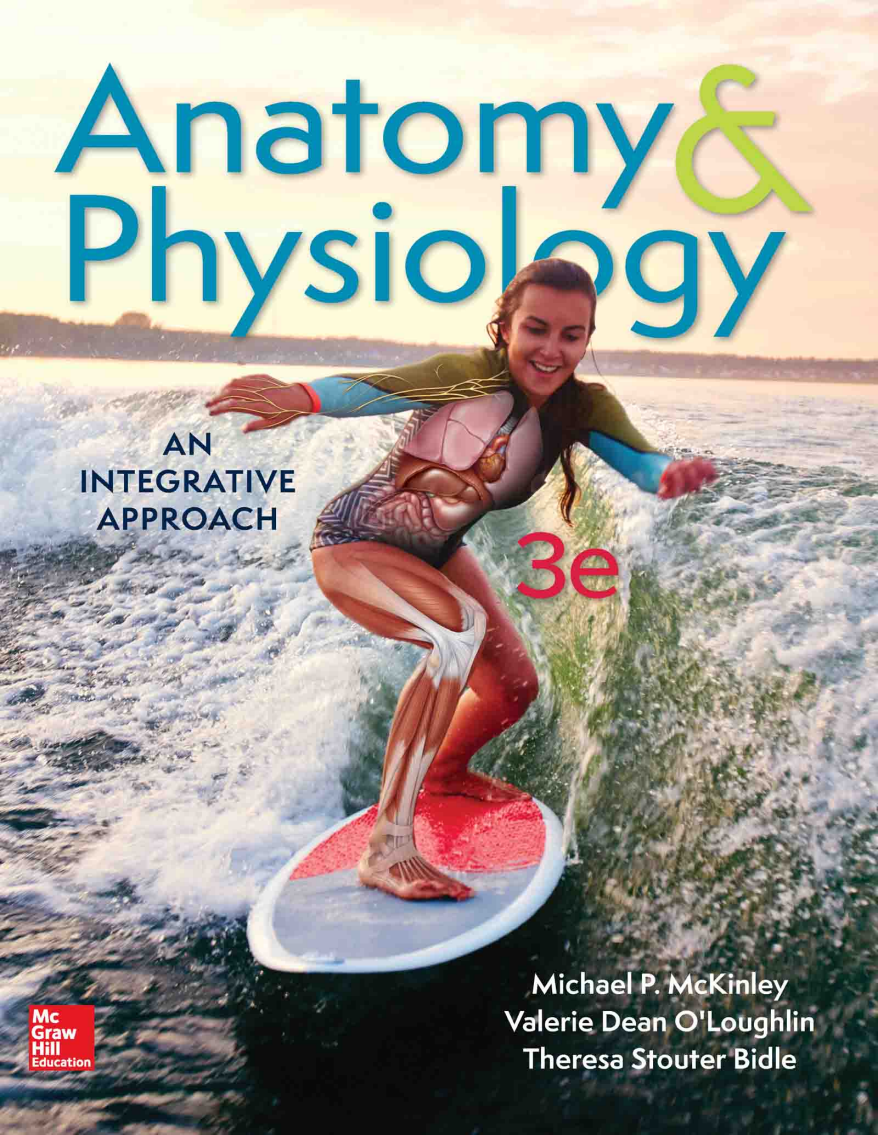
# Anatomy & Physiology

AN INTEGRATIVE APPROACH

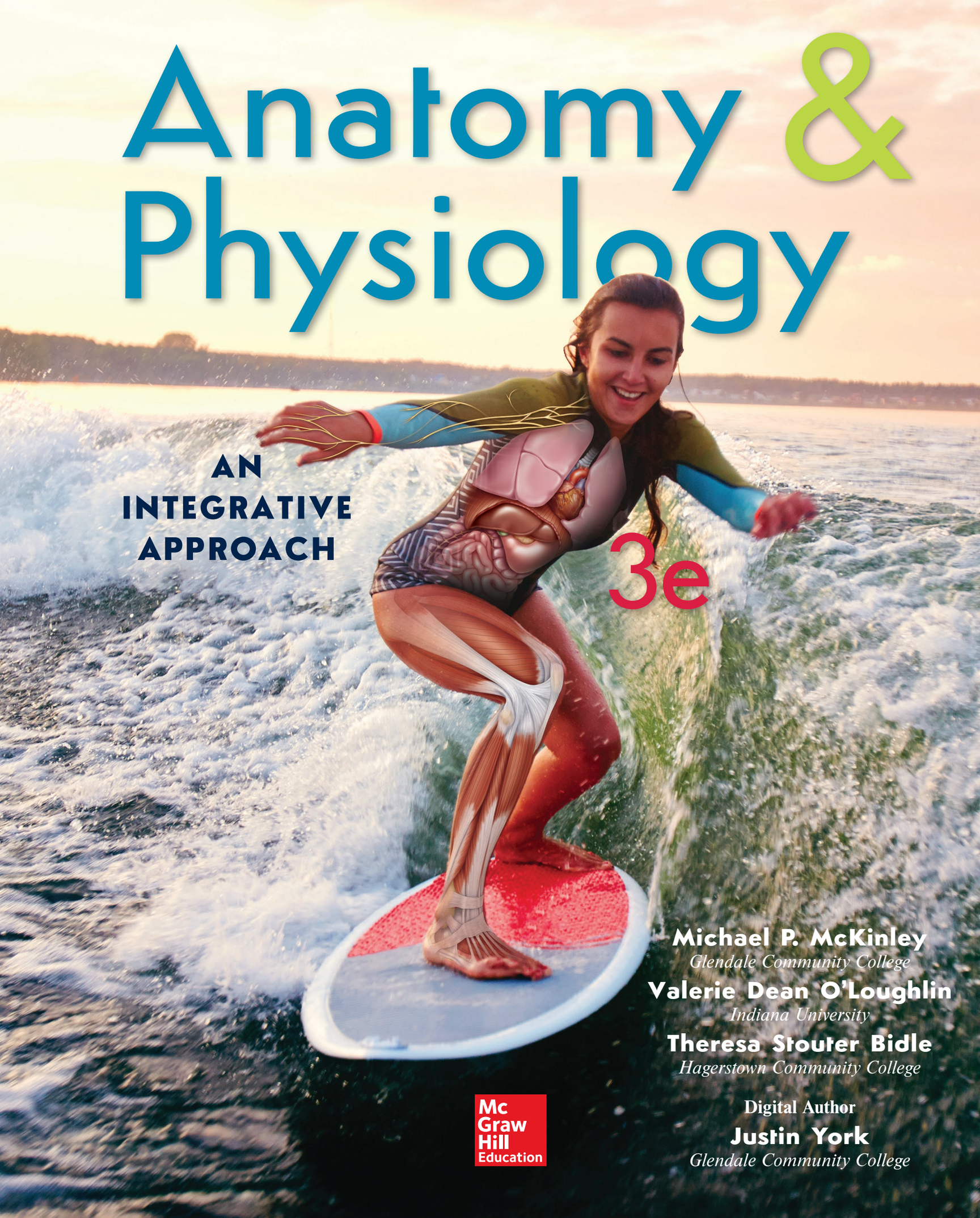
3e



Michael P. McKinley
Valerie Dean O'Loughlin
Theresa Stouter Bidle

Mc Graw Hill Education

# Anatomy & Physiology



AN INTEGRATIVE APPROACH

3e


**Michael P. McKinley**
*Glendale Community College*

**Valerie Dean O'Loughlin**
*Indiana University*

**Theresa Stouter Bidle**
*Hagerstown Community College*

Digital Author
**Justin York**
*Glendale Community College*



Mc Graw Hill Education

ANATOMY & PHYSIOLOGY: AN INTEGRATIVE APPROACH, THIRD EDITION



This book is printed on acid-free paper.

1 2 3 4 5 6 7 8 9 LWI 21 20 19 18

ISBN 978-1-259-39862-9
MHID 1-259-39862-5

Managing Director: *Thomas Timp*
Portfolio Manager: *Amy Reed*
Product Developer: *Donna Nemmers*
Director of Digital Content: *Michael G. Koot, Ph.D*
Marketing Manager: *James Connely*
Content Project Managers: *Jessica Portz, Brent dela Cruz, and Sandra Schnee*
Buyer: *Sandy Ludovissy*
Design: *David W. Hash*
Content Licensing Specialist: *Lori Hancock*
Cover Image: ©*shironosov/iStock/Getty Images Plus*
Compositor: *MPS Limited*



**Library of Congress Cataloging-in-Publication Data**

McKinley, Michael P., author. | O'Loughlin, Valerie Dean, author. |
Bidle, Theresa Stouter, author.
Anatomy & physiology : an integrative approach / Michael P. McKinley,
Glendale Community College, Valerie Dean O'Loughlin, Indiana University,
Theresa Stouter Bidle, Hagerstown Community College.
Anatomy and physiology
3e. | New York, NY : MHE, [2019] | Includes index.
LCCN 2017040498 | ISBN 9781259398629 (alk. paper)
LCSH: Human anatomy. | Human physiology.
LCC QM25 .M32 2019 | DDC 612–dc23 LC record available
at https://lccn.loc.gov/2017040498



mheducation.com/highered

# about the authors

**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. He taught undergraduate anatomy and physiology, general biology, and genetics at the GCC Main Campus. In 2009, he moved to the GCC North Campus, where he taught anatomy and physiology courses exclusively until he retired in 2012. Between 1991 and 2000, Michael also participated in Alzheimer disease research and served as director of the Brain Donation Program at the Sun Health Research Institute. During this time he also taught developmental biology and genetics at Arizona State University West Campus. He has been an author and co-author of more than 80 scientific papers. Mike's vast experience in histology, neuroanatomy, and cell biology greatly shaped the related content in the market-leading textbook McKinley/O'Loughlin/Pennefather-O'Brien, *Human Anatomy,* 5th edition. Mike is an active member of the Human Anatomy and Physiology Society (HAPS). He resides in Tempe, Arizona with his wife Jan.

**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, 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 Ph.D. students pursuing anatomy education research. She is active in the American Association of Anatomists (AAA) and the Society for Ultrasound in Medical Education (SUSME). She is a President Emeritus of the Human Anatomy and Physiology Society (HAPS) and currently serves on the Steering Committee. She received the AAA Basmajian Award for excellence in teaching gross anatomy and outstanding accomplishments in scholarship in education, and recently was selected for the AAA Henry Gray Distinguished Educator award. Valerie is co-author of the market-leading textbook McKinley/O'Loughlin/Pennefather-O'Brien, *Human Anatomy,* 5th 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 co-author for Eckel/Ross/Bidle, *Anatomy and Physiology Laboratory Manual,* 2nd edition.

©Jan McKinley

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

## *Dedications*

*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

*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

# brief contents

# contents

©Russell Illig/Getty Images RF



©Tony McConnell/Science Source



©Fotosearch/agefotostock



©BSIP/Science Source

## 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. Finally, the digital assets that accompany our book are tied to each section's learning objectives and previewed in the **Integrate: Online Study Tools** boxes at the end of each chapter.

## 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 re-teaching 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. 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 Third 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.
- Terminology has been updated and definitions are added throughout.
- New "What Do You Think?" and "What Did You Learn?" questions were added throughout the text.

### Chapter 1

- New section added about how best to study A&P
- Revised: figure 1.8, figure 1.9, figure 1.13
- Clinical View 1.1: Etiology (Causes) and Pathogenesis (Development) of Disease updated to include more detail on sonography and imaging; added new photos and labeling to images

### Chapter 2

- Moved description of inorganic and organic molecules from section 2.7: Biological Molecules to beginning of section 2.4: Molecular Structure of Water and the Properties of Water
- Revised: figure 2.1b, figure 2.9, figure 2.10, figure 2.13, figure 2.17, figure 2.19, figure 2.20, figure 2.21, figure 2.22, figure 2.24, figures within table 2.4

### Chapter 3

- Revised: figure 3.1, figure 3.3, figure 3.6, figure 3.7, figure 3.10, figure 3.13, figure 3.14, figure 3.16, figure 3.18, figure 3.19
- Revised coverage of ATP cycling in section 3.2b: Classification of Chemical Reactions

### Chapter 4

- Revised: figure 4.4, figure 4.5, figure 4.6, figure 4.7, figure 4.9, figure 4.10, figure 4.11, figure 4.14, figure 4.15, figure 4.17, figure 4.18, figure 4.19, figure 4.20, figure 4.21, figure 4.23, figure 4.27, figure 4.28, figure 4.30, figure 4.32, figure 4.39, figure 4.42 (several new photos)
- New figure 4.38 on genetic code
- Modified section 4.1a: How Cells Are Studied
- Updated section 4.2b: Membrane Proteins
- Revised section 4.3: Membrane Transport
- Revised and reorganized section 4.6b: Non-Membrane-Bound Organelles

### Chapter 5

- Updated art in tables 5.2, 5.3
- Revised: figure 5.4, figure 5.8, figure 5.10, figure 5.11, figure 5.12
- Modified section 5.2b: Functions of Connective Tissue
- Updated text in tables 5.6, 5.10
- Removed coverage of perichondrium (covered in Chapter 7)
- Modified section 5.5b: Body Membranes
- Updated Clinical View 5.4: Stem Cells
- Revised Clinical View 5.5: Gangrene
- Updated Chapter Summary to include lymph in discussion of fluid connective tissue

### Chapter 6

- Updated terminology to use "keratinocyte" instead of "cell" where appropriate
- Updated section on stratum corneum to include coverage of dermidicin
- Removed reference to human pheromones

### Chapter 7

- In section 7.2, added information on the appearance of living bone
- Revised: figure 7.4, figure 7.11, figure 7.15
- Revised discussion of exercise in space
- Clinical View 7.7: Osteoporosis—added information on DEXA scans

### Chapter 8

- Table 8.1 revised to include parietal foramina
- Revised: figure 8.5, figure 8.7a, figure 8.11, figure 8.12a, figure 8.14, figure 8.22a, figure 8.31, figure 8.34b
- In section 8.2b: Views of the Skull and Landmark Features, revised sella turcica information to include hypophyseal fossa
- Table 8.2 and table 8.3 figures were revised to improve clarity and accuracy
- Revised Clinical View 8.2: Craniosynostosis and Plagiocephaly
- In section 8.3: Bones Associated with the Skull, revised information on functions of the hyoid bone's cornua and body
- Revised figure in Clinical View 8.4: Herniated Discs
- Table 8.6 text and figures updated regarding width of pelvis and ilia

## Chapter 9

- Reversed order of sections 9.5 and 9.6, so Movements of Synovial Joints are discussed prior to Synovial Joints and Levers
- Table 9.1 simplified
- Revised: figure 9.2, figure 9.3, figure 9.6, figure 9.14
- Modified description of synovial membrane

## Chapter 10

- Updated section 10.1a: Functions of Skeletal Muscle and section 10.1b: Characteristics of Skeletal Muscle Cells
- Revised section 10.2a: Gross Anatomy of Skeletal Muscle
- Revised section 10.2b: Microscopic Anatomy of Skeletal Muscle to add details of triad
- Revised section 10.4: Skeletal Muscle Metabolism
- Revised section 10.8: Effects of Exercise and Aging on Skeletal Muscle
- New Concept Connection on Excitability
- New Learning Strategy on prefixes *myo-*, *mys-*, *sarco-*
- New Concept Connection on connective tissue coverings
- New Clinical View 10.1: Muscular Dystrophy
- New Concept Connection on nervous system diseases that influence muscle function
- New Clinical View 10.9: Unbalanced Skeletal Muscle Development
- New Concept Connection on Myogenic Response
- Revised: figure 10.1, figure 10.3, figure 10.6, figure 10.7, figure 10.9, figure 10.10, figure 10.11, figure 10.12, figure 10.14, figure 10.15, figure 10.16, figure 10.17, figure 10.20, figure 10.21, figure 10.22, figure 10.30
- Revised figure in Learning Strategy on sarcomere shortening
- New: figure 10.17 on ATP for muscle metabolism; figure 10.21 on recruitment; figure 10.24 comparing isometric and isotonic contractions; figure 10.26 on maximizing force of contractions

## Chapter 11

- Replaced the terms *origin* and *insertion* with *superior attachment* and *inferior attachment* where appropriate
- Revised Clinical View 11.2: Idiopathic Facial Nerve Paralysis (Bell Palsy) to include information on Lyme disease effects
- New photo in Clinical View 11.2: Idiopathic Facial Nerve Paralysis (Bell Palsy)
- Revised: table 11.3, table 11.8, table 11.18
- Revised: figure 11.17, figure 11.19, figure 11.21b, figure 11.22
- New photo in Clinical View 11.7: Lateral Epicondylitis ("Tennis Elbow")
- Revised figure in Clinical View 11.8: Carpal Tunnel Syndrome

## Chapter 12

- Revised section 12.2b: Neuron Structure
- Added section 12.1c: Nerves and Ganglia
- New Concept Connection on bundling by connective tissue
- New Concept Connection on excitability
- New Learning Strategy on glial cells
- Clinical View 12.3: Nervous System Disorders Affecting Myelin now includes Zika virus as it relates to Guillain-Barré syndrome
- New Learning Strategy on states of voltage-gated $Na^+$ channels
- Revised Clinical View 12.6: Altered Acetylcholine Function and Changes in Breathing
- Section 12.1c: Nerves and Ganglia was previously section 12.2e (moved forward in the chapter)
- Revised: figure 12.3, figure 12.5, figure 12.6, figure 12.7, figure 12.9b, figure 12.10, figure 12.11, figure 12.14, figure 12.16, figure 12.17, figure 12.18, figure 12.21, figure 12.22, figure 12.23, figure 12.24, figure 12.25
- New Clinical View 12.1: Pathogenic Agents and Fast Axonal Transport figure of axonal transport for how pathogenic organisms move to cell body
- New illustration of battery for text discussion on Ohm's Law (pg. 457)
- New figure 12.13: Neuron's and Ohm's Law
- New photo in figure 12.17

## Chapter 13

- Revised section 13.1: Brain Organization and Development
- Revised Clinical View 13.1: Traumatic Brain Injuries: Concussion and Contusion
- Revised section 13.1c: Gray Matter and White Matter Distribution
- Revised: figure 13.1, figure 13.4, figure 13.5, figure 13.9, figure 13.12, figure 13.14, figure 13.21, figure 13.23b, figure 13.24a, figure 13.25, figure 13.30, figure 13.31
- Revised table 13.2, table 13.4, table 13.5
- Updated Clinical View 13.3: Meningitis and Encephalitis
- Revised Clinical View 13.6: Mapping Functional Brain Regions
- New Learning Strategy on functions of the hypothalamus
- Revised coverage of medulla autonomic centers

## Chapter 14

- Revised section 14.1: Overview of the Spinal Cord and Spinal Nerves reorganized to provide an overview of the chapter content; section 14.1c: Spinal Nerve Identification and Gross Anatomy now contains content on spinal roots that was moved from section 14.5a
- Section 14.2: Protection and Support of the Spinal Column revised to include more explanation on vertebral column
- Section 14.3: Sectional Anatomy of the Spinal Cord and Spinal Roots provides more information on functional relationship between gray matter and spinal nerve roots, sensory receptors, and effectors.
- Section 14.5a: General Distribution of Spinal Nerves
- Revised: figure 14.1, figure 14.2, figure 14.4, figure 14.5, figure 14.6, figure 14.10, figure 14.14, figure 14.18c

## Chapter 15

- Section 15.3b: Pelvic Splanchnic Nerves rearranged to discuss parasympathetic cranial nerve physiology first, followed by anatomy
- Section 15.5: Autonomic Plexuses and the Enteric Nervous System moved forward to appear after discussion of sympathetic and parasympathetic systems
- New section 15.5b: Enteric Nervous System
- New Learning Strategy on parasympathetic division

- Updated Clinical View 15.3: Raynaud Syndrome, with photo added
- Revised: figure 15.4, figure 15.6, figure 15.7b, figure 15.10, figure 15.11

### Chapter 16

- New Clinical View 16.2: Eye Infections
- Revised: figure 16.2, figure 16.3, figure 16.5, figure 16.7, figure 16.8, figure 16.10, figure 16.15, figure 16.18, figure 16.22, figure 16.26, figure 16.27, figure 16.28

### Chapter 17

- Section 17.1a: Overview of Endocrine System rewritten and expanded
- Revised: Section 17.1b: Comparison of the Two Control Systems
- Section 17.1c: General Functions of the Endocrine System contains added examples for each function of the endocrine system
- Section 17.3b: Local Hormones rewritten, now includes new Concept Connection on local hormones that act as vasoactive substances; new Clinical View 17.1: Synthesis of Eicosanoids
- Section 17.7b: Interactions Between the Hypothalamus and the Posterior Pituitary Gland contains expanded description of ADH and oxytocin
- Section 17.7c: Interactions Between the Hypothalamus and the Anterior Pituitary Gland reorganized and updated to add explanation for figure 17.12
- Revised: figure 17.1, figure 17.5, figure 17.7, figure 17.8, figure 17.10, figure 17.11, figure 17.12, figure 17.14, figure 17.16, figure 17. 17, figure 17.18, figure 17.19, figure 17.20, figure 17.22, figure 17.23

### Chapter 18

- Clinical View 18.3: Transfusions updated to include information on donor wait times between transfusions
- New Clinical View 18.4: Whole Blood Versus Plasma Donations: What's the Difference?
- New Clinical View 18.5: Fetal Hemoglobin and Physiologic Jaundice
- New Learning Strategy on Blood Types
- Revised: figure 18.5a, 18.7, figure 18.8, figure 18.11 (colorized micrograph of blood clotting), figure 18.12

### Chapter 19

- Section 19.1a: General Function contains expanded content of the function of the cardiovascular system in transporting blood, including a new Concept Connection that provides examples of body systems dependent on blood transport
- Section 19.1b: Overview of Components revised to further describe circulation routes through the right and left sides of the heart
- New Clinical View 19.1: Congestive Heart Failure
- Section 19.2b: The Pericardium contains added description of pericardial sac
- Section 19.3a: Superficial Features of the Heart contains added explanation to align with figure 19.7
- Revised Clinical View 19.5: Coronary Heart Disease, Angina Pectoris, and Myocardial Infarction to add content on coronary heart disease
- Added Concept Connection to describe a sinus
- Added Concept Connection on resting membrane potential
- Added Concept Connection on nodal cells compared to neurons
- Added Concept Connection on conductivity
- Section 19.7b: Electrical and Mechanical Events of Cardiac Muscle Cells has been revised to add details on triad
- Revised: figure 19.2, figure 19.3, figure 19.7, figure 19.11, figure 19.13, figure 19.14, figure 19.16, figure 19.18, figure 19.19, figure 19.20, figure 19.21, figure 19.22

### Chapter 20

- Revised: figure 20.1, figure 20.3, figure 20.4, figure 20.5, figure 20.7, figure 20.14, figure 20.18, figure 20.19, figure 20.20, figure 20.22, figure 20.26, figure 20.27

### Chapter 21

- Revised Learning Strategy on lymphocytes to describe origin of name for B-lymphocytes
- Revised: figure 21.1, figure 21.6, figure 21.9

### Chapter 22

- New Table 22.5: Actions of Antibodies Following Antigen Binding
- Section 22.1: Overview of Diseases Caused by Infectious Agents revised to update definition of bacteria
- New Learning Strategy on the study of the immune system
- Revised Section 22.3a: Preventing Entry
- New Learning Strategy on CD4/CD8 with MHC Class I/II
- Section 22.5b: Selection and Differentiation of T-Lymphocytes rearranged for better alignment of illustration and text
- Section 22.8b: Action of Antibodies reorganized into table format for clarity
- Revised: figure 22.1, figure 22.2, figure 22.3, figure 22.4, figure 22.7, figure 22.8, figure 22.10, figure 22.12, figure 22.13, figure 22.14, figure 22.15, figure 22.16, figure 22.17, figure 22.19, figure 22.20

### Chapter 23

- New Learning Strategy on structural and functional organization of the respiratory system
- Revised Section 23.3b: Trachea
- New Clinical View 23.4: Tracheotomy
- Clinical View 23.5: Bronchitis now includes coverage on exercise-induced asthma
- Revised Section 23.3c: Bronchial Tree
- Revised Section 23.3d: Respiratory Zone: Respiratory Bronchioles, Alveolar Ducts, and Alveoli
- New Clinical View 23.7: Pneumonia
- New photos of lungs in Clinical View 23.8: Smoking
- Revised: figure 23.3, figure 23.5, figure 23.6, figure 23.8, figure 23.9, figure 23.10, figure 23.11, figure 23.14, figure 23.19, figure 23.14, figure 23.16, figure 23.19, figure 23.21, figure 23.23, figure 23.25, figure 23.26, figure 23.31
- New figure 23.27: Changes in Respiratory Gas Partial Pressures Within the Blood

### Chapter 24

- New figure in Clinical View 24.1: Renal Ptosis and Hydronephrosis
- Section 24.3c: Juxtaglomerular Apparatus revised to expand coverage of mesangial cells
- Concept Connection on blood pressure expanded
- Revised: figure 24.2, figure 24.3, figure 24.4, figure 24.5, figure 24.6, figure 24.7, figure 24,9, figure 24.11, figure 24.13, figure 24.14, figure 24.15, figure 24.16, figure 24.18, figure 24.19, figure 24.22, figure 24.23, figure 24.24, figure 24.26, figure 24.27, figure 24.28

### Chapter 25

- Section 25.1: Body Fluids introduction revised to emphasize the main points of the chapter
- Figure 25.2: Percentages of Solutes in Body Fluids is new and contains the information from previous edition's Table 25.1
- New Clinical View 25.2: Hemorrhaging
- New Clinical View 25.4: Angiotensin-Converting Enzyme (ACE) Inhibitors
- Section 25.3b: Major Electrolytes: Location, Functions, and Regulation revised to integrate concepts of acid-base balance and hyperkalemia and hypokalemia
- Section 25.5: Acid-Base Balance revised for increased readability
- Section 25.5c: Respiration and Regulation of Volatile Acid has tighter integration with concepts in Chapter 23: Respiratory System
- New Learning Strategy on Type A and Type B Intercalated Cells
- Section 25.6: Disturbances to Acid-Base Balance is revised for increased readability and tighter integration with Clinical View 25.8: Arterial Blood Gas (ABG) and Diagnosing Different Types of Acid-Base Disturbances
- Section 25.6b: Respiratory-Induced Acid-Base Disturbances includes normal values for arterial blood gas
- New: figure 25.2, figure 25.12, figure 25.16
- Revised: figure 25.1, figure 25.4, figure 25.5, figure 25.6, figure 25.7, figure 25.8, figure 25.9, figure 25.10, figure 25.11, figure 25.12, figure 25.13, figure 25.14, figure 25.15

### Chapter 26

- Sections 26.1b, 26.1c, 26.1d, and 26.1e revised for readability
- New Learning Strategy for layers of muscularis in GI tract wall
- New Clinical View 26.3: Achalasia
- New Learning Strategy on gastric gland secretions for parietal cells and chief cells
- Sections 26.3b: Small Intestine and 26.3c: Accessory Digestive Organs and Ducts revised
- New Clinical View 26.10: Pancreatic Cancer
- New Clinical View 26.13: Fecal Transplant
- New Learning Strategy on lipid digestion and absorption
- New Clinical View 26.17: Cystic Fibrosis and the Pancreas
- New Section 26.4e: Water, Electrolyte, and Vitamin Absorption
- Revised: figure 26.2c, figure 26.6, figure 26.8, figure 26.13, figure 26.14, figure 26.15, figure 26.16, figure 26.18, figure 26.20, figure 26.22, figure 26.29

### Chapter 27

- New Clinical View 27.3: Obesity
- New Clinical View 27.5: Heat Related Illnesses
- Expanded Clinical View 27.6: Hypothermia, Frostbite, and Dry Gangrene

### Chapter 28

- Sections 28.3a: Ovaries and 28.3b: Oogenesis and the Ovarian Cycle discussion on primary and secondary follicles revised, and discussion on antral follicles expanded
- Revised information on ovarian ligaments
- Revised Clinical View 28.2: Ovarian Cancer with current statistics
- Revised Clinical View 28.5: Cervical Cancer to include information on recommendations for vaccination
- Updated Clinical View 28.6: Breast Cancer
- Revised: figure 28.4, figure 28.5, figure 28.6, figure 28.7, figure 28.9, figure 28.11, figure 28.12, figure 28.15, figure 28.16, figure 28.18, figure 28.19d

### Chapter 29

- Revised Clinical View 29.2: Infertility and Infertility Treatments
- Revised Clinical View 29.3: Gestational Diabetes
- Revised: figure 29.1, figure 29.3, figure 29.4, figure 29.7, figure 29.16

## 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 75 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!

***Michael P. McKinley***
Glendale Community College, retired
mpmckinley@hotmail.com

***Valerie Dean O'Loughlin***
Medical Sciences
Indiana University
vdean@indiana.edu

***Terri Stouter Bidle***
Science Division
Hagerstown Community College
tsbidle@hagerstowncc.edu

# ACKNOWLEDGMENTS

Many people have worked with us over the last several years to produce this text. We would like to thank the many individuals at McGraw-Hill who worked with us to create this textbook. We are especially grateful to Donna Nemmers, our Product Developer, Amy Reed, our Portfolio Manager, and Jayne Klein and Jessica Portz, our Content Project Managers, for expertly guiding the project through its production phases; David Hash, Designer, for his beautiful interior and cover designs; and Jim Connely, Marketing Manager, for his marketing expertise. We would also like to thank our copyeditor, Deb DeBord, and our proofreaders, Wendy Nelson and Lauren Timmer. We are very grateful for the enthusiasm and expertise of Dr. Justin York, digital author and collaborator on multiple portions of the supporting online assessment and instructor tools that accompany this textbook. Justin's eye to detail also helped us improve the accuracy of several sections of the text.

Finally, we could not have performed this effort were it not for the love and support of our families. Jan, Renee, Ryan, and Shaun McKinley; 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.

## Reviewers

Tim Ballard
*University of North Carolina—Wilmington*

Charles Benton
*Madison College*

Lindsay Biga
*Oregon State University*

Jeff Bolles
*University of North Carolina—Pembroke*

Chester Brown
*University of Illinois—Urbana-Champaign*

Susan C. Burgoon
*Amarillo College*

Dennis Burke
*Quincy College—Plymouth*

Charles Cahill
*West Kentucky Community and Technical College*

Melody Candler-Catt
*Vincennes University*

Ronald A. Canterbury
*University of Cincinnati*

Rajeev Chandra
*Norfolk State University*

Cathleen Ciesielski
*Gardner-Webb University*

Jordan Clark
*Sam Houston State University*

Beth Collins
*Iowa Central Community College*

Andrew Corless
*Vincennes University*

Smruti Desai
*Lone Star College—CyFair*

Cynthia Doffitt
*Northwestern State University*

Bruce Evans
*Huntington University*

David Evans
*Penn College*

Colin Everhart
*St. Petersburg College*

John Fishback
*Ozarks Technical Community College*

Margaret Flemming
*Austin Community College*

Caroline Garrison
*Carroll Community College*

Nola Kelly-Gondek
*Hudson Valley Community College*

Elizabeth Granier
*St. Louis Community College*

Siabhon M. Harris
*Tidewater Community College*

Cynthia A. Herbrandson
*Kellogg Community College*

Lisa Hight
*Baptist College of Health Sciences*

Kendricks D. Hooker
*Baptist College of Health Sciences*

Shahdi Jalilvand
*Tarrant County College—Southeast*

Kurt E. Kwast
*University of Illinois—Urbana-Champaign*

Marta Klesath
*North Carolina State University*

Kristine N. Kraft
*University of Akron*

Paul Luyster
*Tarrant County College—South*

Benjamin Navia
*Andrews University*

Raffaella Pernice
*Hudson County Community College*

Julie L. Posey
*Columbus State Community College*

Laura H. Ritt
*Rowan College—Burlington County*

Corinna Ross
*Texas A&M San Antonio*

Merideth Sellars
*Columbus State Community College*

Michael A. Silva
*El Paso Community College*

William G. Sproat, Jr.
*Walters State Community College*

Michael Thompson
*Jefferson Community and Technical College*

Emmanuel Vrotsos
*Broward College*

Chad Wayne
*University of Houston*

Robinlyn Wright
*Houston Community College*

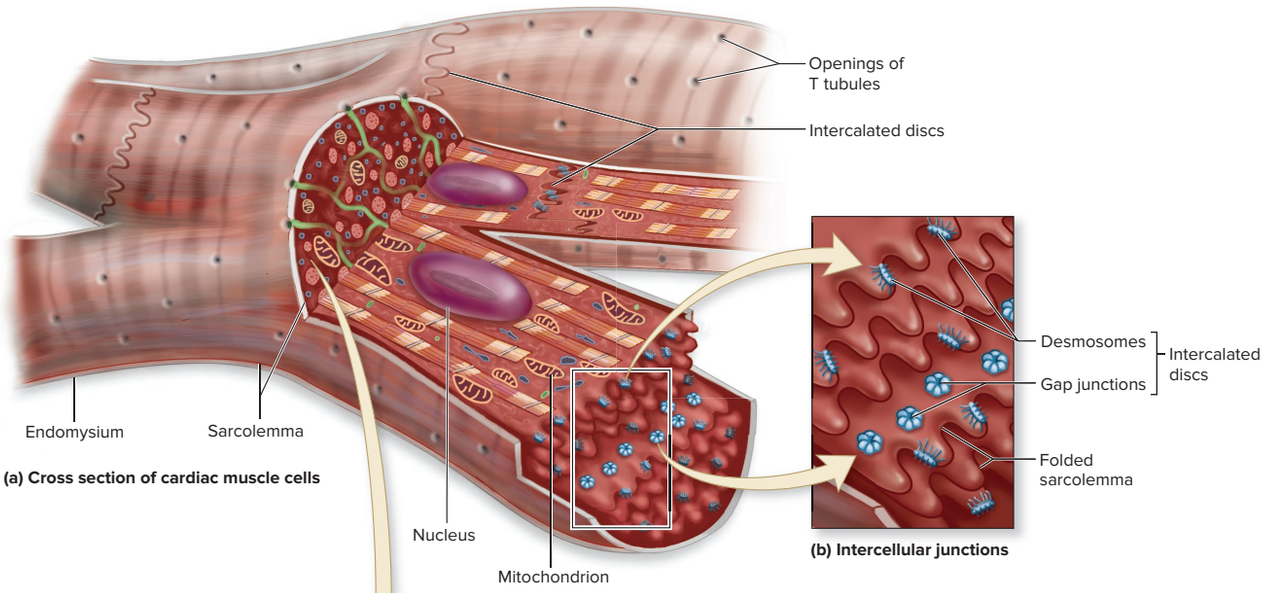
# guided tour

# 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 multi-tiered assessment.

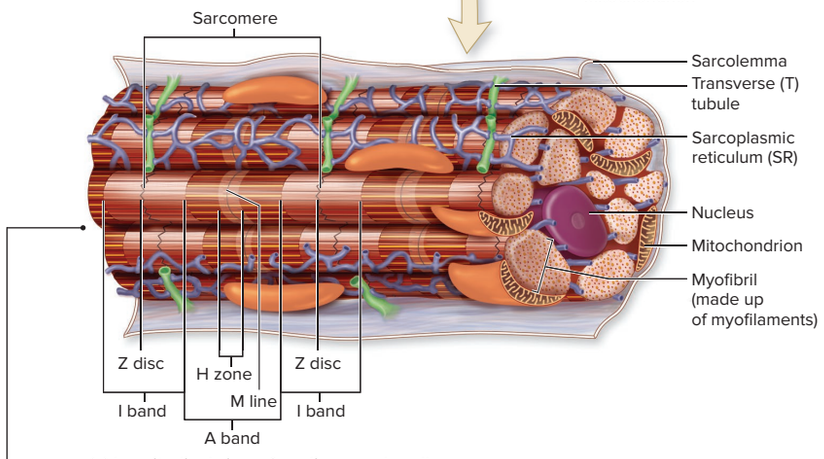
## Unparalleled Art Program

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.

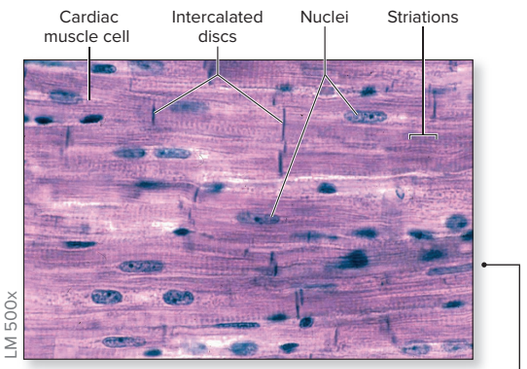



(a) Cross section of cardiac muscle cells

(b) Intercellular junctions




(c) Longitudinal view of cardiac muscle cell




(d) Longitudinal section of cardiac muscle

### Rich Detail

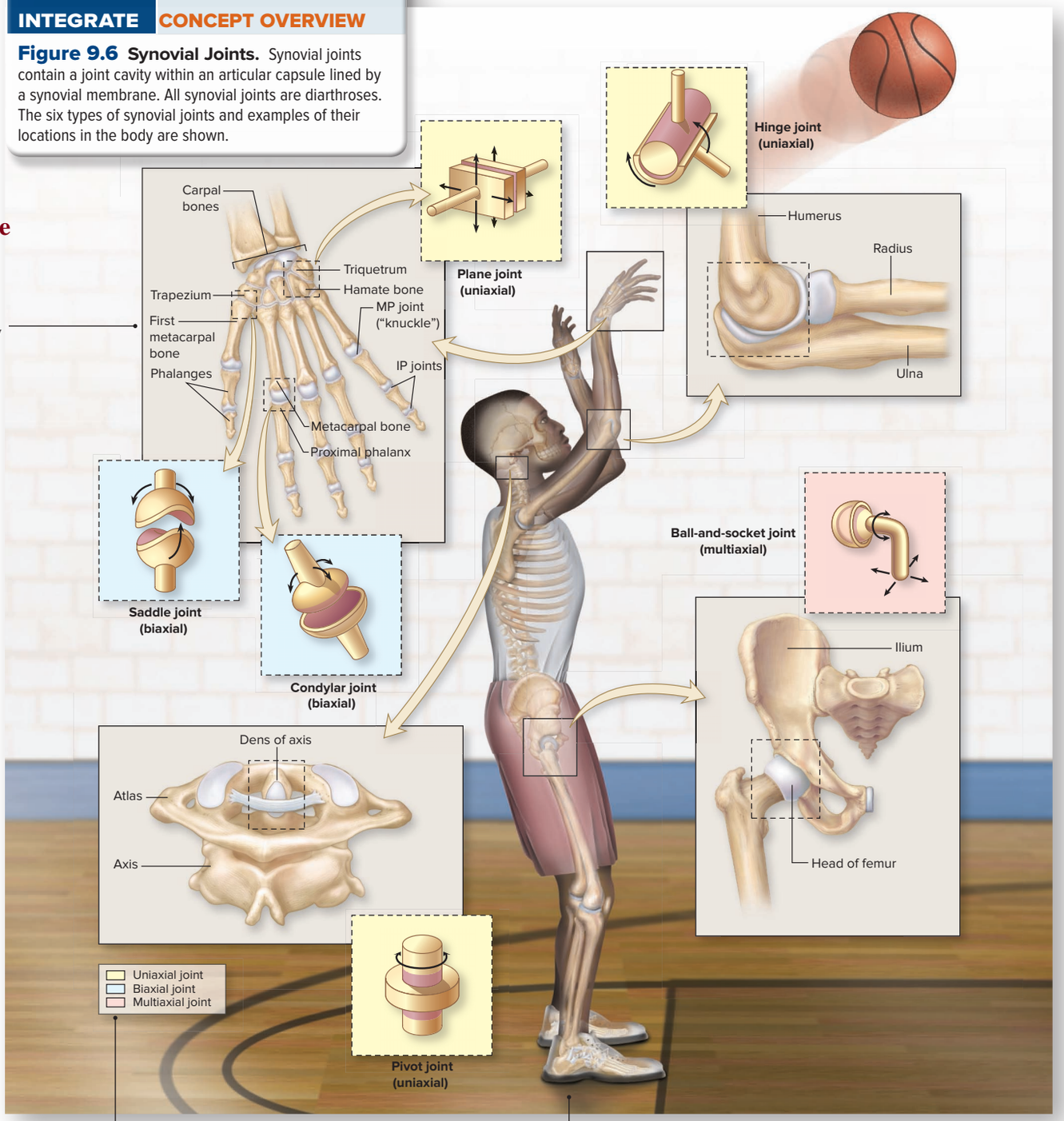
Vibrant colors and three-dimensional shading make it easy to envision body structures and processes.

### 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.

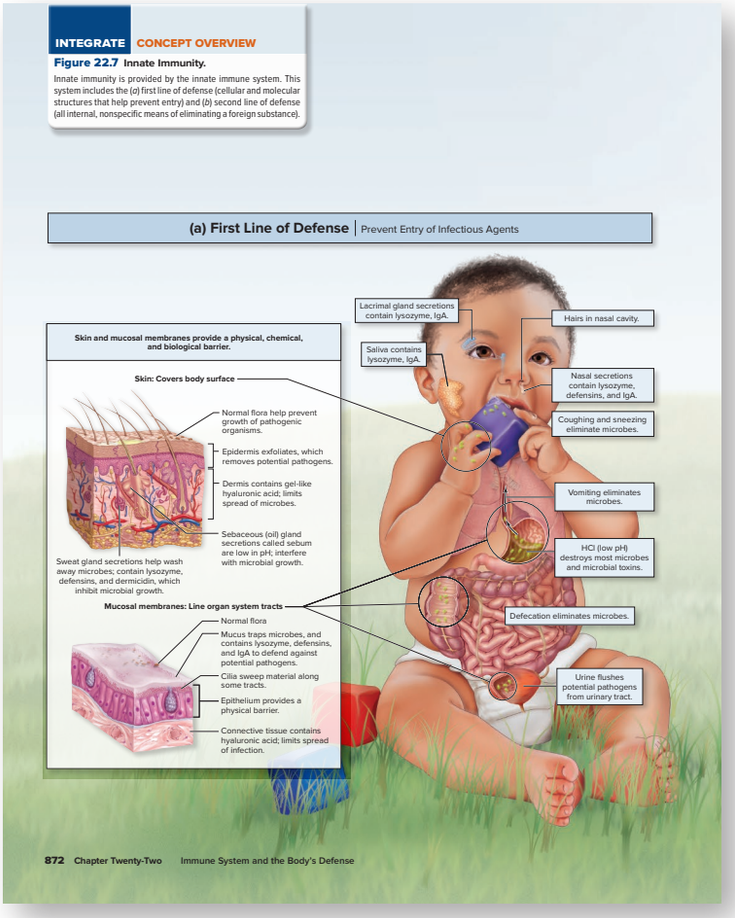
**Real-Life Context**
Illustrations include depictions of realistic people and situations to make figures more relevant and memorable.

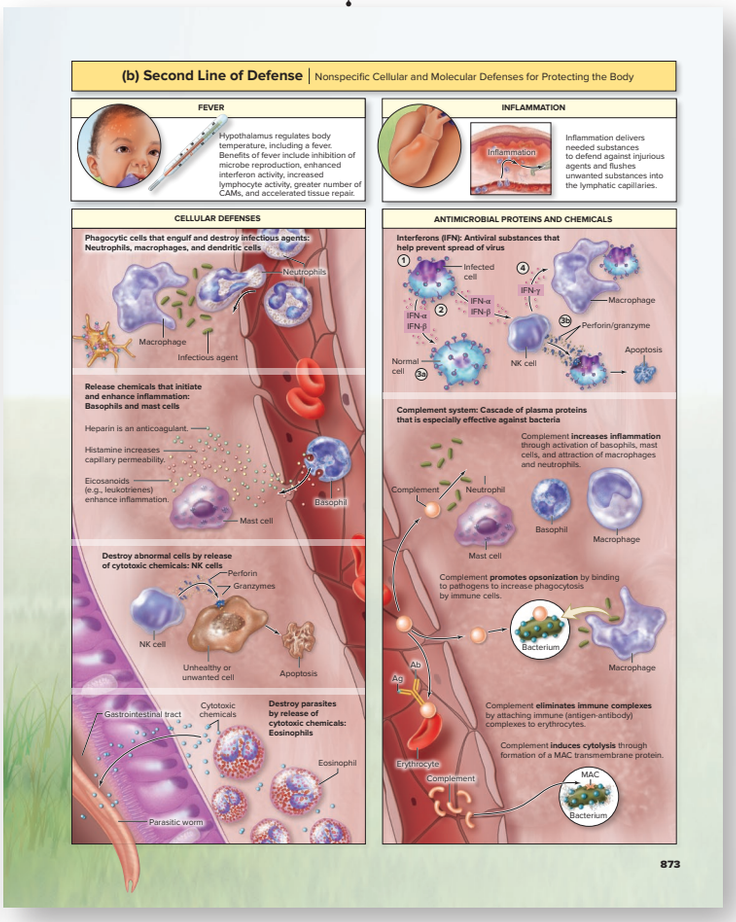
# Integrative Visual Summaries

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.

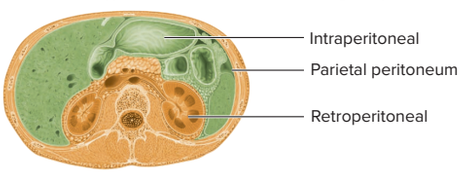
## Learning Strategies

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

**INTEGRATE**

### LEARNING STRATEGY

To understand the retroperitoneal position of the kidneys, imagine placing an eraser against a blackboard, which represents the posterior abdominal wall. Then hang a cloth that represents the parietal peritoneum so that the eraser is between the blackboard and the sheet. The eraser, which is located posterior to the sheet (the *parietal peritoneum*), is in a region called retroperitoneal. Structures that would be in front of (and enclosed by) the sheet are described as being *intraperitoneal*.



## Clinical View

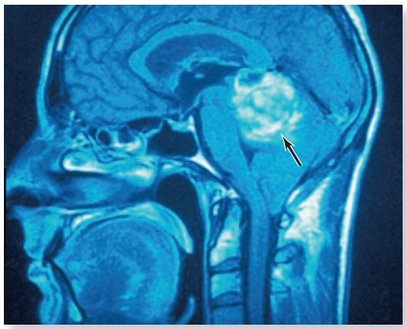
Interesting clinical sidebars reinforce or expand upon the facts discussed within the narrative. The clinical views are adjacent to the facts in the narrative (rather than placed at the end of the chapter) so students may immediately make connections between the narrative and real-life applications.

**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 central nervous system (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).



*An MRI 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.

©Digital Vision RF

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

**LEARNING OBJECTIVES**

35. Compare and contrast the muscles of the three compartments of the leg and their actions.
36. Distinguish between the muscles of the superficial layer and deep layer of the leg's posterior compartment.

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 functions (see figure 11.23).

**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 as *low-molecular-weight heparin,* 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. Compare loose connective tissue to dense connective tissue with respect to fiber density, fiber distribution, and the amount of ground substance.
13. Describe the composition and location of fibrocartilage.
14. Why is blood considered a connective tissue?

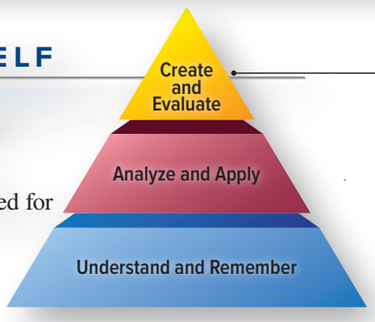
## What Did You Learn?

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




## 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.

### 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. During a microscopy exercise in the anatomy laboratory, a student makes the following observations about a tissue section: (a) The section 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 section 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 section, but these cells are not grouped tightly

# Integrated Digital and Textbook

Each chapter ends with a listing of online tools that may be used to study and master the concepts presented.

**INTEGRATE**

**ONLINE STUDY TOOLS** connect | SMARTBOOK® | APR

**The following study aids may be accessed through Connect.**

**Concept Overview Interactive:** Figure 10.16: Skeletal Muscle Contraction

**Clinical Case Study:** Progressive Weakness in a Young Woman

**Interactive Questions:** This chapter's content is served up in a number of multimedia question formats for student study

**SmartBook:** Topics and terminology include introduction to skeletal muscle; anatomy and physiology of skeletal muscle; skeletal muscle metabolism; skeletal muscle fiber types; measurement of skeletal muscle tension; factors affecting skeletal muscle tension; effects of exercise and aging on skeletal muscle; cardiac muscle tissue; smooth muscle tissue

**Anatomy & Physiology Revealed:** Topics include skeletal muscle; skeletal muscle striations; sarcomere; sliding filament; neuromuscular junction; excitation-contraction coupling; crossbridge cycle; cardiac muscle; smooth muscle

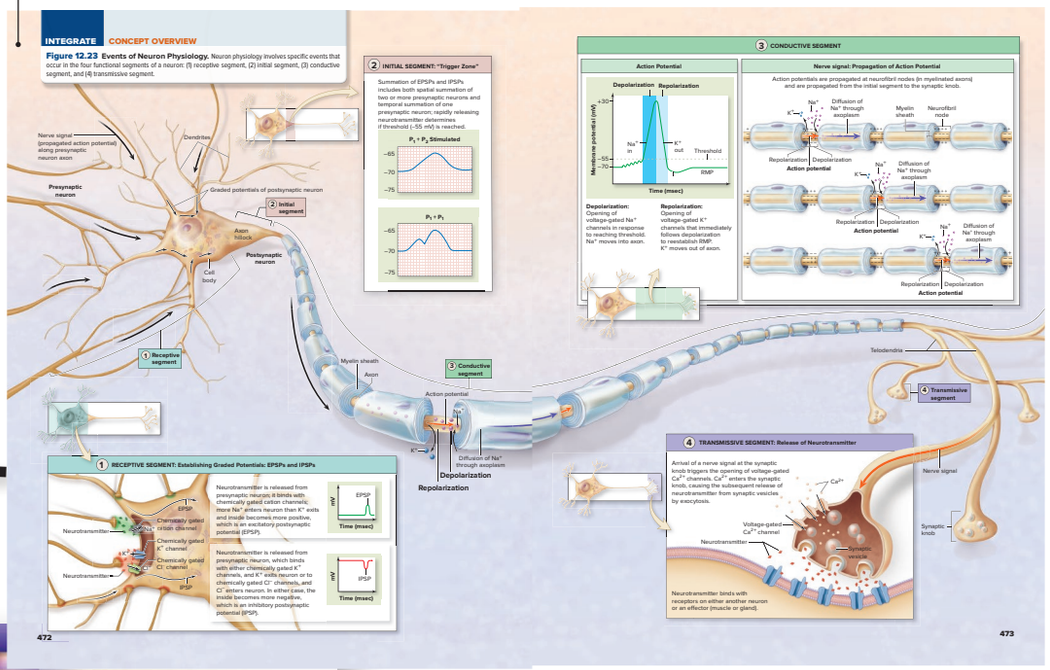
**Animations:** Topics include skeletal muscle; function of the neuromuscular junction; action potentials and muscle contraction; sarcomere shortening; breakdown of ATP and crossbridge movement during muscle contraction; mechanics of single fiber contraction; activation of contraction in smooth vs. skeletal muscle

# Concept Overviews into Digital Learning

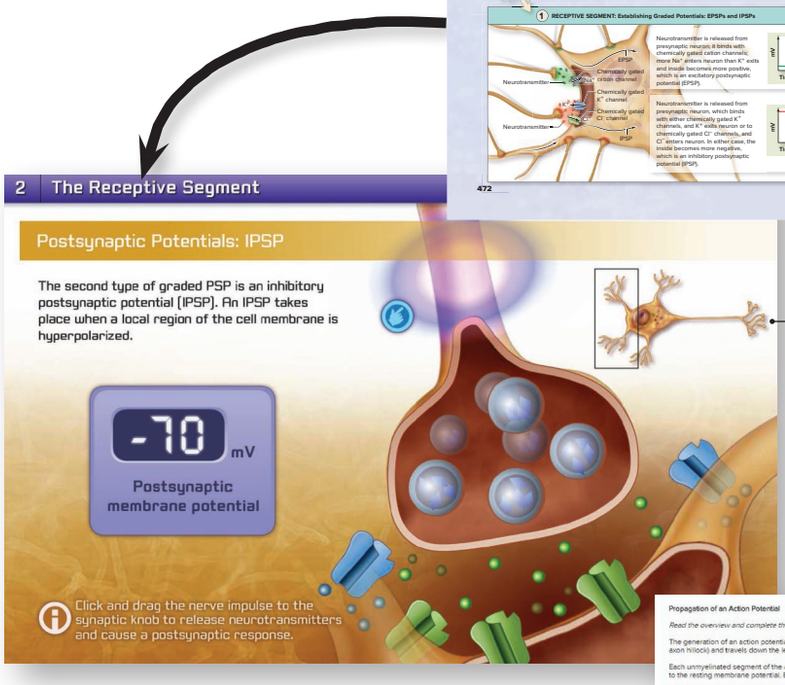
Selected **Concept Overview Figures** from the textbook have been transformed into interactive study modules. This digital transformation process was guided by anatomy and physiology professors who reviewed the modules throughout the development process. Interactive Concept Overview Figures also have 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

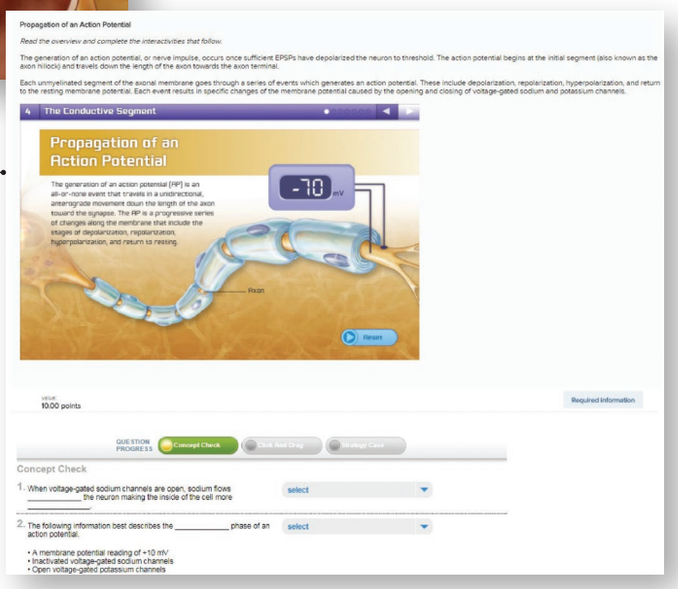
**Concept Overview from Textbook**




**Interactive Presentation Study Tool**




**Assessable Autograded Activity in Connect**



## Lab Manual Options to Fit Your Course

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

- Three versions are available including main, cat, and fetal pig.
- 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 recoring, 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
- Clear, concise writing style

## Student Supplements

McGraw-Hill offers various tools and technology products to support the textbook. Students can order supplemental study materials by contacting their campus bookstore or online at https://create.mheducation.com/shop/

## Instructor Supplements

Instructors can obtain teaching aids by calling the McGraw-Hill Customer Service Department at 1-800-338-3987, vising our online catalog at https://create.mheducation.com/shop/, or by contacting their local McGraw-Hill sales representative.

Mc Graw Hill Education

# Top 10 Tips
## to Thrive in Your Anatomy & Physiology Course



### 1 Preview
Preview assigned material before lecture. Lecture will make much more sense if you've previewed what will be discussed.

### 2 Look
Look at the images to be covered in lecture. Anatomy and Physiology is a very visual course.

### 3 Review
Review the prior lecture's material by re-writing your notes or making summary tables/flow charts.

### 4 Visuals and Notes
Always study your notes along with related visuals. You need to be able to combine visual images with black and white text.

### 5 Avoid Cramming
Study anatomy and physiology every day or at least every other day. More frequent studying is preferable to studying only two or three days per week. Set a schedule where you spend some time every day either previewing or reviewing anatomy and physiology information.

### 6 Organize
Organize the course material in a manner that makes the most sense to you. You can create notecards that summarize similar information, design a flow chart, draw simple line diagrams, create mnemonics, or create a table or chart of information.

### 7 Quiz Yourself
Make your own exam questions. This is a great technique to utilize once you have done a fair amount of studying. Ensure you don't shy away from quizzing yourself on topics you're not confident about.

### 8 Explain
You master a concept best when you are able to explain it. Practice explaining what you've learned–a process or concept–to someone who knows nothing about anatomy and physiology, or to a fellow classmate.

### 9 Study Group
Meet weekly or before every exam with several other students to learn the material. Assign each member different challenging topics and have that person teach it to the others in the group. You could also create a few questions on certain topics and then meet and share them with your group. Through the process of creating the questions you will become an "expert" in those topics and could better explain/clarify this information to each other.

### 10 Office Hours
Make appointments to meet with your instructor to clarify information.

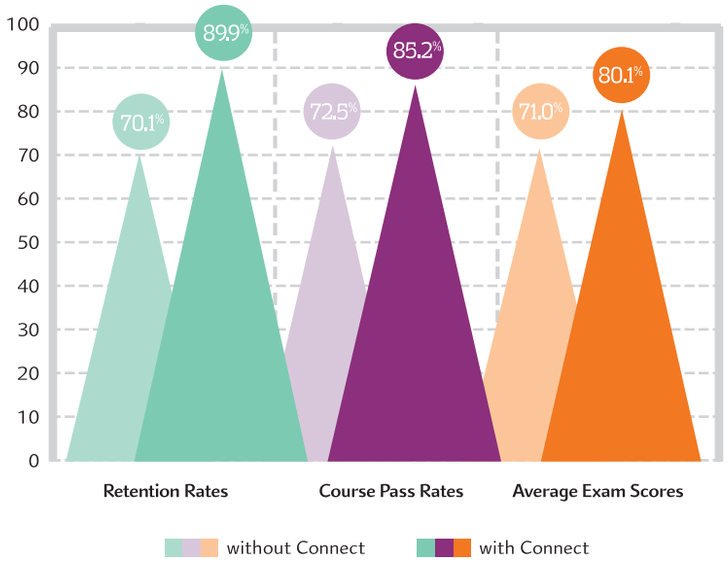
connect®

**McGraw-Hill Connect® is a highly reliable, easy-to-use homework and learning management solution that utilizes learning science and award-winning adaptive tools to improve student results.**

## Homework and Adaptive Learning

- Connect's assignments help students contextualize what they've learned through application, so they can better understand the material and think critically.
- Connect will create a personalized study path customized to individual student needs through SmartBook®.
- SmartBook helps students study more efficiently by delivering an interactive reading experience through adaptive highlighting and review.

### Connect's Impact on Retention Rates, Pass Rates, and Average Exam Scores




Using **Connect** improves retention rates by **19.8%,** passing rates by **12.7%, and** exam scores by **9.1%.**

Over **7 billion questions** have been answered, making McGraw-Hill Education products more intelligent, reliable, and precise.

73% of instructors who use **Connect** require it; instructor satisfaction **increases** by 28% when **Connect** is required.

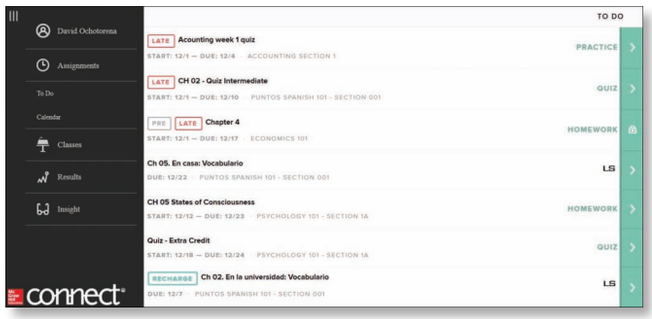
## Quality Content and Learning Resources

- Connect content is authored by the world's best subject matter experts, and is available to your class through a simple and intuitive interface.
- The Connect eBook makes it easy for students to access their reading material on smartphones and tablets. They can study on the go and don't need internet access to use the eBook as a reference, with full functionality.
- Multimedia content such as videos, simulations, and games drive student engagement and critical thinking skills.

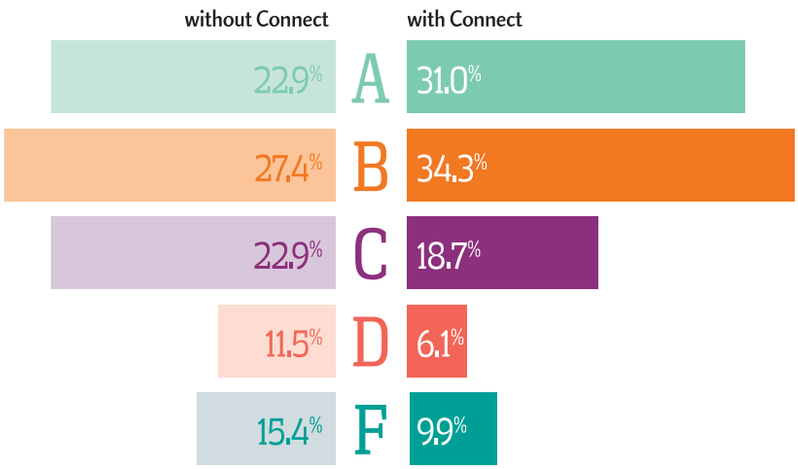
# Robust Analytics and Reporting

- Connect Insight® generates easy-to-read reports on individual students, the class as a whole, and on specific assignments.
- The Connect Insight dashboard delivers data on performance, study behavior, and effort. Instructors can quickly identify students who struggle and focus on material that the class has yet to master.
- Connect automatically grades assignments and quizzes, providing easy-to-read reports on individual and class performance.

©Hero Images/Getty Images




## Impact on Final Course Grade Distribution




More students earn **As** and **Bs** when they use **Connect**.

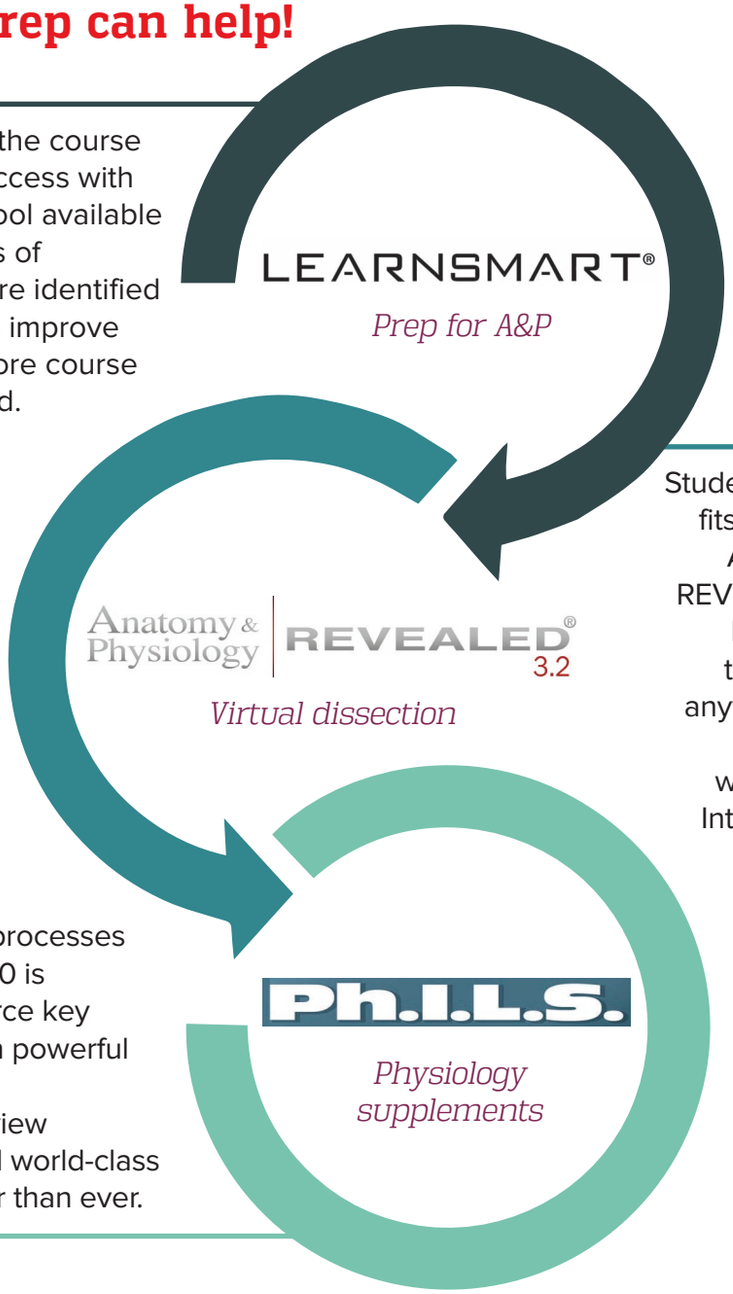
# Trusted Service and Support

- Connect integrates with your LMS to provide single sign-on and automatic syncing of grades. Integration with Blackboard®, D2L®, and Canvas also provides automatic syncing of the course calendar and assignment-level linking.
- Connect offers comprehensive service, support, and training throughout every phase of your implementation.
- If you're looking for some guidance on how to use Connect, or want to learn tips and tricks from super users, you can find tutorials as you work. Our Digital Faculty Consultants and Student Ambassadors offer insight into how to achieve the results you want with Connect.

# 50% of the country's students are not ready for A&P

## LearnSmart® Prep can help!

Improve preparation for the course and increase student success with the only adaptive Prep tool available for students today. Areas of individual weaknesses are identified in order to help students improve their understanding of core course areas needed to succeed.




Students seek lab time that fits their busy schedules. Anatomy & Physiology REVEALED 3.2, our Virtual Dissection tool, allows them practice anytime, anywhere. Now featuring enhanced physiology with Concept Overview Interactives (COVI's) and 3D animations!

Bringing to life complex processes is a challenge. Ph.I.L.S. 4.0 is the perfect way to reinforce key physiology concepts with powerful lab experiments.
Tools like Concept Overview Interactives, Ph.I.L.S., and world-class animations make it easier than ever.

**Since 2009, our adaptive programs in A&P have hosted 900,000 unique users who have answered more than 800 million probes, giving us the only data-driven solutions to help your students get from their first college-level course to program readiness.**

chapter

# 1

# The Sciences of Anatomy and Physiology

INTEGRATE

©Marmaduke St. John/Alamy RF

## CAREER PATH

### Medical Imaging Technologist

A medical imaging technologist is trained to utilize a variety of imaging techniques, such as magnetic resonance imaging (MRI), computed tomography (CT), and sonography. 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® aprevealed.com

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: (1) a comparison of the disciplines of anatomy and physiology; (2) study tips for how to most effectively study for this course; (3) the body's levels of organization; (4) the basic vocabulary of anatomy and physiology that is derived from both Greek and Latin; (5) the core features of homeostasis, which is the general regulatory process for maintaining a healthy body; as well as (6) 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.

**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 promotes 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.

### 1.1a Anatomy: Details of Structure and Form

**LEARNING OBJECTIVES**

1. Describe the science of anatomy.
2. List the 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, a comparative anatomy class may examine 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 sonography, magnetic resonance imaging (MRI), or x-ray. (See Clinical View 1.4: "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 a dynamic, changing science, not a static, unchanging one.

**WHAT DID YOU LEARN?**

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

### 1.1b Physiology: Details of Function

**LEARNING OBJECTIVES**

3. Describe the science of physiology.
4. List 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, 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 blood pressure, contractile force of the heart, and both gas and nutrient exchange may be affected in an individual afflicted with heart disease.

**WHAT DID YOU LEARN?**

2. What is the relationship between anatomy and physiology?
3. _____ 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 23.31) 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**

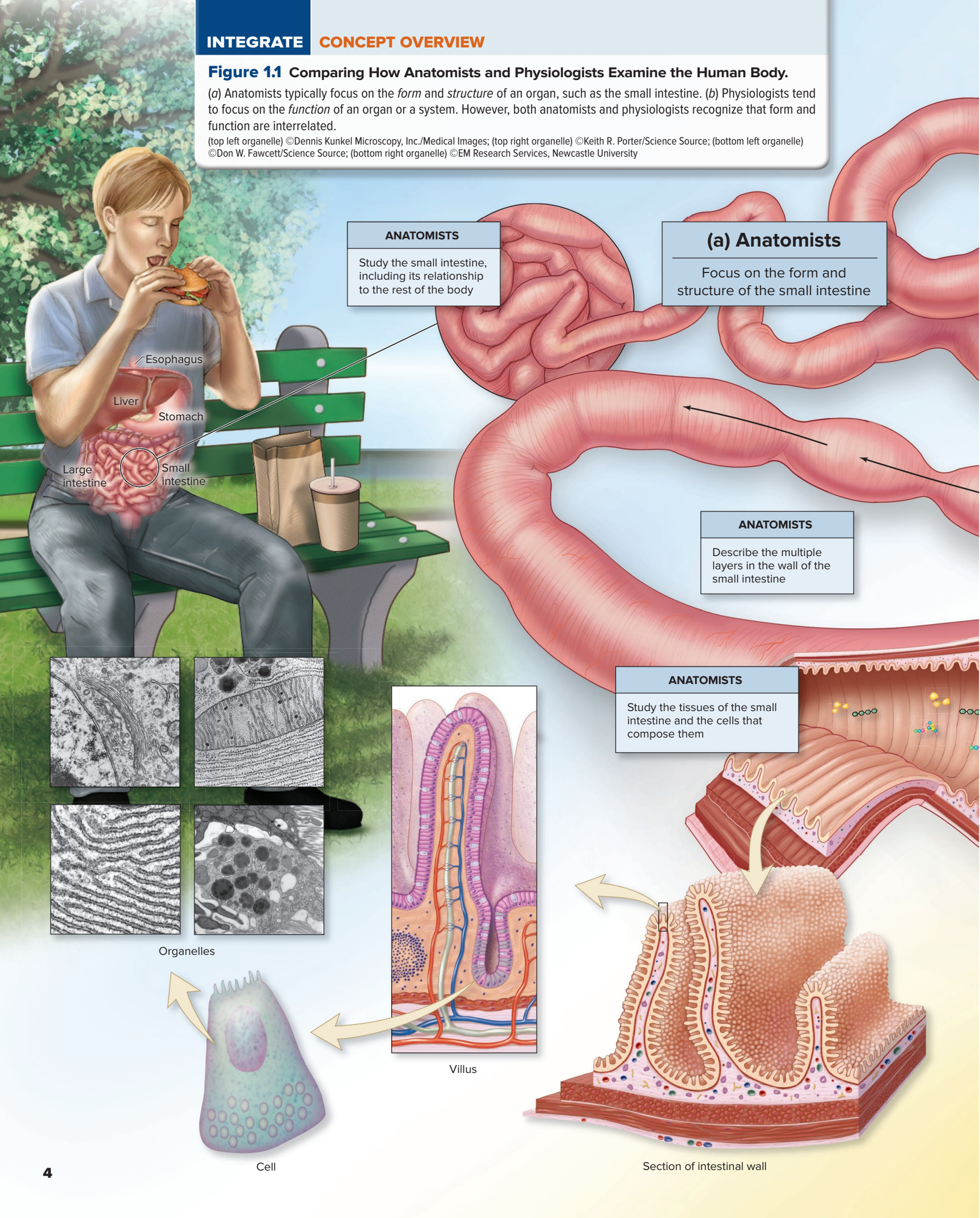
6. Describe best practices for studying anatomy and physiology effectively.

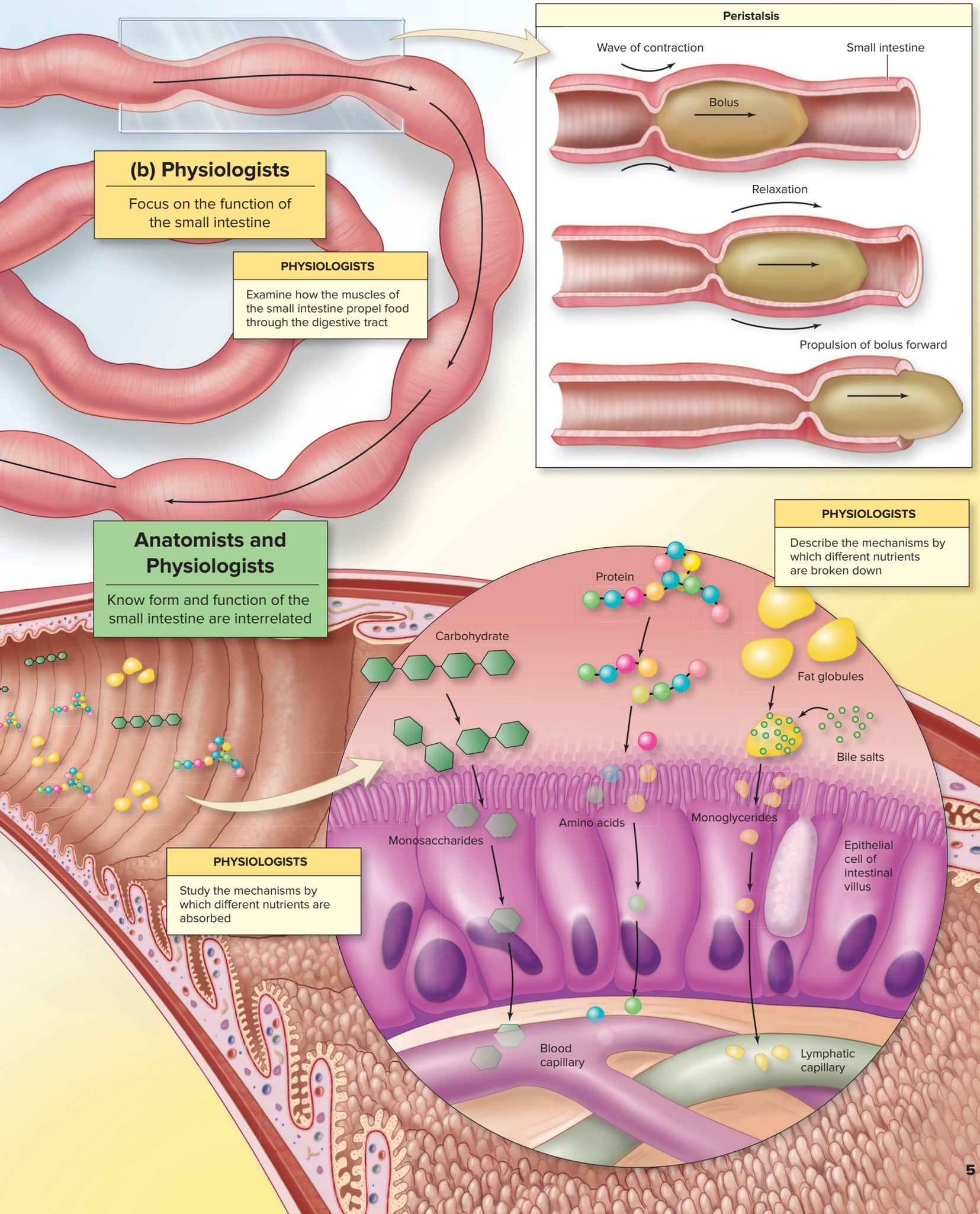
Anatomy and Physiology (A&P) is a content dense course that sometimes may overwhelm learners new to the subject. Success in the course requires careful time management and appropriate study skills for comprehending the material. When we teach our courses, we often encounter students who simply need to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

**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
Wave of contraction
Small intestine
Bolus
Relaxation
Propulsion of bolus forward
Anatomists and Physiologists
Know form and function of the small intestine are interrelated
PHYSIOLOGISTS
Describe the mechanisms by which different nutrients are broken down
Protein
Carbohydrate
Fat globules
Bile salts
Amino acids
Monoglycerides
Monosaccharides
Epithelial cell of intestinal villus
PHYSIOLOGISTS
Study the mechanisms by which different nutrients are absorbed
Blood capillary
Lymphatic capillary

### 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.** Don't 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 doesn't 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 re-reading 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 can't 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 don't 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 don't 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've 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 don't have to be an artist and the drawing doesn't 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 travels 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 has multiple opportunities 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**

**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 don't just read the text—use the following aids provided in each chapter of the text:
   a. **Integrate: Learning Strategy boxes.** These boxes provide analogies, mnemonics, and study tips to help you learn the material.
   b. **Integrate: Concept Connection boxes.** These boxes 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 concepts, 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 *can* be 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 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.

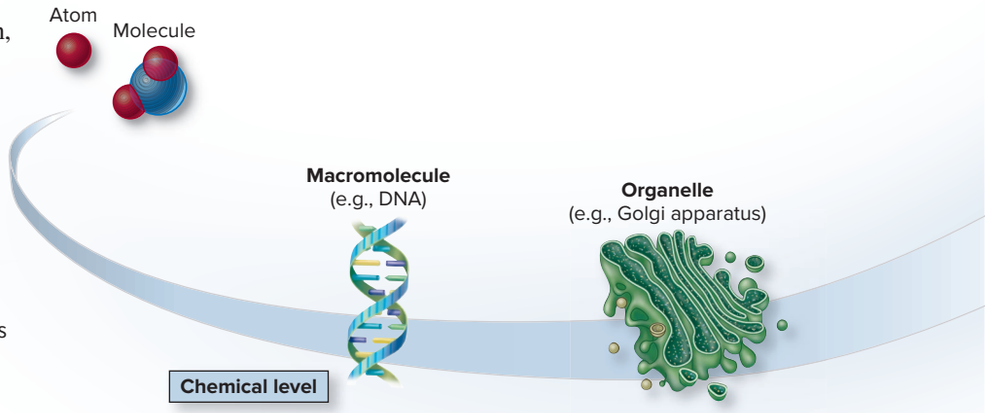
The **chemical level** is the simplest level, and it involves atoms and molecules. **Atoms** are the smallest units of matter that exhibit the characteristics of an element, such as carbon and hydrogen. When two or more atoms combine, they form a **molecule.** Examples of molecules include a sugar, a water molecule, or a vitamin. More complex molecules are called **macromolecules** and include some 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 ex-change 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., oral cavity, stomach, small and large intestine, and 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 Does a higher level of organization contain all the levels beneath it? Explain.

## 1.4c Introduction to Organ Systems

**LEARNING OBJECTIVE**

**9.** Compare 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?

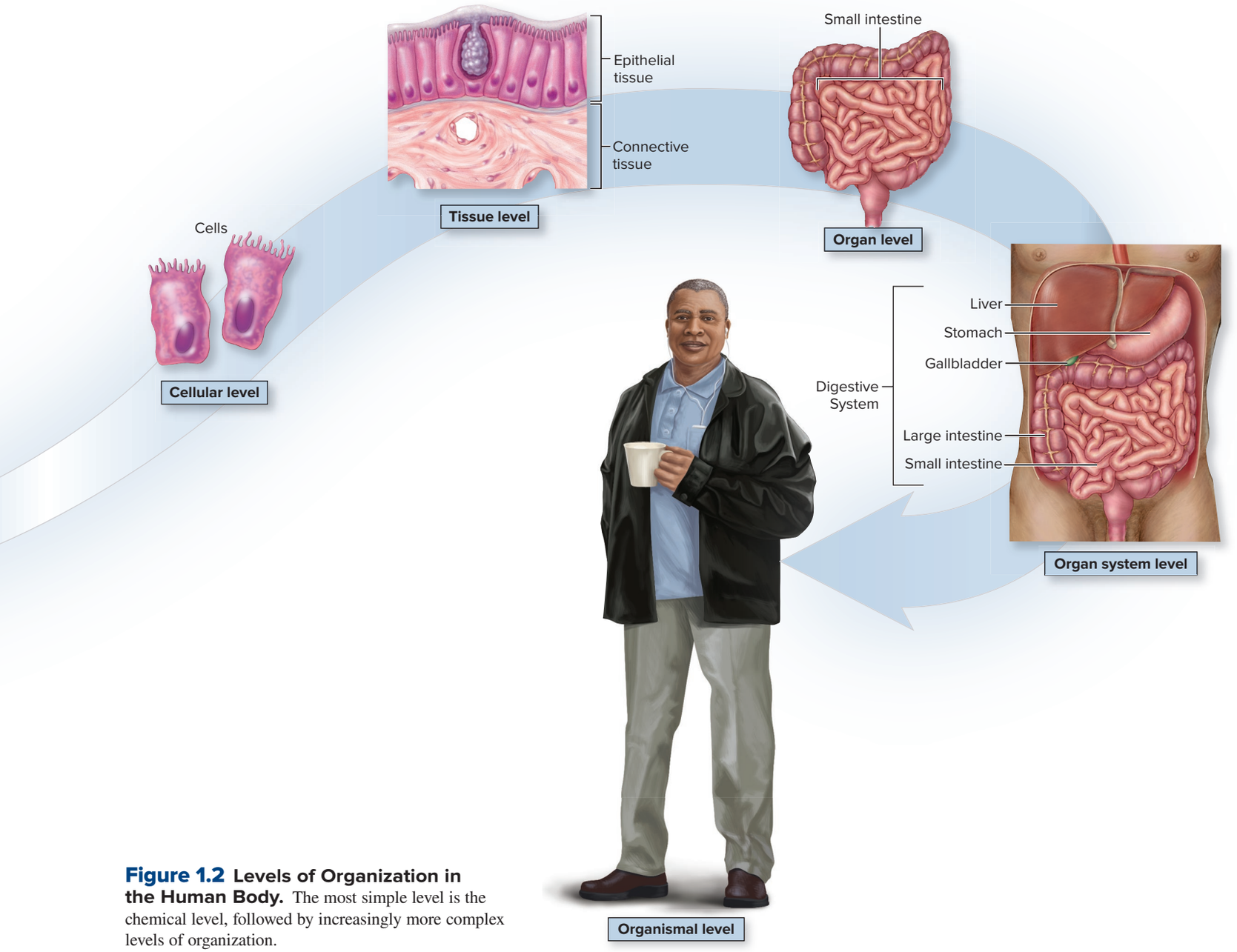



**Figure 1.2 Levels of Organization in the Human Body.** The most simple level is the chemical level, followed by increasingly more complex levels of organization.

## 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.

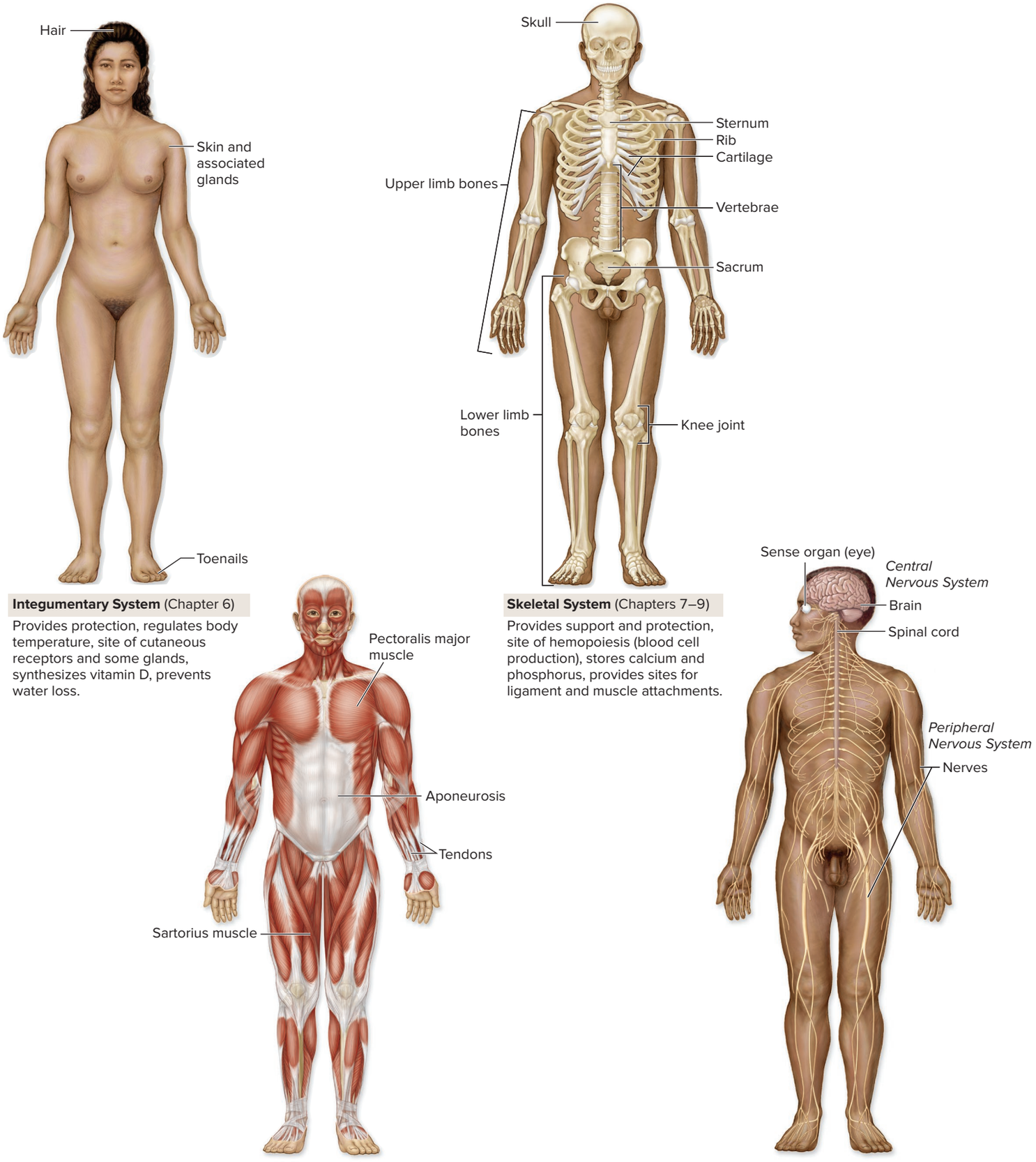
Most anatomic and physiologic terms are derived from Greek or Latin, and we frequently provide word origins, pronunciations, and definitions of terms where appropriate throughout this text. We've used *Stedman's Medical Dictionary* (which defines all medical terms) and *Terminologia Anatomica* (which 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.

**INTEGRATE**

### LEARNING STRATEGY

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.




**Integumentary System** (Chapter 6)

Provides protection, regulates body temperature, site of cutaneous receptors and some glands, synthesizes vitamin D, prevents water loss.

**Skeletal System** (Chapters 7–9)

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

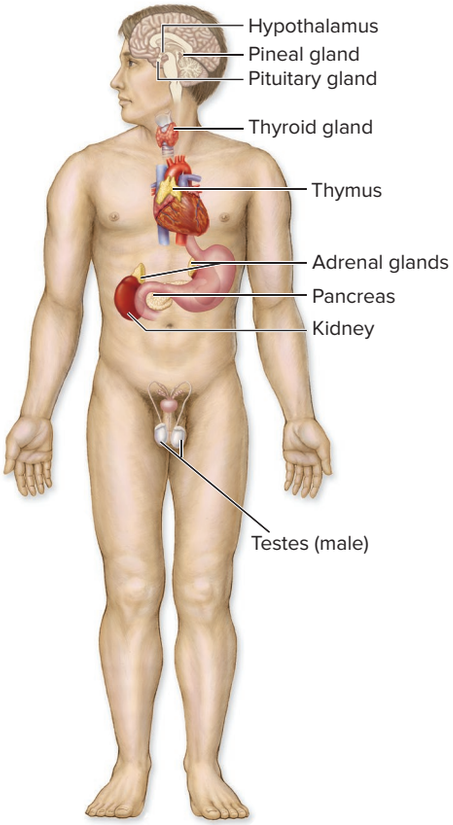
**Muscular System** (Chapters 10–11)

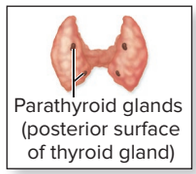
Produces body movement, generates heat when muscles contract.

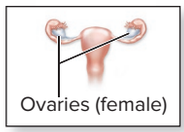
**Nervous System** (Chapters 12–16)

A regulatory system that controls muscles and some glands, responds to sensory stimuli, and helps control all other systems of the body. 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. AP|R

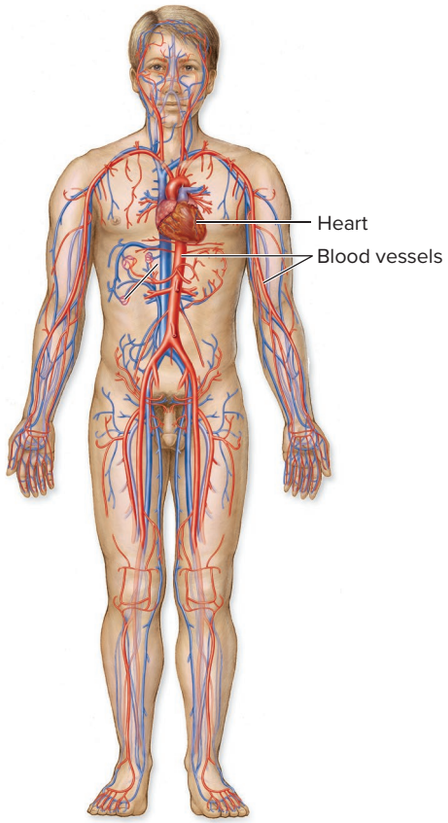


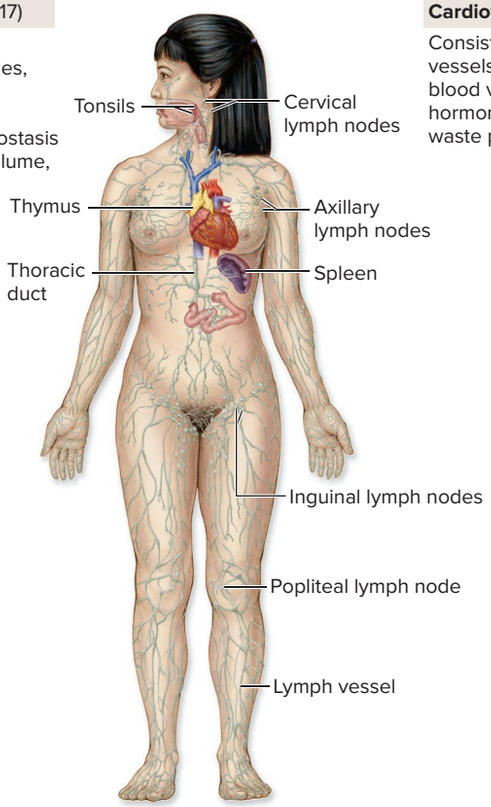

**Endocrine System** (Chapter 17)

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.



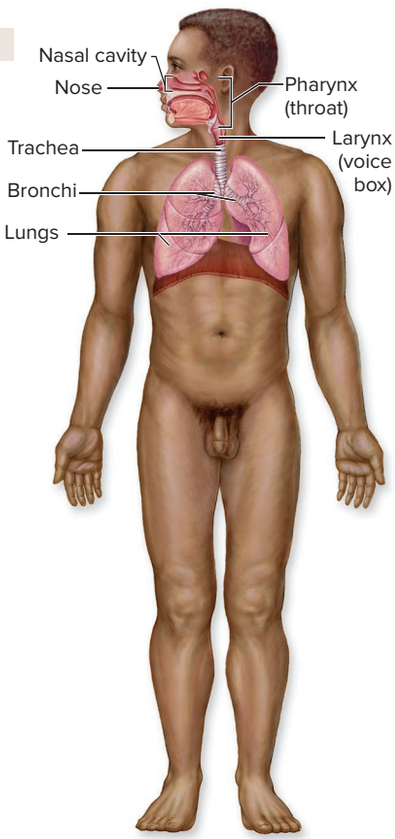

**Cardiovascular System** (Chapters 18–20)

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.



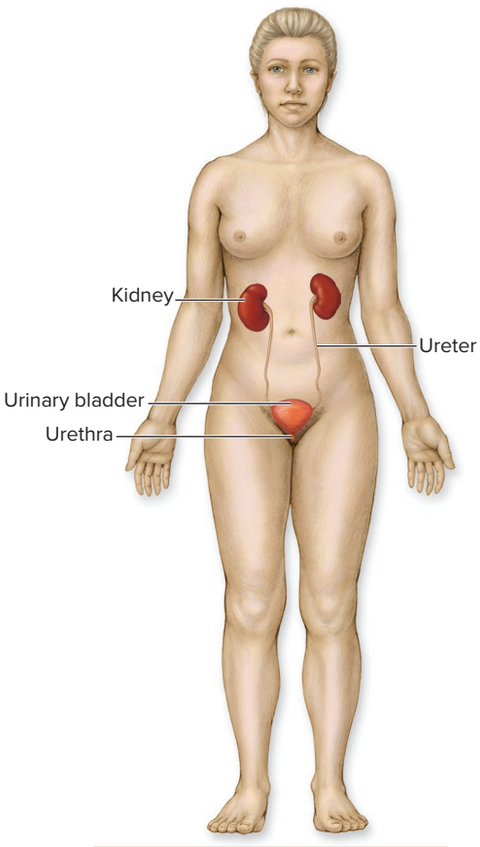

**Lymphatic System** (Chapters 21–22)

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



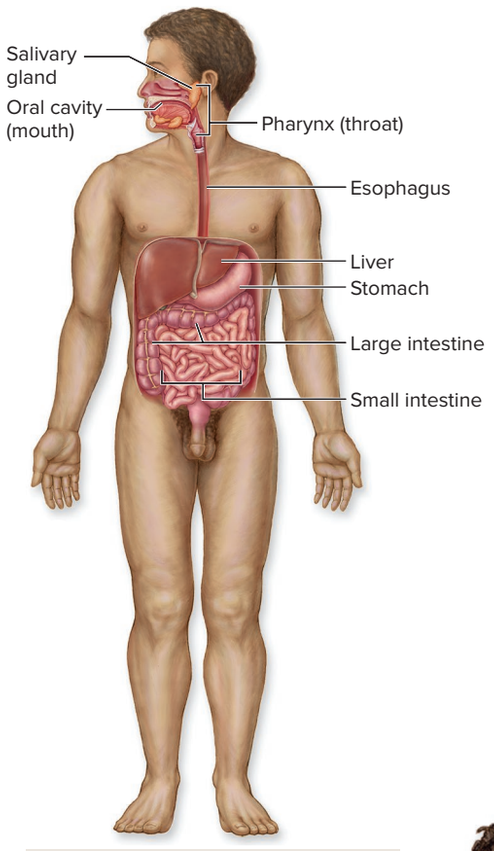

**Respiratory System** (Chapter 23)

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



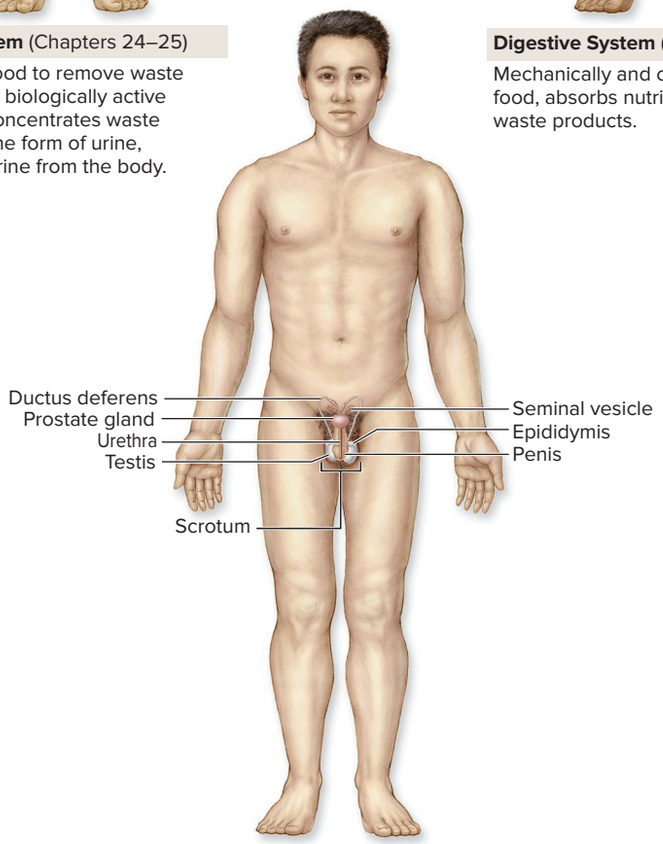

**Urinary System** (Chapters 24–25)

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.



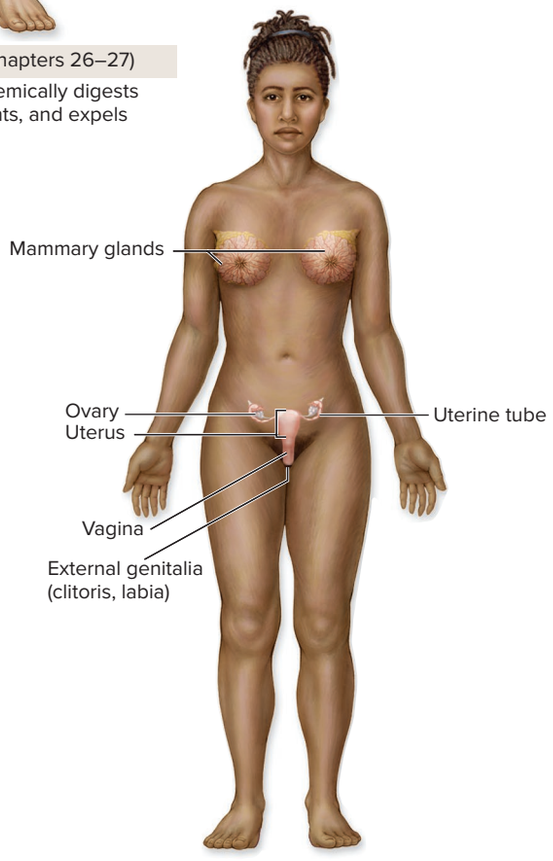

**Digestive System** (Chapters 26–27)

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*) AP|R

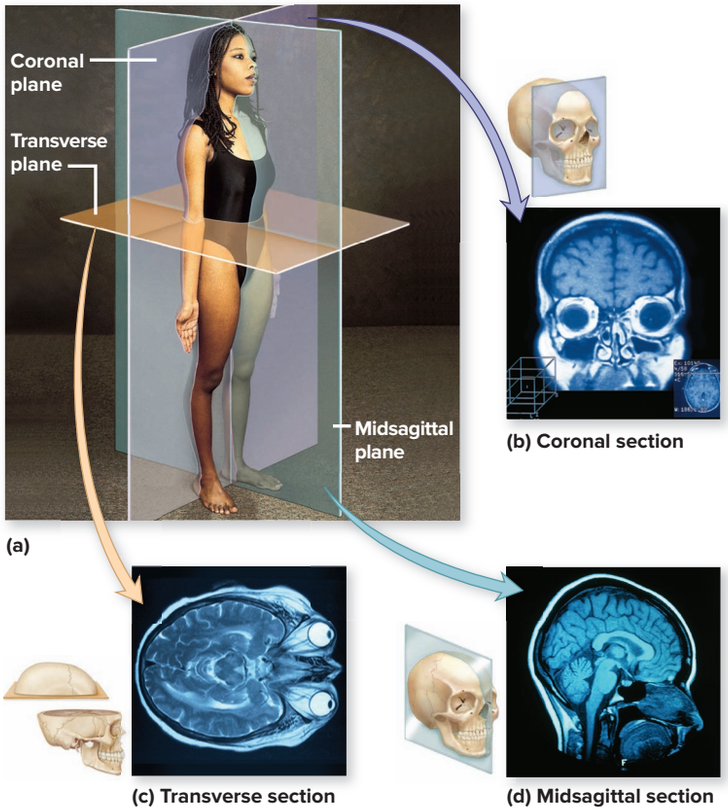



**Figure 1.4 Anatomic Position and Body Planes.** (*a*) In the anatomic position, the body is upright, and the forearms are positioned so the palms are facing anteriorly. A plane is an imaginary surface that slices the body into specific sections. Sections are shown from each of the three major anatomic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

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

## 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). 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).

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 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.

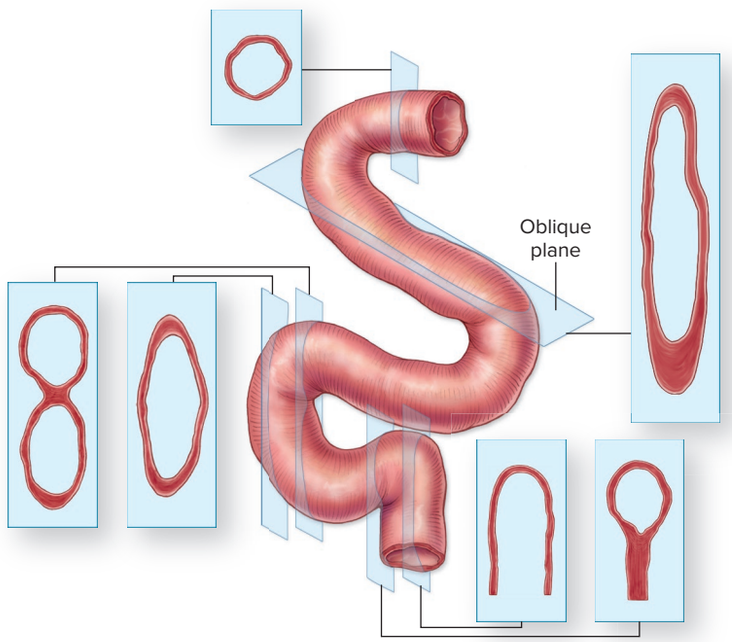



**Figure 1.5 Sections from a Three-Dimensional Structure.** Serial sections through an object are used to reconstruct its three-dimensional structure, as in these sections of the small intestine. Often a single section, such as the plane at the lower part of this figure, misrepresents the complete structure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

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"?

## 1.5d Regional Anatomy

**LEARNING OBJECTIVE**

**13.** Identify 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. Not all regions are shown in figure 1.7.

**WHAT DID YOU LEARN?**

11 The term *antebrachial* refers to which body region?

## 1.5e Body Cavities and Membranes

**LEARNING OBJECTIVES**

**14.** Describe the body cavities and their subdivisions.

**15.** Explain the role of serous membranes in the ventral cavities.

**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. |

Internal organs and organ systems are housed 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

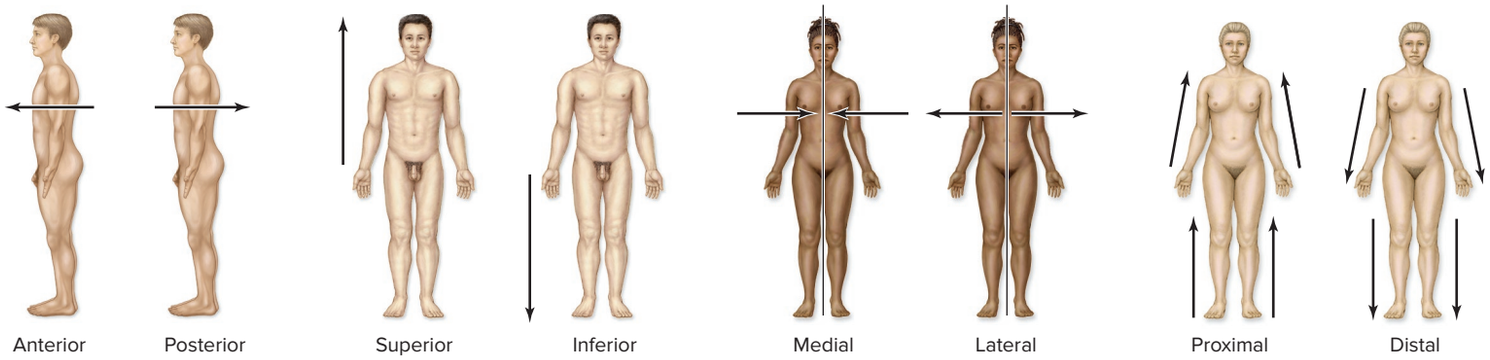



**Figure 1.6 Directional Terms in Anatomy.** Directional terms precisely describe the location and relative relationships of body parts. (See also table 1.1.) AP|R

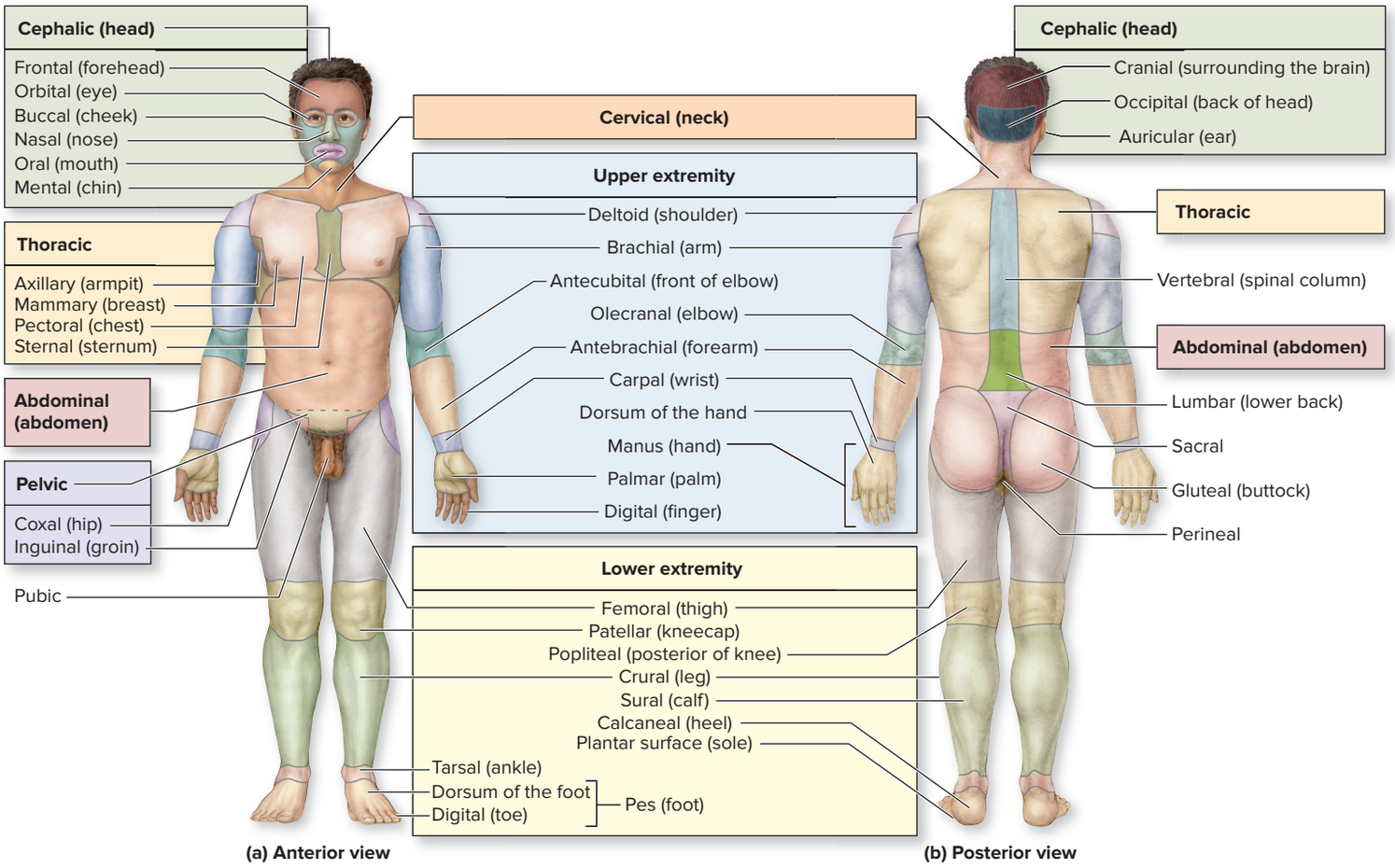



**Figure 1.7 Regional Terms.** (*a*) Anterior and (*b*) posterior views show key regions of the body. Their common names appear in parentheses. AP|R

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 cavity houses 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 houses 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

**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 | Lateral aspect of the leg |
| Frontal | Forehead |
| Gluteal | Buttock |
| Hallux | 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 | 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 | Medial aspect of leg |
| Ulnar | Medial aspect (pinky side) of the forearm |
| Umbilical | Navel |
| Vertebral | Spinal column |

1. The word *region* should follow each region name listed in the table (e.g., femoral region).

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

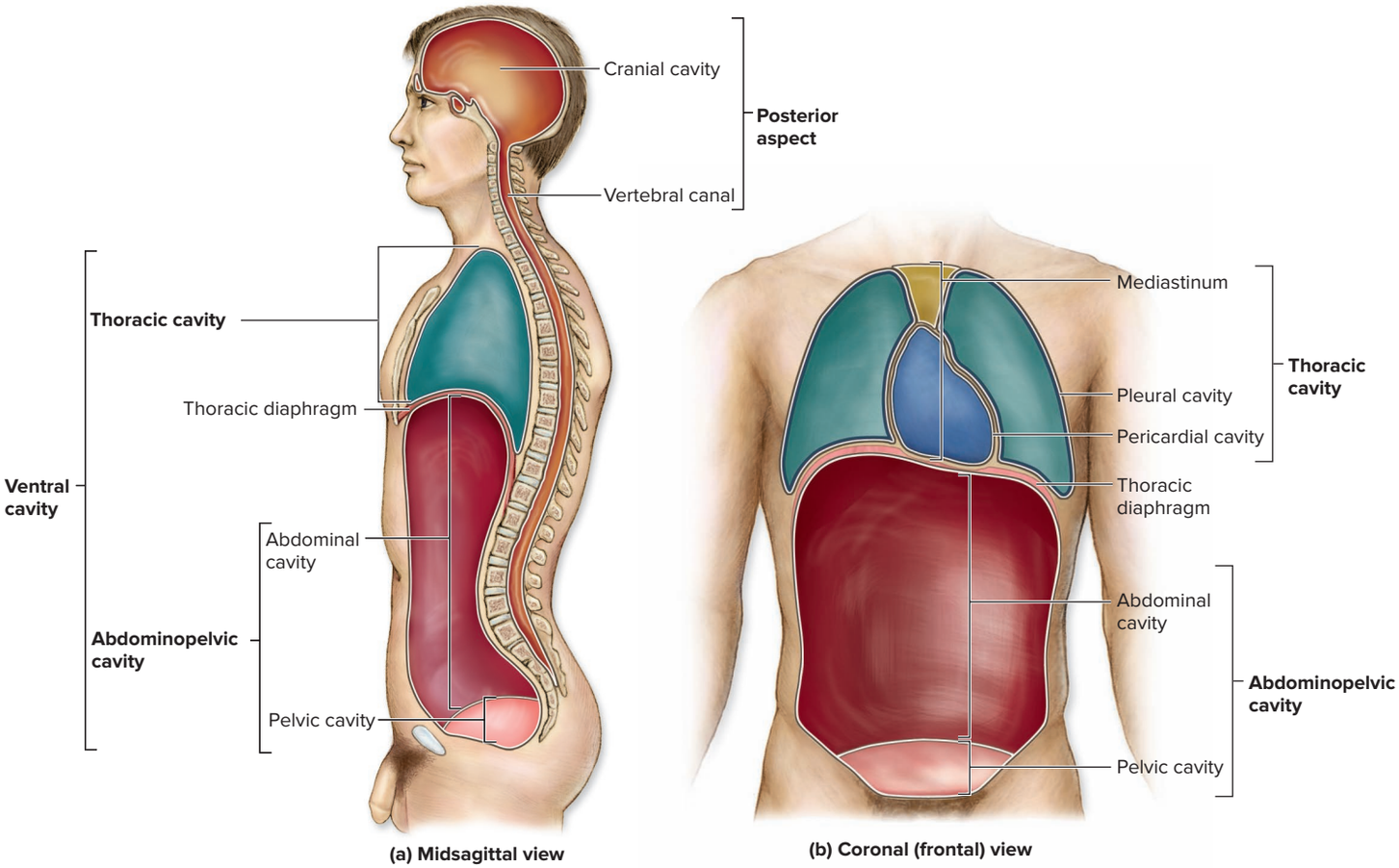



**Figure 1.8 Body Cavities.** The body is composed of two main spaces: the posterior aspect and the ventral cavity. Many vital organs are housed within these spaces. (*a*) A midsagittal view shows both the posterior aspect and the ventral cavity. (*b*) A coronal view shows the relationship between the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

fluid so the organs move more smoothly against one another and the body walls. 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?

Figure 1.9*a* provides a helpful 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 within the balloon, between the two "walls," 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.

***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.

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 outermost layer of the serous membrane and forms the sac around the heart, whereas the **visceral pericardium** forms 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 house the lungs, which are associated with a two-layered serous membrane called the **pleura** (plūr′ă; a rib) (figure 1.9*c*).

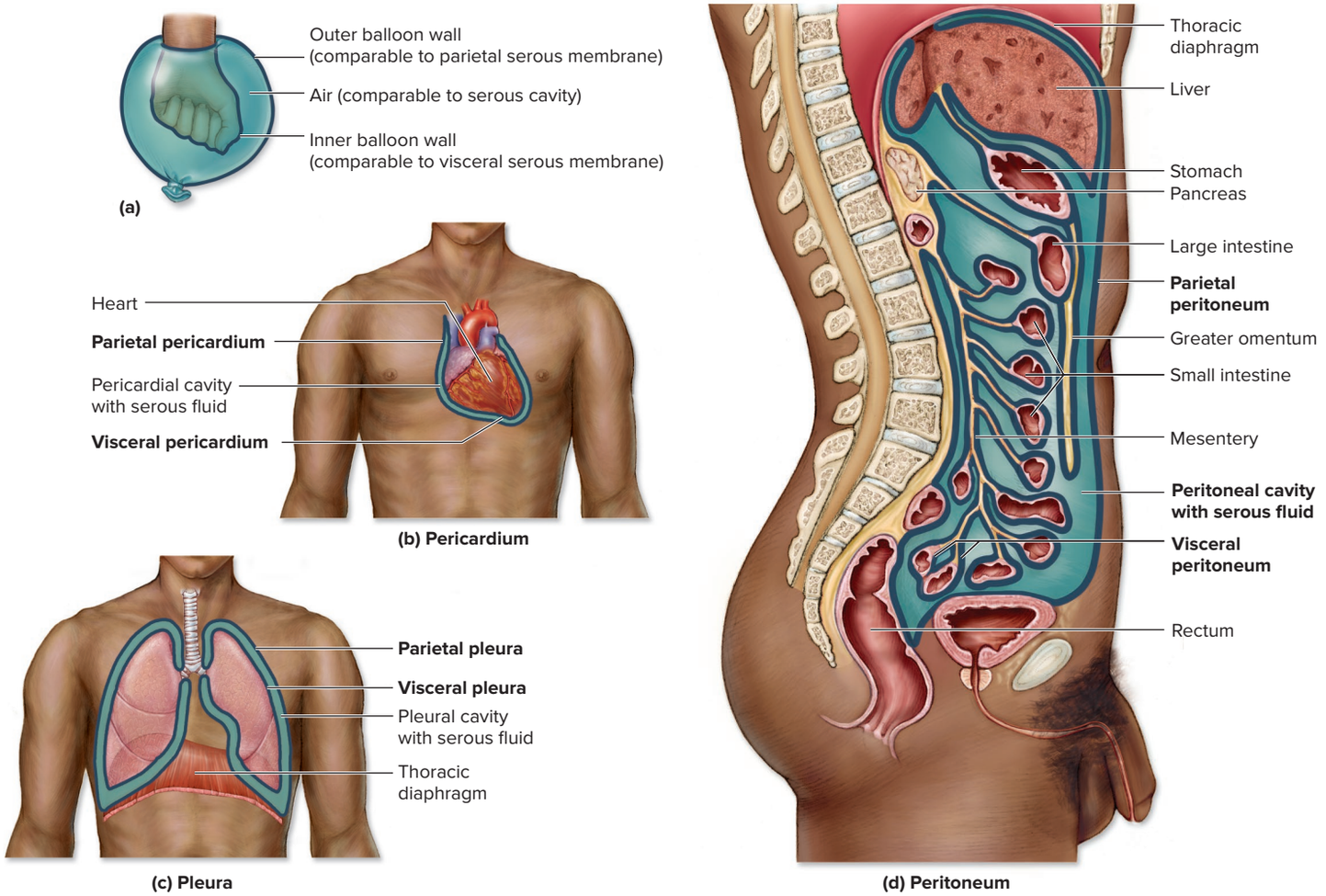



**Figure 1.9 Serous Membranes in the Thoracic and Abdominopelvic Body Cavities.** Serous membranes line the inside of the cavity (parietal layer) and cover the outside of an organ (visceral layer) within the cavity. (*a*) The parietal and visceral serous membranes are similar to the outer and inner balloon walls that wrap around a fist, where the fist represents the body organ. (*b*) Parietal and visceral layers of the 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. AP|R

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 lines 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 of its serous membranes?

## 1.5f Abdominopelvic Regions and Quadrants

**LEARNING OBJECTIVE**

**16.** Compare the terms used to subdivide the abdominopelvic region into nine regions or four quadrants.

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

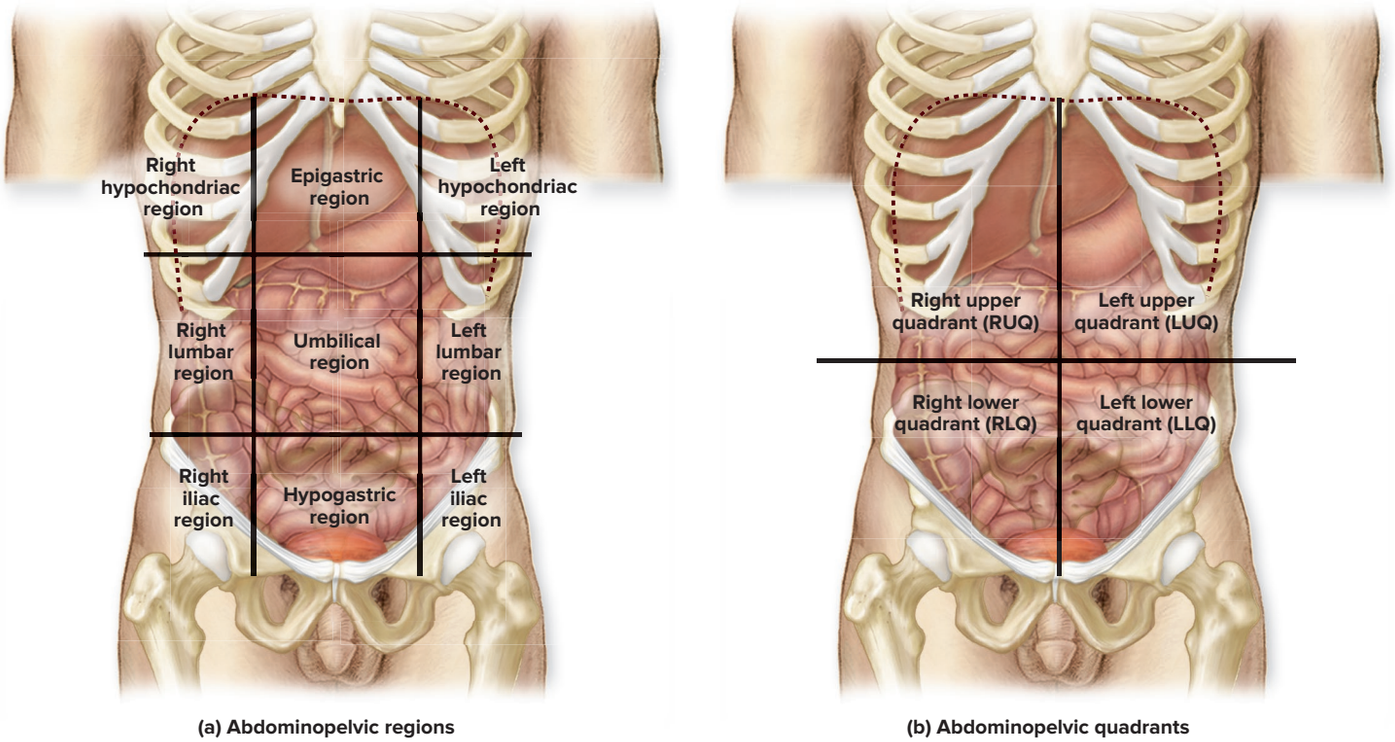



**Figure 1.10 Abdominopelvic Regions and Quadrants.** The abdominopelvic cavity can be subdivided into (*a*) nine regions or (*b*) four quadrants for purposes of description or identification. AP|R

- 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 general 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. Define the components of a homeostatic system.
18. Be able to recognize each of the components in representative 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)**.

#### Receptor

The **receptor** is the body structure that detects changes in a variable, which is a substance or process that is regulated. A receptor

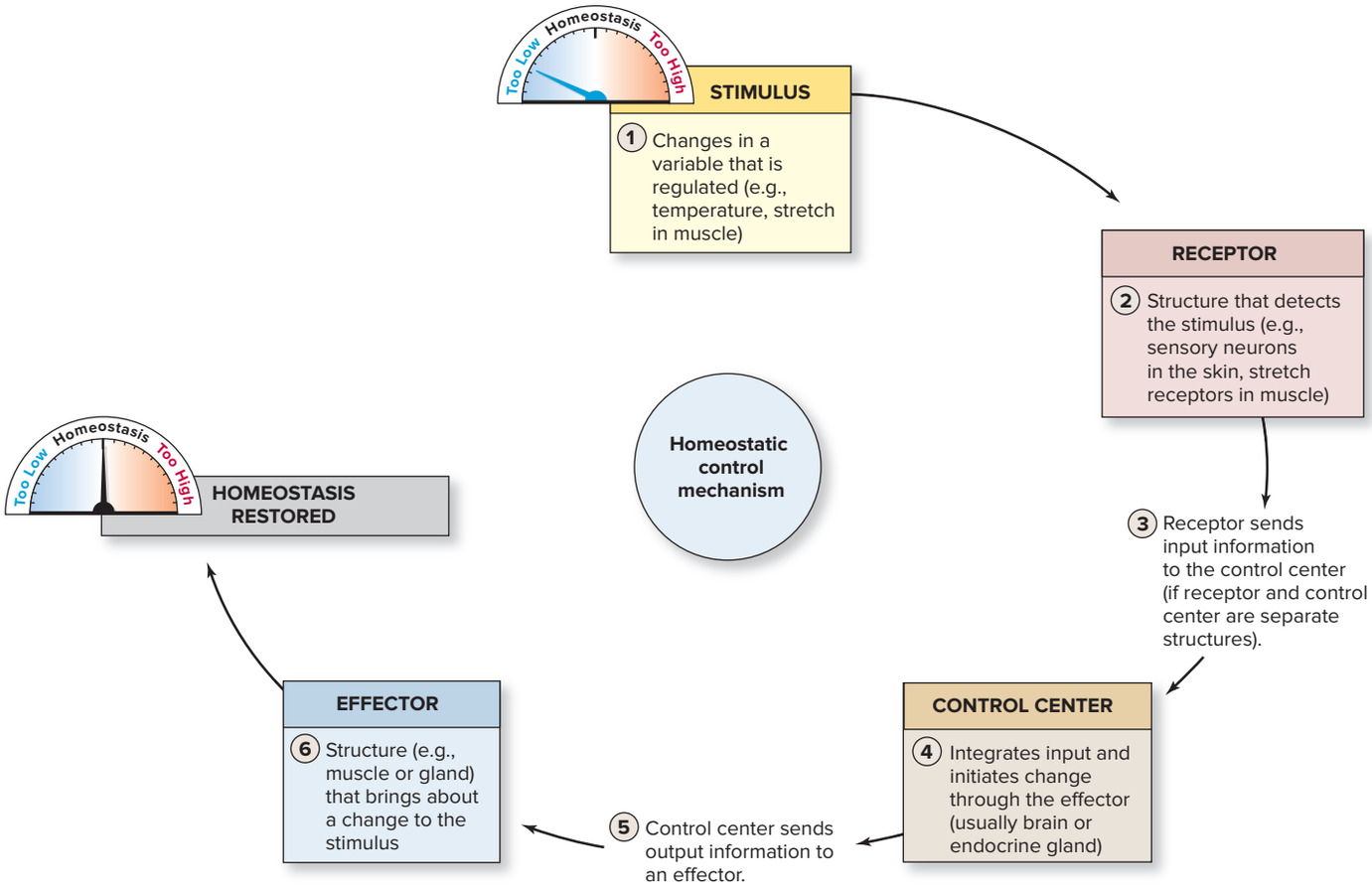



**Figure 1.11 Components of a Homeostatic Control Mechanism.** A homeostatic control mechanism consists of a receptor (detects a stimulus), a control center (integrates input and initiates change through the effector), and an effector (brings about a change in response to the stimulus).

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. 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

**INTEGRATE**

## LEARNING STRATEGY

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.

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 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 is activated to cause 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. This idea is generally better understood by describing a specific example, such as temperature regulation.

### 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 heat pump, which then turns on. The heat pump continues to heat your home until the thermostat reaches 70°F. An electrical signal is then sent from the thermostat to shut off the heat pump.

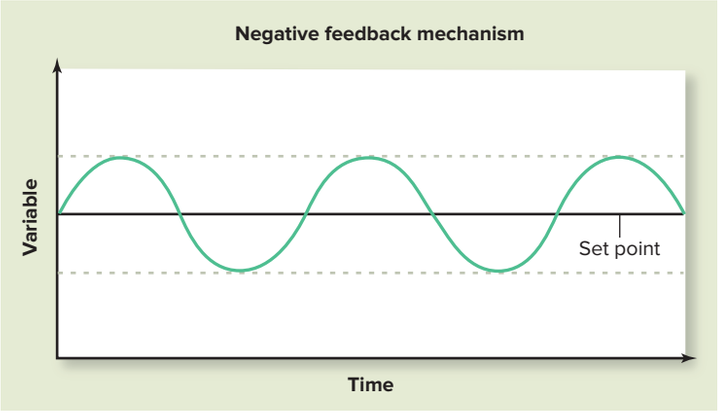



**Figure 1.12 Negative Feedback.** Note that when a variable is regulated by negative feedback, the variable fluctuates around a set point (rather than being a constant).

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 perhaps to smooth muscle associated with hair follicles of the skin, causing "goose bumps."

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.

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?**

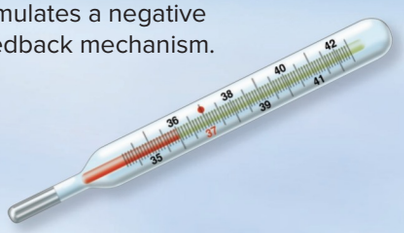
15 On a cold day, what are some of the strategies the body uses to conserve heat?

**Figure 1.13 Negative Feedback Mechanisms for Regulating Body Temperature.**

Feedback mechanisms initiated when body temperature (*a*) falls below normal or (*b*) rises above normal are compared.

## (a) Body Temperature Falls Below Normal

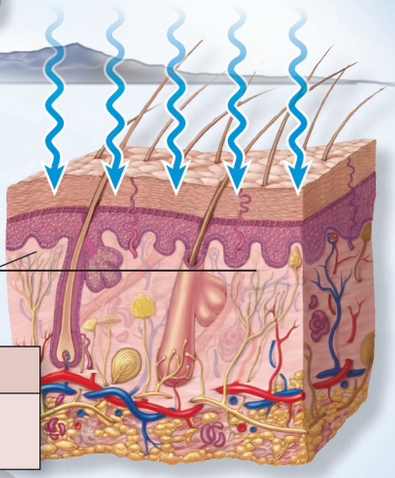
A decrease in body temperature stimulates a negative feedback mechanism.





**STIMULUS**

Cold environmental temperatures lower body temperature to below normal.



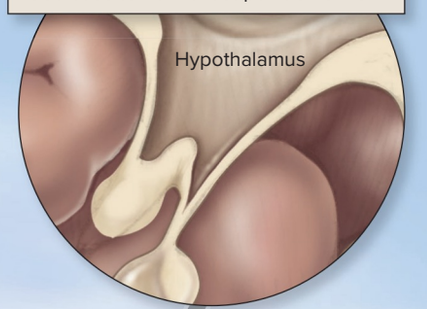

**RECEPTORS**

Sensory receptors in skin detect cold.

Receptors send temperature information to brain.

**CONTROL CENTER**

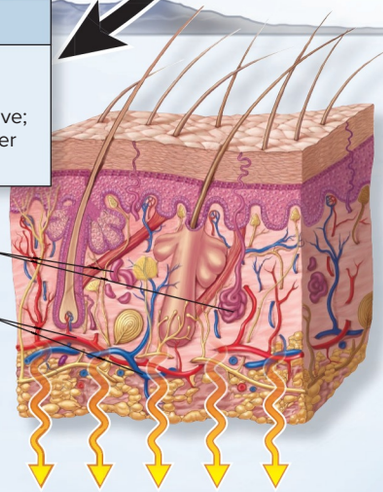
Hypothalamus of brain compares sensory input regarding temperature decrease to normal set point of 37°C.



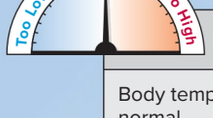

Directs response to effectors

**EFFECTORS**

Blood vessels in skin constrict; sweat glands become inactive; skeletal muscles shiver to generate heat.

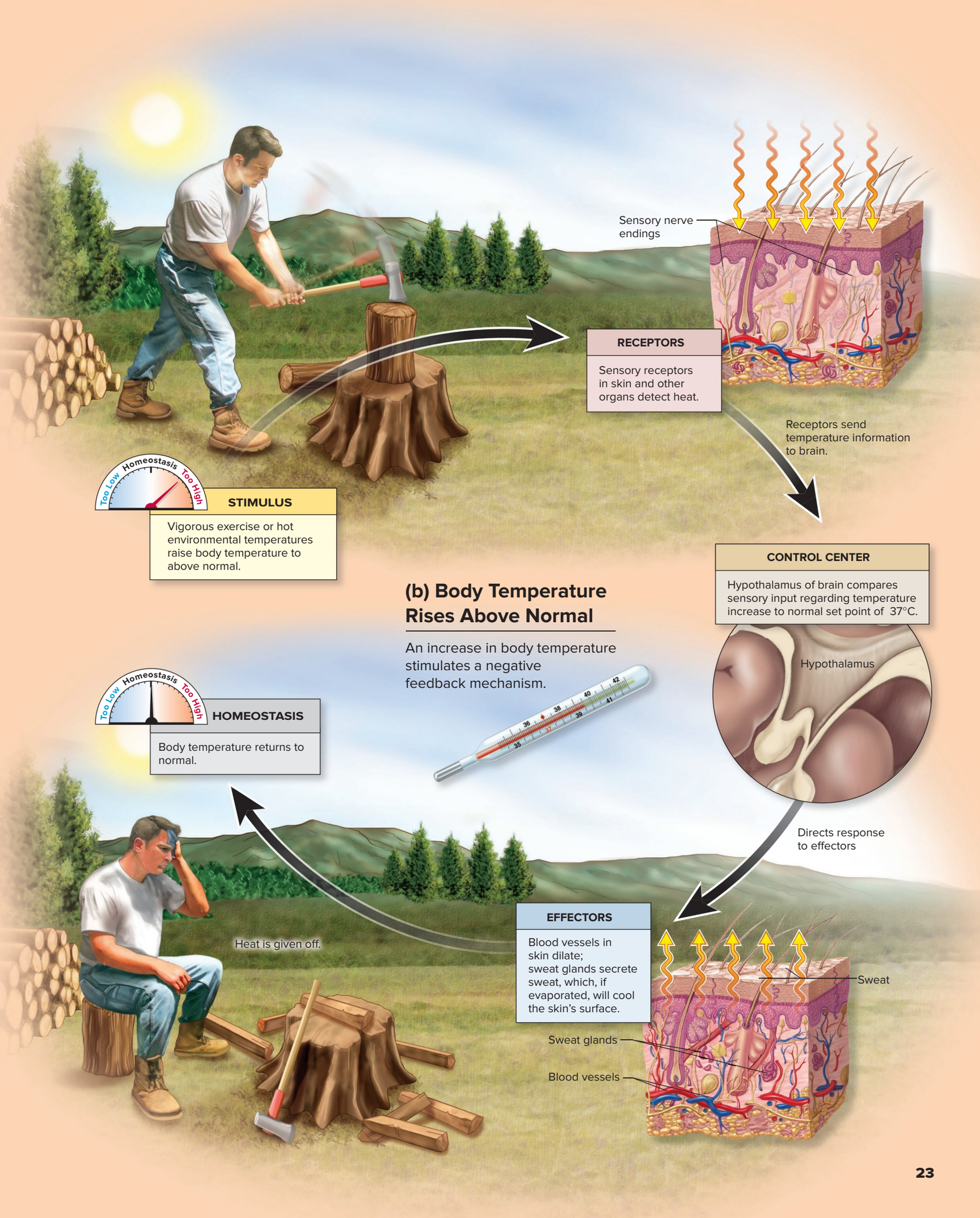



Heat is conserved.




**HOMEOSTASIS**

Body temperature returns to normal.


Too Low
Homeostasis
Too High
STIMULUS
Vigorous exercise or hot environmental temperatures raise body temperature to above normal.
Sensory nerve endings
RECEPTORS
Sensory receptors in skin and other organs detect heat.
Receptors send temperature information to brain.
CONTROL CENTER
Hypothalamus of brain compares sensory input regarding temperature increase to normal set point of 37°C.
Hypothalamus
(b) Body Temperature Rises Above Normal
An increase in body temperature stimulates a negative feedback mechanism.
Directs response to effectors
EFFECTORS
Blood vessels in skin dilate; sweat glands secrete sweat, which, if evaporated, will cool the skin's surface.
Sweat
Sweat glands
Blood vessels
Heat is given off.
HOMEOSTASIS
Body temperature returns to normal.

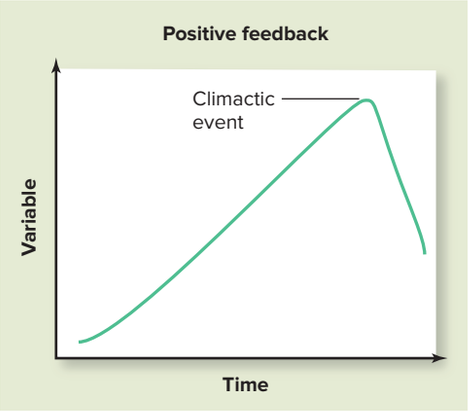



**Figure 1.14 Positive Feedback.**
Positive feedback results in the stimulus being reinforced until a climactic event occurs, and then the body returns to homeostasis.

## 1.6c Homeostatic Systems Regulated by Positive Feedback

### LEARNING OBJECTIVES

**21.** Define positive feedback.

**22.** Describe the actions of a positive feedback loop.

A homeostatic system may also be controlled by **positive feedback.** The stimulus here is reinforced to continue in the *same* direction until a climactic event occurs **(figure 1.14)**. Following the climactic event, the body again returns to homeostasis. Because their end result is to increase the activity (instead of initially returning the body to homeostasis), positive feedback mechanisms occur much less frequently than negative feedback mechanisms.

**Figure 1.15** illustrates one example of a positive feedback mechanism in the human body, when a mother breastfeeds her baby. The baby suckling at the breast is the initial stimulus detected by sensory receptors in the skin of the nipple region. The receptors transmit this input to the control center, which is the hypothalamus of the brain. The hypothalamus signals the posterior pituitary (an endocrine gland) to release the hormone oxytocin into the blood. Oxytocin is the "output" that is sent to the effector, which is the glandular tissue of the breast. Oxytocin stimulates the mammary gland to eject the breast milk. The baby feeds and the cycle repeats as long as the baby suckles. Once the baby stops suckling (and thus the initial stimulus is removed), then the cycle will stop.

Other examples of positive feedback mechanisms include the blood clotting cascade (see section 18.4c) and uterine contractions involved in labor and childbirth (see section 29.6c).

### WHAT DID YOU LEARN?

16 What is the main difference between a homeostatic system regulated by negative feedback and one regulated by positive feedback?

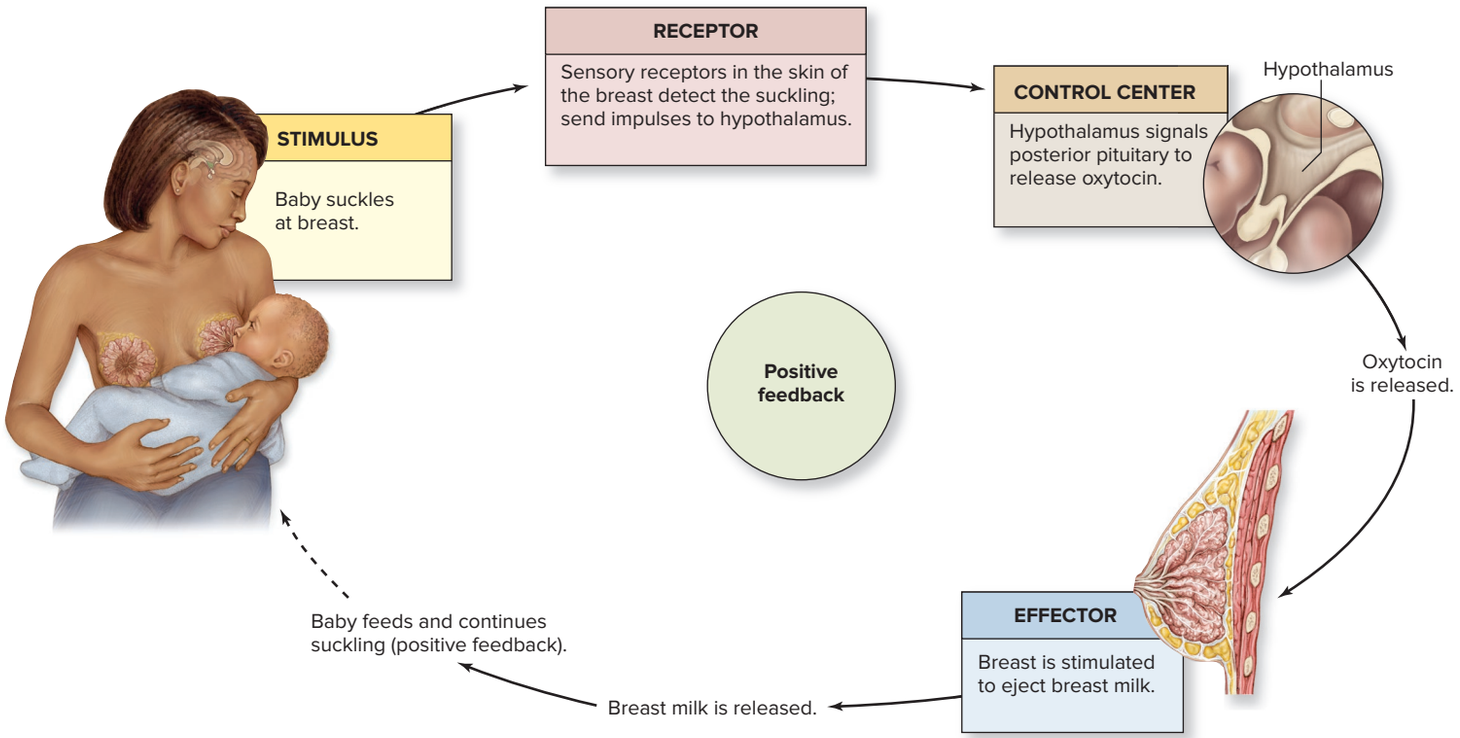



**Figure 1.15 Positive Feedback.** Positive feedback mechanisms often work in loops, where the initial step in the pathway is the stimulus, and the end product of the pathway is to stimulate (not turn off) the pathway activity. In this example of a mother breastfeeding her child, the stimulus of the baby suckling initiates nerve impulses to the brain to cause release of hormones that stimulate the breast to secrete more breast milk.

## 1.7 Homeostasis, Health, and Disease

**LEARNING OBJECTIVE**

**23.** Explain the general relationship of maintaining homeostasis to health and disease.

In summary, *homeostasis* is a term that describes the many physiologic processes to maintain the health of the body. These characteristics are noted about homeostatic systems:

- They are dynamic.
- The control center is generally the nervous system or the endocrine system.
- There are three components: receptor, control center, and effector.
- They are typically regulated through negative feedback to maintain a normal value or set point.
- It is when these systems fail that a homeostatic imbalance or disease potentially results and ultimately may threaten an individual's survival.

Diabetes is an example of a homeostatic imbalance. Diabetes occurs when the homeostatic mechanisms for regulating blood glucose are not functioning normally, and blood glucose fluctuates out of the normal range, sometimes resulting in extremely high blood glucose readings. High blood glucose results in damage to anatomic structures throughout the body. Patients with diabetes must rely on other methods, such as diet restriction, exercise, and perhaps a medication, to lower blood glucose.

Sometimes a homeostatic imbalance results when critical changes from aging or disease cause a variable that is normally controlled by negative feedback to be abnormally controlled by positive feedback. An example is when there is extensive damage to the heart, perhaps from a heart attack. This heart is less able to pump blood to the structures of the body, including the heart itself. Consequently, the heart receives reduced amounts of nutrients and oxygen. The heart becomes progressively weaker, and even less able to pump blood to the body's structure. Ultimately, the heart becomes so weak that the heart stops beating.

Treating patients generally involves determining a **diagnosis,** or a specific cause of the homeostatic imbalance. Once diagnosed, the patient is treated through the administration of medications or through other therapeutic avenues to facilitate the body in maintaining homeostasis.

Health-care practitioners also need to understand how the drugs patients are taking may affect the normal homeostatic control mechanisms. For example, one type of medication for the treatment of depression is an SSRI, which stands for selective serotonin reuptake inhibitor. Paroxetine (Paxil), fluoxetine (Prozac), and sertraline (Zoloft) are examples of SSRIs. Serotonin is a type of neurotransmitter. Normally, a neurotransmitter is released from one nerve cell in response to a stimulation (nerve impulse). The neurotransmitter accomplishes its communication task, and then is taken up again by the nerve cell for future use. Some depressed individuals may have lower levels of serotonin, so an SSRI blocks the reuptake of serotonin into the nerve cell. Therefore, serotonin stays outside the nerve cell for a longer period of time and its effects are prolonged, which may elevate the mood of the patient taking the SSRI.

However, like all drugs, SSRIs come with some undesirable side effects. Some SSRI side effects include digestive system distress, such as nausea, upset stomach, diarrhea, or combinations of all three. As it turns out, serotonin is also used in the nerve cells of the digestive system. By tinkering with the serotonin reuptake in the brain, the drug also affects serotonin reuptake in the digestive system. Essentially, the digestive system becomes more excitable due to the intake of the SSRI drug, with the symptoms just described.

Virtually all medications have some benefits and some side effects, many of which can be explained by examining the homeostatic control mechanisms with which they interact. Thus, an understanding of these mechanisms is a must for anatomists, physiologists, and health-care practitioners.

**WHAT DID YOU LEARN?**

17 What is an example of a disease process by which homeostasis is disrupted?

**INTEGRATE**

### CLINICAL VIEW 1.2

#### Establishing Normal Ranges for Clinical Practice

What is clinically accepted as the "normal range" for a variable, such as body temperature of 98.6°F, blood glucose of 80–110 milligrams/deciliter (mg/dL), or blood pressure of 90–120/60–80 mm Hg is determined by sampling healthy individuals in a population. A normal range for a variable is determined by the value for 95% of the individuals sampled. Health-care practitioners should be aware that this means that 5% of the population, although healthy, will have values for a given variable considered outside of the normal range.

**INTEGRATE**

### CLINICAL VIEW 1.3

#### Clinicians' Use of Scientific Method

Clinicians regularly apply the principles of the scientific method when interacting with patients. Consider what typically occurs when a patient with a health problem or complaint goes in for a doctor's appointment. First, information is gathered. The nurse obtains the patient's weight, blood pressure, and other vital signs. The physician solicits the patient's medical history, asks about his or her specific complaint(s), and completes a physical examination. Based on the information gathered, the clinician forms a hypothesis—a tentative explanation of any specific symptoms the patient may be experiencing. As a follow-up to the initial hypothesis, the clinician orders tests and evaluates the test results. After all information is gathered, the clinician draws a conclusion to make a diagnosis. (Sometimes additional tests may be ordered if the test results are inconclusive.) Following a definitive diagnosis, the clinician treats the patient, and additional information is gathered as the patient's response to the treatment is monitored.

INTEGRATE

# CLINICAL VIEW 1.4

## Medical Imaging

Health-care professionals have taken advantage of sophisticated medical imaging techniques to extend their ability to visualize internal body structures noninvasively (i.e., without inserting an instrument into the body). Some of the most common techniques are radiography, sonography, computed tomography, digital subtraction angiography, dynamic spatial reconstruction, magnetic resonance imaging, and positron emission tomography.

### Radiography

**Radiography** (rā-dē-og′ra-fē; *radius* = ray, *grapho* = to write) is the primary method of obtaining an image of a body part for diagnostic purposes. A beam of **x-rays,** which are a form of high-energy radiation, penetrates solid structures within the body. X-rays can pass through soft tissues but they are absorbed by dense tissues, including bone, teeth, and tumors. Film images produced by x-rays passing through soft tissues leave the film lighter in the areas where x-rays are absorbed. Hollow organs can be visualized if they are filled with a radiopaque (rā-dē-ō-pāk; *opacus* = shady) substance that absorbs x-rays.

*Radiograph (x-ray) of the head and neck, viewed from the right lateral surface.*

©Medical Body Scans/Science Source

The term *x-ray* also applies to the photograph (radiograph) made by this technique. Originally, x-rays got their name because they were an unknown type of radiation, but they are also called roentgen rays in honor of Wilhelm Roentgen, the German physicist who accidentally discovered them. Radiography is commonly used in dentistry, mammography, diagnosis of fractures, and chest examination. Disadvantages of x-rays are that they are difficult to interpret when organs overlap in the images, and they are unable to reveal slight differences in tissue density. In addition, the radiation of an x-ray is not without risk.

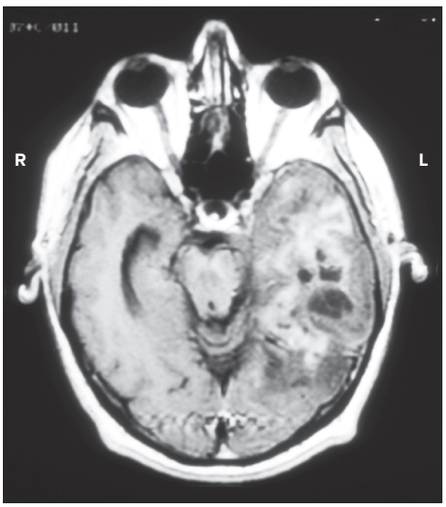
### Sonography

The second most widely used imaging method is **sonography** (sō-nog′ră-fē; *sonus* = sound), also known as *ultrasound.* A technician slowly moves a small, handheld device across the body surface. This device produces high-frequency ultrasound waves and then receives signals that are reflected from internal organs. The image produced is called a **sonogram.** Sonography is the method of choice in obstetrics, where a sonogram can visualize the placenta, examine the fetus, and evaluate fetal age, position, and development. Sonography avoids the harmful effects of x-rays, and the equipment is relatively inexpensive and portable. Once limited to the fields of obstetrics and cardiology, sonography is now widely used in most fields of medicine. For example, orthopedists may quickly examine a shoulder with ultrasound for a rotator cuff tear, and emergency medicine doctors use ultrasound imaging to quickly assess the status of a patient's internal organs.

*Sonogram of a fetus.*

©ATL/Science Source

Improvements in sonography include three-dimensional and four-dimensional ultrasound. In three-dimensional ultrasound, sound waves are emitted in various angles and processed in a computer. This creates a three-dimensional view. A two-dimensional ultrasound is a flat image and a three-dimensional ultrasound shows depth, contour, and detail. Four-dimensional ultrasound shows movement using a compilation of three-dimensional images. Movements like heart motion and yawning can be seen in real time. When radiography or sonography fail to produce the desired images, other more detailed but much more expensive imaging techniques are available.




*Computed tomography (CT) scan of the head at the level of the eyes, viewed in transverse section.*

©SIU BioMed Com/Custom Medical Stock Photo

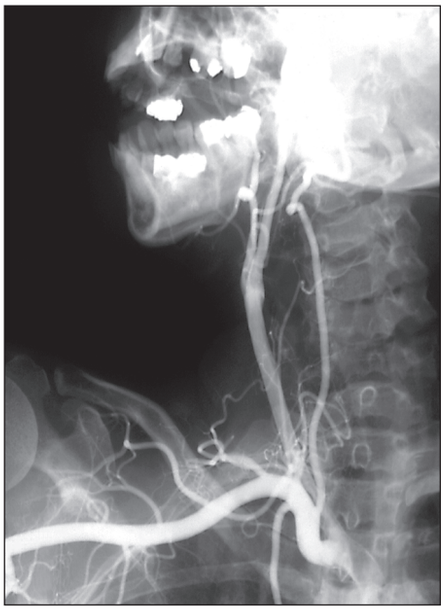
### Computed Tomography (CT)[1]

A **computed tomography (CT)** (tō′mō-graf-ē; *tomos* = a section) scan, previously termed a computerized axial tomography (CAT) scan, is a more sophisticated application of x-rays. A patient is slowly moved through a cylindrical, doughnut-shaped machine while low-intensity x-rays are emitted on one side of the cylinder, passed through the body, collected by detectors, and then processed and analyzed by a computer. These signals produce an image of the body that is about the thickness of a dime. Continuous thin "slices" can be used to reconstruct a three-dimensional image of the body. Little overlap of organs occurs in these thin sections, and the image is much sharper than one obtained by a conventional x-ray. CT scanning is useful for identifying tumors, aneurysms, kidney stones, cerebral hemorrhages, and other abnormalities. A drawback to CTs is that they expose the patient to higher doses of radiation than a traditional x-ray.

### Digital Subtraction Angiography (DSA)

**Digital subtraction angiography (DSA)** is a modified three-dimensional x-ray technique used primarily to view blood vessels. It involves taking radiographs both prior to and after injecting an opaque medium into a blood vessel. The computer compares the before and after images, and removes or subtracts the data from the before image from the data generated by the after image, thus leaving an image that may indicate evidence of vessel blockages. DSA is useful in the procedure in which a physician directs a catheter through a blood vessel and puts a stent in the area where a blood vessel is blocked. The image produced by the DSA allows the physician to accurately guide the catheter to the blockage.

1. CT and MRI films taken in the transverse plane are usually, but not always, read from an inferior view. So the right side of the body is on the left side of the image, and the left side of the body is on the right side of the image. Thus, when reading a CT or MRI scan in transverse section, check the orientation of the image. There should be L and R letters to let you know which side of the film corresponds to the left or right side of the patient.



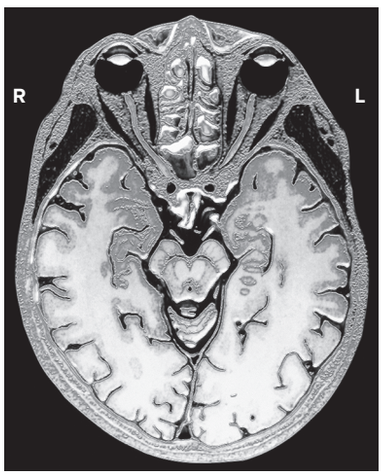
*Digital subtraction angiography (DSA) shows three-dimensional images of blood vessels and normal changes in these vessels.*
©ISM/Athenais/Medical Images

## Dynamic Spatial Reconstruction (DSR)

Using modified CT scanners, a special technique called **dynamic spatial reconstruction (DSR)** provides two important pieces of medical information: (1) three-dimensional images of body organs, and (2) information about the normal organ movement as well as changes in its internal volume. Unlike traditional static CT scans, DSR allows the physician to see the movement of an organ. This type of observation, at slow speed or halted in time completely, has been invaluable in observations of the heart and the flow of blood through blood vessels.

## Magnetic Resonance Imaging (MRI)[1]

**Magnetic resonance imaging (MRI),** previously called *nuclear magnetic resonance (NMR) imaging,* was developed as a noninvasive technique to visualize soft tissues. The patient is placed in a supine position within a cylindrical chamber that is surrounded by a large electromagnet. The magnet generates a strong magnetic field that causes protons in the nuclei of hydrogen atoms in the tissues to align. Thereafter, upon exposure to radio waves, the protons absorb additional energy and align in a different direction. The hydrogen atoms then abruptly realign themselves to the magnetic field immediately after the radio waves are turned off. This results in the release of the atoms' excess energy at different rates, depending on the type of tissue. A computer analyzes the emitted energy to produce an image of the body. MRI is better than CT for distinguishing between soft tissues, such as the white and gray matter of the nervous system. However, dense structures (e.g., bone) do not show up well in MRI. Formerly, another disadvantage of MRI was that patients felt claustrophobic while isolated in the closed cylinder. However, newer MRI technology has improved the hardware and lessened this effect.

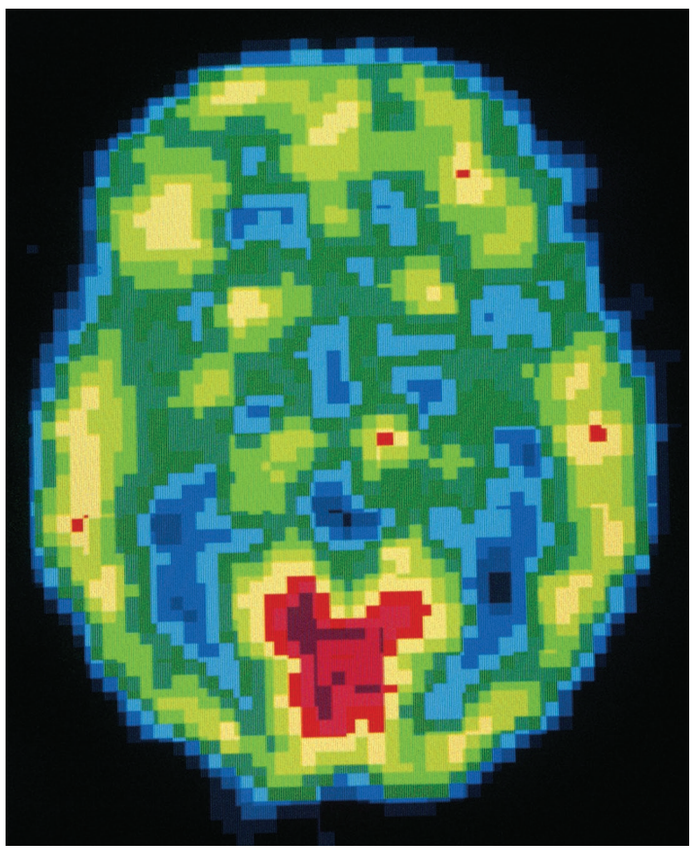



*Magnetic resonance imaging (MRI) scan of the head at the level of the eyes, viewed in transverse section.*
©Alfred Pasieka/Science Source

A specific type of MRI, called **functional MRI (fMRI),** maps brain function based on local oxygen concentration differences in blood flow. Increased blood flow relates to increased brain activity and is detected by a decrease in deoxyhemoglobin (the form of hemoglobin lacking oxygen) in the blood.

## Positron Emission Tomography (PET)

The **positron emission tomography (PET) scan** is used both to analyze the metabolic state of a tissue at a given moment in time and to determine which tissues are most active. The procedure begins with an injection of radioactively labeled glucose (sugar), which emits particles called positrons (like electrons, but with a positive charge). Collisions between positrons and electrons cause the release of gamma rays that can be detected by sensors and analyzed by computer. The result is a brilliant color image that shows which tissues were using the most glucose at that moment. In cardiology, the image can reveal the extent of damaged heart tissue—because damaged heart tissue consumes little or no glucose, the damaged tissue will appear dark. PET scans have been used to illustrate activity levels in the brain and, in so doing, have been useful in examining the effects of neurologic ailments (e.g., schizophrenia, Alzheimer disease). They also may detect whether certain cancers have metastasized throughout the body, because cancerous cells will take up more glucose and show up as a *hot spot* on the scan. The PET scan is an example of nuclear medicine, which uses radioisotopes (see section 2.1b) to form anatomic images of the body.



*Positron emission tomography (PET) scan of the brain of an unmedicated schizophrenic patient. Red areas indicate high glucose use (metabolic activity). The visual center at the posterior region of the brain was especially active when the scan was made.*
©Hank Morgan/Science Source