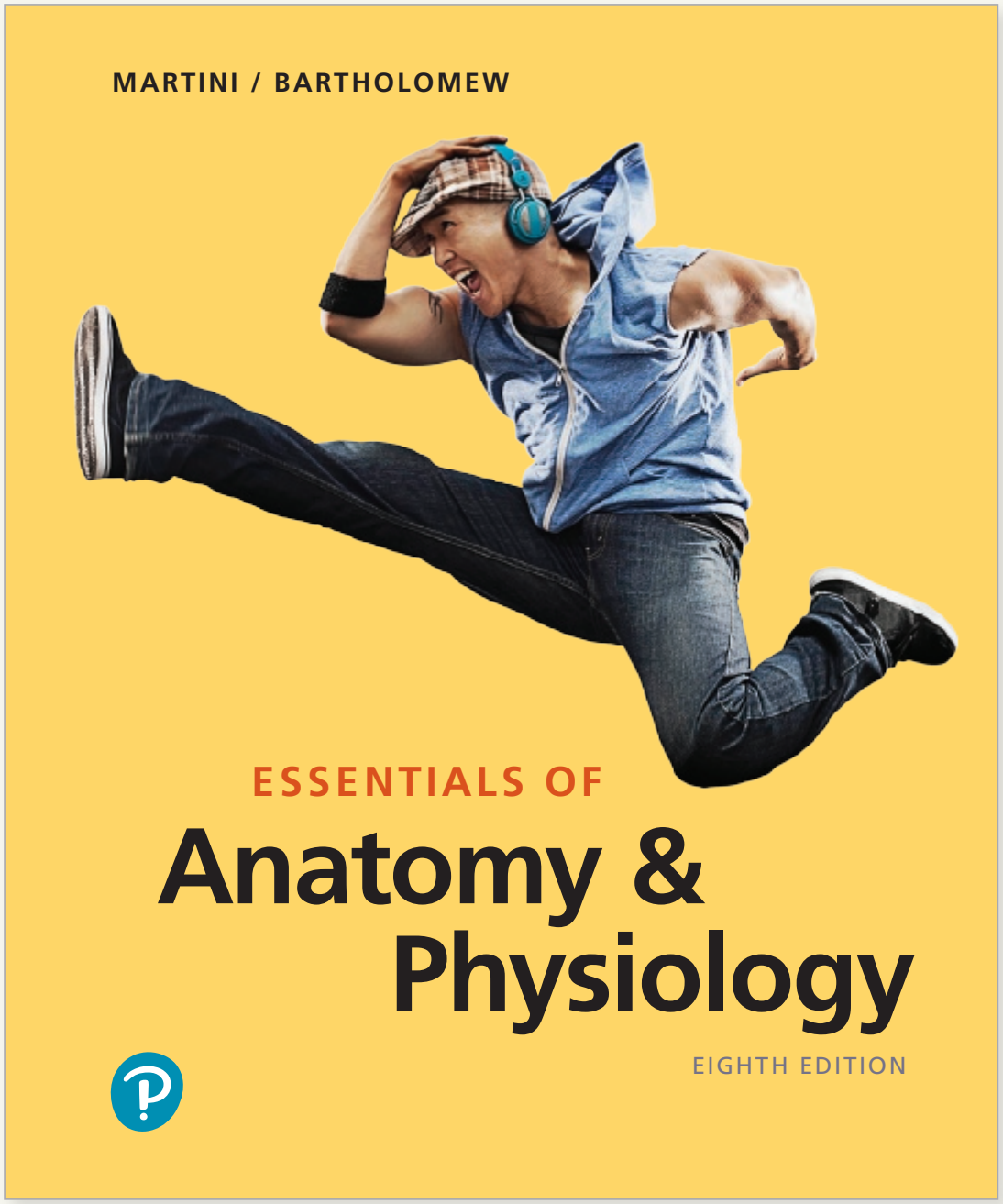

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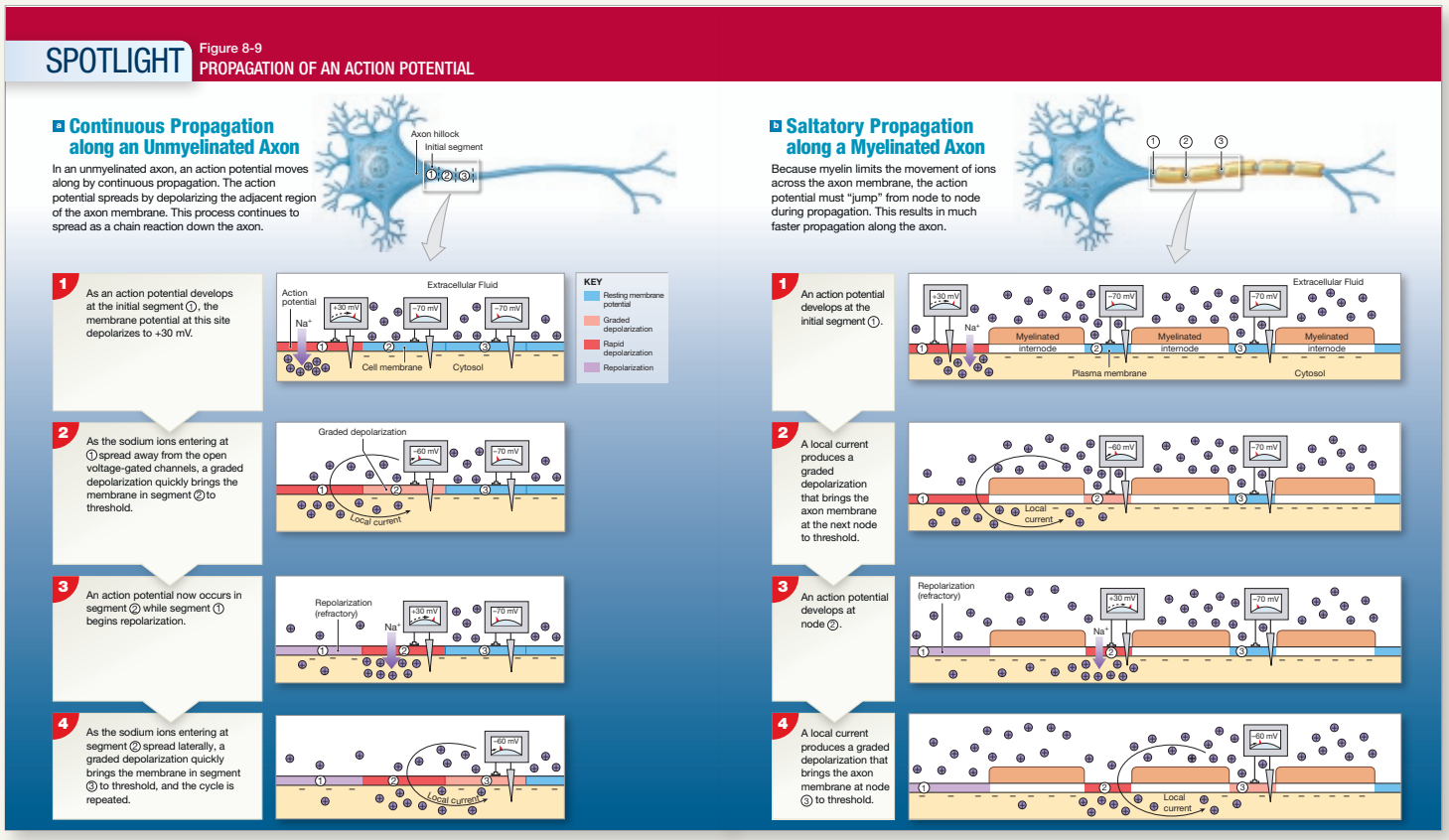

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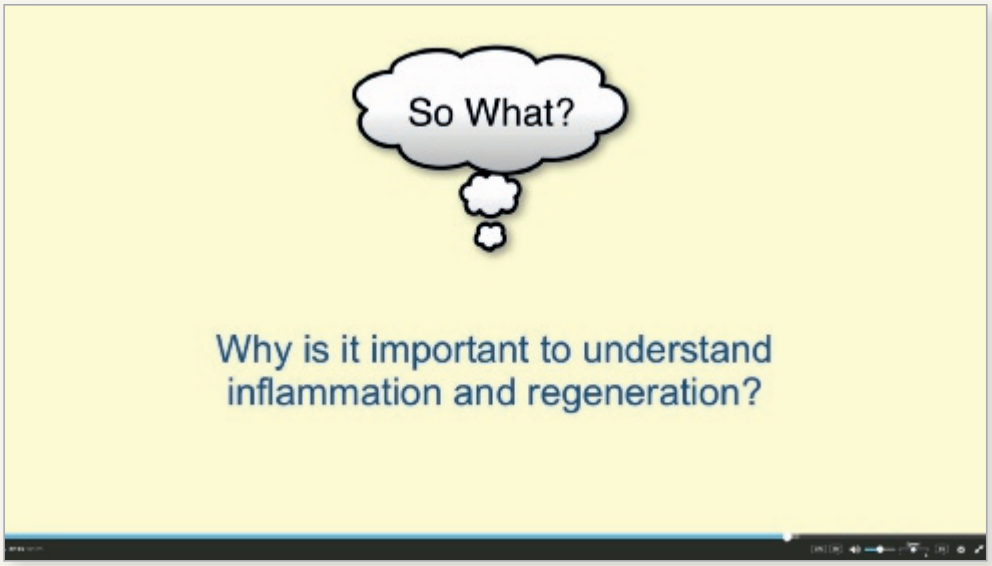

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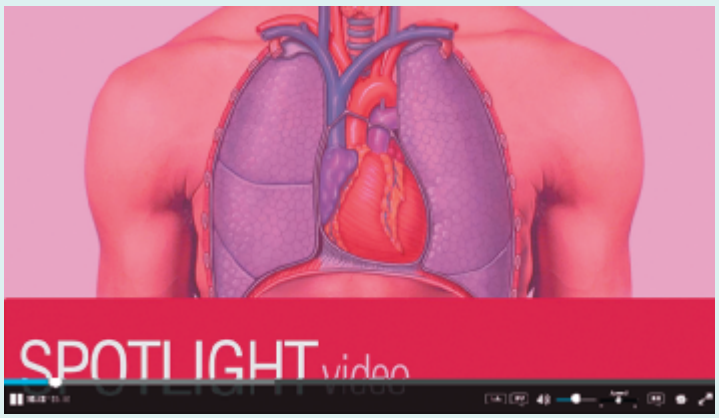
SmartArt Video: Endochondral Ossification

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

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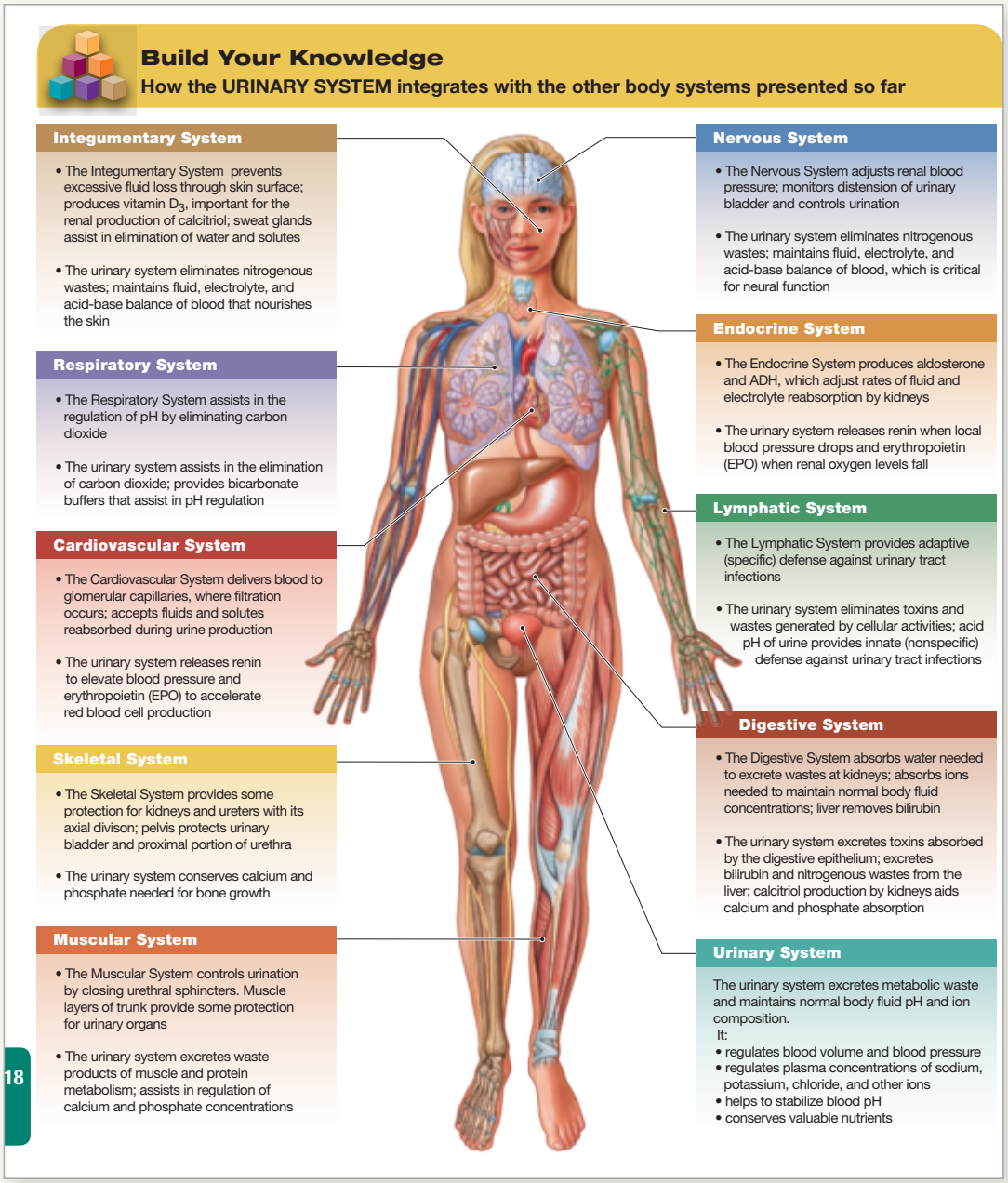

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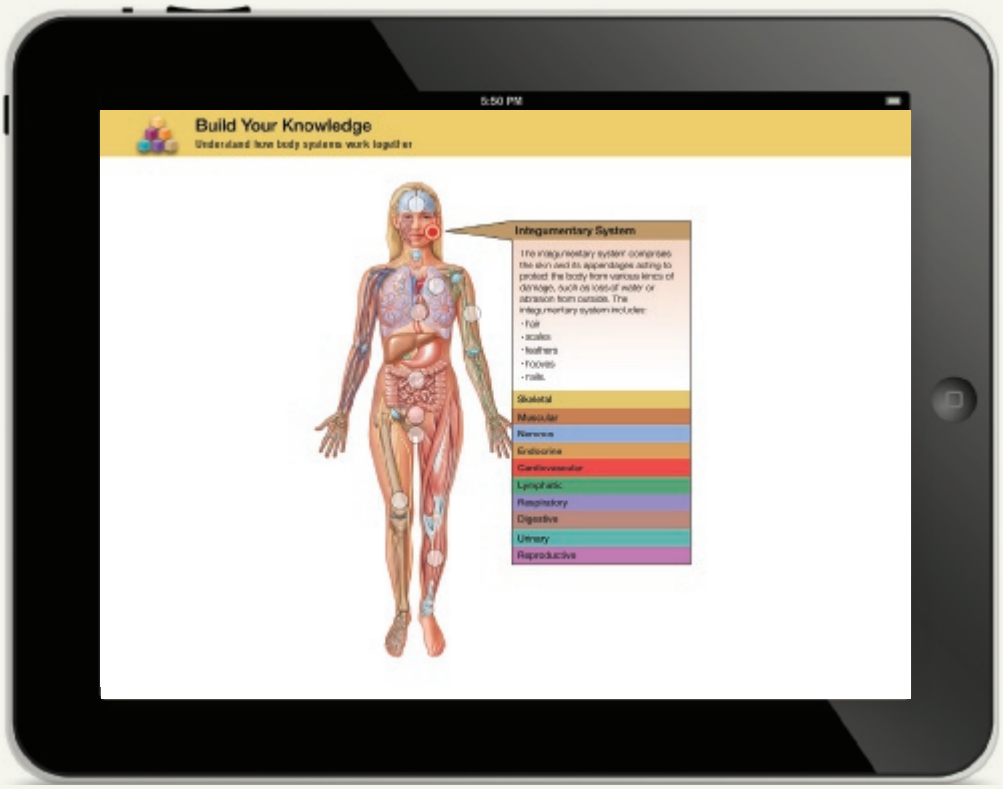

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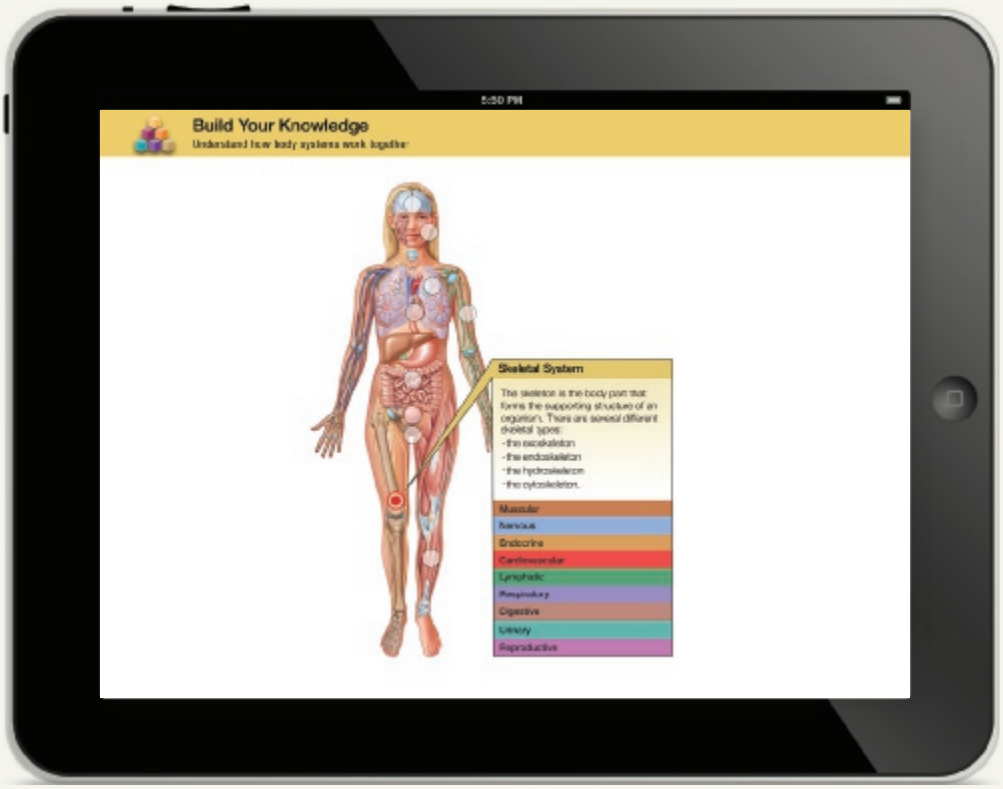

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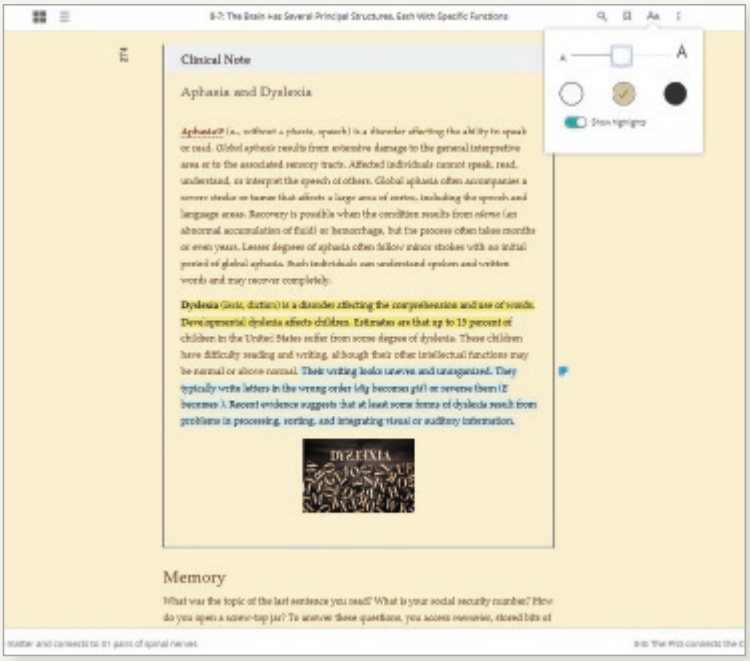

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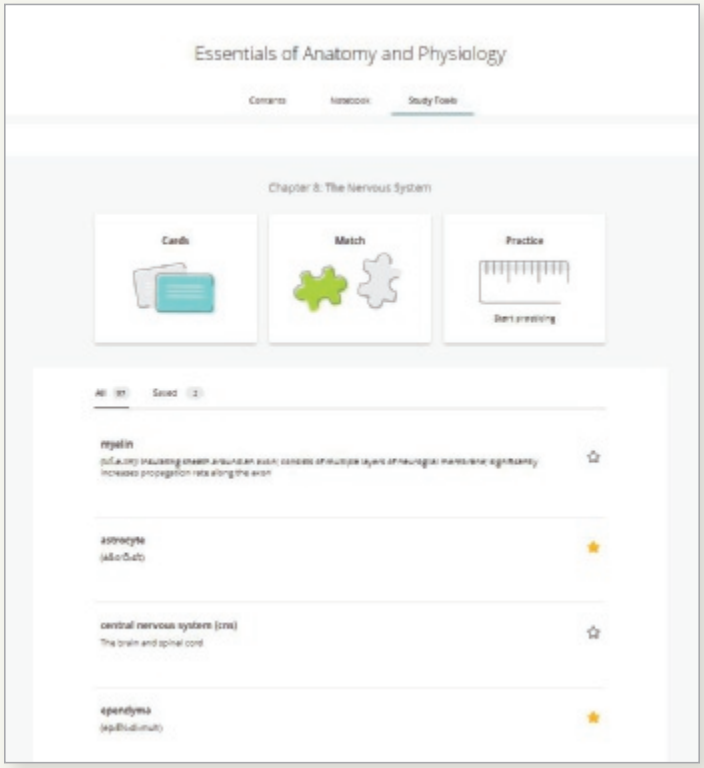

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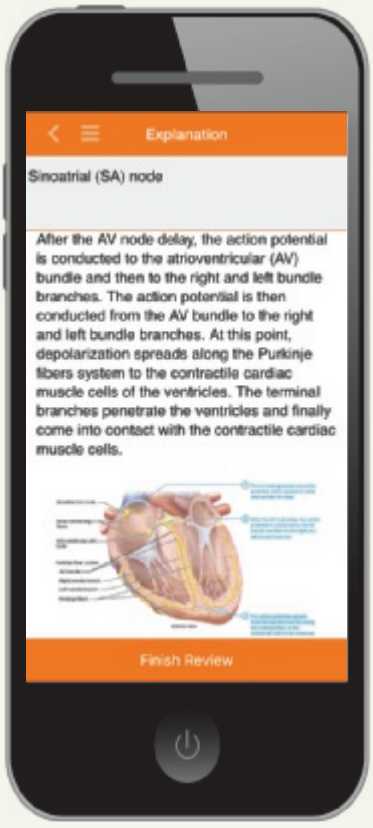

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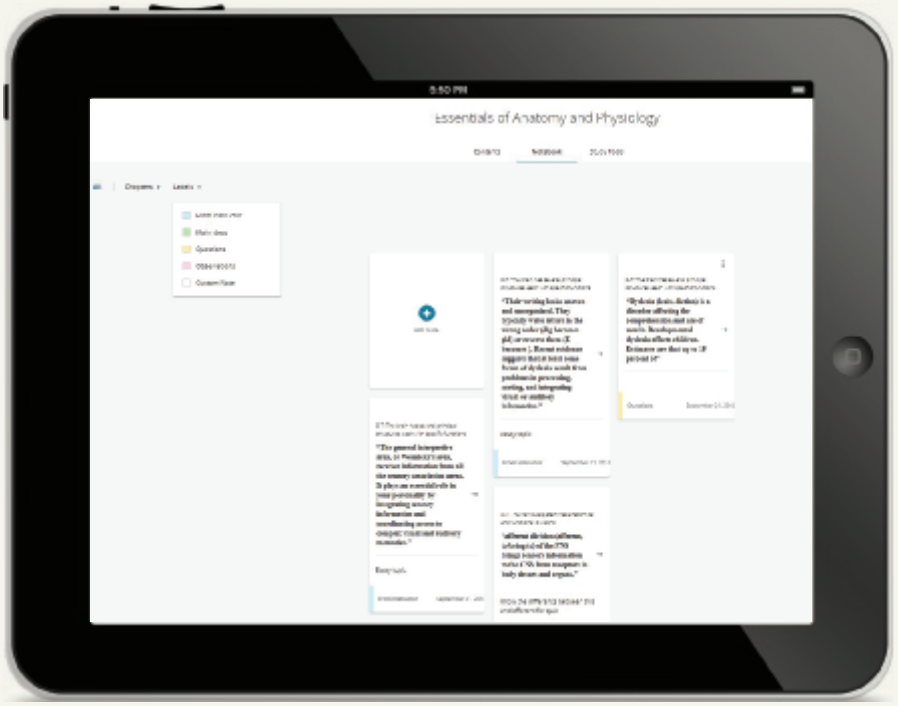

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DEDICATION

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 [II]* 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 Utricla and Saccule 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 D_3 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 [N X]*)

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 *hemiazygos*)
- Figure 13-19 A Flowchart of the Tributaries of the Superior and Inferior Venae Cavae revised (*Hemi-azygos* replaces *Hemiazygos*)

- 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*)

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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 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.

1

Physiology

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

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

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

CHECKPOINT

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

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

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

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

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

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

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

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

SPOTLIGHT

Figure 1-1
LEVELS OF ORGANIZATION

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