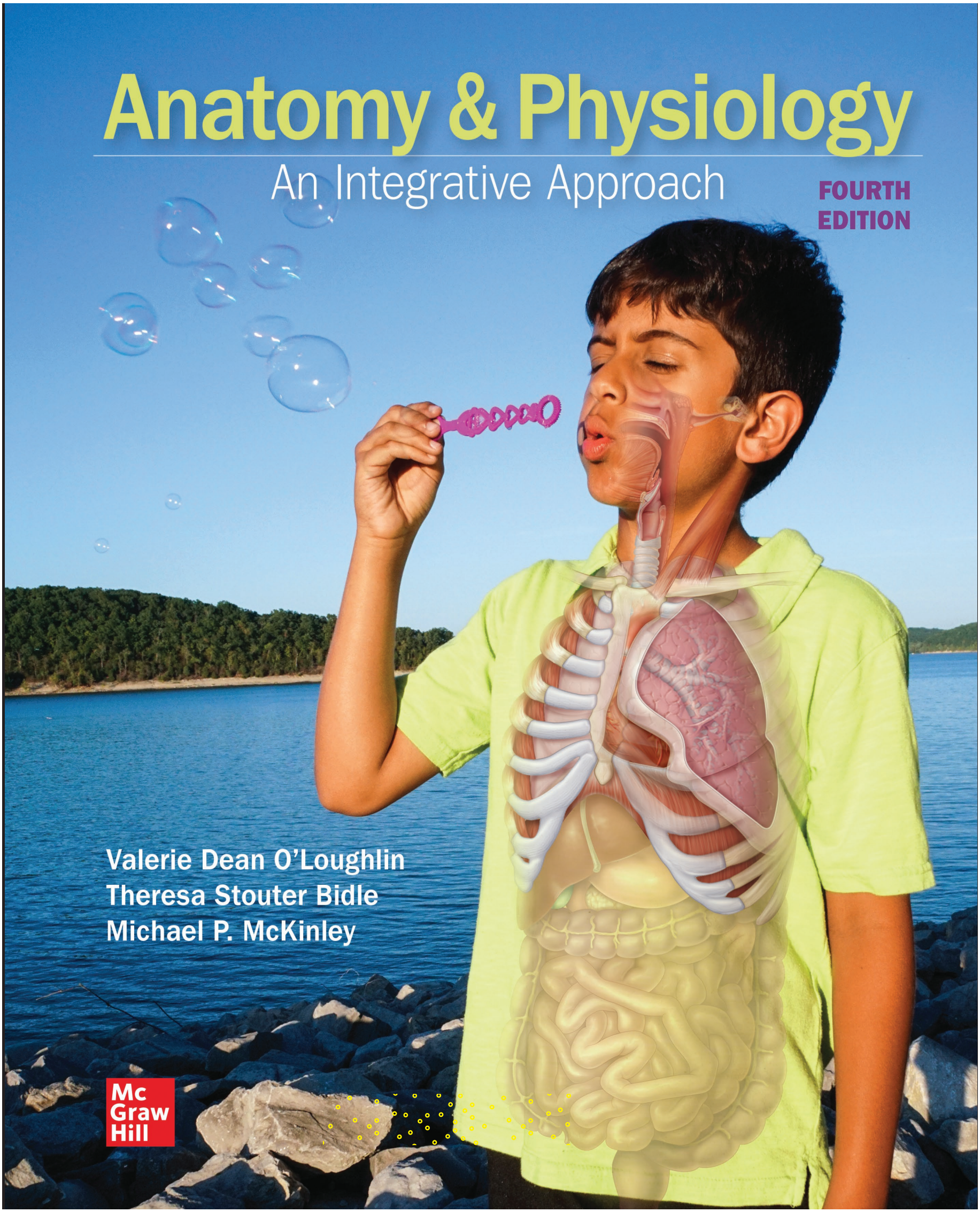
Anatomy & Physiology

An Integrative Approach

FOURTH EDITION



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ANATOMY & PHYSIOLOGY: AN INTEGRATIVE APPROACH, FOURTH EDITION

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about the authors

VALERIE DEAN O'LOUGHLIN received her undergraduate degree from the College of William and Mary, and her M.A. and Ph.D. degrees in biological anthropology from Indiana University. She is a professor of anatomy at Indiana University School of Medicine–Bloomington, where she teaches human gross anatomy to medical students, basic human anatomy to undergraduates, and human anatomy for medical imaging evaluation to undergraduate and graduate students. She also teaches a pedagogical methods course and mentors anatomy education Ph.D. students. She is a Fellow of the American Association for Anatomy (AAA), President Emeritus of the Human Anatomy and Physiology Society (HAPS), and serves on the HAPS Steering Committee. She received the AAA Basmajian Award for excellence in teaching gross anatomy and outstanding accomplishments in scholarship in education, and in 2018 was chosen for the AAA Henry Gray Distinguished Educator Award. She also received the Scholar Educator Award from Indiana University School of Medicine, which recognizes a single faculty member who approaches teaching through a scholarly lens. Valerie is coauthor of the market-leading textbook McKinley/O'Loughlin/Pennefather-O'Brien, *Human Anatomy,* 6th edition.

THERESA STOUTER BIDLE received her undergraduate degree from Rutgers University, her M.S. degree in biomedical science from Hood College in Maryland, and has completed additional graduate coursework in genetics at the National Institutes of Health and in science education at the University of Maryland. She is a professor at Hagerstown Community College, where she teaches anatomy and physiology and nutrition to pre–allied health students. She also mentors new full-time and adjunct faculty who teach anatomy and physiology. Before joining the faculty in 1990, she was the coordinator of the Science Learning Center, where she developed study materials and a tutoring program for students enrolled in science classes. Terri has been a developmental reviewer, has written supplemental materials for both textbooks and lab manuals, and is coauthor for Eckel/Ross/Bidle, *Anatomy and Physiology Laboratory Manual,* 2nd edition. She recently received the Faculty of the Year Award at Hagerstown Community College.

MICHAEL MCKINLEY received his undergraduate degree from the University of California at Berkeley, and both his M.S. and Ph.D. degrees from Arizona State University. He did his postdoctoral fellowship at the University of California Medical School–San Francisco (UCSF) in the laboratory of Dr. Stanley Prusiner, where he worked for 12 years investigating prions and prion diseases. During this time, he was also a member of the UCSF Medical School anatomy faculty and taught medical histology for 10 years. In 1991, Michael became a member of the biology faculty at Glendale Community College (GCC) in Glendale, Arizona, where he taught anatomy and physiology courses exclusively until he retired in 2012. He is a coauthor of McKinley/O'Loughlin/Pennefather-O'Brien, *Human Anatomy.* He resides in Tempe, Arizona, with his wife Jan.

©Jan McKinley

Author team: Michael McKinley, Valerie Dean O'Loughlin, and Theresa Bidle

Dedications

To my husband Bob and my daughter Erin:
Thank you for always being there for me.

—Valerie Dean O'Loughlin

With love and thanks to my husband Jay
and my daughter Stephanie for the many ways
that they have supported me during this project.

—Terri Stouter Bidle

I am indebted to Jan (my wife); Renee, Ryan, and Shaun
(my children); and Connor, Eric, Patrick,
Keighan, Aydan, and Abbygail (my grandchildren).
They are the love of my life and my inspiration always.

—Michael P. McKinley

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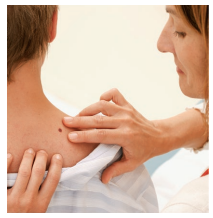
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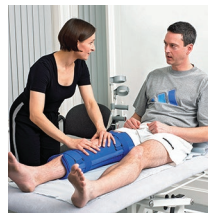

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MAINTENANCE AND REGULATION


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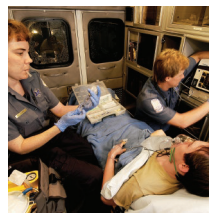
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CLINICAL VIEW BOXES

preface

Human anatomy and physiology is a fascinating subject. However, students can be overwhelmed by the complexity, the interrelatedness of concepts from different chapters, and the massive amount of material in the course. Our goal was to create a textbook to guide students on a clearly written and expertly illustrated beginner's path through the human body.

An Integrative Approach

One of the most daunting challenges that students face in mastering concepts in an anatomy and physiology course is integrating related content from numerous chapters. Understanding a topic like blood pressure, for example, requires knowledge from the chapters on the heart, blood vessels, kidneys, and how these structures are regulated by the nervous and endocrine systems. The usefulness of a human anatomy and physiology text is dependent in part on how successfully it helps students integrate these related concepts. Without this, students are only acquiring what seems like unrelated facts without seeing how they fit into the whole.

To adequately explain such complex concepts to beginning students in our own classrooms, we as teachers present multiple topics over the course of many class periods, all the while balancing these detailed explanations with refreshers of content previously covered and intermittent glimpses of the big picture. Doing so ensures that students learn not only the individual pieces, but also how the pieces ultimately fit together. This book represents our best effort to replicate this teaching process. In fact, it is the effective integration of concepts throughout the text that makes this book truly unique from other undergraduate anatomy and physiology texts.

Our goal of emphasizing the interrelatedness of body systems and the connections between form and function necessitates a well-thought-out pedagogical platform to deliver the content. First and foremost, we have written a very user-friendly text with concise, accurate descriptions that are thorough, but don't overwhelm readers with nonessential details. The text narrative is deeply integrated with corresponding illustrations drawn specifically to match the textual explanations. In addition, we have included a set of "Integrate" features that support our theme and work together to give the student a well-rounded introduction to anatomy and physiology. **Integrate: Concept Overview** figures are one- or two-page visual summaries that aggregate related concepts in a big-picture view. These comprehensive figures link multiple sections of a chapter together in a cohesive snapshot ideal for study and review. **Integrate: Concept Connections** boxes provide glimpses of how concepts at hand will play out in upcoming chapters, and also pull vital information from earlier chapters back into the discussion at crucial points when relevant to a new topic. **Integrate: Clinical View** discussions apply concepts from the surrounding narrative to practical or clinical contexts, providing examples of what can go wrong in the human body to help crystallize understanding of the "norm." **Integrate: Learning Strategy** boxes infuse each chapter with practical study tips to understand and remember information. Learning strategies include mnemonics, analogies, and kinesthetic activities that students can perform to relate the anatomy and physiology to their own bodies.

Chapter Organization

In order to successfully execute an integrative approach, foundational topics must be presented at the point when it matters most for understanding. This provides students with a baseline of knowledge about a given concept before it comes time to apply that information in a more complex situation. Topics are thus subdivided and covered in this sequence:

- **Chapter 2: Atoms, Ions, and Molecules** Most students taking an A&P course have limited or no chemistry background, which requires a textbook to provide a detailed, organized treatment of atomic and molecular structure, bonding, water, and biological macromolecules as a basis to understanding physiological processes.
- **Chapter 3: Energy, Chemical Reactions, and Cellular Respiration** ATP is essential to all life processes. A solid understanding of ATP furthers student comprehension of movement of materials across a membrane, muscle contractions, production of needed replacement molecules and structures in cells, action potentials in nerves, pumping of the heart, and removal of waste materials in the kidneys. This textbook elevates the importance of the key concept of ATP by teaching it early. We then utilize this knowledge in later chapters as needed, expanding on what has already been introduced rather than reteaching it entirely.
- **Chapter 13: Nervous System: Brain and Cranial Nerves and Chapter 14: Nervous System: Spinal Cord and Spinal Nerves** Instead of subdividing the nervous system discussion into separate central nervous system (CNS) and peripheral nervous system (PNS) chapters, nervous system structures are grouped by region. Thus, students can integrate the cranial nerves with their respective nuclei in the brain, and they can integrate the spinal cord regions with the specific spinal nerves that originate from these regions.
- **Chapter 17: Endocrine System** We have organized both the endocrine system chapter and the specific coverage of the many hormones released from endocrine glands to most effectively and efficiently guide students in understanding how this system of control functions in maintaining homeostasis. Within the chapter on the endocrine system, we provide an introduction and general discussion of the endocrine system's central concepts and describe selected representative hormones that maintain body homeostasis. The details of the actions of most other hormones—which require an understanding of specific anatomic structures covered in other chapters—are described in those chapters; for example, sex hormones are discussed in Chapter 28: Reproductive System. Learning the various hormones is facilitated by the inclusion of a "template" figure for each major hormone; each visual template includes the same components (stimulus, receptor, control center, and effectors) organized in a similar layout. In addition, information on each major hormone described in this text can be quickly accessed in the summary tables following chapter 17.

- **Chapter 21: Lymphatic System and Chapter 22: Immune System and the Body's Defense** A single chapter that discusses both the lymphatic system and immune system is overwhelming for most students. Thus, we separated the discussion into two separate chapters. The lymphatic system chapter focuses on the anatomic structures that compose the system, and provides a brief functional overview of each structure. This allows us to provide a thorough discussion and overview of the immune system in a separate chapter, where we frequently reference and integrate material from the earlier chapter.
- **Chapter 29: Development, Pregnancy, and Heredity** Coverage of heredity is included in the chapter on pregnancy and human development as a natural extension of Chapter 28: Reproductive System. This introduction will serve well as a precursor for students who follow their A&P course with a genetics course.

Changes to the Fourth Edition

Real student data points derived from thousands of SmartBook users have guided the revision process for this edition. In addition, this revision has been informed by dozens of chapter reviews by A&P instructors. The following global changes have been implemented throughout all chapters:

- Additional references were added to concepts previously covered, as well as to related material in upcoming sections and chapters, to further connect concepts.
- Art or photos added to many of the Clinical Views throughout the text.
- Terminology has been updated and definitions are added throughout.
- Learning Objectives were updated throughout the text.
- New "What Do You Think?" and "What Did You Learn?" questions were added throughout the text.
- Adjusted wording in text throughout to be more gender inclusive.
- Numbered Learning Strategies.
- Edited chapter questions to include more active learning exercises.

Chapter 1

- New section 1.1a: Anatomy, Physiology, and the Scientific Method
- Revised: figure 1.3, figure 1.7, figure 1.13
- New Clinical View 1.2: The Human Microbiome, which examines the microbiome's effect on health
- New Learning Strategy 1.3 for the serous membranes
- Revised section 1.6b (homeostasis)
- Updated Clinical View 1.5: Medical Imaging, the term *ultrasound* replacing *sonography*, updated information about DSA, reorganized discussion

Chapter 2

- Modified section 2.2a: Ions
- Edited section 2.3b: Covalent Bonds
- Revised section 2.5c: pH, Neutralization, and the Action of Buffers
- Revised: figure 2.2, figure 2.11, figure 2.15, figure 2.17
- Modified table 2.6: Protein Functions, to include six functions with images

Chapter 3

- Revised: figure 3.1, figure 3.2, figure 3.5, figure 3.6, figure 3.7, figure 3.14, figure 3.16, figure 3.18, and figure 3.19

Chapter 4

- Reorganized section 4.1a: How Cells Are Studied
- Updated section 4.3a: Passive Processes: Diffusion
- Edited section 4.3b: Passive Processes: Osmosis
- Added Concept Connection regarding solvent, solutes, and solutions.
- Edited section 4.5: Active Transport including additional content on H^+ pumps
- Added Concept Connection on concentration gradient in various cell types
- Edited section 4.6d: Membrane Junctions
- New Learning Strategy on functions of the Golgi apparatus
- Edited section 4.8 Function of the Nucleus and Ribosomes
- Revised: figure 4.1, figure 4.5, figure 4.7, figure 4.8, figure 4.13, figure 4.15, figure 4.16, figure 4.19, figure 4.23, figure 4.28, figure 4.32, figure 4.33, figure 4.35, figure 4.39

Chapter 5

- Updated text in table 5.1
- Tables 5.2 through 5.9 reformatted and reorganized to maximize size of art and photomicrographs.
- Revised: figure 5.2, figure 5.10, figure 5.12, figure 5.13
- Modified section 5.1d: Glands
- Section 5.2a: Characteristics of Connective Tissue was simplified and updated
- Updated Clinical View 5.2: What Are You Planning to Do with Your Baby's Umbilical Cord?
- Replaced the term *hemopoieis* with *hematopoiesis* in discussions of bone and blood
- Updated section 5.3 to explicitly state the general functions and characteristics of skeletal muscle tissue
- Updated Clinical View 5.4: Stem Cells to include information about induced pleuripotent stem cells
- Section 5.6b: Tissue Modification, updated the discussion of necrosis to include discussion of necrotizing fasciitis

Chapter 6

- Updated section 6.1a: Epidermis to include more detail about the types of melanin and carotene
- Revised: figure 6.5, figure 6.6, figure 6.8
- Revised section 6.1d: Functions of the Integument
- Updated Clinical View 6.3: Nail Disorders to include discussion about nail pitting (and its relationship to psoriasis) and nail clubbing
- Updated Clinical View 6.5: Psoriasis
- Updated section 6.4a: Development of the Integument and Its Derivatives
- Updated section 6.4b: Aging of the Integument to discuss p53 gene mutations
- Updated table 6.2

Chapter 7

- In section 7.2, adjusted definition and description of metaphysis, included more information about periosteum and endosteum
- Revised: figure 7.3, figure 7.5, figure 7.9, figure 7.11, figure 7.12
- Revised discussion of epiphyseal plate formation to discuss osteoprogenitor cells and osteoblasts
- Updated and clarified Clinical View 7.4: Achondroplastic Dwarfism
- Replaced the term *hemopoiesis* with *hematopoiesis* in discussions of red bone marrow
- Expanded section 7.5b: Bone Remodeling to include more detail
- Table 7.2 updated
- Updated Clinical View 7.7: Osteoporosis to include information about cancer patients

Chapter 8

- Updated table 8.2, table 8.3, table 8.4, table 8.5, table 8.6
- Revised: figure 8.2, figure 8.3, figure 8.4, figure 8.7, figure 8.8, figure 8.9, figure 8.12a, and figure 8.30
- Reorganized section 8.1b to reflect the order presented in figure 8.2
- Added new Learning Strategy 8.2
- Replaced the phrase *sex differences* with *sexually dimorphic features* in discussions of skull and pelvis in order to use more appropriate and gender-inclusive language
- Revised Clinical View 8.3: Spinal Curve Abnormalities to use the more appropriate terms *hyperkyphosis* and *hyperlordosis*
- Revised Clinical View 8.4: Herniated Discs to include more recent treatments for herniated discs
- New Learning Strategy 8.4
- In section 8.11b: Tibia and Fibula, added information about how the fibula may be used for bone grafts
- Reorganized discussion in Clinical View 8.9: Pathologies of the Foot

Chapter 9

- New Learning Strategy 9.2
- Section 9.4: Synovial Joints reorganized and edited; simplified discussion about synovial fluid, more consistent use of the term *articular capsule*
- Revised: figure 9.6, figure 9.7, figure 9.11, figure 9.15
- Updated table 9.2, table 9.4
- New Learning Strategy 9.3
- Removed discussion of hyperextension, as it is not a normal movement
- New photo for Clinical View 9.4: Shoulder Joint Dislocations, comparing normal and abnormal shoulder joints
- Included discussion about Tommy John surgery in section 9.7c: Elbow Joint
- Updated Clinical View 9.9: Arthritis to include mention of DMARDS (disease-modifying antirheumatic drugs)

Chapter 10

- Revised section 10.2b: Microscopic Anatomy of Skeletal Muscle to align with changes to figure 10.3: Structure and Organization of a Skeletal Muscle Fiber
- In section 10.2c: Innervation of Skeletal Muscle Fibers, reformatted resting conditions of synaptic knobs as bullet list
- Updated section 10.3a: Neuromuscular Junction: Excitation of a Skeletal Muscle Fiber to align steps in the text with sequence in figure 10.10
- Revised section 10.3b: Sarcolemma, T-Tubules, and Sarcoplasmic Reticulum: Excitation-Contraction Coupling to align steps in text with sequence in figure 10.11
- Edited section 10.3c: Sarcomere: Crossbridge Cycling to align steps in text with sequence in figure 10.13
- Updated table 10.1: Structural and Functional Characteristics of Different Types of Skeletal Muscle Fibers
- Updated Clinical View 10.6: Muscle Pain Associated with Exercise
- Revised section 10.7d: Muscle Fatigue
- Revised: figure 10.3, figure 10.5, figure 10.6, figure 10.7, figure 10.8, figure 10.9, figure 10.10, figure 10.11, figure 10.12, figure 10.16, figure 10.22, figure 10.23, and figure 10.28
- New figure for Clinical View 10.3: Muscular Paralysis and Neurotoxins

Chapter 11

- Revised headers and table with more accurate wording, such as “move the arm at the glenohumeral joint”
- Removed the outdated and technically incorrect term *urogenital diaphragm* from text and images
- Edited section 11.8c to clarify brachioradialis compartment classification
- Edited and clarified section 11.9a
- New Clinical View 11.9: Thigh Muscle Injuries
- Added information about variability of fibularis tertius in section 11.9c
- Revised: table 11.12, table 11.14, table 11.15, table 11.16, table 11.21
- Revised: figure 11.1, figure 11.17, figure 11.19, figure 11.22, figure 11.34
- Extensive revisions for COV figure 11.12, COV figure 11.23

Chapter 12

- Revised section 12.1b: Organization of the Nervous System to align with changes to figure 12.1: Organization of the Nervous System
- New Learning Strategy 12.1 comparing nerves to city streets
- Section 12.4: Nervous Tissue: Glial Cells, updated numbers of cells and functions of astrocytes
- Updated Clinical View 12.3: Nervous System Disorders Affecting Myelin
- New figure for Learning Strategy 12.5 on summation
- New Learning Strategy 12.3 on myelination
- Updated section 12.7: Introduction to Neuron Physiology
- Revised section 12.8a: Receptive Segment to align text on generation of an EPSP with figure 12.17: Postsynaptic Potentials in the Receptive Segment: Generation of an EPSP
- Revised section 12.8a: Receptive Segment to align text on generation of an IPSP with figure 12.18: Postsynaptic Potentials in the Receptive Segment: Generation of an IPSP

- Revised section 12.8c: Conductive Segment to align text with figure 12.20: Generation of an Action Potential: Depolarization and Its Propagation
- Revised section 12.8c: Conductive Segment to align text with figure 12.21: Generation of an Action Potential: Repolarization and Its Propagation
- Revised section 12.8d: Transmissive Segment to align steps in text with figure 12.25: Transmissive Segment: Release of Neurotransmitter
- Revised: figure 12.1, figure 12.3, figure 12.5, figure 12.6, figure 12.11, figure 12.13, figure 12.17, figure 12.18, figure 12.19, figure 12.20, figure 12.21, figure 12.22, figure 12.23, figure 12.24, figure 12.25, figure 12.26, and figure 12.28
- New figure 12.13: Electrical Energy in a Battery

Chapter 13

- Revised section 13.1: Brain Organization and Development
- Revised section 13.2a: Cranial Meninges
- New Learning Strategy 15.2 about remembering the cerebral lobes
- Revised: figure 13.6, figure 13.12, figure 13.13, figure 13.15, figure 13.22b, figure 13.26, and figure 13.32a
- Extensive reorganization and clarification of section 13.3c: Functional Areas of the Cerebrum
- Edited and updated section 13.3f: Cerebral Nuclei
- New Learning Strategy 13.5 about the cerebellar peduncles
- Updated and edited section 13.6: Cerebellum to include information about the nonmotor functions of the cerebellum
- New section 13.6c discussing how the midbrain, cerebellum, cerebral nuclei, and frontal lobes coordinate to control somatic motor movement
- Simplified section 13.7a: Limbic System
- Updated and revised Clinical View 13.12: Pathologic States of Unconsciousness

Chapter 14

- Revised Clinical View 14.1: Lumbar Puncture
- Revised section 14.4b and table 14.1 for posterior funiculus–medial lemniscal pathway
- Updated Clinical View 14.4: Shingles (Herpes Zoster)
- Updated table 14.1, table 14.4, table 14.5, and table 14.6
- Revised section 14.6d: Spinal Reflexes
- Revised: figure 14.3, figure 14.4, figure 14.11, and figure 14.22

Chapter 15

- Extensive reorganization of entire chapter to provide consistent discussion in tables, figures, and text
- Revised figure 15.1, figure 15.2, figure 15.4, figure 15.5, figure 15.6, figure 15.8, figure 15.10, figure 15.11
- Reorganized and updated table 15.1, table 15.3, table 15.5, table 15.6
- New Clinical View 15.2: Drug Binding of Nicotinic and Muscarinic Receptors
- New Clinical View 15.5: Drugs That Affect Pupil Size
- Updated and edited section 15.3a: Cranial Components regarding vagus functions
- New Learning Strategy 15.4 about parasympathetic activities
- Section 15.4b: clarification of adrenal medulla pathway in text and table 15.3
- New section 15.4c: Effector Stimulation by the Sympathetic Division to summarize the physiological changes that occur
- Simplified section 15.5a: Autonomic Plexuses
- Edited section 15.6c: Adrenergic Receptors

Chapter 16

- New introductory text for section 16.2: The General Senses
- New section 16.2b: Proprioceptors with new table
- Updated section 16.2c: Referred Pain for referred pain of the heart
- Edited section 16.3a: Olfaction: The Sense of Smell
- New Learning Strategy 16.2 on similarities of gustation and smell
- Edited section 16.4b: Eye Structure, including aligning text with figure 16.10
- Edited section 16.4c: Physiology of Vision: Refraction and Focusing of Light
- New Learning Strategy 16.3 on functions of rods and cones
- Revised: figure 16.4, figure 16.5, figure 16.10, figure 16.13, figure 16.14, figure 16.17, figure 16.21, figure 16.22, figure 16.25, figure 16.26, figure 16.27, figure 16.29, figure 16.32, figure 16.34, and figure 16.37
- New photo for Clinical View 16.2: Eye Infections
- New table 16.3: Proprioceptors with figures

Chapter 17

- Updated Clinical View 17.2: Hormone Analogs
- Updated section 17.7d: Growth Hormone: Its Regulation and Effects and aligned with steps in figure 17.13: Regulation and Action of Growth Hormone
- Updated section 17.8b: Thyroid Hormone: Its Regulation and Effects and aligned with steps in figure 17.17: Regulation and Action of Thyroid Hormone
- Revised subheadings in section 17.9a: Anatomy of the Adrenal Glands
- Updated section 17.9b: Cortisol: Its Regulation and Effects and aligned with steps in figure 17.19: Regulation and Action of Cortisol Hormone
- Updated Clinical View 17.7: The Stress Response (General Adaptation Syndrome)
- Updated section 17.10b: Pancreatic Hormones and aligned with steps in figure 17.22: Regulation and Action of Insulin and figure 17.23: Regulation and Action of Glucagon
- Revised: figure 17.1, figure 17.6, figure 17.8, figure 17.10, figure 17.11, figure 17.12, figure 17.13, figure 17.14, figure 17.16, figure 17.17, figure 17.19, figure 17.22, and figure 17.23
- New image for Clinical View 17.1: Synthesis of Eicosanoids

Chapter 18

- Throughout chapter, the term *hemopoiesis* replaced by the more appropriate term *hematopoiesis*
- Section 18.3a: Hematopoiesis edited to introduce an alternative model of hematopoiesis, and explain why we still use the classical model

- In section 18.3b: Erythrocytes, removed discussion of rouleau (abnormal accumulation of erythrocytes)
- Updated Clinical View 18.2: Anemia to include information about erythroblastic anemia
- New Learning Strategy 18.2 to remember which blood type may be safely transfused to a recipient
- Edited section 18.3c: Leukocytes
- New Learning Strategy 18.5 about blood clots
- Revised: figure 18.3, figure 18.5, figure 18.7, figure 18.8, and figure 18.10
- New figure 18.9c, a table listing which blood types can donate blood to and receive blood from other blood types
- New figure 18.11a showing electron micrograph of platelets

Chapter 19

- Edited Clinical View 19.1: Congestive Heart Failure
- Edited section 19.1b: Overview of Components to align with changes to figure 19.2: Significant Anatomic Features of the Heart
- New Learning Strategy 19.2 on how to remember heart valve locations
- Content of former figure 19.3 incorporated into COV figure 19.3: Blood Flow Through the Heart and Circulatory Routes
- Edited section 19.2b: The Pericardium
- Updated Clinical View 19.3, including title change from Teenage Athletes and Sudden Cardiac Death to Cardiomegaly and Hypertrophic Cardiomyopathy
- New photo for Clinical View 19.3: Cardiomegaly and Hypertrophic Cardiomyopathy
- Edited Clinical View 19.4: Heart Sounds and Heart Murmurs
- Edited Clinical View 19.5: Coronary Heart Disease, Angina Pectoris, and Myocardial Infarction and new photo
- New photo for Clinical View 19.6: Ectopic Pacemaker
- Former section 19.4: Coronary Vessels: Blood Supply Within the Heart Wall is now section 19.3f
- Former section 19.3f: Microscopic Structure of Cardiac Muscle is now section 19.4
- Organized section 19.4: Microscopic Structure and Metabolism of Cardiac Muscle to include two subheadings, 19.4a: Microscopic Structure of Cardiac Muscle, and 19.4b: Metabolism of Cardiac Muscle
- Added Concept Connection on atrial natriuretic peptide (ANP)
- Edited introduction to section 19.6: Stimulation of the Heart
- Revised section 19.6a: SA Nodal Cells at Rest
- Edited section 19.6b: Electrical Events at the SA Node: Initiation of the Action Potential, with two new subheadings, Autorhythmicity and Pacemaker Potential of SA Nodal Cells, and SA Nodal Cells as the Heart Pacemaker
- Edited section 19.7d: Electrocardiogram (ECG) to align with new figure 19.22: Integration of Heart Activity and an ECG
- Updated section 19.8b: Events of the Cardiac Cycle and aligned with steps in figure 19.23: Phases of the Cardiac Cycle
- New Learning Strategy 19.7 on cardiac cycle, with new image
- Revised: figure 19.2, figure 19.4, figure 19.7, figure 19.9, figure 19.10, figure 19.13, figure 19.14, figure 19.15, figure 19.16, figure 19.18, figure 19.19, figure 19.23, figure 19.24, figure 19.25, figure 19.26, and figure 19.29
- New figure 19.22: Integration of Heart Activity and an ECG
- New figure 19.27: The Frank-Starling Law

Chapter 20

- Edited Clinical View 20.1: Atherosclerosis
- Modified section 20.6b: Hormonal Regulation of Blood Pressure
- Edited section 20.8b: Characteristics of the Pulmonary Circulation
- Edited section 20.10a: Head and Neck, the subsection "Venous Drainage"
- Section 20.10c: Thoracic Organs and Spinal Cord, new title and new content on blood flow to spinal cord
- New Learning Strategy 20.5 for location of cephalic and basilic veins
- New Learning Strategy 20.6 on relationship of great saphenous vein and great toe
- Revised figure 20.4, figure 20.10, figure 20.14, and figure 20.29

Chapter 21

- Updated terminology, replacing the term *lymphatic* with *lymphoid* throughout the chapter
- Edited section 21.4c: Lymphoid Nodules and MALT
- Revised: figure 21.1, figure 21.6, figure 21.8, and figure 21.9
- New image for Concept Connection on lacteals

Chapter 22

- Throughout the chapter, replaced the term *lymphatic* with *lymphoid*
- Throughout chapter, replaced term *humoral immunity* with *antibody-mediated immunity*
- Throughout the chapter, replaced the term *innate immune system* with *innate immunity*, and replaced the term *adaptive immune system* with either *adaptive immunity* or *adaptive immune response*
- Updated chapter introduction
- Edited table 22.2: Major Categories of Cytokines
- Edited section 22.2c: Comparison of Innate Immunity and Adaptive Immunity
- Changed title of section 22.3a to First Line of Defense: Preventing Entry
- Added new section 22.3b: Second Line of Defense: Nonspecific Internal Defenses
- Modified section 22.3c: Nonspecific Internal Defenses: Cells
- Updated section 22.3d: Nonspecific Internal Defenses: Antimicrobial Proteins, including aligning steps in text with figure 22.4: Effects of Interferon Against a Virus
- Modified section 22.3e: Nonspecific Internal Defenses: Inflammation to have steps that align with figure 22.6
- Edited table 22.3: First Line of Defense: Preventing Entry of Pathogens
- Updated Clinical View 22.2: Applying Ice for Acute Inflammation
- Edited section 22.3f: Nonspecific Internal Defenses: Fever
- Updated Clinical View 22.3: Chronic Inflammation

- Changed title for Clinical View 22.4 to General Causes of Autoimmune Disorders
- Edited Section 22.4a: Antigens
- Edited section 22.4c: Antigen-Presenting Cells and MHC Molecules
- Updated Learning Strategy 22.5 for MHC interaction with T-lymphocytes
- Edited introduction to section 22.5: Formation and Selection of T-Lymphocytes in Primary Lymphoid Structures
- Edited section 22.5b: Selection and Differentiation of T-Lymphocytes
- Edited introduction to section 22.6: Activation and Clonal Selection of Lymphocytes
- Modified section 22.6a: Activation of T-Lymphocytes
- Modified introduction to section 22.7: Effector Response at Infection Site
- Integrated content in section 22.7a: Effector Response of T-lymphocytes with discussion of NK cells
- Clinical View 22.7: added content on herd immunity and changed title to Vaccinations and Herd Immunity
- Updated figures in table 22.1: Major Categories of Infectious Agents
- Revised: figure 22.1, figure 22.2, figure 22.4, figure 22.5, figure 22.6, figure 22.7, figure 22.8, figure 22.10, figure 22.11, figure 22.12, figure 22.13, figure 22.14, figure 22.15, figure 22.16, figure 22.18, and figure 22.20

Chapter 23

- Throughout the chapter replaced the term *alveolar gas exchange* with *pulmonary gas exchange*
- Throughout the chapter replaced the term s*ystemic gas exchange* with *tissue gas exchange*
- Moved section 23.3a: Larynx to become section 23.2d, so that larynx is discussed with upper respiratory tract
- Moved Clinical View on Cystic Fibrosis to section 23.1
- Clinical View 23.5: added content and changed title to Tracheotomy and Cricothyrotomy
- Deleted table 23.1: Structures of the Lower Respiratory Tract
- Edited Clinical View 23.8: Pneumonia
- Edited section 23.3c: Respiratory Zone: Respiratory Bronchioles, Alveolar Ducts, and Alveoli
- Edited section 23.3d: Respiratory Membrane
- Edited section 23.4a: Gross Anatomy of the Lung
- Combined Clinical View on Lung Cancer with Clinical View 23.9 on Smoking and changed title to Smoking and Lung Cancer
- Edited introduction to section 23.5: Respiration: Pulmonary Ventilation
- Integrated former table 23.2: Respiration Processes into figure 23.18: Overview of Respiration
- Added Learning Strategy 23.2 on pulmonary ventilation
- Edited section 23.5b: Mechanics of Breathing, including integration with updated figure 23.21: Pressure Gradients and the Respiratory System and integration of steps in text to align with updated figure 23.22: Volume and Pressure Changes Associated with the Mechanics of Quiet Breathing
- Incorporated the content of former table 23.3: Changes Associated with Quiet Breathing into section 23.5b: Mechanics of Breathing
- Edited section 23.5c: Nervous Control of Breathing
- Added new Learning Strategy 23.3 on respiratory center
- Updated Clinical View 23.12: Apnea including new photo
- Edited heading for section 23.5d to read Pressure Gradients, Resistance, and Airflow
- Edited section 23.5d: Pressure Gradients, Resistance, and Airflow to integrate content with concepts on pressure gradients, resistance, and blood flow
- Added image to Concept Connection on blood pressure gradients, resistance, and blood flow
- Added Learning Strategy 23.5 on compliance
- Changed heading for section 23.5e from Pulmonary and Alveolar Ventilation to Minute Volume and Alveolar Ventilation and edited content
- Changed heading for section 23.5f from Volume and Capacity to Measuring Respiratory Function and edited content
- Edited section 23.6a: Chemical Principles of Gas Exchange
- Edited section 23.6b: Pulmonary Gas Exchange to align with new figure 23.28
- New introduction for section 23.6c: Tissue Gas Exchange
- Edited Clinical View 23.15: Emphysema
- Edited section 23.7c: Hemoglobin as a Transport Molecule
- Revised: figure 23.1, figure 23.2, figure 23.3, figure 23.5, figure 23.6, figure 23.12, figure 23.17, figure 23.18, figure 23.19, figure 23.21, figure 23.22, figure 23.23, figure 23.25, figure 23.27, figure 23.28, figure 23.29, figure 23.30, figure 23.32, figure 23.33, figure 23.34, and figure 23.35
- New figure 23.24: Factors That Influence Airflow
- New Figure 23.26: Partial Pressure
- New photo for Clinical View 23.14: Decompression Sickness and Hyperbaric Oxygen Chambers
- New photo for Clinical View 23.17: Measuring Blood Oxygen Levels with a Pulse Oximeter
- New table 23.1: Gas Laws Associated with Respiration, with images

Chapter 24

- Edited Clinical View 24.2: Renal Ptosis and Hydronephrosis and updated figure
- New photo in Clinical View 24.2: Kidney Variations and Anomalies
- Added image for Learning Strategy 24.3 for filtration membrane as a sieve
- Edited section 24.5e: Regulation of Glomerular Filtration Rate
- Added image to Learning Strategy 24.4 on tubular fluid
- Edited section 24.6b: Transport Maximum and Renal Threshold
- New figure 24.18: Reclaiming Filtered Protein
- Edited section 24.6d: Substances with Regulated Reabsorption
- Edited section 24.6f: Establishing the Concentration Gradient
- New Learning Strategy 24.6 on transitional epithelium
- New image for Clinical View 24.7: Renal Calculi

- Updated section 24.8b: Urinary Tract (Ureters, Urinary Bladder, Urethra)
- Added image to Clinical View 24.8: Urinary Tract Infections
- Revised: figure 24.13, figure 24.15, figure 24.17, figure 24.19, figure 24.20, figure 24.21, figure 24.23, figure 24.25, figure 24.27, and figure 24.28

Chapter 25

- New photo for Clinical View 25.1: Intravenous (IV) Solution
- Edited section 25.2c: Regulation of Fluid Balance
- New Clinical View 25.4: Cerebral Edema
- Edited section 25.4a:: Angiotensin II including aligning steps with figure 25.8 Renin-Angiotensin System
- Edited section 25.4b: Antidiuretic Hormone including aligning steps with figure 25.9: Actions and Effects of Antidiuretic Hormone
- Edited Section 25.4c: Aldosterone including aligning steps with figure 25.10: Actions and Effects of Aldosterone
- Edited section 25.4d: Atrial Natriuretic Peptide including aligning steps with figure 25.11: Actions and Effects of Atrial Natriuretic Peptide
- Edited section 25.5a: Categories of Acid
- Edited section 25.5b: The Kidneys and Regulation of Fixed Acids
- Added image to Learning Strategy 25.4 on chemical buffers
- Changed title of section 25.6a to Overview of Acid-Base Disturbances and edited content
- Edited section 25.6b: Respiratory-Induced Acid-Base Disturbances
- Edited section 25.6c: Metabolic-Induced Acid-Base Disturbances
- Changed title of section 25.6d to Compensation for Acid-Base Disturbances and edited content
- Edited Clinical View 25.9: Arterial Blood Gas (ABG) and Diagnosing Different Types of Acid-Base Disturbances
- Revised: figure 25.2, figure 25.3, figure 25.5, figure 25.8, figure 25.9, figure 25.10, figure 25.11, figure 25.12, and figure 25.14

Chapter 26

- Changed title of section 26.2 to Upper Gastrointestinal Tract and Associated Accessory Digestive Structures
- Changed title of section 26.2a to Overview
- Changed title of section 26.3 to Lower Gastrointestinal Tract and Associated Accessory Digestive Organs
- Changed title of section 26.3a to Overview
- Added image for Learning Strategy 26.1 for structures that are retroperitoneal
- Edited section 26.1: Introduction to the Digestive System (Introductory paragraph)
- Edited section 26.1d: Overview of the Regulation of the Digestive System, including adding content on receptors
- Added image to Concept Connection on cranial nerves involved in regulating digestive activities
- Edited section 26.1e: Serous Membranes of the Abdominal Cavity
- Edited section 26.2c: Pharynx and Esophagus
- Added image to Clinical View 26.4: Gastric Bypass
- Updated Clinical View 26.9: Gallstones
- Edited Clinical View 26.10: Pancreatic Cancer
- Revised section 26.3d: Large Intestine to include content on microbiota
- Added image to Clinical View 26.16: Celiac Disease (Gluten-Sensitive Enteropathy)
- Edited section 26.4a Carbohydrate Digestion including aligning steps with figure 26.26: Carbohydrate Digestion in the Small Intestine
- Edited section 26.4b: Protein Digestion including aligning steps with figure 26.27: Protein Digestion in the Small Intestine
- Edited section 26.4c: Lipid Digestion including aligning steps with figure 26.28: Lipid Digestion and Absorption in the Small Intestine
- Revised: figure 26.2, figure 26.6, figure 26.7, figure 26.10, figure 26.11, figure 26.12, figure 26.14, figure 26.16, figure 26.20, figure 26.24, figure 26.25, and figure 26.29
- Updated table 26.1: Primary Hormones That Control Digestion

Chapter 27

- Added content to the introduction regarding the Mediterranean diet
- Throughout chapter, replaced the term *absorptive state* with f*ed (absorptive) state*, and replaced the term *post-absorptive state* with *fasting (postabsorptive) state*
- Edited section 27.2a: Carbohydrates
- Edited section 27.2c: Proteins
- Edited section 27.3a: Vitamins
- Updated Clinical View 27.2: Iron Deficiency
- Updated Clinical View 27.3: Obesity
- Revised figure 27.2, figure 27.4, and figure 27.5

Chapter 28

- In Section 28.1, added a paragraph explaining how gender identity and genetic sex might not align and that we will try to use gender-inclusive terms throughout this chapter
- In section 28.2, description of meiosis was clarified
- Simplified discussion of the ligaments in section 28.3a: Ovaries
- Section 28.3b: Oogenesis and the Ovarian Cycle extensively revised to better describe the length of the ovarian cycle, as well as the preantral and antral stages of folliculogenesis
- Section 28.3e: External Genitalia edited to include information about shape and structure of the hymen
- In section 28.3g: Female Sexual Response, added hypotheses about the biologic purpose of the female orgasm
- Updated Clinical View 28.5: Cervical Cancer to include information about high-risk HPV and treatment procedures
- Updated Clinical View 28.7: Contraception Methods
- New Learning Strategy 28.4 about spermatogenesis
- Updated section 28.5: Development and Aging of Female and Male Reproductive Systems

- Revised: figure 28.2, figure 28.5, figure 28.6, figure 28.7, figure 28.8, figure 28.11, and figure 28.14
- Updated Clinical View 28.11: Circumcision, to discuss female genital mutilation and how it should not be equated with male circumcision.

Chapter 29

- In section 29.1, added a footnote to clarify variation in the length of a pregnancy
- Reorganized section 29.2: Pre-Embryonic Period
- Updated Clinical View 29.1: Infertility and Infertility Treatments to clarify that not all *in vitro* fertilization techniques involve injecting a sperm into an oocyte
- New Clinical View 29.3: Amniocentesis and Chorionic Villus Sampling
- Updated section 29.3c: Organogenesis to include explicit definition of *peak development period*
- In section 29.5b: Hormonal Changes, removed discussion about human chorionic thyrotropin, as research has shown that it is hCG that performs the thyrotropic effects
- Former Clinical View 29.4: Hyperemesis Gravidarum was deleted and pertinent information incorporated directly into the text
- New Clinical View 29.9: Vaginal Bacteria and the Infant Microbiome
- New Clinical View 29.10: Preterm (Premature) Birth
- Footnote added to section 29.9: Heredity, stating this discussion was intentionally left brief, but more detailed genetic information may be found online
- Revised table 29.1, table 29.2, and table 29.3
- Revised: figure 29.2

We Welcome Your Input!

We hope you enjoy reading this textbook, and that it becomes central to mastering the concepts in your anatomy and physiology course. This text is a product that represents over 90 years of combined teaching experience in anatomy and physiology. We are active classroom instructors, and are well aware of the challenges that current students face in mastering these subjects. We have taken what we have learned in the classroom and have created a textbook truly written for students.

Please let us know what you think about this text. We welcome your thoughts and suggestions for improvement, and look forward to your feedback!

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Finally, we could not have performed this effort were it not for the love and support of our families: Bob and Erin O'Loughlin; and Jay and Stephanie Bidle—thank you and we love you! We are blessed to have you all.

Many instructors and students across the country have positively affected this text through their careful reviews of manuscript drafts, art proofs, and page proofs, as well as through class tests and through their attendance at focus groups and symposia. We gratefully acknowledge their contributions to this text.

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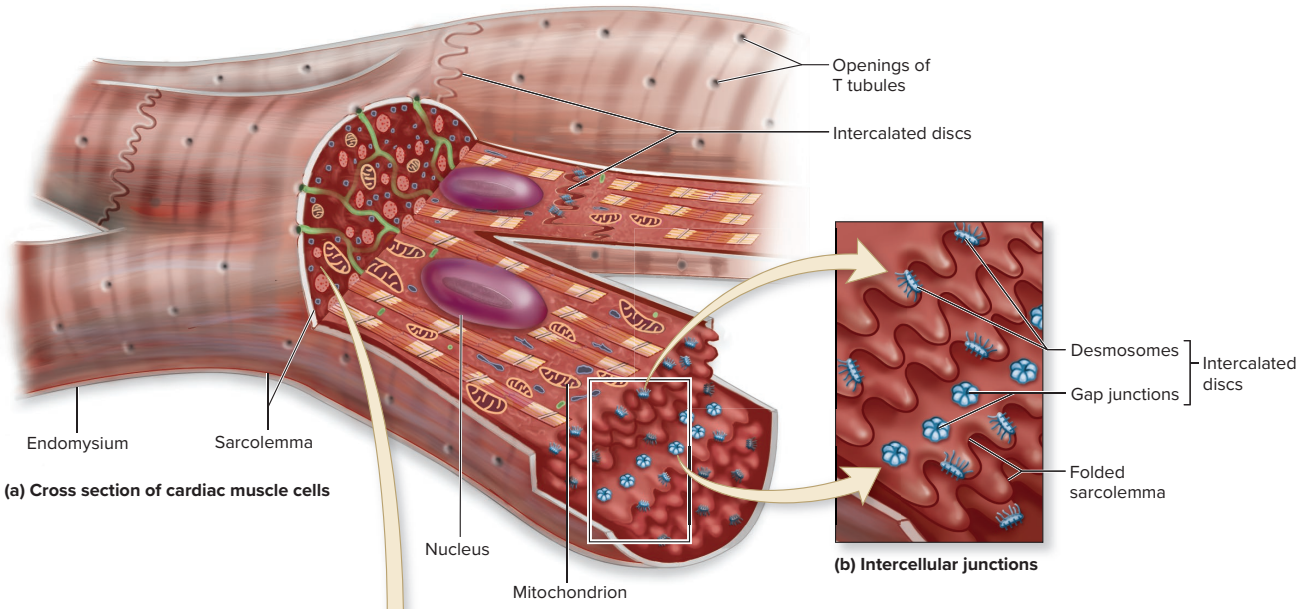
guided tour

Fully Integrated Content and Pedagogy

Anatomy and Physiology: An Integrative Approach is structured around a tightly integrated learning system that combines illustrations and photos with textual descriptions; focused discussions with big-picture summaries; previously learned material with new content; factual explanations with practical and clinical examples; and bite-sized topical sections with multitiered assessment.

Unparalleled Art Program

In a visually oriented subject like A&P, quality illustrations are crucial to understanding and retention. The brilliant illustrations in *Anatomy and Physiology: An Integrative Approach* have been carefully rendered to convey realistic, three-dimensional detail while incorporating pedagogical conventions that help deliver a clear message. Each figure has been meticulously reviewed for accuracy and consistency, and precisely labeled to coordinate with the text discussions.



(a) Cross section of cardiac muscle cells

(b) Intercellular junctions

(c) Longitudinal view of cardiac muscle cell

(d) Longitudinal section of cardiac muscle

Victor P. Eroschenko

Rich Detail

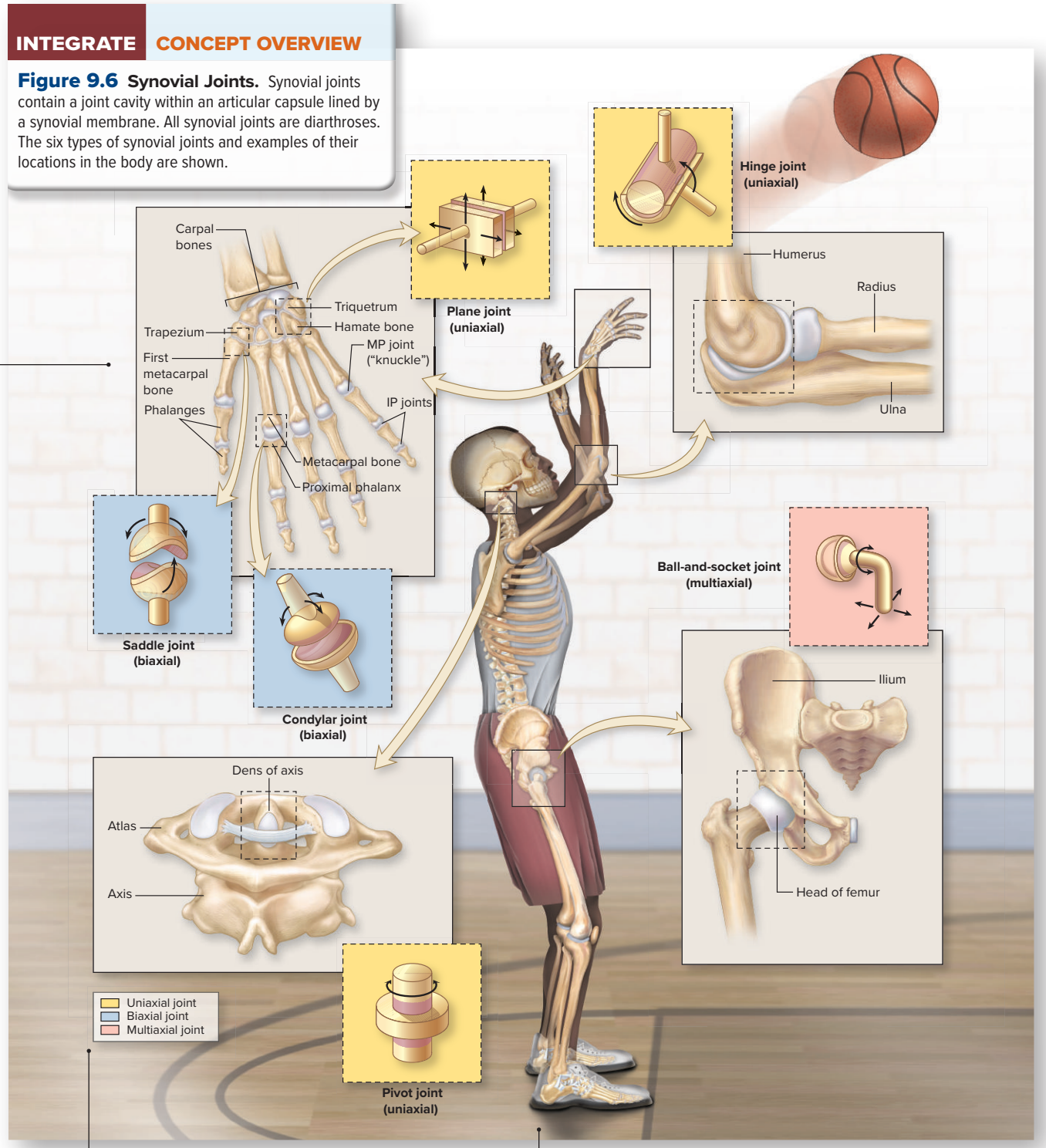
Vibrant colors and three-dimensional shading make it easy to envision body structures and processes.

Photographs

Atlas-quality micrographs and cadaver images are frequently paired with illustrations to expose students to the appearance of real anatomic structures.

INTEGRATE **CONCEPT OVERVIEW**

Figure 9.6 Synovial Joints. Synovial joints contain a joint cavity within an articular capsule lined by a synovial membrane. All synovial joints are diarthroses. The six types of synovial joints and examples of their locations in the body are shown.



Multilevel Perspective
Microscopic structures are connected to macroscopic views to show changes in perspective between increasingly detailed drawings.

Color Coding
Many figures use color coding to organize information and clarify concepts for visual learners.

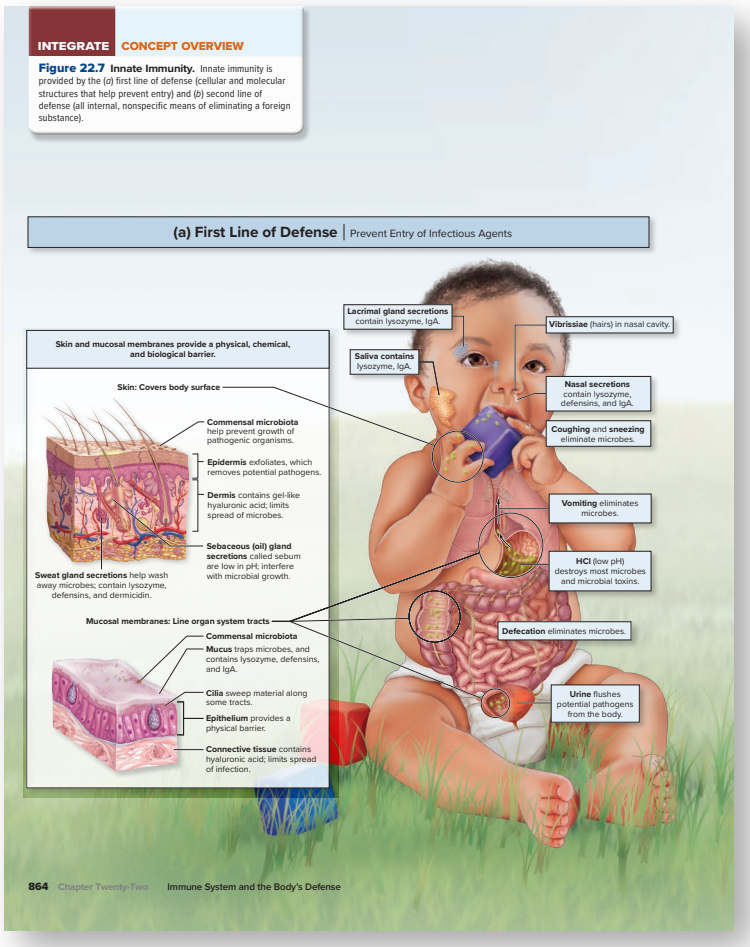
Real-Life Context
Illustrations include depictions of realistic people and situations to make figures more relevant and memorable.

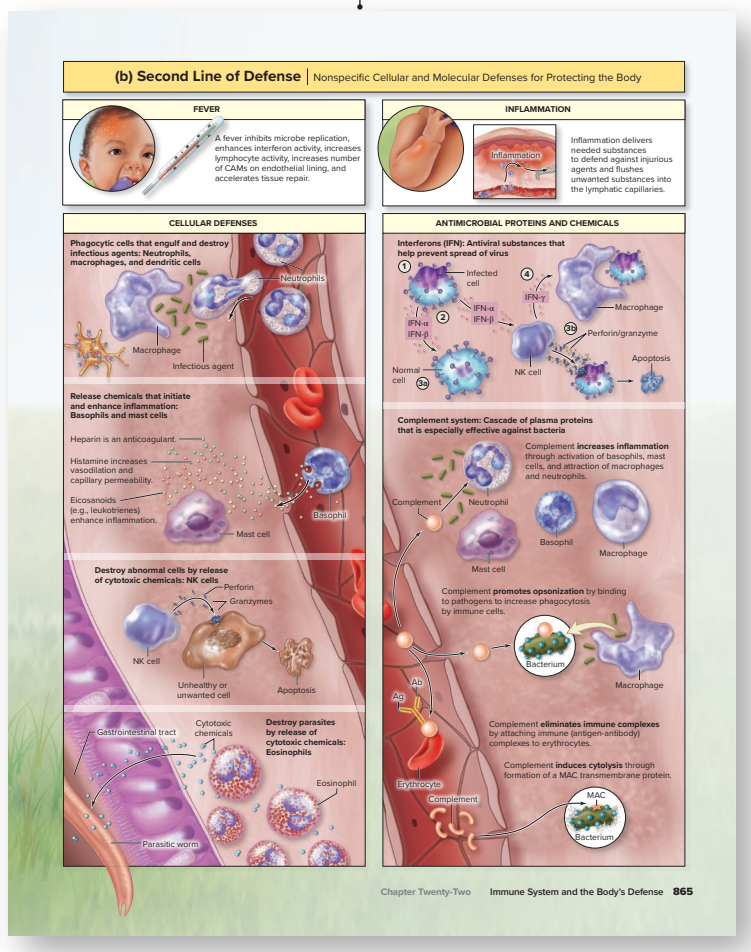
Integrative Visual Summaries

The groundbreaking **Integrate: Concept Overview** figures combine multiple concepts into one big-picture summary. These striking, visually dynamic presentations offer a review of previously covered material in a creatively designed environment to emphasize how individual parts fit together in the understanding of a larger mechanism or concept.

Integrate: Concept Overview Figures

Multifaceted concepts are brought together in captivating one- or two-page visual presentations.



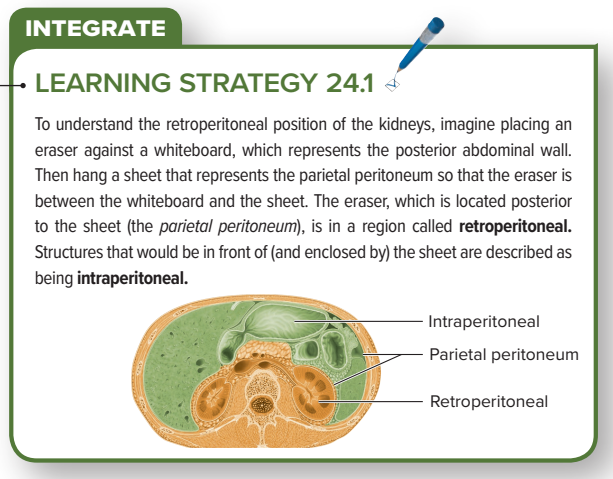


Practical and Clinical Applications

Integrating familiar contexts into the study of A&P makes seemingly abstract concepts more relevant and memorable. **Integrate: Learning Strategy** boxes provide simple, practical advice for learning the material. **Integrate: Clinical View** readings offer insight on how complex physiologic processes or anatomic relationships affect body functioning.

Learning Strategies

Classroom tried-and-tested learning strategies offer everyday analogies, mnemonics, and useful tips to aid understanding and memory.



Clinical View

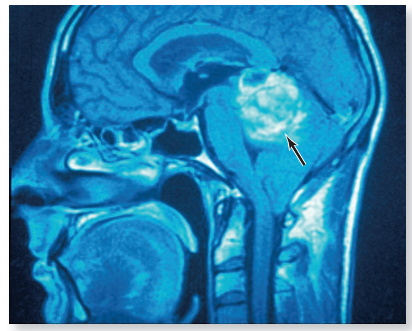
Interesting clinical sidebars reinforce or expand upon the facts discussed within the narrative. The clinical views are adjacent to the facts in the narrative (rather than placed at the end of the chapter) so students may immediately make connections between the narrative and real-life applications.

INTEGRATE

CLINICAL VIEW 12.2

Tumors of the Central Nervous System

Neoplasms resulting from unregulated cell growth, commonly known as **tumors,** sometimes occur within the CNS. A tumor that originates within the organ where it is found is called a **primary tumor.** Because most mature neurons cannot undergo mitosis, primary CNS tumors typically originate in supporting tissues within the brain or spinal cord that have retained the capacity to undergo mitosis: the meninges (protective membranes of the CNS) or the glial cells. Glial cell tumors, termed **gliomas,** may be either relatively benign and slow-growing or malignant (capable of metastasizing or spreading to distant sites).



A midsagittal magnetic resonance imaging (MRI) of the head shows a glioma (arrow).
©Simon Fraser/Science Source

Concept Integration

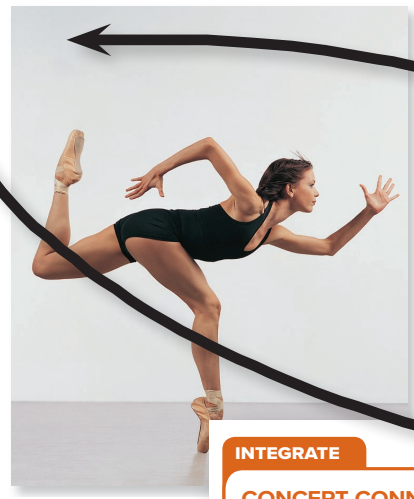
Both backward and forward references are supplied throughout the text to remind the reader of the significance of previously covered material, and to foreshadow how knowledge of a topic at hand will come into play in a later discussion. Simple references appear in the flow of the text, while more detailed refreshers are presented in **Integrate: Concept Connection** boxes.

11.9c Leg Muscles That Move the Ankle, Foot, and Toes

LEARNING OBJECTIVE

30. Compare and contrast the muscles of the three compartments of the leg and their actions.

The muscles that move the ankle, foot, and toes are housed within the leg and are called the **crural muscles.** Some of these muscles also help flex the leg. The deep fascia partitions the leg musculature into three compartments (anterior, lateral, and posterior), each with its own blood supply and innervation, and muscles in the same compartment tend to share common actions (see figure 11.23).



Chris Nash/DigitalVision/Get

INTEGRATE

CONCEPT CONNECTION

You will learn in section 20.5a that venous circulation of the lower limbs is reliant upon the muscular system. Specifically, the regular contraction and relaxation of the leg muscles works as a skeletal muscle "pump" to propel venous blood from the lower limb back to the torso. When the lower limbs are immobile for long periods of time (e.g., during long plane rides or when a person is bedridden), the skeletal muscle pump is inactive, and the risk of developing a blood clot in the lower limb veins increases (see Clinical View 20.6: "Deep Vein Thrombosis").

INTEGRATE

CLINICAL VIEW 20.6

Deep Vein Thrombosis

Deep vein thrombosis (throm-bō'sis; a clotting) **(DVT)** refers to a **thrombus** (blood clot) in a vein. The most common site for the thrombus is a vein in the sural region (calf). DVT typically occurs in individuals with heart disease or those who are inactive or immobile for a long period of time, such as bedridden patients. Even healthy individuals who have been on a long airline trip may develop DVT.

Initial signs of DVT include fever, tenderness and redness in the affected area, severe pain and swelling in the areas drained by the affected vein, and rapid heartbeat. The most serious complication of DVT is a **pulmonary embolus** (em'bō-lūs; a plug), in which a blood clot breaks free and is transported to the lung, eventually blocking a branch of the pulmonary artery and potentially causing respiratory failure and death. If a DVT is diagnosed, the patient is given anticoagulation medication, such heparin or warfarin, to help prevent further clotting and break up the existing clot.

Integrated Assessments

Throughout each chapter, sections begin with learning objectives and end with questions intended to assess whether those objectives have been met. Critical-thinking questions within the narrative prompt students to apply the material as they read. A set of tiered questions at the end of the chapter, as well as additional online problems, further challenge students to master the material.

What Do You Think?

These critical-thinking questions engage students in application or analysis and encourage them to think more globally about the content.

WHAT DO YOU THINK?

3. What type of connective tissue have you damaged when you sprain your ankle?

WHAT DID YOU LEARN?

12. Make a flow chart that starts with the common origin of all types of connective tissue, and then classifies each of the different types of connective tissue.
13. Describe the composition and location of fibrocartilage.
14. Why is blood considered a connective tissue?

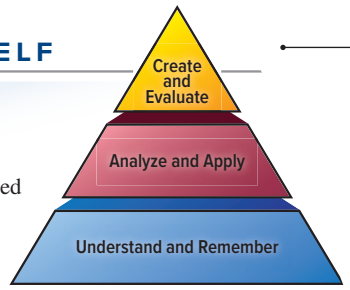
What Did You Learn?

These mini self-tests at the end of each section help students determine whether they have a sufficient grasp of the information before moving on to the next section.

CHALLENGE YOURSELF

Do You Know the Basics?

1. Which tissue contains a calcified ground substance and is specialized for structural support?
   a. muscle tissue
   b. dense regular connective tissue
   c. areolar connective tissue
   d. bone connective tissue



Can You Apply What You've Learned?

1. John is a 53-year-old construction worker who has come into your office complaining of a sore knee joint. You see a buildup of fluid close to the patella (kneecap) but deep to the skin and suspect the soreness is due to bursitis, an inflammation of membranes that surround some joints. Which type of body membrane is inflamed?
   a. cutaneous membrane
   b. serous membrane
   c. synovial membrane
   d. mucous membrane

Can You Synthesize What You've Learned?

1. While examining a tissue using light microscopy, a student makes the following observations: (a) The tissue contains some different types of scattered protein fibers—that is, they exhibit different widths, some are branched, and some are long and unbranched. (b) The observed tissue has some "open spaces"—that is, places between both cells and the fibers that appear clear with no recognizable features. (c) Several connective tissue cell types are scattered throughout the tissue, but these cells are not grouped tightly together. What type of tissue is this, and where may this tissue be found in the body?

Challenge Yourself

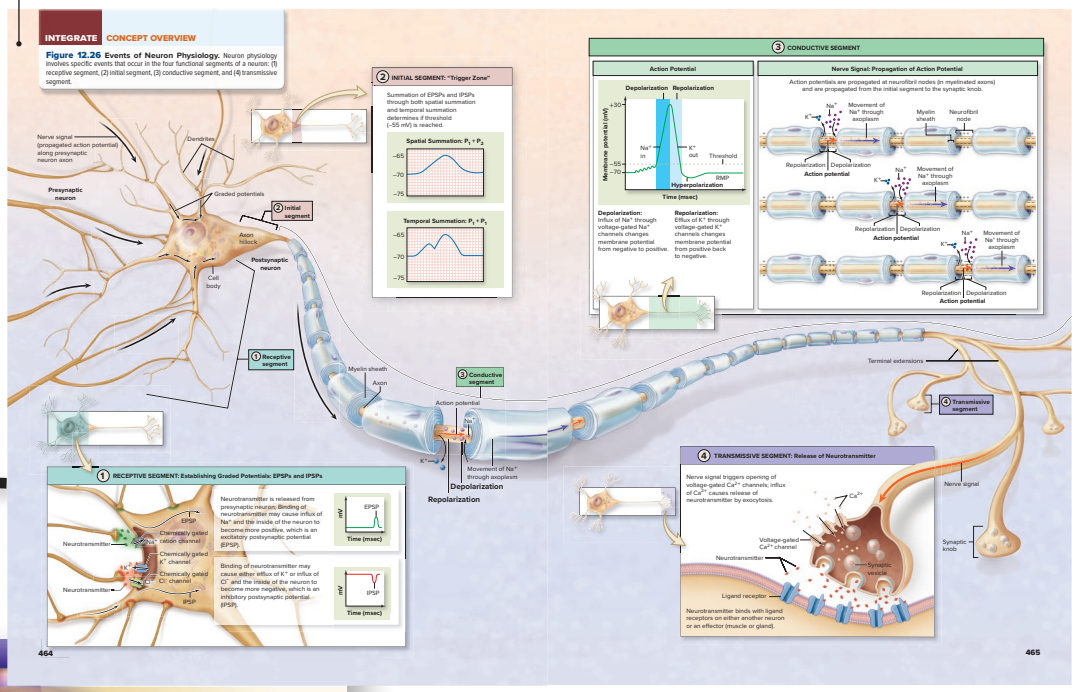
Assessments at the end of each chapter are correlated with Bloom's Taxonomy and progress through knowledge-, application-, and synthesis-level questions. The "Can You Apply …" and "Can You Synthesize …" question sets are clinically oriented to encourage concept application, and expose students who may be pursuing health-related careers to problem solving in clinical contexts.

Concept Overviews into Digital Learning

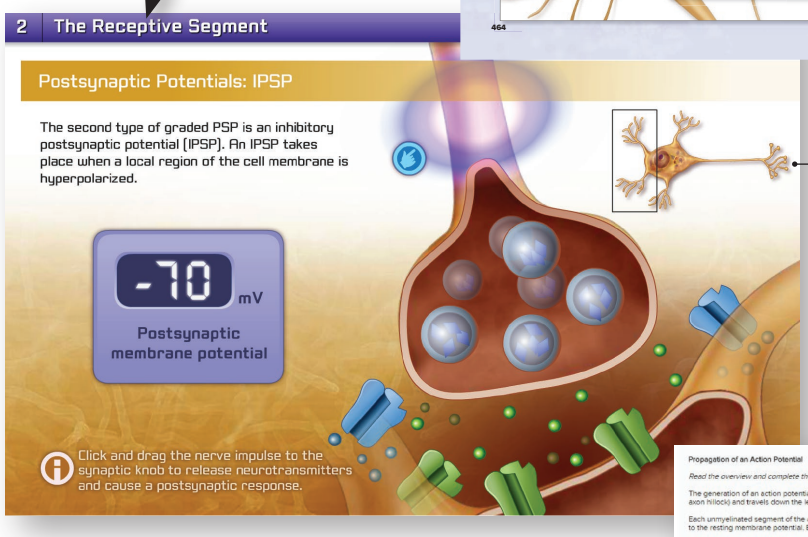
Selected **Concept Overview Figures** from the textbook have been transformed into interactive study modules. This digital transformation process was guided by anatomy and physiology professors who reviewed the modules throughout the development process. Interactive Concept Overview Figures also have assessable, autograded learning activities in Connect®, and are also provided separately to instructors as classroom presentation tools.

Concept Overview Interactives are available for the following topics:
Membrane Transport
Muscle Contraction
Neuron Physiology
Endocrine System (New)
Cardiac Cycle
Blood Pressure (New)
Innate Immunity (New)
Adaptive Immunity (New)
Respiration
Glomerular Filtration
Tubular Resorption/Secretion

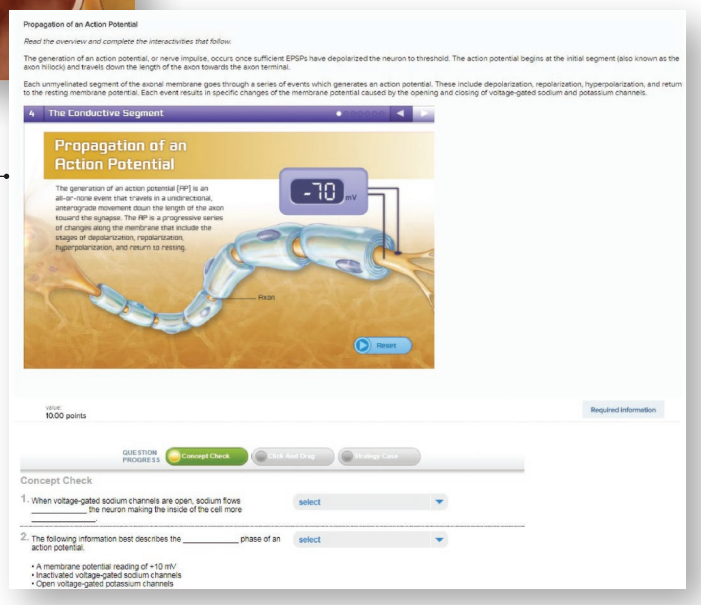
Concept Overview from Textbook



Interactive Presentation Study Tool



Assessable Autograded Activity in Connect



Lab Manual Options to Fit Your Course

Anatomy & Physiology Laboratory Manual by Kyla Turpin Ross, Leslie Day, Joseph Comber, and Christine M. Eckel is a laboratory manual specifically developed for the O'Loughlin/Bidle/McKinley *Anatomy and Physiology: An Integrative Approach* text:

- One version that includes both cat and fetal pig dissection.
- Each chapter opens with a set of learning objectives that are keyed to the post-laboratory worksheet to ensure student understanding of each chapter's objectives.
- The manual includes the highest-quality photographs and illustrations of any laboratory manual in the market.
- Laboratory exercises are "how-to" guides that involve touch, dissection, observation, experimentation, and critical-thinking exercises.
- In-chapter learning activities offer a mixture of labeling exercises, sketching activities, table completion exercises, data recording, palpation of surface anatomy, and other sources of learning.
- Numerous exercises throughout the manual utilize Physiology Interactive Lab Simulations (Ph.I.L.S.) 4.0 Online to provide additional student understanding of physiology.
- Pre-Laboratory Worksheet questions and Post-Laboratory Worksheet questions from each chapter are assignable in Connect.
- Ph.I.L.S. 4.0 is included with each new laboratory manual.

Laboratory Manual for Human Anatomy & Physiology by Terry Martin is written to coincide with any A&P textbook:

- Three versions available, including main, cat, and fetal pig
- Includes Ph.I.L.S. 4.0 Online
- Outcomes and assessments format
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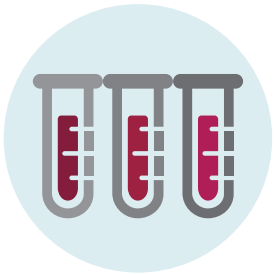

PhILS

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Practice Atlas for A&P is an interactive tool that pairs images of common anatomical models with stunning cadaver photography, allowing students to practice naming structures on both models and human bodies, anytime, anywhere. **The result? Students are better prepared, engaged, and move beyond basic memorization.**

*Statistic courtesy of The New England Journal of Higher Education

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Connect Virtual Labs helps connect the dots between lab and lecture, boosts student confidence and knowledge, and improves student success rates. **The result? Students are engaged, prepared, and utilize critical thinking skills.**

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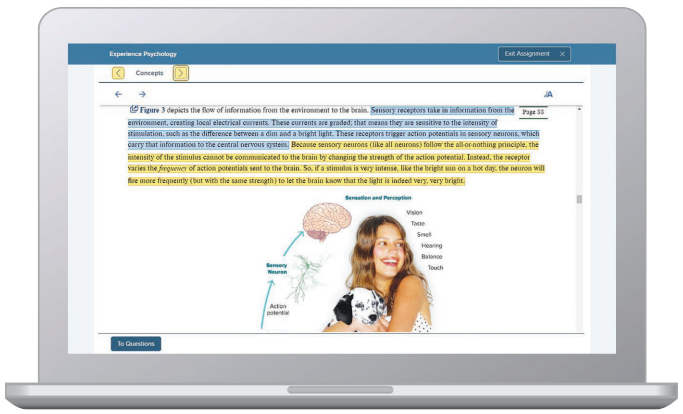

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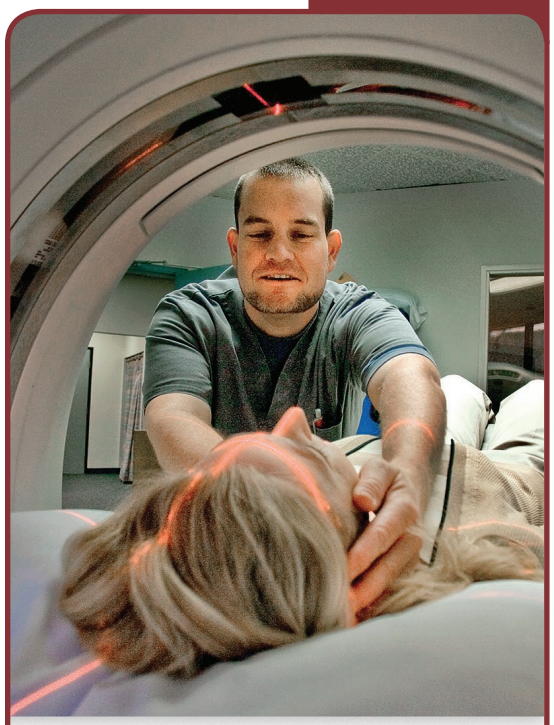
chapter

1

The Sciences of Anatomy and Physiology

INTEGRATE



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CAREER PATH
Medical Imaging Technologist

A medical imaging technologist is trained to utilize a variety of imaging techniques, such as ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI). The technologist must be able to correctly interpret the physician's instructions, operate the imaging machinery, and communicate with the patient during the procedure. The accompanying image shows a CT technician positioning a patient for a cranial CT scan. This technician must understand relevant brain anatomy and be able to interpret the sectional images produced of the brain.

Anatomy & Physiology Revealed® 4.0

Module 1: Body Orientation

You are about to embark on an adventure into the amazing world of human anatomy and physiology. Both fields explore the incredible workings of the human body. Anatomy studies the form and structure of the body, whereas physiology examines how the body functions. In this book, you will learn that structure and function are inseparable. Together, these applied sciences provide the basis for understanding health and human performance.

We introduce you to a number of concepts in this chapter that will be used throughout the text and will prove central to your study of anatomy and physiology. These diverse topics include: (a) a comparison of the disciplines of anatomy and physiology; (b) study tips for how to most effectively study for this course; (c) the body's levels of organization; (d) the basic vocabulary of anatomy and physiology that is derived from both Greek and Latin; (e) the core features of homeostasis, which is the general regulatory process for maintaining a healthy body; and (f) the general relationship between homeostasis, health, and disease. We welcome you to the exciting and challenging study of human anatomy and physiology!

1.1 Anatomy and Physiology Compared

In this section, we compare anatomy and physiology and present the general subdivisions of these sciences, including an overview of how the scientific method is used in both of these disciplines.

1.1a Anatomy, Physiology, and the Scientific Method

LEARNING OBJECTIVES

1. Compare and contrast the sciences of anatomy and physiology.
2. List the steps involved in the scientific method and explain how the scientific method has been used in the fields of anatomy and physiology.

Anatomy is the study of structure and form. The word *anatomy* is derived from the Greek word *anatome,* which means to cut apart or dissect. Anatomists are scientists who study the form and structure of organisms. Specifically, they examine the relationships among parts of the body as well as the structure of individual organs. **Physiology** is the study of function of the body parts. Physiologists are scientists who examine how organs and body systems function under normal circumstances, as well as how the functioning of these organs may be altered via medication or disease. For example, when studying blood capillaries (the smallest of blood vessels), an anatomist may describe the composition of the thin wall. In contrast, a physiologist will explain how the thin wall allows for effective gas and nutrient exchange between the blood within the capillary and the tissue cells external to the capillary.

Anatomists and physiologists are professionals who use the scientific method to explain and understand the workings of the body. The **scientific method** is a systematic and rigorous process by which scientists:

- Examine natural events (or phenomena) through observation
- Develop a **hypothesis** (possible explanation) for explaining these phenomena
- Experiment and test the hypothesis through the collection of data
- Determine if the data support the hypothesis, or if the hypothesis needs to be rejected or modified

For example, early anatomists and physiologists used the scientific method to explain how blood circulates through the body. Today, we continue to use the scientific method for a variety of topics, such as to understand how the brain stores memories or explain how cancer may spread throughout the body.

Throughout this text, we have attempted to integrate the study of both anatomy and physiology, showing how form and function are interrelated.

WHAT DID YOU LEARN?

1. What is the relationship between anatomy and physiology?

1.1b Anatomy: Details of Structure and Form

LEARNING OBJECTIVE

3. Compare and contrast subdivisions in both microscopic and gross anatomy.

The discipline of anatomy is extremely broad and can be divided into several more specific fields. **Microscopic anatomy** examines structures that cannot be seen by the unaided eye. For most of these studies, scientists prepare individual cells or thin slices of body structures and examine these specimens under the microscope. Microscopic anatomy has several subdivisions with two main divisions:

- **Cytology** (sī-tol′ō-jē; *kytos* = a hollow [cell], *logos* = study), or *cellular anatomy,* is the study of body cells and their internal structure.
- **Histology** (his-tol′ō-jē; *histos* = web, tissue) is the study of body tissues.

Gross anatomy, also called *macroscopic anatomy,* investigates the structure and relationships of body parts that are visible to the unaided eye, such as the intestines, stomach, brain, heart, and kidneys. In these macroscopic investigations, specimens or their parts are often dissected (cut open) for examination. Gross anatomy may be approached in several ways:

- **Systemic anatomy** studies the anatomy of each functional body system. For example, studying the urinary system would involve examining the kidneys (where urine is formed) and the organs of urine transport (ureters and urethra) and storage (urinary bladder). Most undergraduate anatomy and physiology classes use this systemic approach.
- **Regional anatomy** examines all of the structures in a particular region of the body as a complete unit. For example, one may study the axillary (armpit) region of the body, and in so doing examine the blood vessels (axillary artery and vein), nerves (branches of the brachial plexus), lymph nodes (axillary lymph nodes), musculature, connective tissue, and skin. Most medical school gross anatomy courses are taught using a regional anatomy approach.
- **Surface anatomy** focuses on both superficial anatomic markings and the internal body structures that relate to the skin covering them. Health-care providers use surface features to identify and locate important landmarks, such as pulse locations or the proper body region on which to perform cardiopulmonary resuscitation (CPR). Most anatomy and physiology classes also instruct students on important surface anatomy locations.
- **Comparative anatomy** examines the similarities and differences in the anatomy of different species. For example, students in a comparative anatomy class may examine and compare limb structure in humans, chimps, dogs, and cats.
- **Embryology** (em′brē-ol′o-jē; *embryon* = young one) is the discipline concerned with developmental changes occurring from conception to birth.

Several specialized branches of anatomy focus on the diagnosis of medical conditions or the advancement of basic scientific research. **Pathologic** (path-ō-loj′ik; *pathos* = disease) **anatomy** examines all anatomic changes resulting from disease. Both gross anatomic changes and microscopic structures are examined. **Radiographic anatomy** investigates the relationships among internal structures that may be visualized by specific scanning procedures, such as radiography (x-ray), ultrasound, and magnetic resonance imaging (MRI). (See Clinical View 1.5: "Medical Imaging.")

It may seem as though nothing new can be learned about anatomy—after all, the body has been much the same for thousands of years. Yet in fact, new information is being learned from ongoing anatomic studies, some of which displace the traditional thinking about the workings of various organs. Never forget that anatomy is not a static unchanging science, but rather, is a dynamic changing science.

WHAT DID YOU LEARN?

2 How might knowledge of surface anatomy be important for a health-care worker during a CPR emergency?

1.1c Physiology: Details of Function

LEARNING OBJECTIVE

4. Compare and contrast the subdivisions in physiology.

Physiologists examine the function of various organ systems, and they typically focus on the molecular or cellular level. Thus, a basic knowledge of both chemistry and cells is essential in understanding physiology, and that's why we've included several early chapters on these topics. Mastery of these early chapters on chemistry and cells is critical to understanding the physiologic concepts that are covered throughout the text.

The discipline of physiology parallels anatomy because it also is very broad and may be subdivided into smaller groups. Many specific physiology subdisciplines focus their studies on a particular body system. For example, **cardiovascular physiology** examines the functioning of the heart, blood vessels, and blood. Cardiovascular physiologists examine how the heart pumps the blood, what are the parameters for healthy blood pressure within the blood vessels, and details of the cellular exchange mechanisms by which respiratory gases, nutrients, and wastes move between blood and body structures. Other examples include **neurophysiology** (which examines how nerve impulses are propagated throughout the nervous system), **respiratory physiology** (which studies how respiratory gases are transferred by gas exchange between the lungs and the blood vessels), and **reproductive physiology** (which explores how the regulation of reproductive hormones can drive the reproductive cycle and influence sex cell production and maturation).

Pathophysiology investigates the relationship between the functioning of an organ system and disease or injury to that organ system. For example, a pathophysiologist would examine how contractile force of the heart, blood pressure, and both gas and nutrient exchange may be affected in an individual afflicted with heart disease.

WHAT DID YOU LEARN?

3 Which field of physiology examines how the heart, blood vessels, and blood function?

INTEGRATE

CLINICAL VIEW 1.1

Etiology (Causes) and Pathogenesis (Development) of Disease

All health-care professionals must understand both how body structures function normally and how disease or injury can affect them. Throughout the chapters in this book, Clinical View boxes (which are always enclosed in the color *blue*) provide you with selected pathologies and how these pathologies affect the anatomy and physiology of those structures.

1.2 Anatomy and Physiology Integrated

LEARNING OBJECTIVE

5. Explain how the studies of form and function are interrelated.

The sciences of anatomy and physiology are intertwined; one must have some understanding of anatomic form to study physiologic function of a structure. Likewise, one cannot adequately describe and understand the anatomic form of an organ without learning that organ's function. This interdependence of the study of anatomy and physiology reflects the inherent and important interrelationship of how the structure and form of a component of the body determine how it functions. This concept is central to mastering the study of anatomy and physiology.

Integrating the disciplines of anatomy and physiology, rather than trying to separate discussion of form and function, is the most effective way to learn about both fields. Anatomists and physiologists may be describing the organs slightly differently, but both disciplines must use information from the other field for a full understanding of the organ system. You cannot fully understand *how* the small intestine propels food and digests or absorbs nutrients unless you also know about the *structure* of the small intestine wall. **Figure 1.1** visually compares how anatomists and physiologists examine the human body, using the small intestine as an example. Note that anatomists (left side of the figure) tend to focus on the form and structure, whereas physiologists (right side of figure) focus on the mechanisms and functions of these structures. However, both anatomists and physiologists understand that the form and function of structures are interrelated. Throughout this text, we integrate these disciplines so you can more easily see that anatomic form and physiologic function are inseparable.

Note that figure 1.1 is an example of a central feature of this text called **Concept Overview (COV) figures.** These specialized illustrations are included in each chapter (e.g., figures 4.19 and 23.35) and are designed to help you to visually connect and integrate content that has been previously discussed within the chapter.

WHAT DID YOU LEARN?

4 Compare and contrast how anatomists and physiologists specifically describe the small intestine.

1.3 How to Study Anatomy and Physiology Effectively

LEARNING OBJECTIVE

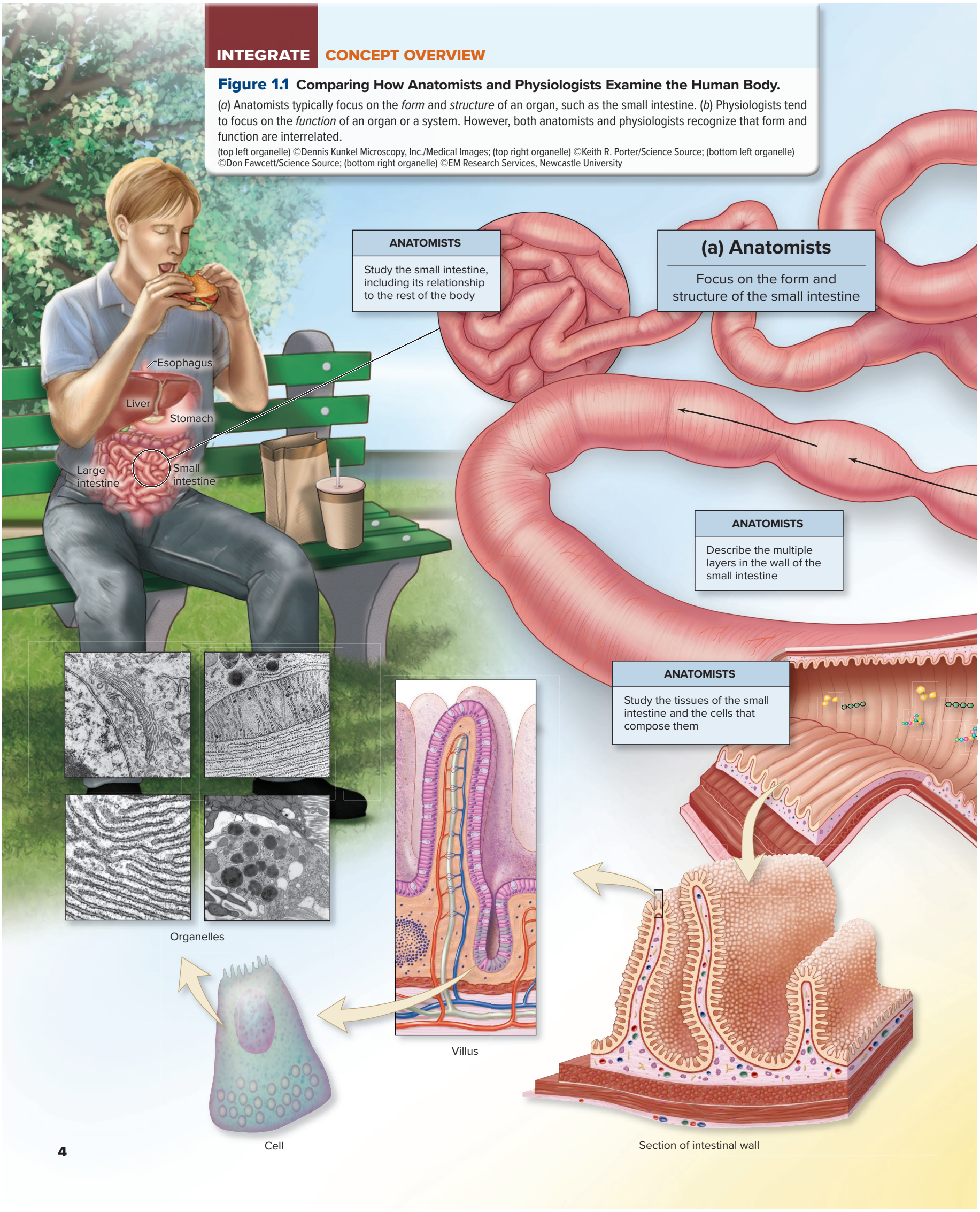
6. Describe best practices for studying anatomy and physiology effectively.

Anatomy and Physiology (A&P) is a content dense course that sometimes may overwhelm learners new to the subject. Success in the course requires careful time management and appropriate study skills for comprehending the material. When we teach our courses, we often encounter students who simply need to adopt more effective study strategies to perform well. In this section, we discuss some of these strategies.

INTEGRATE **CONCEPT OVERVIEW**

Figure 1.1 Comparing How Anatomists and Physiologists Examine the Human Body.

(*a*) Anatomists typically focus on the *form* and *structure* of an organ, such as the small intestine. (*b*) Physiologists tend to focus on the *function* of an organ or a system. However, both anatomists and physiologists recognize that form and function are interrelated.



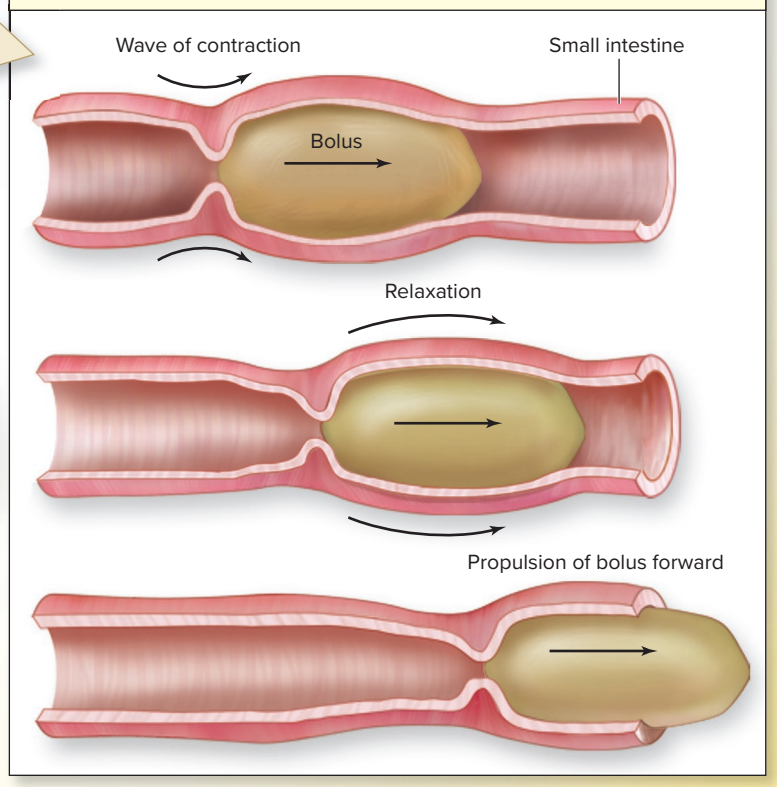
(b) Physiologists

Focus on the function of the small intestine

PHYSIOLOGISTS

Examine how the muscles of the small intestine propel food through the digestive tract

Peristalsis



Anatomists and Physiologists

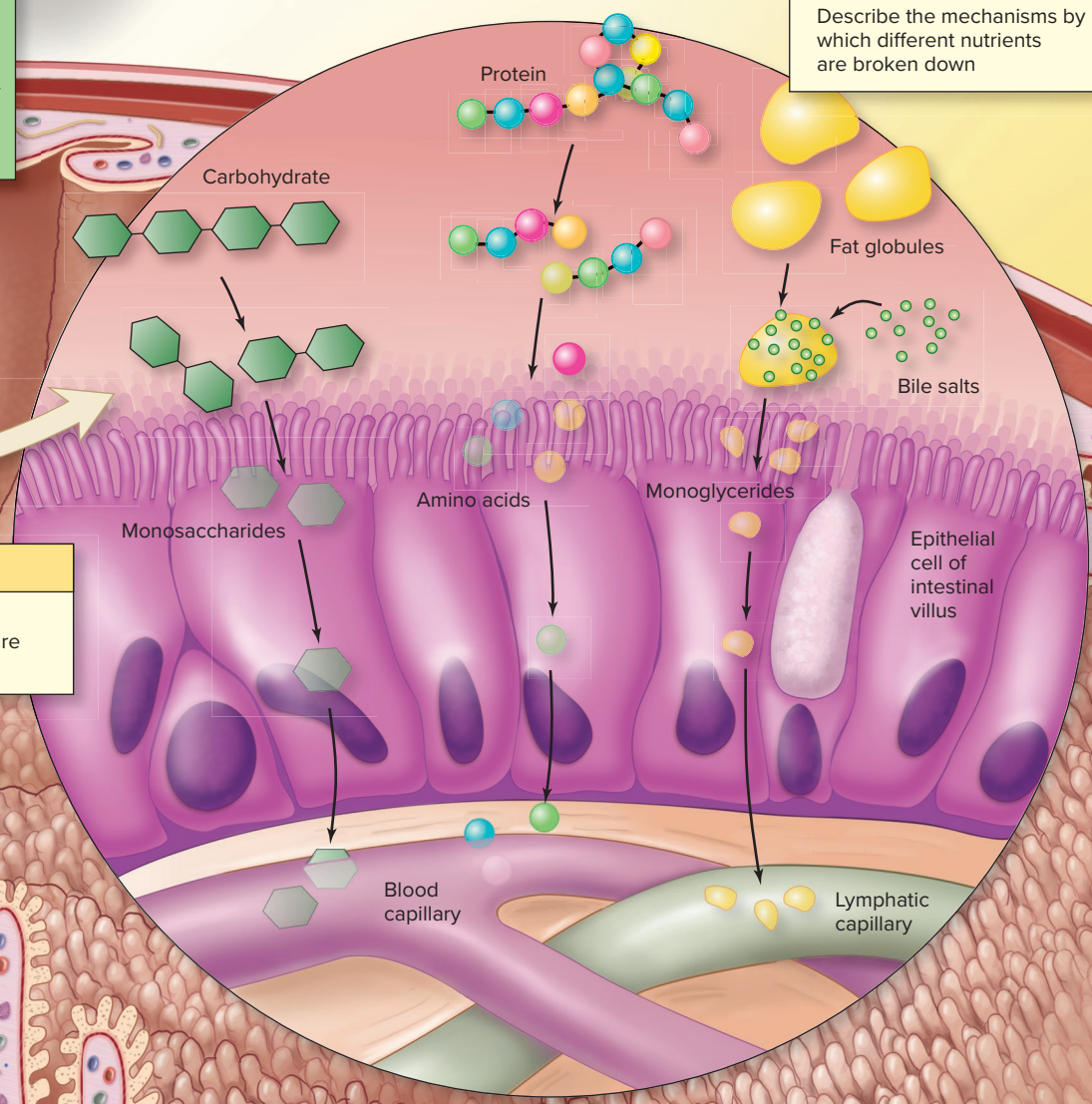
Know form and function of the small intestine are interrelated

PHYSIOLOGISTS

Describe the mechanisms by which different nutrients are broken down

PHYSIOLOGISTS

Study the mechanisms by which different nutrients are absorbed



How *NOT* to Study for A&P

1. **Wait until the last minute to study.** As previously mentioned, A&P is content rich and requires the learner to be able to understand many complex processes. Beginning your studying a few days before an exam is simply *not* enough time for you to understand the material and truly learn it.
2. **Study for long periods of time without breaks.** Your brain works best if you study for shorter periods of time (½ hour or less) and then take a short break before studying again. A 4-hour marathon study session will just leave you feeling overwhelmed, and you likely will not remember anything you studied.
3. **Study with multiple distractions.** Do you try to study with the TV on, your phone available to answer texts, and your computer open to your social media account? If so, the time you think you are spending studying is not effective. For each time you take a break to answer a text, check email, or listen to TV, you are not focusing on the material. Multitasking is a myth—in reality, you are quickly switching from one task to another without staying focused on any one thing. This type of study method is disjointed and will prevent you from engaging in the material.
4. **Simply passively read over your notes.** Do not simply read over your notes multiple times as a form of studying. This study method is referred to as *passive learning*—it is called *passive* because the person does not have to do much in the process! Although you may *think* you are learning the material, in fact, you are only acquiring a superficial recognition of the material. Unless you practice quizzing yourself over the material to repeatedly *retrieve* the material from your memory and do other active learning methods, your brain will not be able to quickly access what you've learned for an exam. Students who rely solely on rereading their notes often will say, "I recognized the material on the exam, but I wasn't sure of what answer to choose."
5. **Study by yourself only.** When you study by yourself only, you cannot accurately gauge if you know the material well and can explain it to others. You also are more likely to reinforce a misconception if you do not have a study partner who can help you work through some of the more difficult concepts.

So now that we've discussed some of the big mistakes in studying A&P, what are more effective ways of studying? The following is a list of best practices for studying.

Best Practices for Studying A&P

1. **Schedule regular daily study sessions well before the upcoming exam.** Your studying should begin the first week of class and should be a part of a daily or every-other-day schedule. Do not wait until the week prior to an exam to first become acquainted with the material! The night after a lecture or lab, review the material you've learned with some of the methods outlined in this list. Connect the material you are learning with A&P material previously covered. If you follow this plan, then you may spend the week prior to the exam reviewing material you've already studied, rather than starting your study process.
2. **Study for multiple, *short* periods of time.** During these daily (or every-other-day) study periods, set a timer for ½ hour or a little less and promise yourself you will focus just on the A&P material at hand. Select a study topic that you can review effectively in that ½ hour. For example, you could compare and contrast the epidermis and the dermis of the skin during that time. After ½ hour has passed, reward yourself with a short (~5-minute) break, and then reset the timer to study again. After three of these short periods, reward yourself with a longer break. You will be able to review more material, and *remember* the material you've reviewed, better than if you tried to study in one long 4-hour block.
3. **Minimize your distractions.** Put away the phone, turn off the TV, and shut down your email. Research has shown that people Do not multitask—rather, the brain jumps from one task to another quickly, so the activity for each task is disjointed and may not be well organized. You will be amazed at how much more efficient your studying becomes when you minimize the distractions and focus on the material. If you use the timer technique mentioned previously (study for ½ hour with no distractions), you can reward yourself during those short breaks by looking at your texts or social media.
4. **Utilize *active learning* methods when you study. Active learning** is defined as a process by which you are engaged in the material, problem solving, and applying what you have learned to previous knowledge. It is the opposite of passive learning. Examples of active learning include
   a. **Make your own tables to organize material.** Take your lecture notes and reorganize them into tabular form. For example, you can group muscles of similar functions. The act of writing out the muscles and reorganizing the information in tabular form will help you remember the material better than if you just read over your notes.
   b. **Draw and label anatomic structures.** Make your own sketches of organs and tissues, and label the key features. When you draw, you are integrating multiple pieces of information into one diagram. You do not have to be an artist and the drawing does not have to be pretty—rather, it simply has to make sense to you.
   c. **Make flowcharts of physiological processes.** Map out the pathway that filtrate becomes urine in the kidney. Create a flowchart to illustrate how blood is transported from the heart to the lungs, and back to the heart.
   d. **Quiz yourself repeatedly on the material.** Educational research has shown that long-term learning is most likely to occur when an individual practices and retrieves that material on multiple occasions. Your textbook provides various ways to quiz yourself—you can use the end-of-chapter questions, LearnSmart modules associated with the e-text, and the quizzing feature in the Anatomy and Physiology | Revealed program associated with the McGraw-Hill Connect site. If you are studying with a partner, take turns quizzing each other. When you can retrieve the information accurately, you know the material. You do not want to wait until you are taking the exam to determine if you can do this.

INTEGRATE

LEARNING STRATEGY 1.1

Learning Strategy boxes like this one (which are always enclosed in the color *green*) provide you with helpful analogies, memory aids, and other study tips to help you better understand and learn the material. Look for these boxes throughout each chapter.

INTEGRATE

CONCEPT CONNECTION

Throughout future chapters, **Concept Connection** boxes like this one (which are always enclosed in the color *orange*) will highlight how various organ systems do not work in isolation, but rather are interconnected to carry out overlapping functions. For example, the cardiovascular system and respiratory system work together in the transport of respiratory gases (oxygen and carbon dioxide) by the blood throughout the body.

e. **Explain/teach a concept to a partner.** There is a saying that when one person teaches another, both learn. Your teachers have reinforced their A&P knowledge by teaching students year after year. As you are learning new concepts, meet with a study partner and explain that concept to him or her in your own words. The act of explaining the concept and answering your partner's questions will help *you* solidify your knowledge. Utilize the Concept Overview (COV) figures (e.g., figure 1.1) in the textbook to explain concepts to someone else.

5. **Study with a partner or group.** A lot of the active study methods mentioned work best when you are studying with a partner. It is difficult to quiz yourself and know for sure if you truly understand a concept. You and your study partner can each help determine where gaps in knowledge are, keep study sessions focused and on track, and serve as a "sounding board" when trying to explain a concept.
6. **Utilize *all* of the resources your textbook has to offer.** Your textbook and its accompanying digital platform contain numerous resources to help you learn anatomy and physiology more efficiently. So do not just read the text—use the following aids provided in each chapter of the text:

a. **Integrate: Learning Strategy boxes.** These boxes (which are always enclosed in the color *green*) provide analogies, mnemonics, and study tips to help you learn the material.

b. **Integrate: Concept Connection boxes.** These boxes (which are always enclosed in the color *orange*) provide summaries of topics that may be discussed and presented across multiple chapters, such as acid-base balance or hormonal regulation of growth. Read these boxes to help you connect material among different chapters.

c. **Integrate: Concept Overview figures.** Each chapter has one or more of these figures, designed to provide a big-picture summary of a major concept in that chapter. For example, figure 1.1 provides a comparison of how anatomists and physiologists study the body. Let these figures guide your explanation of a concept to a study partner.

d. **Integrated, multiple assessments in each chapter.** As you read, write out your answers for the What Did You Learn? questions at the end of each section of text. When you are done reading a chapter, use the end-of-chapter questions to test your knowledge.

e. **LearnSmart.** Each chapter is associated with an interactive e-module that allows you to test yourself on concepts you have read. The program will highlight topics you have not yet mastered and create a study plan for you about these topics.

f. **Anatomy and Physiology | REVEALED (APR).** APR is an interactive cadaver dissection tool that allows you to highlight anatomic features and review lab and lecture concepts. You can view both gross anatomy and histology images, watch animations about particular physiologic processes, and test yourself with the lab quiz tool.

This list of best practices is not exhaustive; you may have some additional study strategies that are equally effective. Although we cannot guarantee you will earn an A, we *are* reasonably certain that your understanding of anatomy and physiology will greatly increase if you adopt the best practices outlined here. We encourage you to use these best practices for your other courses as well.

WHAT DID YOU LEARN?

5 Why would studying with a partner be more effective than just studying alone?

1.4 The Body's Levels of Organization

Scientists group the body's components into an organizational hierarchy of form and function. In thinking about these levels, it is helpful to know the characteristics common to living things and how each organizational level supports these characteristics. For example, the organ system concept allows functions to be considered as an interaction between many organs.

1.4a Characteristics That Describe Living Things

LEARNING OBJECTIVE

7. List and explain the characteristics common to all living things.

Several distinctive properties are common to all organisms, including humans:

- **Organization.** All organisms exhibit a complex structure and order. In section 1.4b, we describe the increasingly complex levels of organization of the human body.
- **Metabolism.** All organisms engage in **metabolism** (mĕ-tab′ō-lizm; *metabole* = change), which is defined as the sum of all of the chemical reactions that occur within the body. Metabolism consists of both **anabolism** (ă-nab′ō-lizm; *anabole* = a raising up), in which small molecules are joined to form larger molecules, and **catabolism** (kă-tab′ō-lizm; *katabole* = a casting down), in which large molecules are broken down into smaller molecules. An example of a metabolic reaction is the use of cellular energy (called ATP; see section 2.7d) for muscle contraction (see section 10.3). The concepts of chemical reactions and metabolism are discussed in sections 3.2a and 3.2b, respectively.

WHAT DO YOU THINK?

1 When you digest a meal, what type of metabolic reactions do you think you are utilizing primarily: *anabolic* or *catabolic* chemical reactions? Why?

- **Growth and development** During their lifetime, organisms assimilate materials from their environment and often exhibit increased size (growth) and increased specialization as related to form and function (development). As the human body grows and develops, structures such as the brain become more complex and elaborately integrated.

- **Responsiveness.** All organisms exhibit **responsiveness,** which is the ability to detect and react to **stimuli** (changes in the external or internal environment). A stimulus to the skin of the hands, such as an extremely hot temperature, causes the human to withdraw the hand from the stimulus so as to prevent injury or damage. Responsiveness occurs at almost all levels of organization.
- **Regulation.** An organism must be able to adjust internal bodily function in response to environmental changes. When body temperature rises, more blood is circulated near the body's surface to facilitate heat loss, and thus return body temperature to within the normal range. (The process of maintaining body structures and function is called homeostasis, which is discussed in greater depth in section 1.6.)
- **Reproduction.** All organisms produce new cells for growth, maintenance, and repair. The somatic (body) cells divide by a process called mitosis (see section 4.9), whereas sex cells (called gametes) are produced by another type of cell division called meiosis (see section 28.2). The sex cells, under the right conditions, have the ability to develop into a new living organism.

WHAT DID YOU LEARN?

6 What does it mean if an organism is "responsive," and how does this characteristic relate to the survival of this organism?

1.4b The View from Simplest to Most Complex

LEARNING OBJECTIVE

8. Describe the levels of organization in the human body.

Anatomists and physiologists recognize several levels of increasingly complex organization in humans, as illustrated in **figure 1.2**. These levels, from simplest to most complex, are the chemical level, cellular level, tissue level, organ level, organ system level, and organismal level.

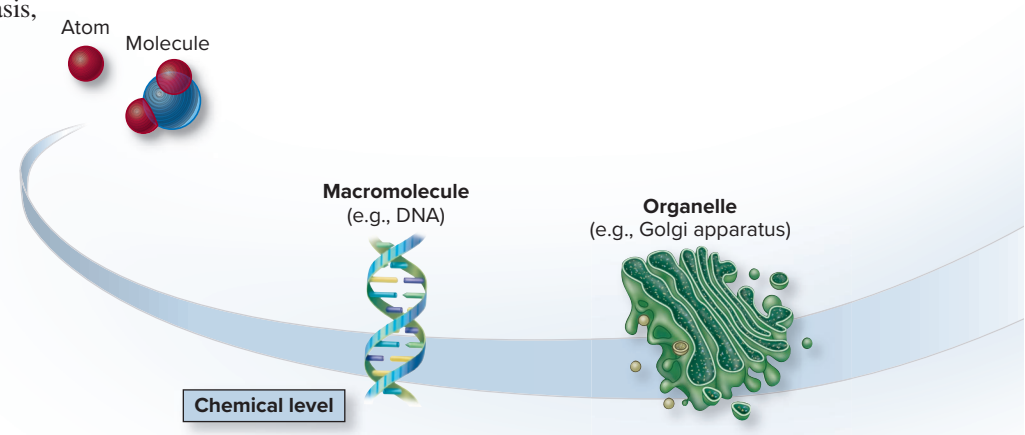
The **chemical level** is the simplest level, and it involves atoms and molecules. **Atoms** are the smallest units of matter that exhibit the characteristics of an element, such as carbon and hydrogen. When two or more atoms combine, they form a **molecule.** Examples of molecules include a sugar, a water molecule, or a vitamin. More complex molecules are called **macromolecules** and include proteins and the deoxyribonucleic acid (DNA) molecules. Macromolecules form specialized microscopic subunits in cells, called **organelles.** Chemical structures are described in chapter 2.

The **cellular level** consists of **cells,** which are the smallest living structures and serve as the basic units of structure and function in organisms. Cells and their components are formed from the atoms and molecules from the chemical level. The structures of cells vary widely, reflecting the specializations needed for their different functions. For example, a skeletal muscle cell may be very long and contain numerous organized protein filaments that aid in muscle contraction, whereas a red blood cell is small and has a flattened disc shape that facilitates the quick and effective exchange of respiratory gases. Cells and cellular organelles are discussed in chapter 4.

The **tissue level** consists of **tissues,** which are groups of similar cells that perform common functions. There are four major types of tissues. Epithelial tissue covers exposed surfaces and lines body cavities. Connective tissue protects, supports, and binds structures and organs. Muscle tissue produces movement. Finally, nervous tissue conducts nerve impulses for communication.

The **organ level** is composed of organs. An **organ** contains two or more tissue types that work together to perform specific, complex functions. The small intestine is an example of an organ that is composed of all four tissue types, which work together to process and absorb digested nutrients. The general features of body tissues and their organization within organs are covered in chapter 5.

The **organ system level** contains multiple related organs that work together to coordinate activities and achieve a common function. For example, the organs of the digestive system (e.g., stomach, small and large intestine, liver) work together to digest food particles, absorb nutrients, and expel the waste products. The 11 organ systems are introduced in section 1.4c.



The highest level of structural organization in the body is the **organismal level.** All body systems function interdependently in an **organism,** which is the living person.

WHAT DID YOU LEARN?

7 Practice using some of the active learning strategies we suggested in section 1.3 by making a table that lists the levels of organization, the structural units in that level, an example found in the body, and whether this level is simple or complex.

1.4c Introduction to Organ Systems

LEARNING OBJECTIVE

9. Compare and contrast the organ systems of the human body.

All organisms must exchange nutrients, wastes, and gases with their environment to remain alive and healthy. Simple organisms (e.g., bacteria) may exchange these substances directly across their surface cell boundaries. In contrast, complex, multicellular organisms require sophisticated organ systems with specialized structures and functions to perform the many activities required for the routine events of life. In humans, 11 **organ systems** are commonly denoted, each composed of interrelated organs that work in concert to perform specific functions **(figure 1.3)**. A person maintains a healthy body through the intricate interworkings of all of its organ systems. Subsequent chapters examine each of these organ systems in detail.

WHAT DID YOU LEARN?

8 Which organ system is responsible for filtering the blood and removing the waste products of the blood in the form of urine?

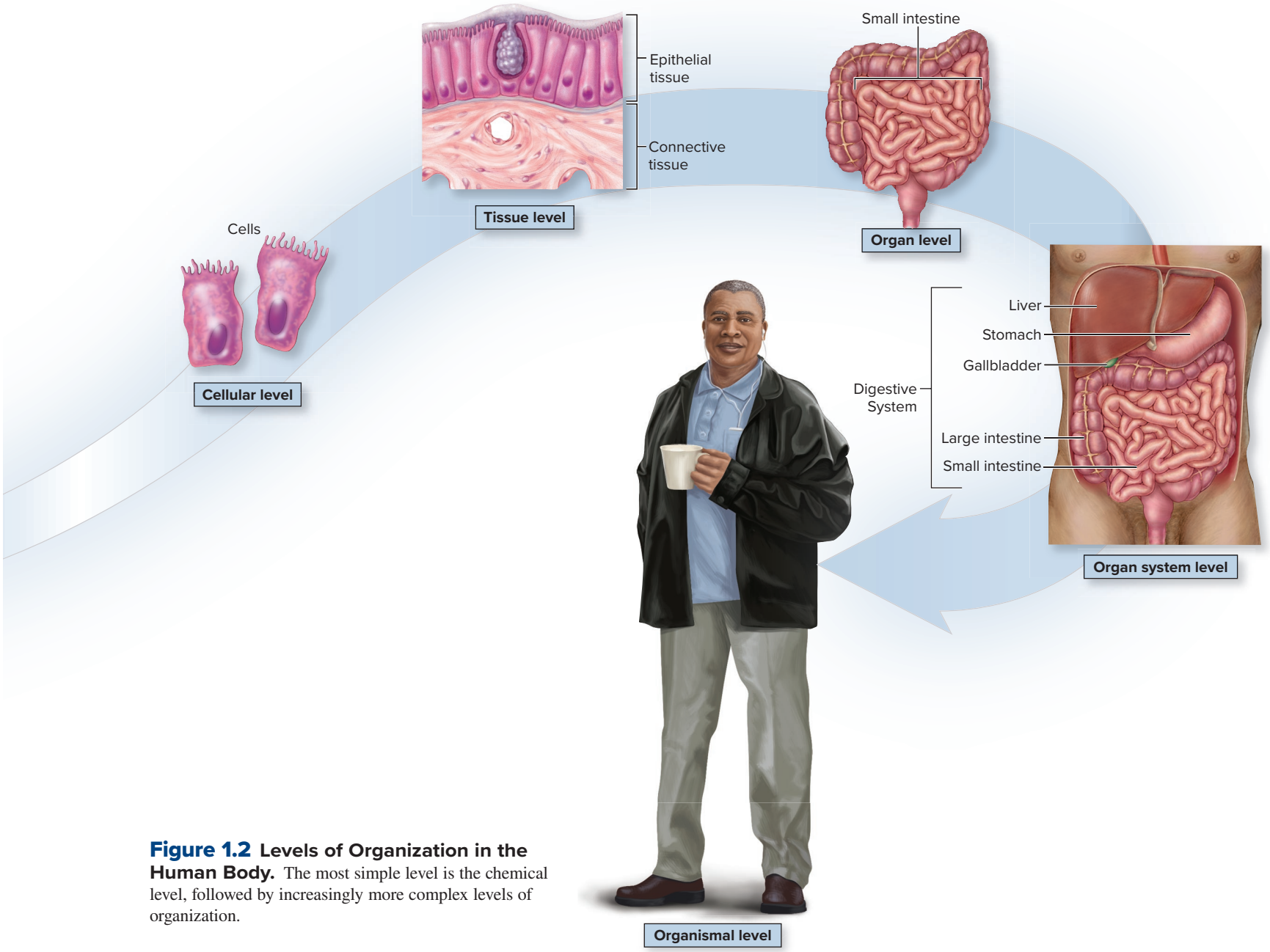


Figure 1.2 Levels of Organization in the Human Body. The most simple level is the chemical level, followed by increasingly more complex levels of organization.

INTEGRATE

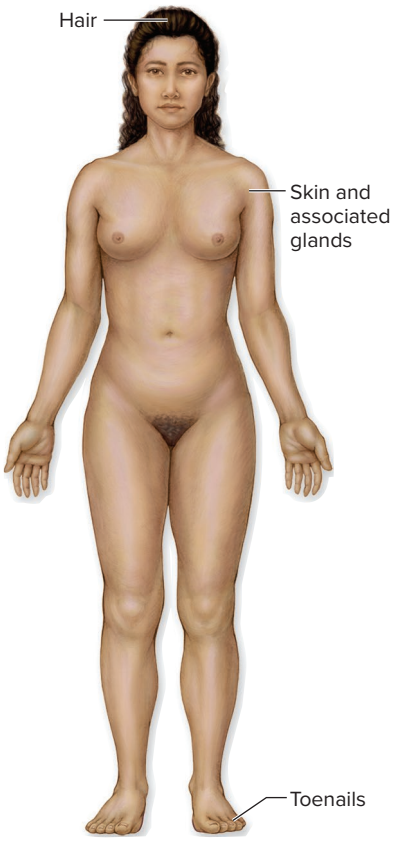
CLINICAL VIEW 1.2

The Human Microbiome: Another Human Organ?

The **human microbiome** is the total collection of microorganisms (i.e., bacteria, archaea, viruses, fungi, and protists) residing on and within the body. The ratio of human cells to microbial cells in an average person is approximately 1:1. The human body contains around 30 to 40 trillion human cells and about the same number of resident microbial cells. Human cells contain approximately 20,000 genes, whereas the total number of unique microbial genes in our resident microorganisms is around 500 times greater. The result is a treasure trove of metabolic pathways and products in the human microbiome, many of which are deeply woven into our physiology and therefore have profound effects on our health.

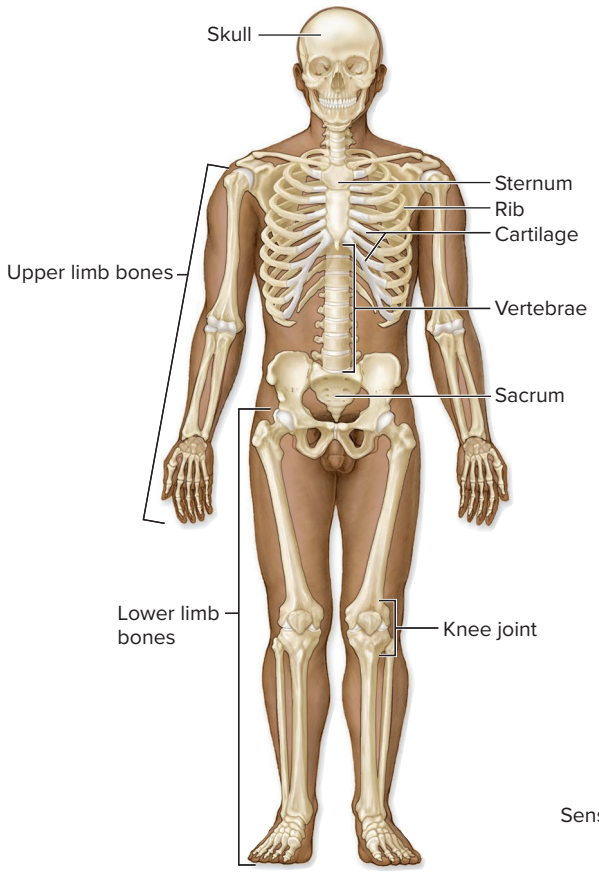
Improved genomic technologies have led to a new era of microbiome research, such as the multi-institutional collaboration known as the **Human Microbiome Project** (https://hmpdacc.org/). As a result, we have learned a great deal about the composition and range of this microbial world. For example, our microbiome is approximately 99% bacterial. These bacteria flourish in every available body site that is exposed to the outside world, including the skin, respiratory, digestive, urinary, and reproductive tracts. Some areas are more hospitable to the microbiome than others are, so the number and types of microbes vary across body locations. For instance, the skin posterior to the ear has relatively few bacteria compared to the skin of the forearm. In the digestive tract, the microbiome's bacterial numbers are low in the stomach and in parts of the small intestine, whereas the large intestine contains 70% of the entire human microbiome. Even areas conventionally thought to be sterile, such as the uterine environment during pregnancy, are inhabited by bacteria. These organisms have been found in the human placenta, umbilical cord, amniotic fluid, and the meconium (first stool) of newborns.

We are learning that these microbial residents interact with the workings of numerous body systems and have important effects on human health. The human microbiome has been shown to: (a) influence the nervous system, (b) protect us from infection, (c) assist with digestion, energy harvest, and energy utilization, and (d) influence the development of the immune system. As a result, the human microbiome has been compared to a bodily organ, in that it is as essential as any other part of us to our health and well-being. This comparison signifies our growing appreciation for the importance of the human microbiome, and continuing research in this area promises to be exciting.



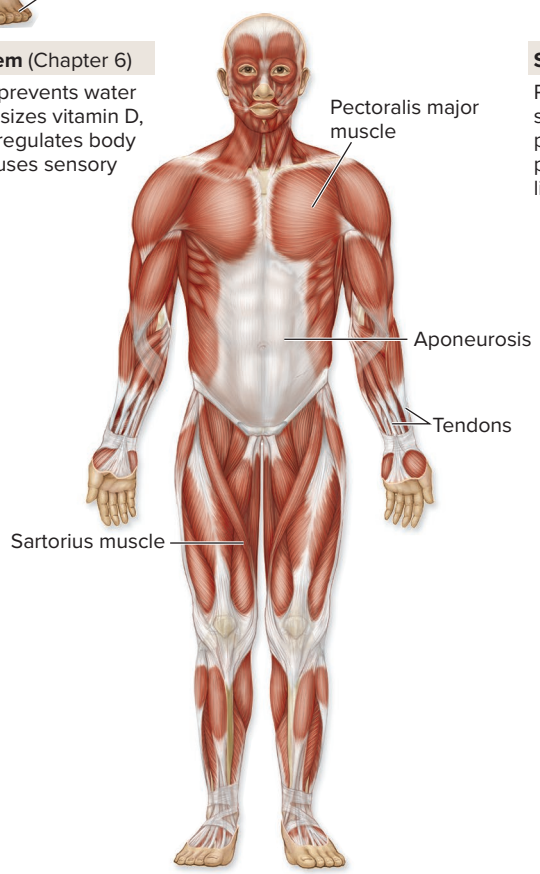
Integumentary System (Chapter 6)

Provides protection, prevents water loss and gain, synthesizes vitamin D, releases secretions, regulates body temperature, and houses sensory receptors.



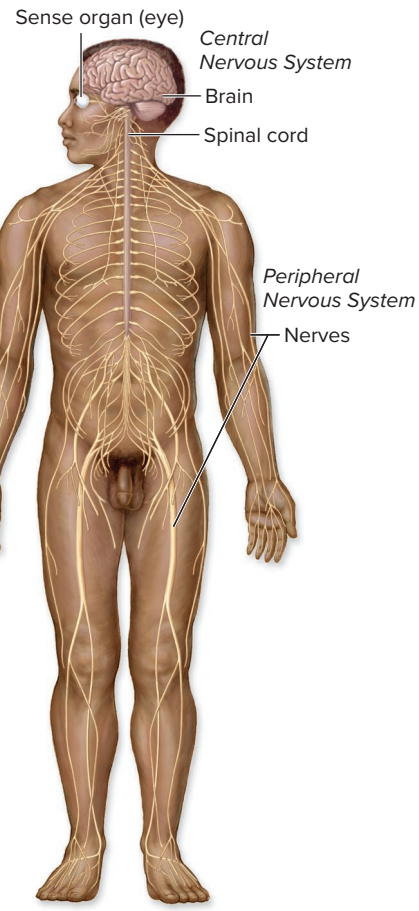
Skeletal System (Chapters 7–9)

Provides support and protection, site of hematopoiesis (blood cell production), stores calcium and phosphorus, provides sites for ligament and muscle attachments.



Muscular System (Chapters 10–11)

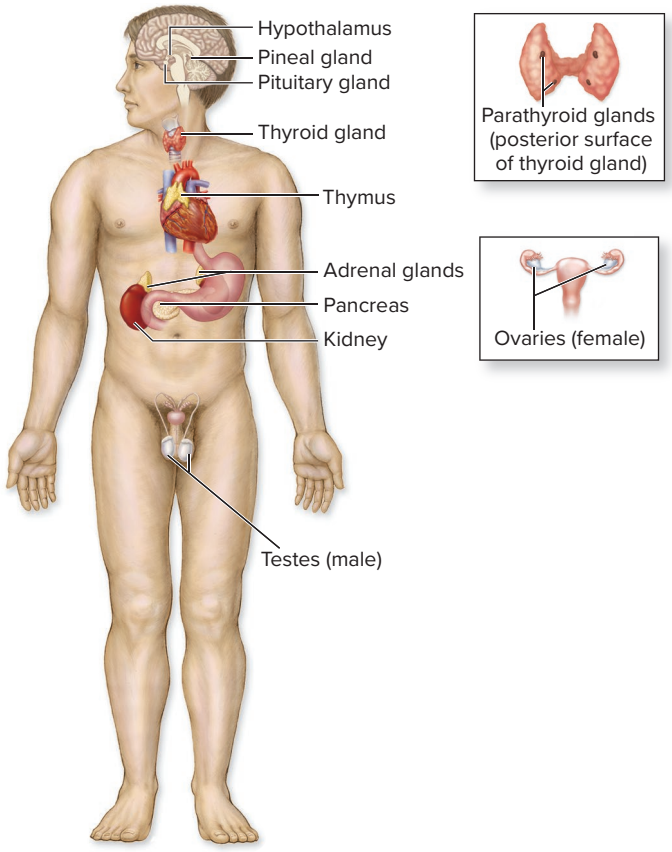
Produces body movement, generates heat when muscles contract.



Nervous System (Chapters 12–16)

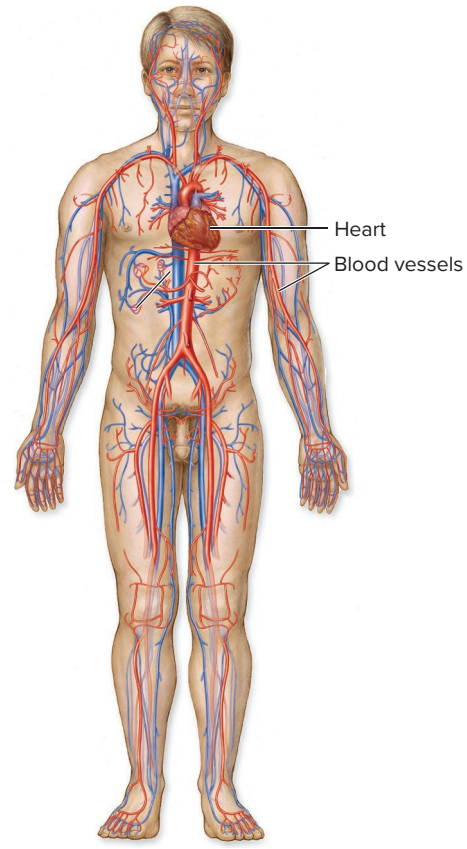
A regulatory system that responds to sensory stimuli, and controls muscles and some glands. Also responsible for consciousness, intelligence, memory.

Figure 1.3 Organ Systems. Major components and characteristics of the 11 organ systems of the human body are presented. APR



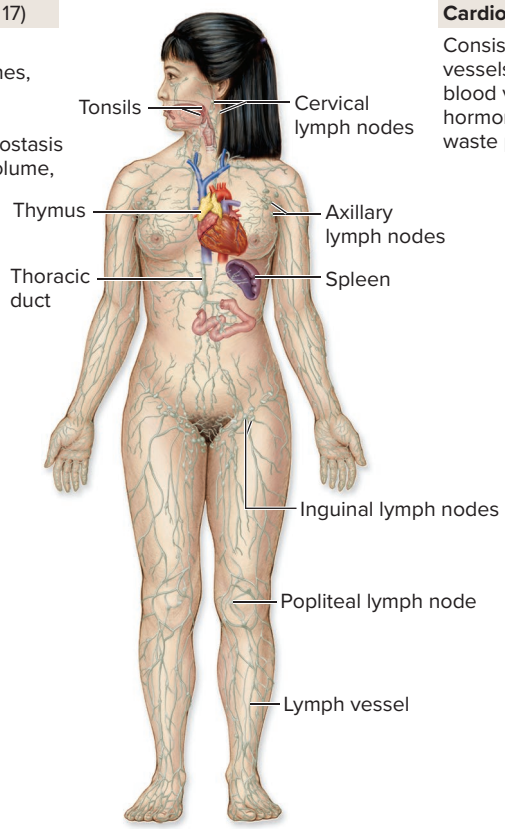
Endocrine System (Chapter 17)

Consists of glands and cell clusters that secrete hormones, (some of which regulate development, growth, and metabolism); maintain homeostasis of blood composition and volume, control digestive processes, and control reproductive functions.



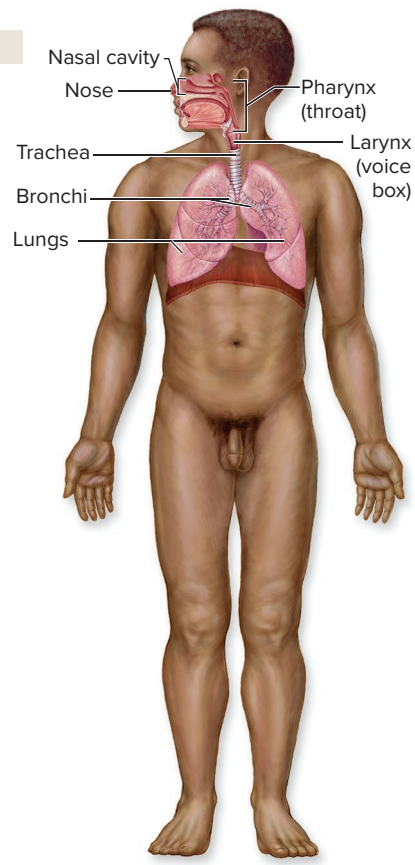
Cardiovascular System (Chapters 18–20)

Consists of the heart (a pump) and blood vessels; the heart moves blood through blood vessels in order to distribute hormones, nutrients, gases, and pick up waste products.



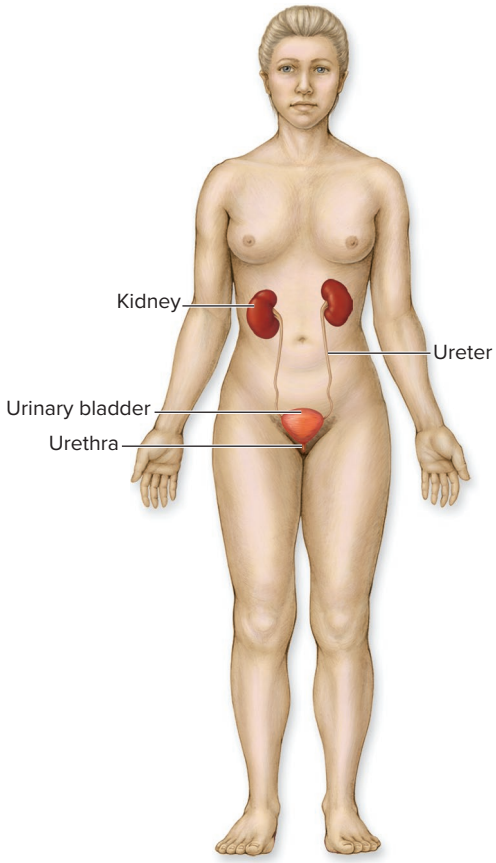
Lymphatic System (Chapters 21–22)

Transports and filters lymph (interstitial fluid that is collected in and transported through lymph vessels) and may participate in an immune response.



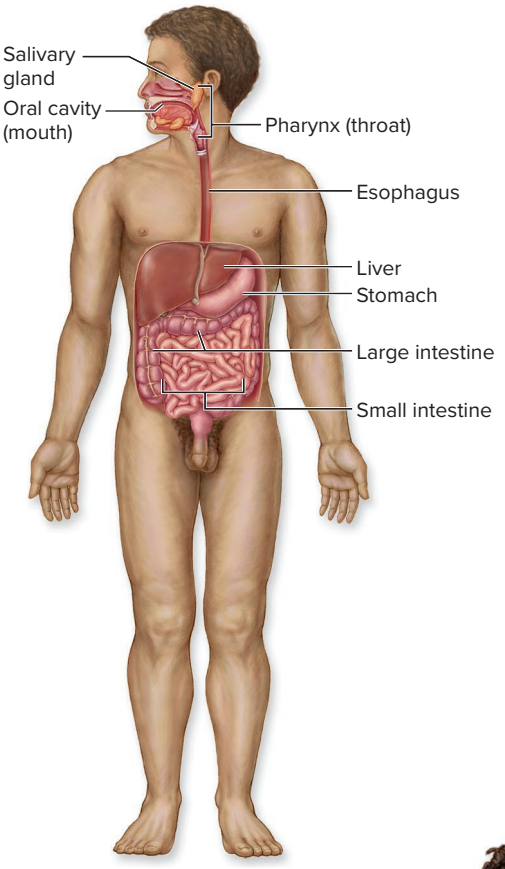
Respiratory System (Chapter 23)

Responsible for exchange of gases (oxygen and carbon dioxide) between blood and the air in the lungs.



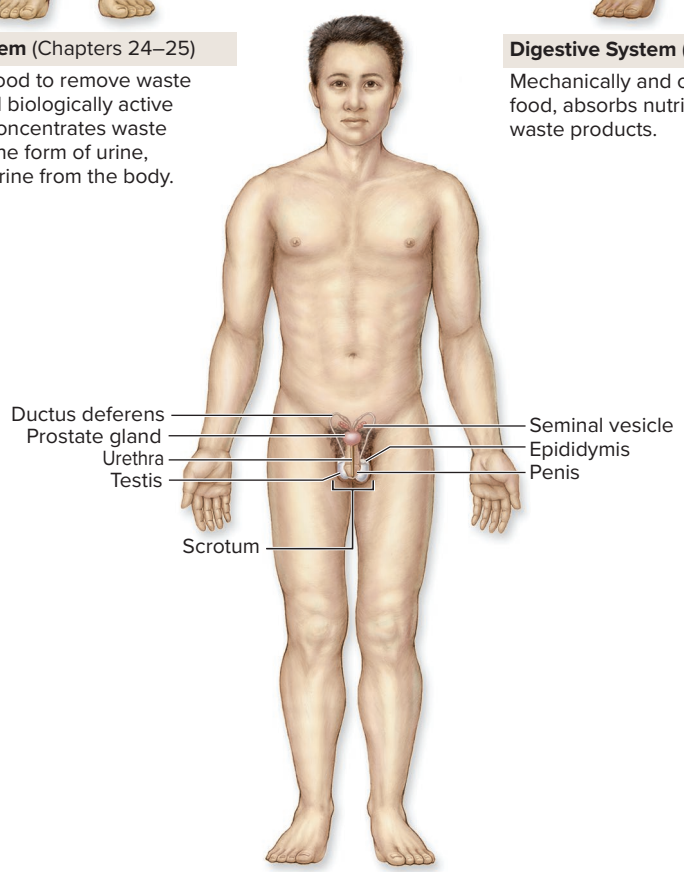
Urinary System (Chapters 24–25)

Filters the blood to remove waste products and biologically active molecules, concentrates waste products in the form of urine, and expels urine from the body.



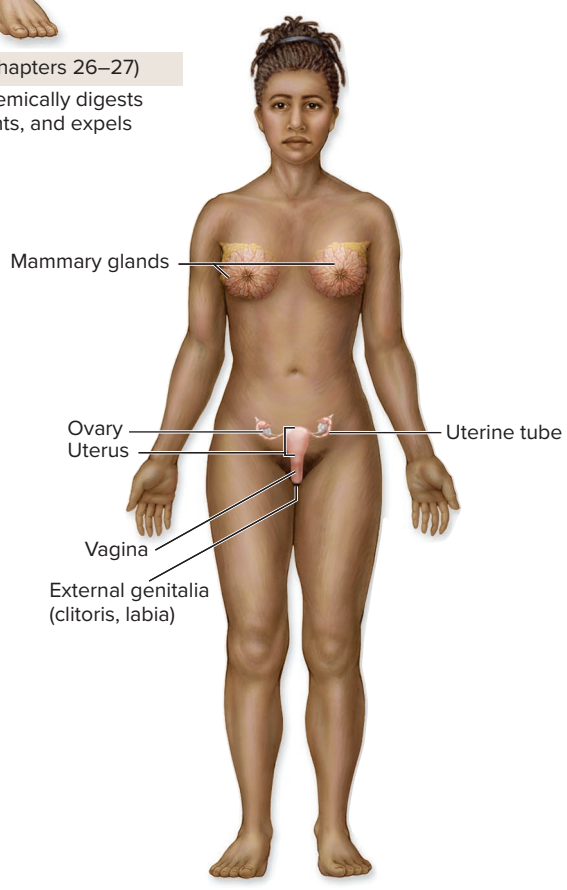
Digestive System (Chapters 26–27)

Mechanically and chemically digests food, absorbs nutrients, and expels waste products.



Male Reproductive System (Chapter 28)

Produces male sex cells (sperm) and male hormones (e.g., testosterone), transfers sperm to the female.



Female Reproductive System (Chapters 28–29)

Produces female sex cells (oocytes) and female hormones (e.g., estrogen and progesterone), receives sperm from male, site of fertilization of oocyte, site of growth and development of embryo and fetus, produces and secretes breast milk for nourishment of newborn.

Figure 1.3 Organ Systems. (*continued*) APR

1.5 The Precise Language of Anatomy and Physiology

Clinicians and researchers in anatomy and physiology require a precise language to ensure that they are all discussing the same features and functions. A technical terminology has been developed that describes body position, direction, regions, and body cavities. These technical terms are different from those used in everyday conversation, because the more conversational terms often do not accurately describe location and position or identify structures. For example, the term *arm* in everyday conversation refers to the entire upper limb, but in anatomy the specific portions of the upper limb are named, and the term *arm* or *brachium* refers only to that part of the upper limb between the shoulder and the elbow.

Most anatomic and physiologic terms are derived from Greek or Latin, and we frequently provide word origins, pronunciations, and definitions of terms where appropriate throughout this text. A listing of the common prefixes, suffixes, and word roots used in anatomy and physiology are listed in appendix B. We've used *Stedman's Medical Dictionary* (which defines all medical terms) and *Terminologia Anatomica* (which lists and categorizes the modern, proper anatomic terms) as references. If you actively practice the vocabulary and descriptive terminology presented here, your understanding and appreciation of body structure and function will be enhanced significantly.

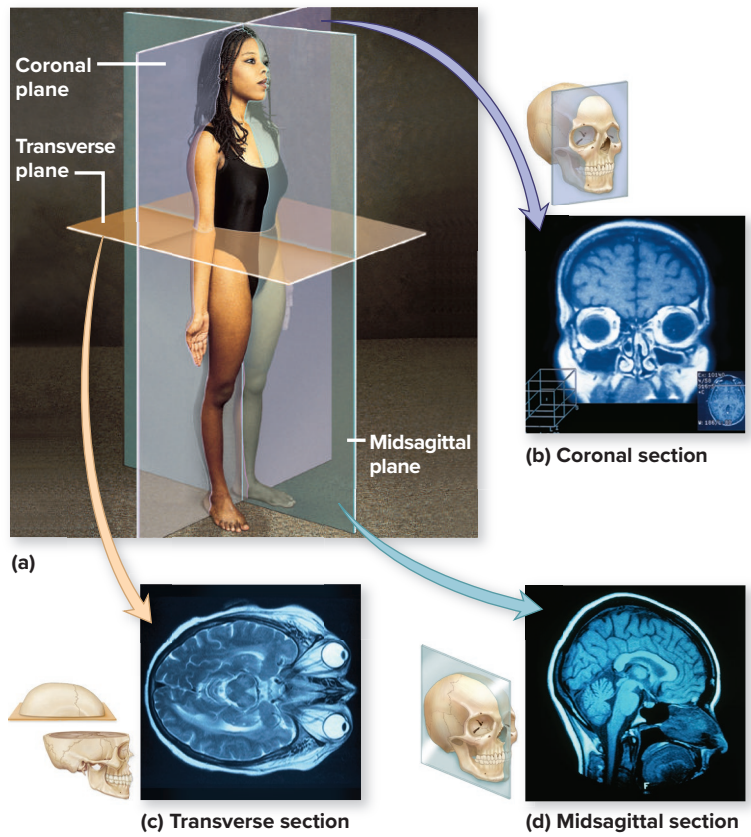


Figure 1.4 Anatomic Position and Body Planes. (*a*) In the anatomic position, the body is upright, and the forearms are positioned so the palms are facing anteriorly. A plane implies an imaginary flat surface that slices the body into specific sections. Sections are shown from each of the three major anatomic planes of reference: (*b*) coronal, (*c*) transverse, and (*d*) midsagittal planes. APR

(a) ©McGraw-Hill Education/Joe DeGrandis; (b) ©James Cavallini/Science Source; (c) ©Trevor Lush/The Image Bank/Getty Images; (d) ©Stevie Grand/Science Source

INTEGRATE

LEARNING STRATEGY 1.2

Breaking a word into smaller parts can help you understand and remember its meaning. In this book, we provide word derivations for new terms following their pronunciations. For example, in the case of *histology,* the study of tissues, we provide the following: (*histos* = web, tissue, *logos* = study).

Many biological terms share some of the same prefixes, suffixes, and word roots, so learning the meanings of these common terms can help you figure out the meanings of unfamiliar terms.

1.5a Anatomic Position

LEARNING OBJECTIVE

10. Describe the anatomic position and its importance in the study of anatomy.

Descriptions of any body region or part require a common initial point of reference. Note that terms such as *superior* and *inferior* can be relative terms. For example, when a person is standing it would be accurate to say "the heart is superior to the stomach," yet if that person were in a **supine** (lying down, face upward) position, this statement would seem not to be true. For accuracy and clarity, anatomists and physiologists describe these parts based on the premise that the body is in what is termed the anatomic position, which is then the point of common reference. An individual in the **anatomic position** stands upright with the feet parallel and flat on the floor, the upper limbs are at the sides of the body, and the palms face anteriorly (toward the front); the head is level, and the eyes look forward toward the observer **(figure 1.4*a*)**. All of the anatomic and directional terms used in this book refer to the body in anatomic position.

1.5b Sections and Planes

LEARNING OBJECTIVE

11. Describe the anatomic sections and planes through the body.

Anatomists and physiologists refer to real or imaginary "slices" of the body, called sections or planes, to examine the internal anatomy and describe the position of one body part relative to another. The term **section** implies an actual cut or slice to expose the internal anatomy, whereas the word **plane** implies an imaginary flat surface passing through the body. The three major anatomic planes are the coronal, transverse, and midsagittal planes (figure 1.4*b-d*).

A **coronal** (kōr′o-năl; *korone* = crown) **plane,** also called a *frontal plane,* is a vertical plane that divides the body or organ into *anterior* (front) and *posterior* (back) parts. When a coronal plane is taken through the trunk, the anterior portion contains the chest and the posterior portion contains the back and buttocks.

A **transverse plane,** also called a *horizontal plane* or *cross-sectional plane,* divides the body or organ into *superior* (top) and *inferior* (bottom) parts. If a transverse plane is taken through the middle of the trunk, the superior portion contains the chest and the inferior portion contains the abdomen.

A **midsagittal** (mid-saj′ĭ-tăl; *sagitta* = arrow) **plane,** or *median plane,* is a vertical plane and divides the body or organ into equal *left* and *right halves.* A midsagittal plane through the head will split it into a left half and a right half (each containing one eye, one ear, and half of the nose and mouth). A plane that is parallel to the midsagittal

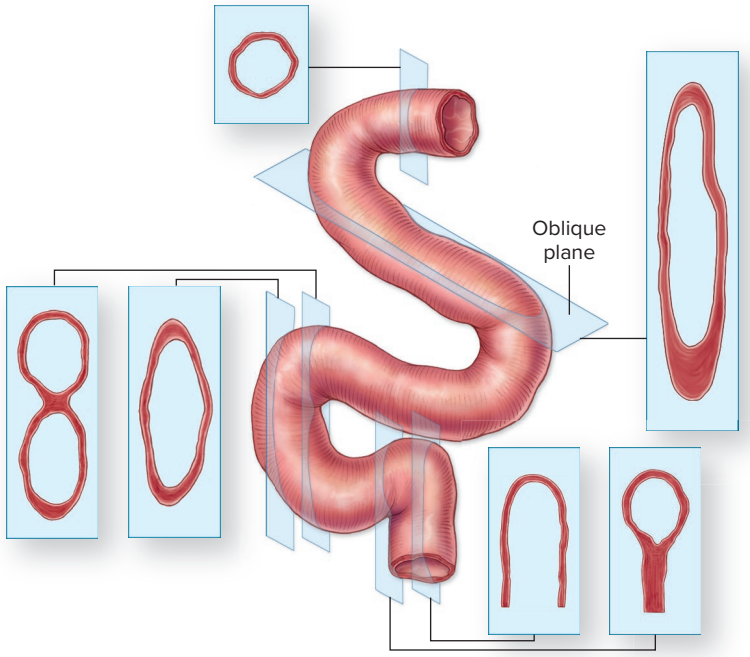


Figure 1.5 Sections from a Three-Dimensional Structure. Serial sections through an object are used to reconstruct its three-dimensional structure, as in these sections of the small intestine. Often a single section, such as the plane at the lower part of this figure, misrepresents the complete structure of the object. An oblique plane is labeled for reference.

plane, but either to the left or right of the midsagittal plane, is termed a **sagittal plane.** A sagittal plane divides a structure into left and right portions that are not equal. Although there is only one midsagittal plane, an infinite number of sagittal planes are possible.

In addition to these major planes, there are numerous minor planes called **oblique** (ob-lēk′) **planes** that pass through a structure at an angle **(figure 1.5)**.

Interpreting body sections has become increasingly important for health-care professionals. Technical advances in medical imaging have produced sectional images of internal body structures (figures 1.4*b-d*). To determine the shape of any object within a section, we must be able to reconstruct its three-dimensional shape by observing many serial sections.

Sectioning the body or an organ along different planes often results in very different views of that organ or region. For example, different sections through the abdominal cavity exhibit multiple profiles of the long, twisted tube that is the small intestine. These sections may appear as circles, ovals, a figure eight, or maybe a long tube with parallel sides, depending on where the section was taken (figure 1.5). Being able to convert and interpret two-dimensional images into three-dimensional structures is especially important when comparing and understanding histologic and gross anatomic views of the same organ.

WHAT DID YOU LEARN?

9 What type of plane would separate the nose and mouth into superior and inferior structures?

1.5c Anatomic Directions

LEARNING OBJECTIVE

12. Define the different anatomic directional terms.

When the body is in the anatomic position, we can precisely describe the relative positions of structures by using specific directional terms. These directional terms are precise and usually presented in opposing pairs. Examples include **anterior** (in front of) and **posterior** (in back of), and **proximal** (nearer to the trunk) and **distal** (farther from the trunk). **Table 1.1** and **figure 1.6** describe some commonly used directional terms. Studying the table and figure together, and referring back to them as needed, will maximize your understanding of anatomic directions and aid your study of anatomy throughout the rest of this book.

WHAT DID YOU LEARN?

10 Which directional term would be most appropriate in the sentence "The elbow is _____ to the wrist"?

Table 1.1 Anatomic Directional Terms

Direction	Term	Meaning	Example
Relative to front (belly side) or back of the body	Anterior	In front of; toward the front surface	The stomach is *anterior* to the spinal cord.
	Posterior	In back of; toward the back surface	The heart is *posterior* to the sternum.
	Dorsal	Toward the back side of the human body	The spinal cord is on the *dorsal* side of the body.
	Ventral	Toward the belly side of the human body	The umbilicus (navel, belly button) is on the *ventral* side of the body.
Relative to the head or bottom of the body	Superior	Closer to the head	The chest is *superior* to the pelvis.
	Inferior	Closer to the feet	The stomach is *inferior* to the heart.
	Cranial (cephalic)	Toward the head end	The shoulders are *cranial* to the feet.
	Caudal	Toward the rear or tail end	The buttocks are *caudal* to the head.
	Rostral	Toward the nose or mouth	The frontal lobe of the brain is *rostral* to the back of the head.
Relative to the midline or center of the body	Medial	Toward the midline of the body	The lungs are *medial* to the shoulders.
	Lateral	Away from the midline of the body	The arms are *lateral* to the heart.
	Ipsilateral	On the same side	The right arm is *ipsilateral* to the right leg.
	Contralateral	On the opposite side	The right arm is *contralateral* to the left leg.
	Deep	Closer to the inside, internal to another structure	The heart is *deep* to the rib cage.
	Superficial	Closer to the outside, external to another structure	The skin is *superficial* to the biceps brachii muscle.
Relative to point of attachment of appendage	Proximal	Closer to point of attachment to trunk	The elbow is *proximal* to the hand.
	Distal	Farther away from point of attachment to trunk	The wrist is *distal* to the elbow.

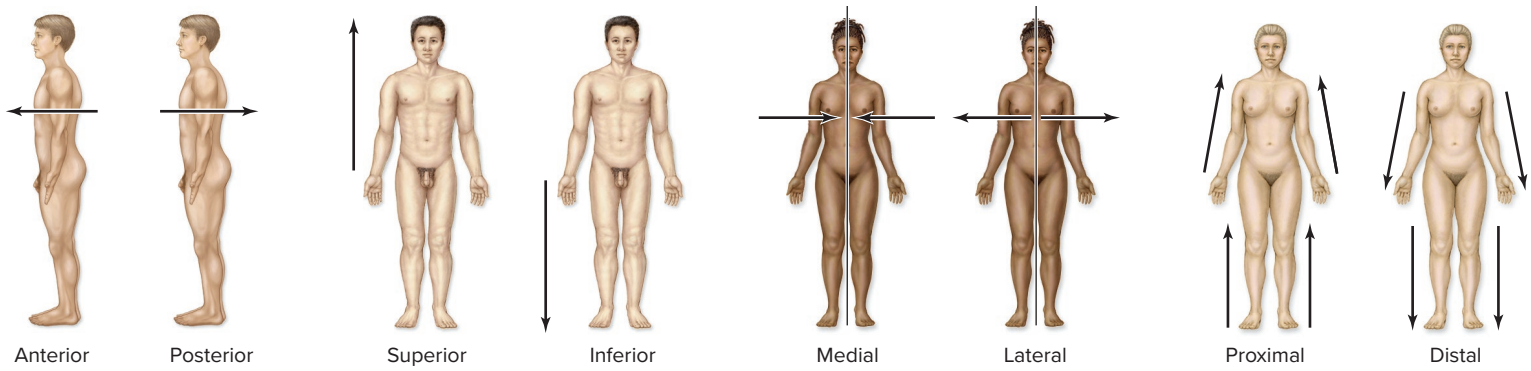


Figure 1.6 Directional Terms in Anatomy. Directional terms precisely describe the location and relative relationships of body parts. (See also table 1.1.) APR

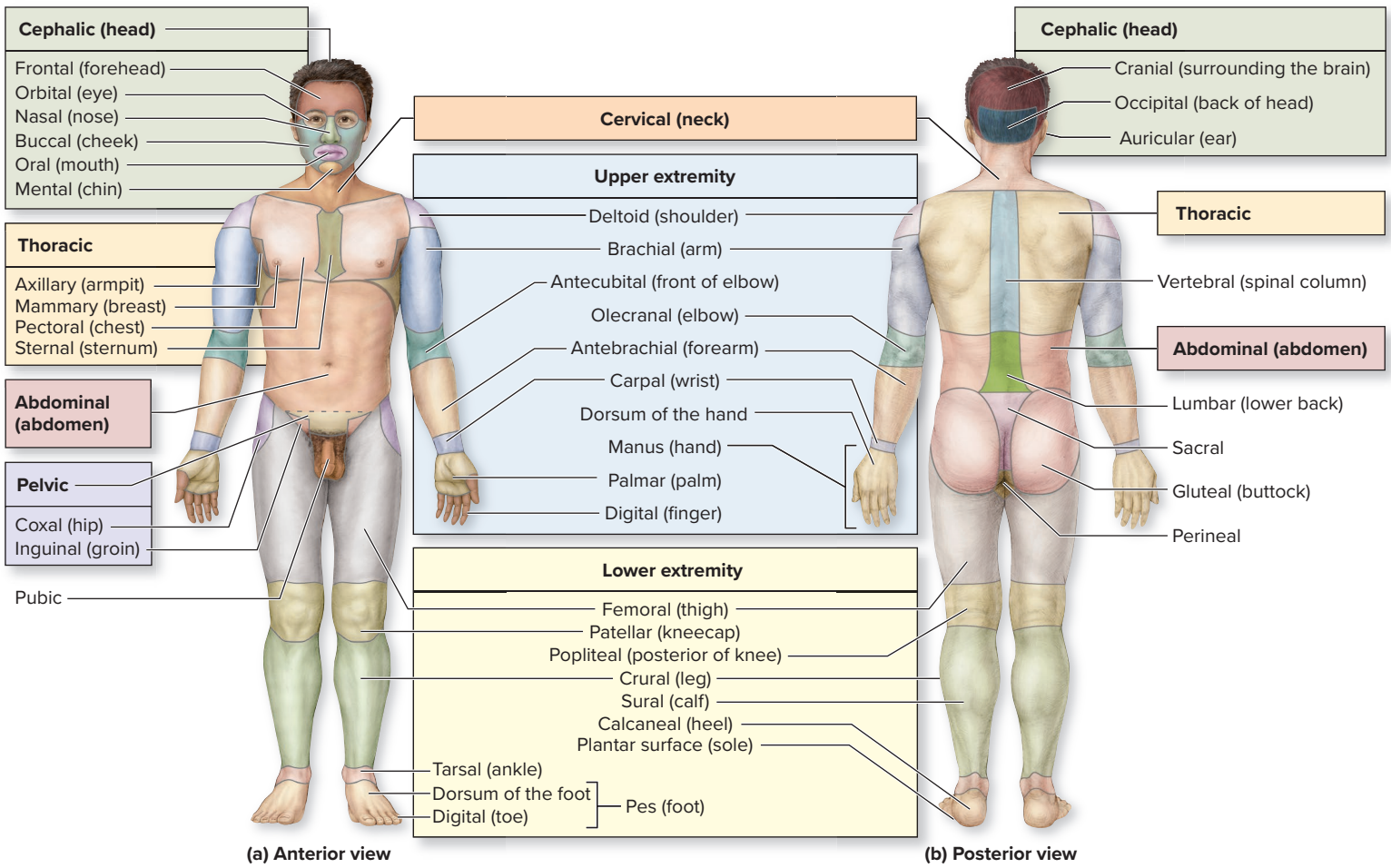


Figure 1.7 Major Regional Terms. (*a*) Anterior and (*b*) posterior views show key regions of the body. Their common names appear in parentheses. APR

1.5d Regional Anatomy

LEARNING OBJECTIVE

13. Identify and describe the major regions of the body, using proper anatomic terminology.

The human body is partitioned into two main regions, the axial and appendicular regions. The **axial** (ak′sē-ăl) **region** includes the head, neck, and trunk; it forms the main vertical axis of the body. The **appendicular** (ap′en-dik′ū-lăr) **region** is composed of the upper and lower limbs, which attach to the axial region. Several more specific regions are located within these two main ones, and they are identified by proper anatomic terminology. Figure 1.7 and table 1.2 identify the major regional terms and some additional minor ones, as well. Not all regions are shown in figure 1.7.

WHAT DID YOU LEARN?

11 Draw an outline of the human body, and label your figure with the regional anatomy terms your instructor requires you to know. The act of drawing and writing out the terms will help you remember the terms better.

Table 1.2 Human Body Regions[1]

Region Name	Description
Abdominal	Region inferior to the thorax (chest) and superior to the pelvic brim of the hip bones
Antebrachial	Forearm (the portion of the upper limb between the elbow and the wrist)
Antecubital	Region anterior to the elbow; also known as the cubital region
Auricular	Visible surface structures of the ear
Axillary	Armpit
Brachial	Arm (the portion of the upper limb between the shoulder and the elbow)
Buccal	Cheek
Calcaneal	Heel of the foot
Carpal	Wrist
Cephalic	Head
Cervical	Neck
Coxal	Hip
Cranial	Skull
Crural	Leg (the portion of the lower limb between the knee and the ankle)
Deltoid	Shoulder
Digital	Fingers or toes (also called phalangeal)
Dorsal/Dorsum	Back
Facial	Face
Femoral	Thigh
Fibular[2]	Lateral aspect of the leg
Frontal	Forehead
Gluteal	Buttock
Hallux[2]	Great toe
Inguinal	Groin (sometimes used to indicate the crease or junction of the thigh with the trunk)
Lumbar	The "small of the back": the inferior part of the back between the ribs and the pelvis
Mammary	Breast
Manus	Hand
Mental	Chin
Nasal	Nose
Occipital	Posterior aspect of the head
Olecranal	Posterior aspect of the elbow
Oral	Mouth
Orbital	Eye
Palmar	Palm (anterior surface) of the hand
Patellar	Kneecap
Pectoral	Chest, includes mammary region
Pelvic	Pelvis; region inferior to the pelvic brim of the hip bones
Perineal	Diamond-shaped region between the thighs that contains the anus and external reproductive organs
Pes	Foot
Plantar	Sole of the foot
Pollex[2]	Thumb
Popliteal	Area posterior to the knee
Pubic	Anterior region of the pelvis
Radial	Lateral aspect (thumb side) of forearm
Sacral	Posterior region between the hip bones
Scapular	Shoulder blade
Sternal	Anterior middle region of the thorax
Sural	Calf (posterior part of the leg)
Tarsal	Proximal part of the foot and ankle
Thoracic	Part of torso superior to thoracic diaphragm; contains the pectoral, axillary, and sternal regions
Tibial[2]	Medial aspect of leg
Ulnar	Medial aspect (pinky side) of the forearm
Umbilical[2]	Navel
Vertebral	Spinal column

1. The word *region* should follow each region name listed in the table (e.g., femoral region).
2. Not shown in figure 1.7.

1.5e Body Cavities and Membranes

LEARNING OBJECTIVES

14. Describe the body cavities and their subdivisions.

15. Explain the structure and function of serous membranes in the ventral cavities.

Internal organs and organ systems are located within enclosed spaces, or cavities. These body cavities are named according to either the bones that surround them or the organs they contain. For purposes of discussion, these body cavities are grouped into a posterior aspect and a ventral cavity.

Posterior Aspect

The **posterior aspect** of the body is different from the ventral cavity, in that the posterior aspect contains cavities that are completely encased in bone and are physically and developmentally different from the ventral cavity. The term *dorsal body cavity* has been used by others to describe this posterior aspect but is not used here because of these differences between the ventral cavity and posterior aspect.

The posterior aspect is subdivided into two enclosed cavities (figure 1.8*a*). A **cranial cavity** is formed by the bones of the cranium, and so it also goes by the name *endocranium.* The cranial

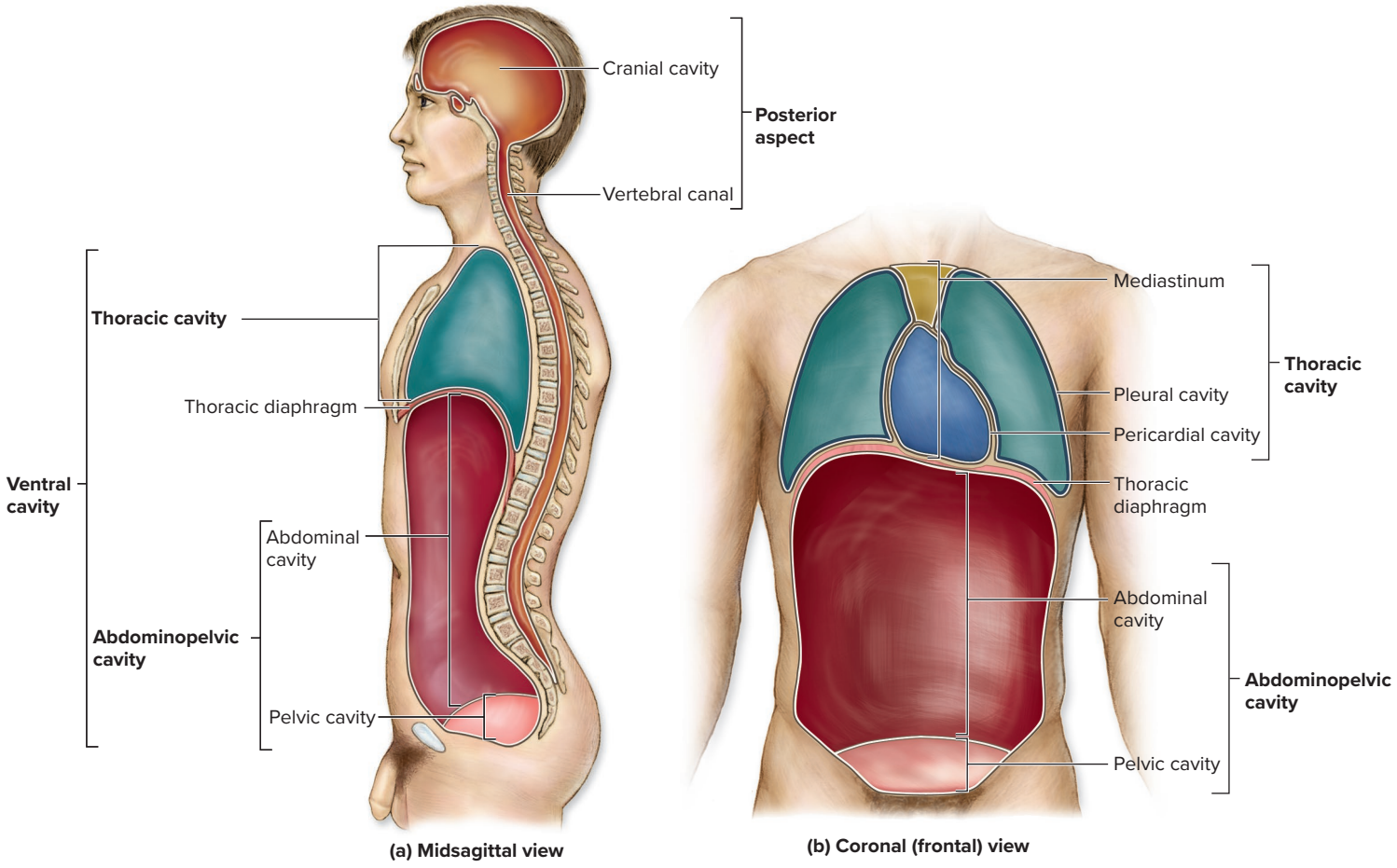


Figure 1.8 Body Cavities. The body is composed of two main spaces: the posterior aspect and the ventral cavity. Many vital organs are contained within these spaces. (*a*) A midsagittal view shows both the posterior aspect and the ventral cavity. (*b*) A coronal view shows the relationship between the thoracic and abdominopelvic cavities within the ventral cavity. APR

cavity contains the brain. The second cavity is the **vertebral** (ver′te-brăl) **canal,** which is formed by the bones of the vertebral column. The vertebral canal contains the spinal cord.

Ventral Cavity

The **ventral cavity** is the larger, anteriorly placed cavity in the body (figure 1.8). Unlike the posterior aspect, the ventral cavity and its subdivisions do not completely encase their organs in bone. The ventral cavity is partitioned by the **thoracic diaphragm** into a superior **thoracic** (thō-ras′ik) **cavity** and an inferior **abdominopelvic** (ab-dom′i-nō-pel′vik) **cavity.**

Another significant difference between the posterior aspect and the ventral cavity is that the subdivisions of the ventral cavity are lined with thin **serous membranes.** (Posterior aspect cavities have no serous membranes.) In this usage, a *membrane* is a continuous layer of cells, as compared to the plasma membrane that surrounds a single cell (see section 4.1c). Serous membranes form two layers: (1) a **parietal** (pă-rī′ĕ-tăl) **layer** that typically lines the internal surface of the body wall and (2) a **visceral** (vis′er-ăl) **layer** that covers the external surface of the organs **(viscera)** within that cavity. Between the parietal and visceral serous membrane layers is a potential space called the **serous cavity.** (Note: A potential space is capable of becoming a larger opening under certain physiological or pathological conditions.) Serous membranes secrete a liquid called **serous fluid** within a serous cavity. Serous fluid has the consistency of oil and serves as a lubricant. In a living person, organs (e.g., heart, lungs, intestines) move and rub against each other and the body wall. Friction caused by this movement is reduced by the serous fluid so the organs move more smoothly against one another and the body walls **(figure 1.9)**. Serous membranes will be discussed again in section 5.5b.

WHAT DO YOU THINK?

2 What do you think would happen to your body organs if there were no serous fluid between the parietal and visceral layers?

Thoracic Cavity Within the thoracic cavity, the median space between the lungs is called the **mediastinum** (mē-dē-as-tī′nŭm; *medius* = middle) (figure 1.8*b*). It contains the heart, thymus, esophagus, trachea, and major blood vessels that connect to the heart.

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LEARNING STRATEGY 1.3

Figure 1.9*a* provides an analogy for visualizing the serous membrane layers. The closed fist is comparable to an organ, and the balloon is comparable to a serous membrane. When a fist is pushed against the wall of the balloon, the inner balloon wall that surrounds the fist is comparable to the visceral layer of the serous membrane. The outer balloon wall is comparable to the parietal layer of the serous membrane. The thin, air-filled space between the two "walls" of the balloon is comparable to the serous cavity. Note that the organ is not *inside* the serous cavity; it is actually *outside* the cavity and merely covered by the serous membrane.

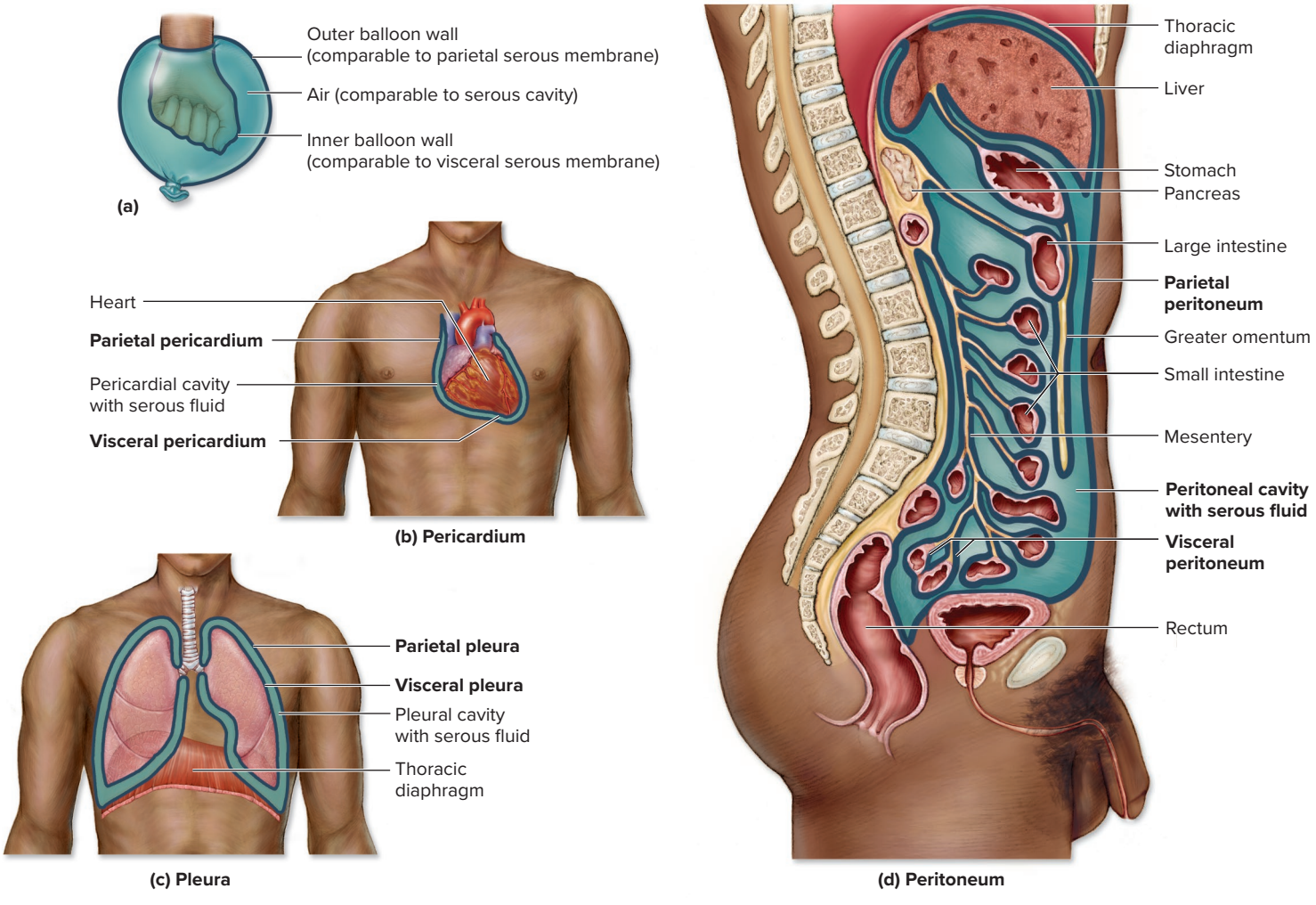


Figure 1.9 Serous Membranes in the Thoracic and Abdominopelvic Body Cavities. Serous membranes are internal membranes within the ventral cavity. (*a*) The parietal and visceral serous membranes are similar to the outer and inner balloon walls that wrap around a fist, where the fist represents the body organ. (*b*) Parietal and visceral layers of the serous pericardium line the pericardial cavity around the heart. (*c*) Parietal and visceral layers of the pleura line the pleural cavity between the chest wall and the lungs. (*d*) Parietal and visceral layers of the peritoneum line the peritoneal cavity that is located between the body wall of the abdominopelvic region and the abdominopelvic organs. APR

Within the mediastinum, the heart is enclosed by a two-layered serous membrane called the serous **pericardium** (per-ĭ-kar′dē-ŭm; *peri* = around, *kardia* = heart). The **parietal pericardium** is the outer layer of the serous membrane and forms the inner lining of the sac around the heart, whereas the **visceral pericardium** covers the heart's external surface (figure 1.9*b*). The **pericardial cavity** is the serous cavity between the parietal and visceral layers of the pericardium, and it contains serous fluid (see section 19.2b).

The right and left sides of the thoracic cavity contain the lungs, which are associated with a two-layered serous membrane called the **pleura** (plūr′ă; a rib) (figure 1.9*c*). The **parietal pleura** is the outer layer of the serous membrane and lines the internal surface of the thoracic wall. The inner layer is the **visceral pleura,** which covers the external surface of each lung. The **pleural cavity** is the serous cavity between these parietal and visceral layers, and it contains serous fluid (see section 23.4c).

Abdominopelvic Cavity The abdominopelvic cavity consists of an **abdominal cavity,** which is superior to the pelvic brim of the hip bones (see section 8.10b), and a **pelvic cavity,** which is inferior to the pelvic brim. The abdominal cavity contains most of the digestive system organs, as well as the kidneys and most of the ureters. The pelvic cavity contains the distal part of the large intestine, the remainder of the ureters and the urinary bladder, and the internal reproductive organs.

The **peritoneum** (per′i-tō-nē′um; *periteino* = to stretch over) is the two-layered serous membrane that is associated with the abdominopelvic cavity (figure 1.9*d*). The **parietal peritoneum,** the outer layer of this serous membrane, lines the internal walls of the abdominopelvic cavity. The **visceral peritoneum** is the inner layer of this serous membrane, and it covers the external surfaces of most abdominal and pelvic organs. The serous cavity between these serous membrane layers is the **peritoneal cavity,** which contains and is lubricated by serous fluid.

WHAT DID YOU LEARN?

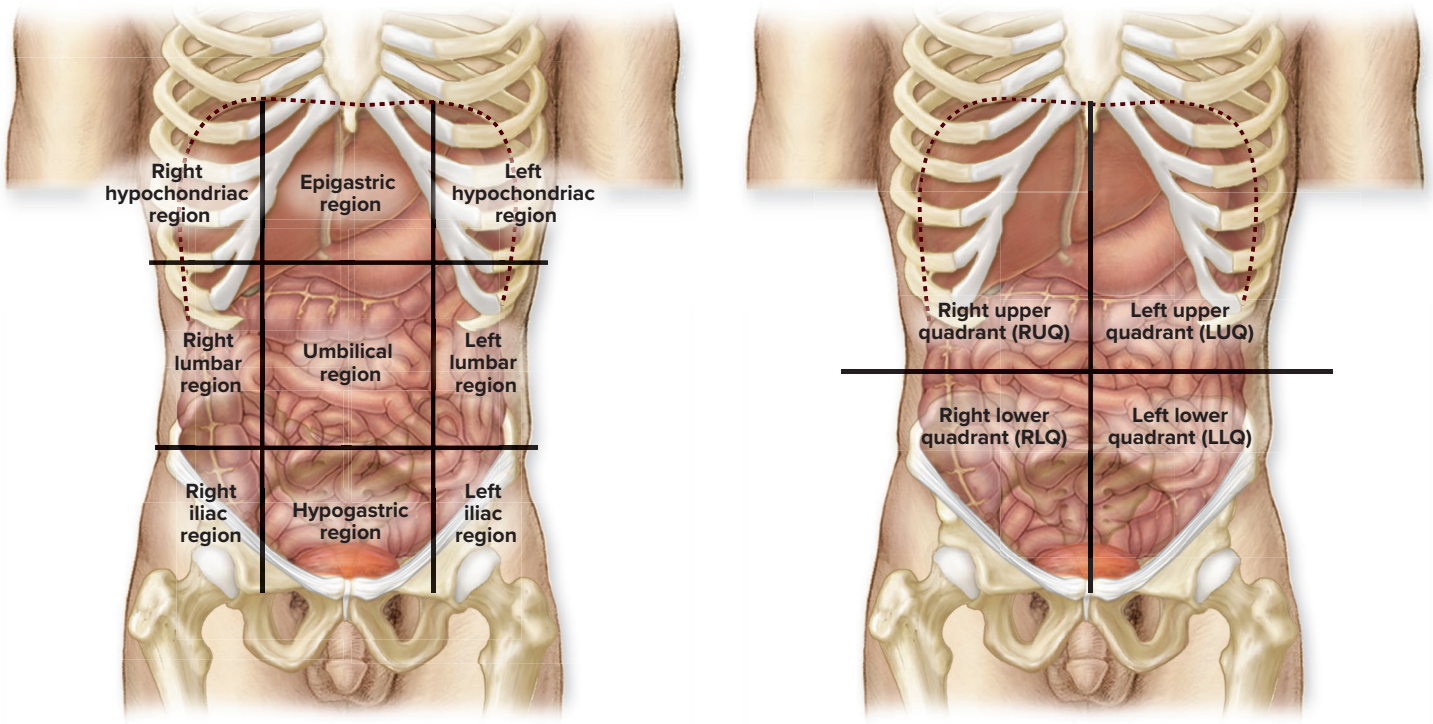
12 Which body cavity is associated with the lungs, and what are the names and specific location of its serous membranes?

1.5f Abdominopelvic Regions and Quadrants

LEARNING OBJECTIVE

16. Identify and list the four quadrants and nine regions of the abdominopelvic region, using the anatomic terms for each.

To more accurately describe organ location, anatomists and health-care professionals commonly partition the large abdominopelvic cavity into smaller compartments. Nine compartments, called



(a) Abdominopelvic regions

(b) Abdominopelvic quadrants

Figure 1.10 Abdominopelvic Regions and Quadrants. The abdominopelvic cavity can be subdivided into (*a*) nine regions or (*b*) four quadrants for purposes of description or identification. APR

abdominopelvic regions, are delineated by using two transverse planes and two sagittal planes.

These nine regions are shown in **figure 1.10*a*** and summarized here:

- The **umbilical** (ŭm-bil′i-kăl; navel) **region** is the middle region and is named for the umbilicus, or navel (belly button) that lies in its center.
- The **epigastric** (ep-ĭ-gas′trik; *epi* = above, *gaster* = belly) **region** is superior to the umbilical region.
- The **hypogastric** (hī-pō-gas′trik; *hypo* = under) **region** lies inferior to the umbilical region.
- The **right** and **left hypochondriac** (hī-pō-kon′drē-ak; *chondr* = cartilage) **regions** are inferior to the costal cartilages (cartilage attached to the ribs) and lateral to the epigastric region.
- The **right** and **left lumbar regions** are lateral to the umbilical region.
- The **right** and **left iliac** (il′ē-ak; *eileo* = to twist) **regions** are lateral to the hypogastric region.

Some health-care professionals prefer to partition the abdomen more simply into four quadrants, using the umbilicus as the central point and having imaginary transverse and midsagittal planes pass through the umbilicus (figure 1.10*b*). The quadrants are named **right upper quadrant (RUQ), left upper quadrant (LUQ), right lower quadrant (RLQ),** and **left lower quadrant (LLQ).** These quadrants, like the abdominopelvic regions, are used to accurately locate and describe various aches, pains, injuries, or other abnormalities.

WHAT DID YOU LEARN?

13 If a physician makes an incision into the abdomen along the midsagittal plane, superior to the umbilicus and just inferior to the thoracic diaphragm, then the skin of the _____ abdominopelvic region has been incised.

1.6 Homeostasis: Keeping Internal Conditions Stable

Have you ever noticed that your body maintains an average internal temperature of about 37°C (98.6°F), regardless of the outside temperature? Perhaps you also have noticed that the size of your pupil is altered in response to light intensity entering your eye, or that your breathing returns to normal shortly after exercise. Likewise, your heart rate, blood pressure, and blood levels of sugar (glucose) and oxygen (O_2) are also regulated and maintained within certain parameters. In fact, there are hundreds of anatomic structures and physiologic processes that are continuously monitored and adjusted within your body so that they are kept within normal limits.

The term **homeostasis** (*homoios* = similar, *stasis* = standing) refers to the ability of an organism to maintain a consistent internal environment, or "steady state," in response to changing internal or external conditions. Homeostasis is a central theme throughout this text, and you will be learning the specific details about homeostasis in each chapter. This section introduces you to the general concept of homeostasis. We describe the components of homeostatic systems, provide specific examples of these regulatory processes, and then describe the relationship among homeostasis, health, and disease.

1.6a Components of Homeostatic Systems

LEARNING OBJECTIVES

17. List and describe the components of a homeostatic system.
18. List examples of homeostatic system components in representative organ systems.

The body maintains homeostasis by utilizing homeostatic control systems. Three components are associated with each homeostatic system: receptor, control center, and effector **(figure 1.11)**.

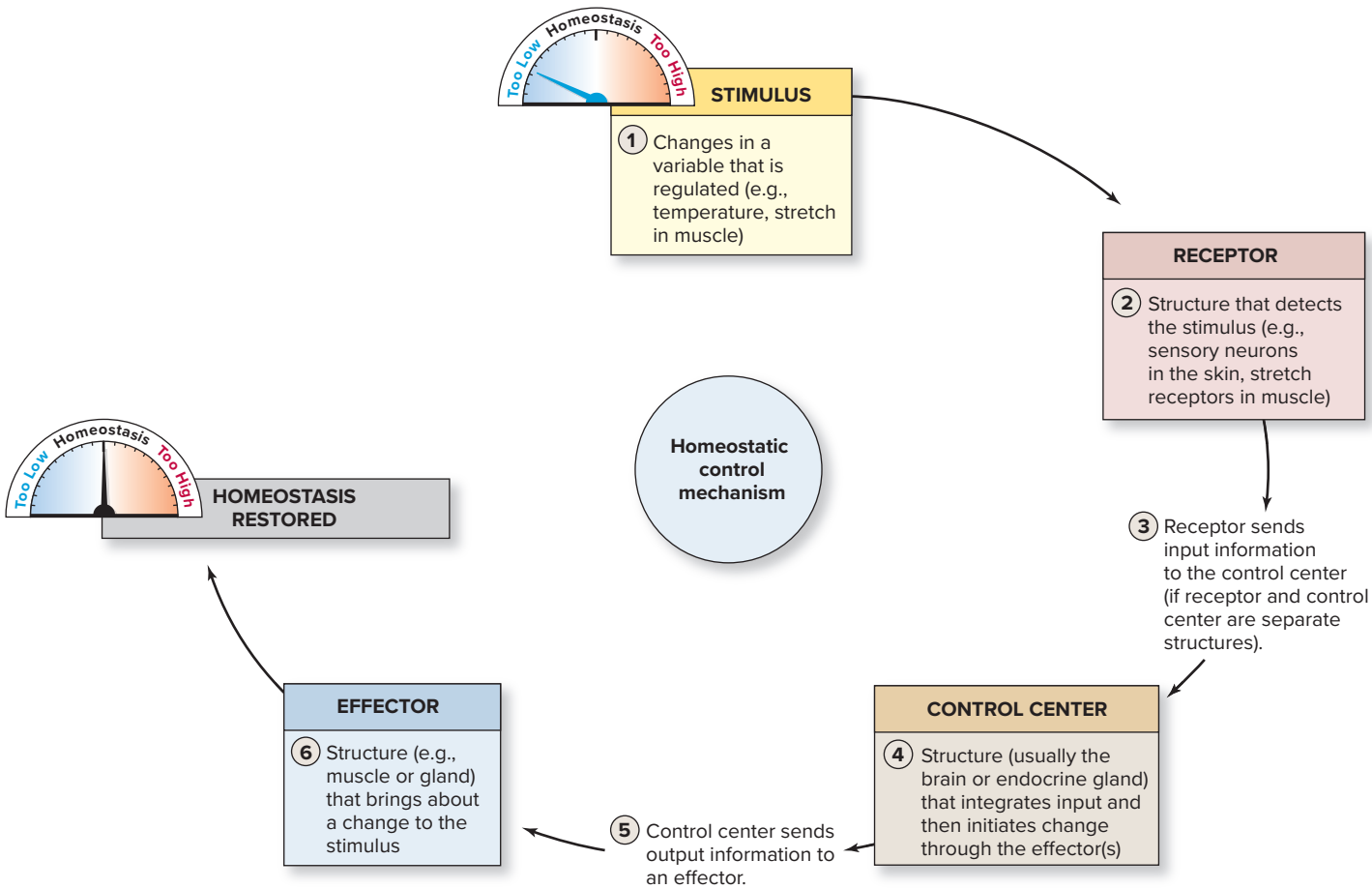


Figure 1.11 Components of a Homeostatic Control Mechanism. A homeostatic control mechanism consists of a receptor (detects a stimulus), a control center (integrates input and initiates change through the effector), and an effector (brings about a change in response to the stimulus).

Receptor

The **receptor** is the body structure that detects changes in a variable, which is a substance or process that is regulated. A receptor typically consists of sensory neurons (nerve cells). These neurons may be in the skin, internal organs of the body, or specialized organs such as the eye, ear, tongue, or nose. A **stimulus** is a change in the variable (a physical or chemical factor), such as a change in light, temperature, chemicals (e.g., glucose or oxygen levels), or stretch in muscle. Thus, a receptor is the structure that detects a stimulus. For example, the retina of the eye (receptor) detects a change in light (stimulus) entering the eye.

Control Center

The **control center** is the structure that both interprets input from the receptor and initiates changes through the effector. You can think of it as the "go between" for the other two components of a homeostatic system. The control center is generally a portion of the nervous system (brain or spinal cord) or an organ of the endocrine system (e.g., the thyroid gland). A homeostatic system involving the nervous system provides a relatively quick means of responding to change. An example is regulating blood pressure when you rise from bed in the morning (see section 20.6a). In contrast, the endocrine system usually provides a means of a more sustained response over several hours or days through the release of hormones. An example is when the parathyroid hormone continuously regulates blood calcium levels, a process that is essential for the normal function of both muscles and nerves (see section 17.10b). Note that the control center is sometimes the same structure as the receptor because it both detects the stimulus and causes a response to regulate it. For example, the pancreas acts as a receptor because it detects an increase in blood glucose and acts as a control center because it releases the hormone insulin in response (see section 17.9b).

Effector

The **effector** is the structure that brings about the change to alter the stimulus (i.e., the effector causes an "effect"). Most body structures can serve as effectors, although muscles and exocrine glands (see section 5.1d) are often the effectors. For example, smooth muscle in the walls of air passageways (bronchioles) regulates airflow into and out of the lungs. Salivary glands increase their release of saliva to moisten the mouth.

As you view figure 1.11, notice that the response of a homeostatic system occurs through a feedback loop that includes the following:

- A *stimulus,* which is the change in the variable
- A *receptor* that detects the stimulus
- The *control center,* which both integrates input information from the receptor and initiates output to the effectors
- The *effectors* that cause the change (or effect)
- *Homeostasis restored* as a result of the changes from the effectors

Homeostatic control systems are separated into two broad categories based on whether the system maintains the variable within a normal range by moving the stimulus in the opposite direction, or amplifies the

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LEARNING STRATEGY 1.4

You may find it useful to compare the components of a homeostatic control mechanism to the people working at a company:

- The *receptor* is the worker who first detects a change or problem in workflow and reports to the boss of the company.
- The *control center* is the boss of the company. After receiving information from the receptor, the boss will decide what action needs to be implemented.
- The *effectors* are the workers who receive the boss's plan of action and implement the plan to cause the effect or change.

stimulus in the same direction. These two types of feedback control are called negative feedback and positive feedback, respectively.

WHAT DID YOU LEARN?

14 List and describe the three components of a homeostatic system, and give examples of each in the human body.

1.6b Homeostatic Systems Regulated by Negative Feedback

LEARNING OBJECTIVES

19. Define negative feedback.

20. Explain how homeostatic mechanisms regulated by negative feedback detect and respond to environmental changes.

Most processes in the body are controlled by negative feedback. If a homeostatic system is controlled by **negative feedback,** the resulting action will always be in the *opposite* direction of the stimulus. In this way, the variable is maintained within a normal level, or what is called its **set point.**

How a variable that is regulated by negative feedback fluctuates over time can be viewed in **figure 1.12**. Notice that the variable does not remain constant over time but instead fluctuates, and its fluctuation occurs around the set point. If the stimulus increases, the homeostatic system causes a decrease in the stimulus until it returns to the set point. In contrast, if the stimulus decreases, the homeostatic system causes an increase in the stimulus until it returns to normal. Note that the regulation of the variable by the homeostatic control system is not simply "on" and "off," but is continuous—similar to how the speed of a car is controlled with the cruise control. The concept of homeostasis is generally better understood by describing a specific example, such as temperature regulation.

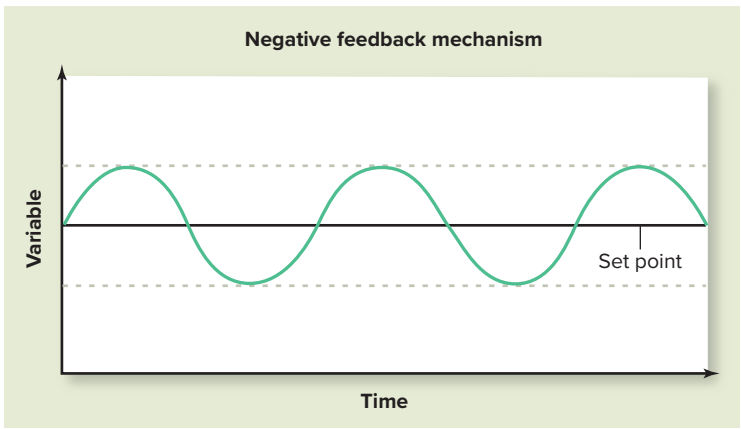

Figure 1.12 Negative Feedback. Note that when a variable is regulated by negative feedback, the variable fluctuates around a set point (rather than being a constant).

Temperature Regulation

We begin by first explaining how a negative feedback mechanism works to maintain the temperature of your home at a set point of 70°F. On a very cold day, the indoor temperature drops. This drop in temperature is detected by the thermostat. The drop in temperature is relayed through the electrical wiring of your home to the furnace, which then turns on. The furnace continues to heat your home until the thermostat reaches 70°F. An electrical signal is then sent from the thermostat to shut off the furnace.

Body temperature is regulated in an analogous way to how the temperature of your home is regulated **(figure 1.13*a*)**. If you venture outside on a cold day, body temperature may begin to drop. This decrease in body temperature is detected by the sensory receptors of the skin, which send nerve impulses to the hypothalamus (a component of the brain; see section 13.4c). (The hypothalamus can also directly detect changes in body temperature by monitoring blood temperature as it passes through this region of the brain.) The hypothalamus compares sensory input to body temperature set point (e.g., 37°C or 98.6°F), and initiates motor output to blood vessels in the skin to decrease the diameter of the inside opening (lumen) of the vessels, thus decreasing the amount of blood circulating to the surface of the body. As a result, less heat is released through the skin. Nerve impulses are also sent to skeletal muscles, which cause shivering, and to the arrector pili (smooth muscle associated with hair follicles), causing "goose bumps." Note that in this example the *receptors* are within the skin and hypothalamus; the *control center* is the hypothalamus; and the *effectors* are the blood vessels, skeletal muscles, and smooth muscle.

In contrast, on a very hot day (figure 1.13*b*), or when you are engaging in strenuous exercise, an increase in body temperature is detected by the sensory receptors of the skin or hypothalamus. The hypothalamus detects the difference between the increased body temperature and the original temperature set point, and initiates motor output to the blood vessels of the skin. This change increases the lumen diameters of blood vessels so that additional blood is brought near the surface of the body for the release of heat through the skin. Nerve impulses are also sent from the hypothalamus to the sweat glands to initiate sweating. Both responses help cool the body by the loss of heat from its surface. In these examples, regulation occurs through the nervous system. Here, the *receptors* are the skin and hypothalamus, and the *control center* is the hypothalamus. However, the *effectors* are the blood vessels and sweat glands.

Other examples of homeostatic regulation through the nervous system include the withdrawal reflex in response to injury from stepping on glass or burning your hand (see section 14.6), regulating heart rate and blood pressure when you exercise (see section 20.6a), or changing breathing rate in response to an increase in carbon dioxide levels (see section 23.5).

Recall that the control center may also be an organ of the endocrine system. Examples of homeostatic systems that regulate through the endocrine system include the parathyroid gland release of parathyroid hormone in response to a decrease in blood calcium (see section 7.6b) or pancreas release of insulin in response to an increase in blood glucose (see section 17.9b).

WHAT DID YOU LEARN?

15 Which body structures act as the receptor, control center, and effectors when the body is regulating temperature?