Anatomy & Physiology

AN INTEGRATIVE APPROACH

Michael P. McKinley
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Theresa Stouter Bidle

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Mc Graw Hill Education

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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

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—Valerie Dean O'Loughlin

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—Terri Stouter Bidle

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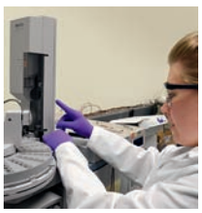

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preface

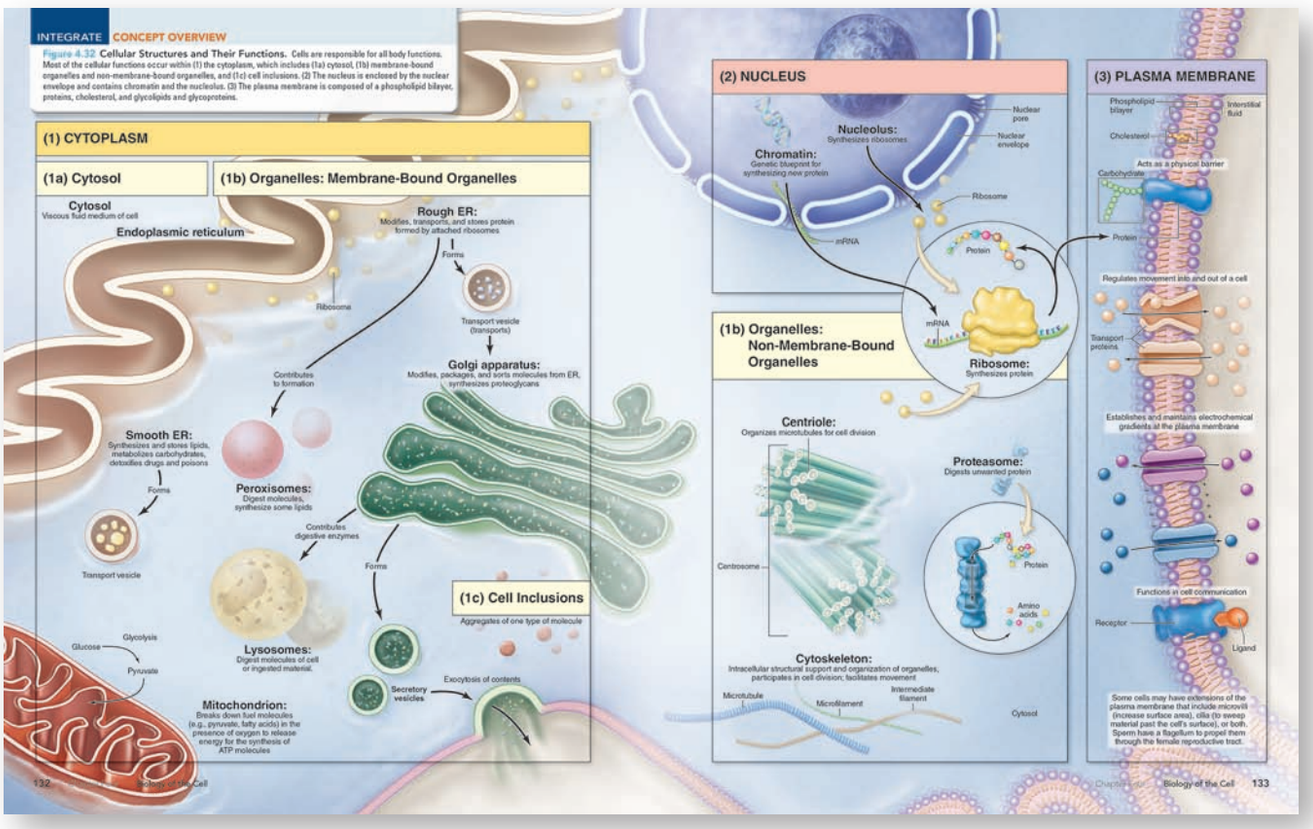
Human anatomy and physiology is a fascinating subject. However, students can be overwhelmed by the complexity, the interrelatedness of concepts from different chapters, and the massive amount of material in the course. Our goal was to create a textbook to guide students on a clearly written and expertly 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 media 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 Second Edition

The McKinley/O'Loughlin/Bidle textbook remains a resource that guides students on a clearly written and expertly illustrated beginner's path through the human body. Four core principles guided the authors as they made changes for the second edition:

1. Maximize the organization and clarity of the written text to provide instructors an excellent resource in developing their lectures, and provide students with a text that is easy to read and comprehend independently from a classroom environment (an important consideration with an increasing number of students enrolled in online anatomy and physiology courses). To accomplish these goals, 10 sections were added, 7 sections were expanded, and 29 sections were reorganized.
2. Facilitate lecture development and student learning through figures and tables that are well integrated with the text. To this end, 23 new figures and tables were developed, 33 figures and tables were updated, and 12 new photos were added.
3. Further integrate concepts between chapters to best facilitate instructor delivery and student understanding.
   - Some instructors follow the conventional order of teaching muscle physiology prior to neuron physiology, whereas other instructors teach neuron physiology prior to muscle physiology. To provide instructors with the most flexibility in teaching, and provide students with the background concepts that are needed regardless of the order the material is covered, chapter 4 now has a new section on establishing and maintaining resting membrane potential. This section provides the background information for graded potentials and action potentials that are discussed in both chapters 10 and 12.
   - The hormone reference section (10 tables on hormone details) has been relocated to follow immediately after chapter 17. This content applies to the whole book and is now more centrally located for student access.
   - The number and description of both "forward" and "backward" references to other specific chapter sections throughout the book has been increased (thereby increasing the integration of topics in the text).
   - Ten new Concept Connections were added.
4. Aid students in becoming aware of various career paths and clinical applications.

- Chapter opener pages now include a new "Integrate" feature called "Integrate: Career Path," which highlights a career relevant to the chapter material.
- Many students in this course are pursuing a health sciences career. This edition contains 23 added or updated Clinical View boxes to provide further connections to practical applications in the health-care field.

Changes by Chapter

The following changes are not an exhaustive list, but note the most significant changes in this second edition.

Chapter 1

- Updated section 1.1: Anatomy and Physiology Compared
- Updated section 1.2: Anatomy and Physiology Integrated
- New Clinical View: Clinicians' Use of Scientific Method

Chapter 2

- New Concept Connection on electrolytes
- Updated section 2.5c: pH, Neutralization, and the Action of Buffers

Chapter 3

- Updated figure 3.16: Metabolic Pathway of Glycolysis
- Updated figure 3.19: The Electron Transport System
- New figure 3.20: Summary of Stages of Cellular Respiration
- Updated Clinical View: Lactose Intolerance
- Updated section 3.4f: ATP Production

Chapter 4

- New figure 4.7: Membrane Transport—flowchart organized into passive processes and active processes
- New section 4.4: Resting Membrane Potential, which includes new figure 4.20: Resting Membrane Potential (RMP)
- New Concept Overview figure 4.32: Cellular Structures and Their Functions

Chapter 5

- Updated section 5.1: Epithelial Tissue: Surfaces, Linings, and Secretory Functions
- New table 5.1: Overview of Tissues
- New figure 5.3: Organization and Relationship of Epithelia Types
- New photos in expanded table 5.2: Simple Epithelia
- New photo in table 5.3: Stratified Epithelia
- Updated Concept Overview figure 5.4: The Relationship between Epithelial Tissue Type and Function
- New photo in table 5.5: Connective Tissue Proper: Loose Connective Tissue
- Updated Clinical View: Stem Cells
- New photos in table 5.7: Supporting Connective Tissue: Cartilage
- Updated Concept Overview figure 5.10: The Relationship Between Connective Tissue Type and Function
- New photos in table 5.10: Muscle Tissue
- Updated figure 5.12: Body Membranes
- Expanded section 5.6b: Tissue Modification

Chapter 6

- Moved and updated section 6.1d: Functions of the Integument (was previously section 6.3)
- Updated Concept Overview figure 6.8: How Integument Form Influences Its Functions
- Updated section 6.2b: Hair (specifically, Hair Growth and Replacement section)
- New Concept Connection on relationship of wound repair and the immune system
- Updated table 6.2: Skin Cancer

Chapter 7

- New Concept Connection in section 7.2e on stem cells and osteoprogenitor cells
- New photo for bone tissue in figure 7.6: Types of Cells in Bone Connective Tissue
- New photo of spongy bone in figure 7.8: Microscopic Anatomy of Bone
- Updated figure 7.14: Calcitriol Production
- Updated figure 7.16: Classification of Bone Fractures

Chapter 8

- Reversed order of section 8.1a: Axial and Appendicular Skeleton and section 8.1b: Bone Markings
- New Clinical View: Coccyx (Tailbone) Injury

Chapter 9

- Updated figure 9.8: Flexion, Extension, Hyperextension, and Lateral Flexion
- Updated Clinical View: Shoulder Joint Dislocations
- New photo of arthroscopic view of knee joint in Clinical View: Knee Ligament and Cartilage Injuries

Chapter 10

- New section 10.2d: Skeletal Muscle Fibers at Rest, which includes new figure 10.8: Skeletal Muscle Fiber at Rest
- New figure 10.12: Events of an Action Potential at the Sarcolemma
- New figure 10.14: Portion of a Sarcomere (electron micrograph)

Chapter 11

- Expanded section 11.1a: Origin and Insertion
- New Clinical View: Strabismus and Diplopia
- Updated Clinical View: Hernias
- Updated Clinical View: Shin Splints and Compartment Syndrome
- Updated Clinical View: Plantar Fasciitis

Chapter 12

- New section 12.7b: Neurons at Rest, which includes new figure 12.13: Neuron at Rest
- New figure 12.18: Generation of an Action Potential
- New Concept Connection on potential energy and kinetic energy associated with ion gradients
- New Clinical View: Local Anesthetics
- New Clinical View: Neurotoxicity
- Updated Concept Overview figure 12.23: Events of Neuron Physiology
- Revised section 12.9: Characteristics of Action Potentials
- Significantly expanded section 12.10: Neurotransmitters and Neuromodulation, including new figure 12.24: Classification of Neurotransmitters (organizational flowchart), and new figure 12.25: Acetylcholine Release, Removal from Synaptic Cleft, and Action
- Modified table 12.3: Neurotransmitters, now incorporating drugs that influence neurotransmitter release or binding

Chapter 13

- Updated Concept Overview figure 13.12: Anatomic and Functional Areas of the Cerebrum
- Reorganized section 13.3c: Functional Areas of the Cerebrum
- New Concept Connection on action potentials
- New Clinical View: Autism Spectrum Disorder
- New section 13.8b: Electroencephalogram, including new figure 13.28 Electroencephalograms (EEGs)
- New section 13.8c: Sleep, including new figure 13.29: Hypnogram
- Updated Clinical View: Alzheimer Disease: The "Long Goodbye"
- Expanded section 13.8g: Language, including brief discussion of speech disorders
- Updated table 13.5: Cranial Nerves, including specific test to determine nerve damage

Chapter 14

- Reorganized section 14.1: Spinal Cord Gross Anatomy, including modified figure 14.2: Cross Sections of the Spinal Cord
- Reorganized section 14.2: Protection and Support of the Spinal Cord
- New Clinical View: Poliomyelitis
- Reorganized section 14.4a: Overview of Conduction Pathways
- Reorganized section 14.4b: Sensory Pathways
- Updated table 14.1: Functions and Neuron Locations of Principal Sensory Spinal Cord Pathways
- New section 14.6c: Classifying Spinal Reflexes
- Reorganized section 14.6d: Spinal Reflexes
- New Concept Connection on spinal nerves and skeletal muscle innervation

Chapter 15

- Updated section 15.1a: Functional Organization
- Moved CNS Control of the Autonomic Nervous System for earlier chapter position (is now section 15.1c)
- Reorganized table 15.1: Comparison of Somatic and Autonomic Motor Nervous Systems
- New photo for Clinical View: Horner Syndrome
- Reorganized section 15.4b: Sympathetic Pathways
- Expanded section 15.5b: Cholinergic Receptors, including new table 15.4: Cholinergic Receptors
- New table 15.5: Adrenergic Receptors
- New Clinical View: Epinephrine for Treatment of Asthma
- Updated table 15.6: Effects of the Parasympathetic and Sympathetic Divisions
- Updated Concept Overview figure 15.10: Comparison of the Parasympathetic and Sympathetic Divisions of the ANS

Chapter 16

- Reorganized section 16.1: Introduction to Sensory Receptors, including new section 16.1c: Sensory Information Provided by Sensory Receptors
- New Concept Connection on the four cranial nerves associated with the eye
- Reorganized section 16.4: Visual Receptors, discussing the Physiology of Vision: Refraction and Focusing of Light
- Expanded section 16.4d: Physiology of Vision: Phototransduction
- Receptors, on cochlear hair cell stimulation, including new figure 16.28: Inner Hair Cells
- New Clinical View: Deafness
- Updated section 16.5d: Equilibrium and Head Movement

Chapter 17

- Reorganized section 17.2: Endocrine Glands
- Revised table 17.2: Endocrine Glands and Organs Containing Endocrine Cells
- Updated figure 17.5: Eicosanoid Formation
- Expanded section 17.7b: Interactions Between the Hypothalamus and the Anterior Pituitary Gland and revised figure 17.12: Anterior Pituitary Hormones
- Updated figure 17.16: Thyroid Hormone: Synthesis, Storage, and Release
- Added new section 17.10: Other Endocrine Glands (includes pineal gland, parathyroid gland, thymus, heart, kidneys, liver, stomach, small intestine, skin, and adipose connective tissue)
- Tables on major regulatory hormones of the human body now directly follow chapter 17

Chapter 18

- Updated section 18.3a: Hemopoiesis, including new table 18.6: Substances That Influence Hemopoiesis
- Updated Clinical View: Anemia in section 18.3b: Erythrocytes
- Updated Concept Overview figure 18.8: Recycling and Elimination of Erythrocyte Components
- Updated table 18.7: Leukocytes
- New Concept Connection on hemopoiesis and the skeletal system

Chapter 19

- Revised figure 19.14: Anatomic Structures Controlling Heart Activity
- Modified section 19.6a: Nodal Cells at Rest, including modified accompanying figure 19.16: SA Node Cellular Activity
- Modified figure 19.18: Electrical Events of Cardiac Muscle Cells
- Modified section 19.7c: Repolarization and the Refractory Period, including modified figure 19.19: Comparison of Electrical and Mechanical Events in Skeletal Muscle Cells and Cardiac Muscle Cells
- Updated Clinical View: Cardiac Arrhythmias, including added images of abnormal ECGs
- Modified Concept Overview figure 19.22: Changes Associated with a Cardiac Cycle
- New figure 19.23: Sympathetic Innervation of Nodal Cells
- New figure 19.24: Relationship of EDV, ESV, and SV

Chapter 20

- Moved Total Cross-Sectional Area and Velocity of Blood Flow to earlier chapter position (is now section 20.2)
- New section 20.4b: The Myogenic Response
- New image for Clinical View: Tumor Angiogenesis
- Revised figure 20.14: Cardiovascular Center

Chapter 21

- Revised figure 21.1: Lymphatic System
- Revised figure 21.3: Lymphatic Trunks and Ducts
- Modified section 21.4: Secondary Lymphatic Structures, including Lymph Flow Through Lymph Nodes
- Revised Concept Overview figure 21.9: Relationship of the Lymphatic System to Both the Cardiovascular System and Immune System

Chapter 22

- New figure 22.8: Two Branches of Adaptive Immunity (organizational flowchart)
- New figure 22.22: Active and Passive Immunity (organizational flowchart)
- Added information on pattern recognition receptors (e.g., toll-like receptors or TLRs), Tregs, peripheral tolerance, antibody class switching
- New Clinical View: Regulatory T-Lymphocytes and Tumors

Chapter 23

- Reworked section 23.5c: Nervous Control of Breathing
- Modified figure 23.23: Respiratory Center

Chapter 24

- Reorganized section 24.1: Introduction to the Urinary System

Chapter 25

- New figure 25.5: Edema

Chapter 26

- In Clinical View: Reflux Esophagitis and Gastroesophageal Reflux Disease, new photo of normal esophagus to accompany photo of Barrett esophagus
- New Clinical View: Gastric Bypass, including accompanying illustration
- Modified Clinical View: Intestinal Disorders
- New figure 26.14: Regulation of the Digestive Processes in the Stomach

Chapter 27

- Reorganization of section 27.1: Introduction to Nutrition, section 27.2: Macronutrients, section 27.3: Micronutrients, and section 27.4: Guidelines for Adequate Nutrition

Chapter 28

- Updated section 28.3b: Oogenesis and the Ovarian Cycle
- Updated Clinical View: Contraception Methods
- New Clinical View: Paternal Age Risks for Disorders in the Offspring

Chapter 29

- New Concept Connection integrating immunoglobulins (in chapter 22) to specific immunoglobulin classes that are secreted in breast milk

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!

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

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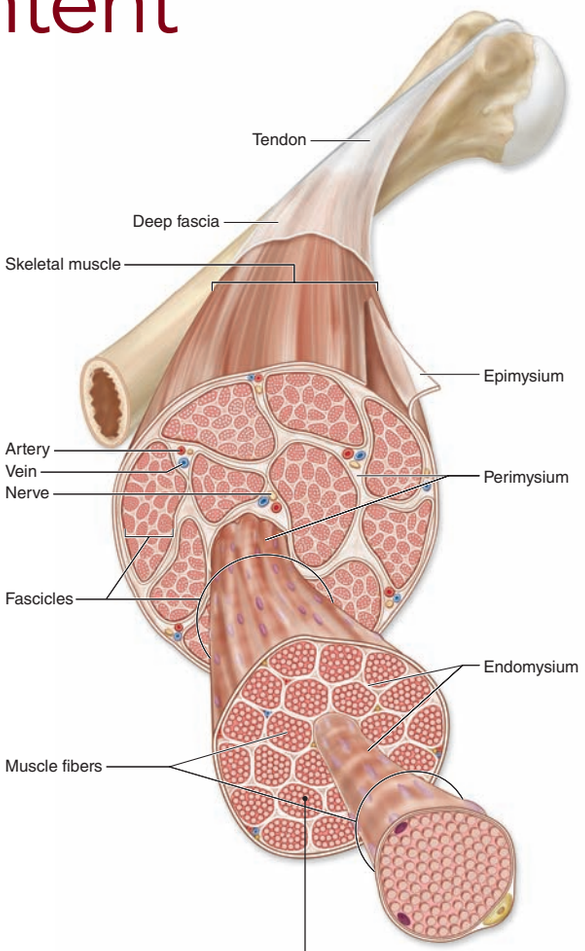
guided tour

Fully Integrated Content and Pedagogy

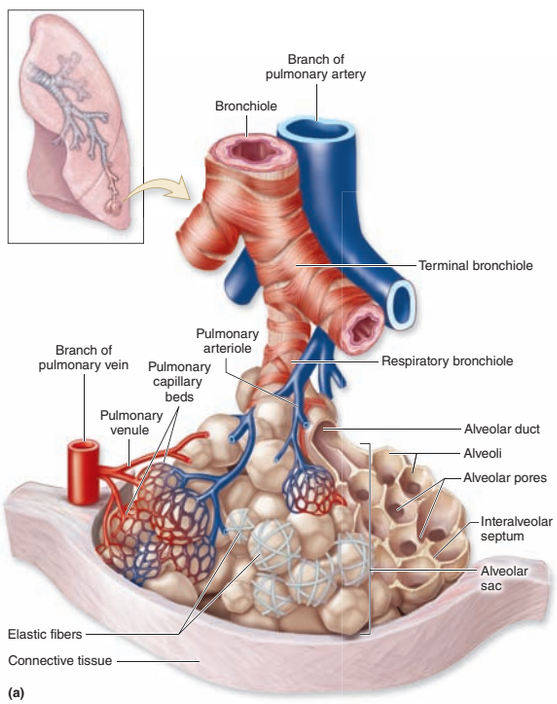
Anatomy and Physiology: An Integrative Approach is structured around a tightly integrated learning system that combines illustrations and photos with textual descriptions; focused discussions with big-picture summaries; previously learned material with new content; factual explanations with practical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

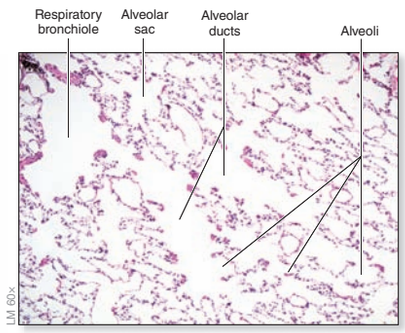
Unparalleled Art Program

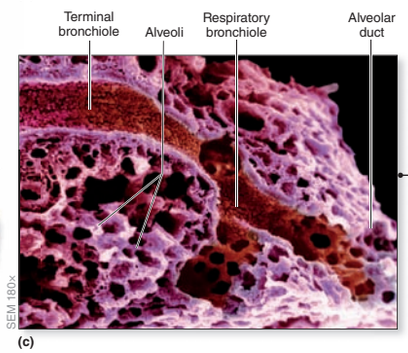
In a visually oriented subject like A&P, quality illustrations are crucial to understanding and retention. The brilliant illustrations in *Anatomy and Physiology: An Integrative Approach* have been carefully rendered to convey realistic, three-dimensional detail while incorporating pedagogical conventions 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.



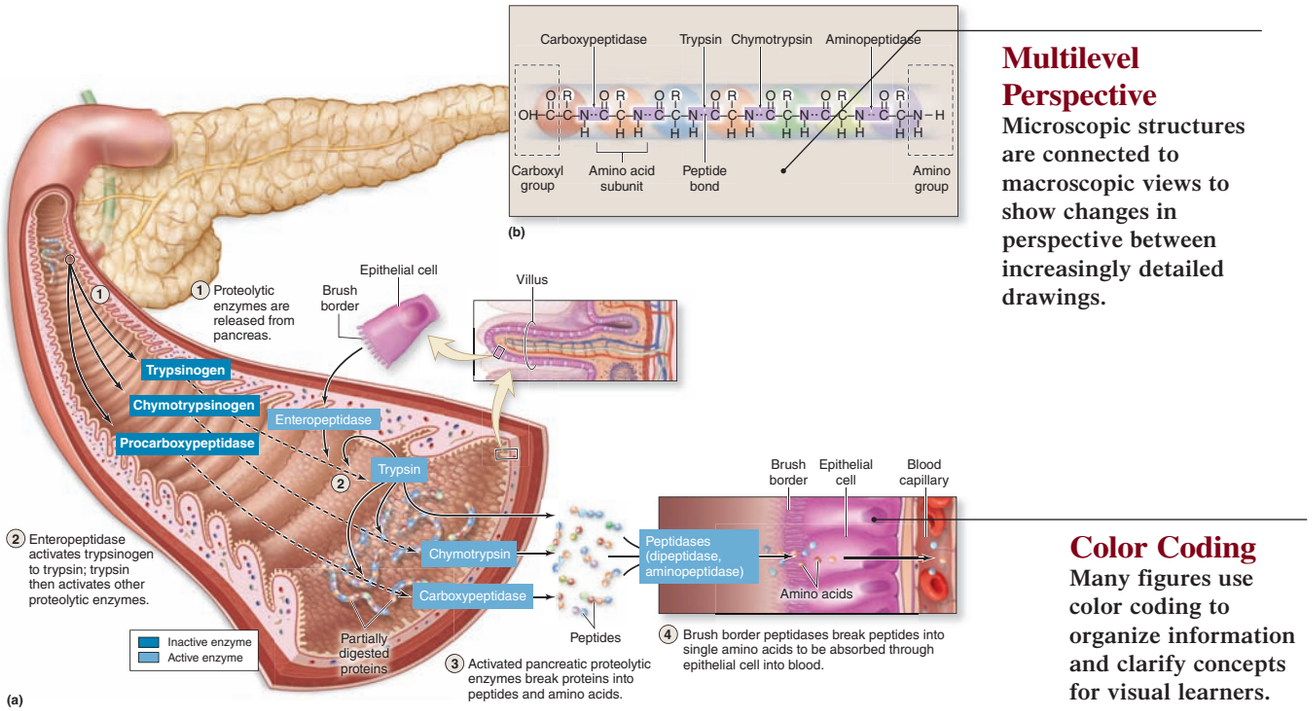
Rich Detail
Vibrant colors and three-dimensional shading make it easy to envision body structures and processes.







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

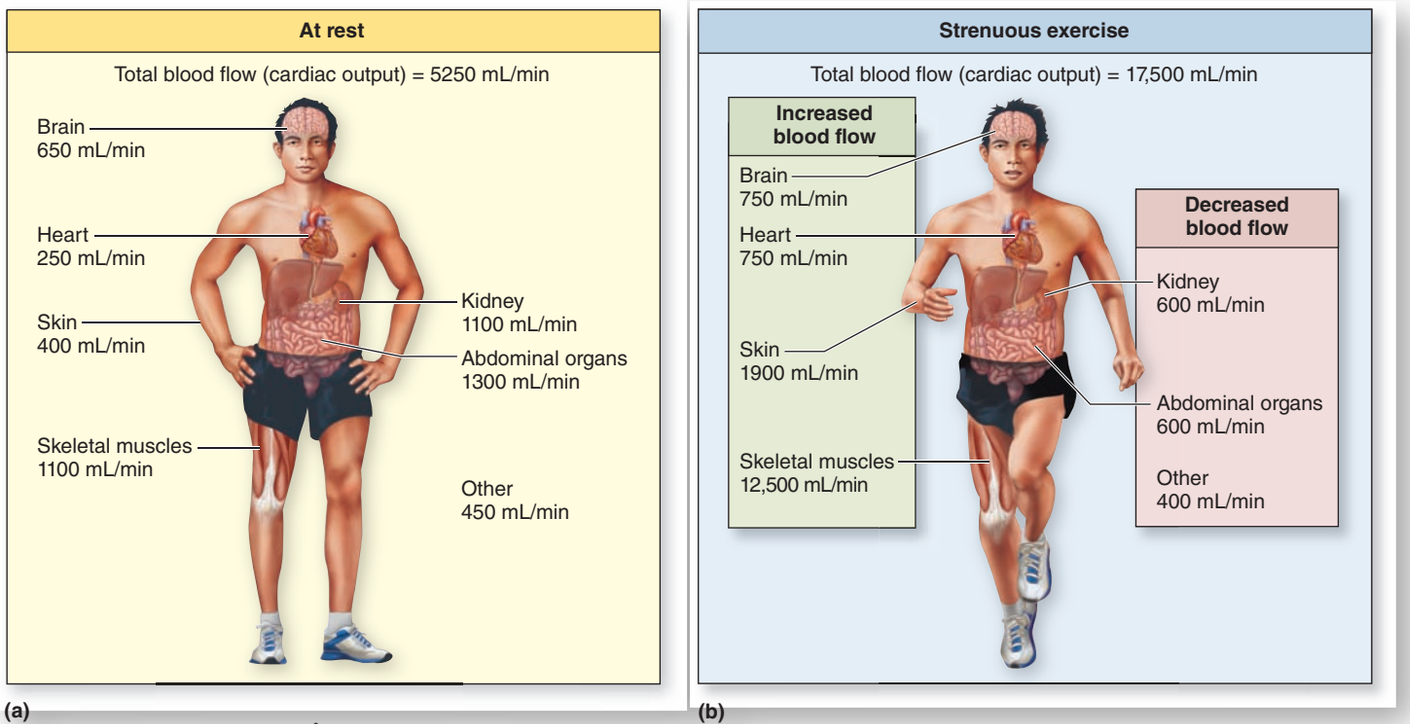


Multilevel Perspective

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

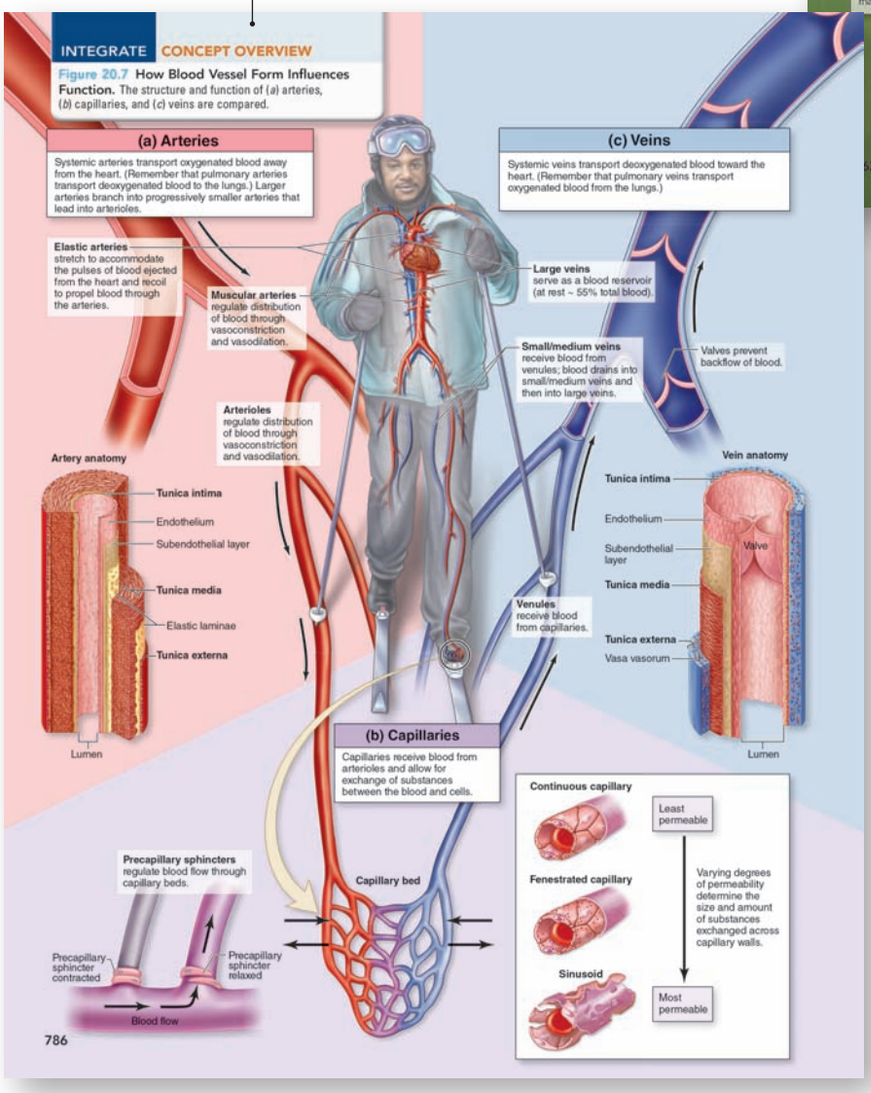
Illustrations include depictions of realistic people and situations to make figures more relevant and memorable.

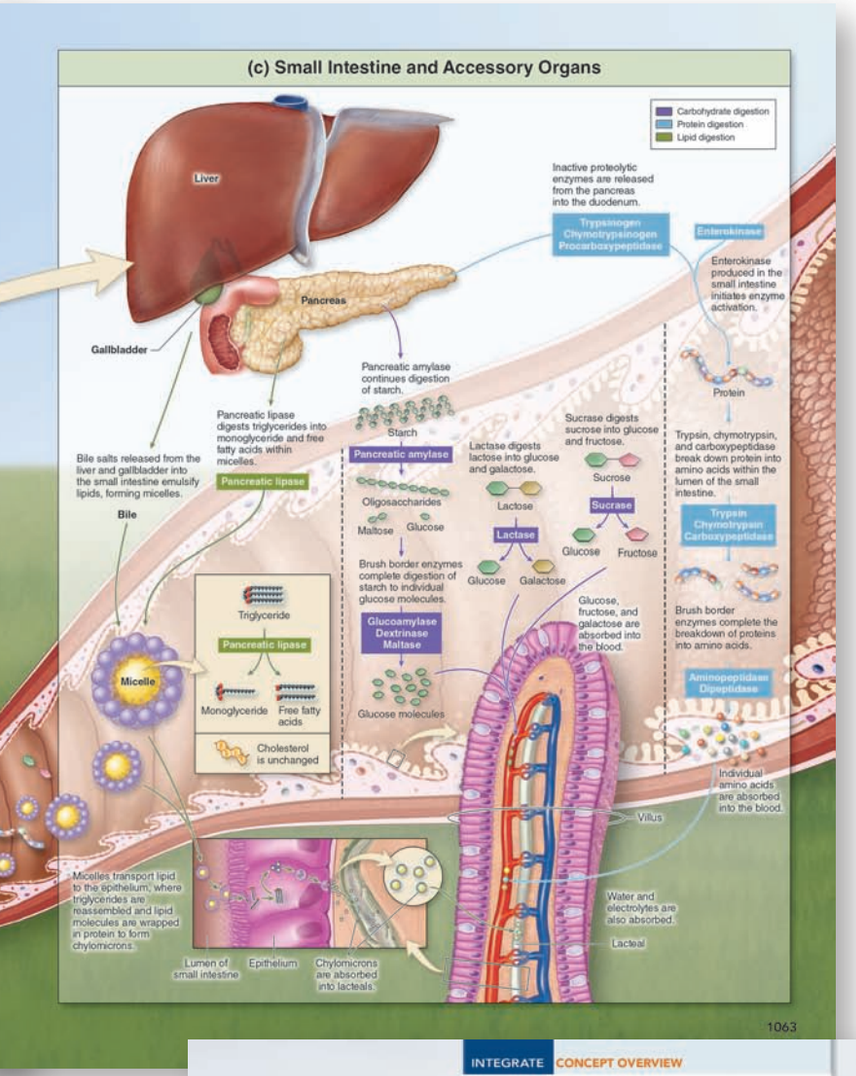
Integrative Visual Summaries

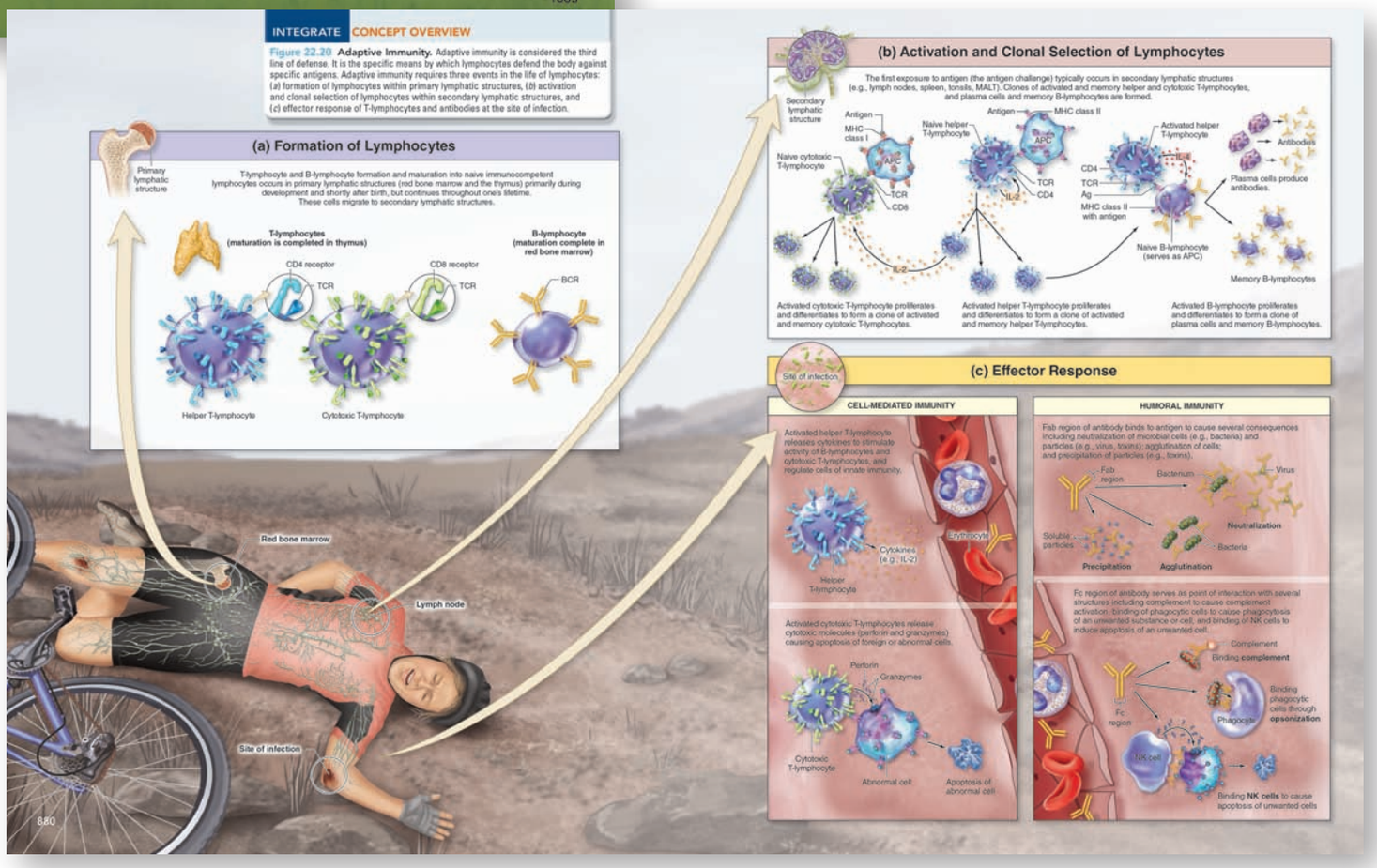
The groundbreaking **Integrate: Concept Overview** figures combine multiple concepts into one big-picture summary. These striking, visually dynamic presentations offer a review of previously covered material in a creatively designed environment to emphasize how individual parts fit together in the understanding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

Integrate: Concept Overview Figures

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







"My students love this artwork, especially the Concept Overview artwork. They use the Concept Overview artwork as a study guide (review) of the text material."

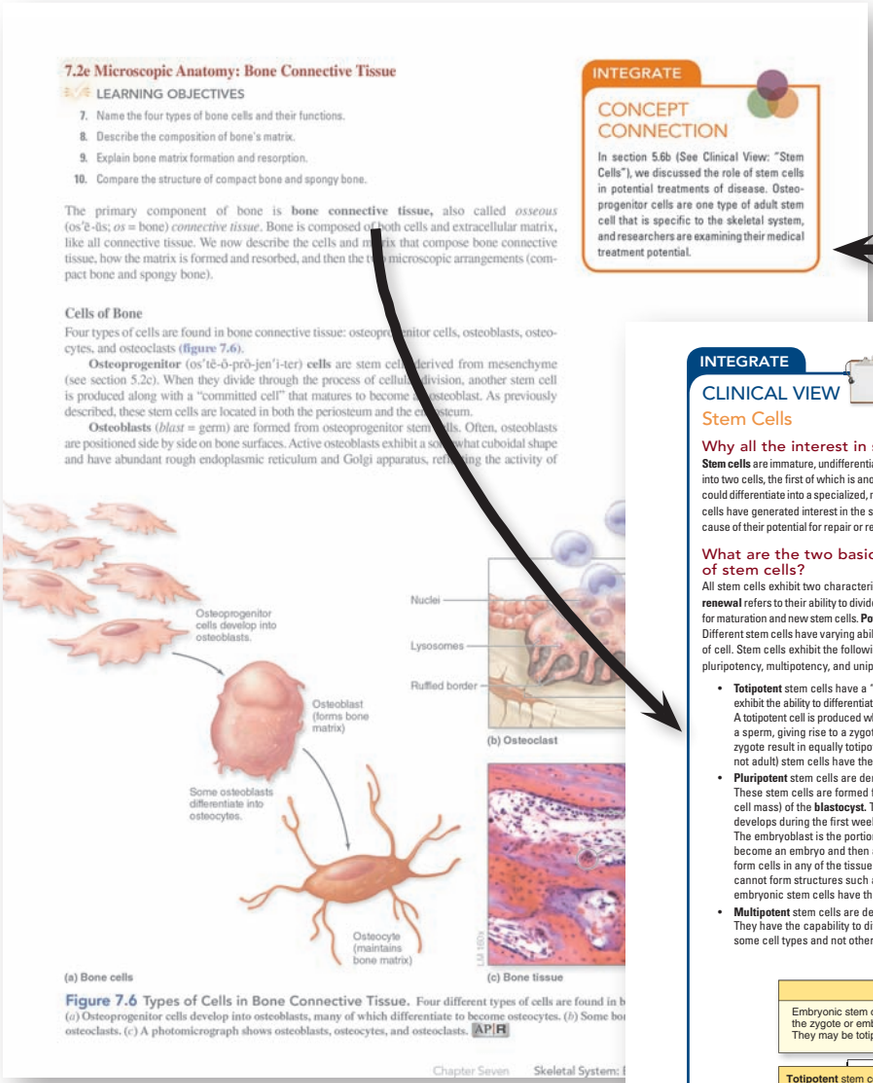
—Jerri K. Lindsey, Tarrant County College–Northeast Campus

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.

"I think [Concept Connections] helps the student see connections between the different topics they learned, rather than viewing the content as separate chunks of material."

—Marta Klesath, North Carolina State University



7.2e Microscopic Anatomy: Bone Connective Tissue

LEARNING OBJECTIVES

7. Name the four types of bone cells and their functions.
8. Describe the composition of bone's matrix.
9. Explain bone matrix formation and resorption.
10. Compare the structure of compact bone and spongy bone.

The primary component of bone is **bone connective tissue,** also called *osseous* (os'ē-ŭs; *os* = bone) *connective tissue*. Bone is composed of both cells and extracellular matrix, like all connective tissue. We now describe the cells and matrix that compose bone connective tissue, how the matrix is formed and resorbed, and then the two microscopic arrangements (compact bone and spongy bone).

Cells of Bone

Four types of cells are found in bone connective tissue: osteoprogenitor cells, osteoblasts, osteocytes, and osteoclasts (figure 7.6).

Osteoprogenitor (os'tē-ō-prō-jen'i-ter) **cells** are stem cells derived from mesenchyme (see section 5.2c). When they divide through the process of cellular division, another stem cell is produced along with a "committed cell" that matures to become an osteoblast. As previously described, these stem cells are located in both the periosteum and the endosteum.

Osteoblasts (*blast* = germ) are formed from osteoprogenitor stem cells. Often, osteoblasts are positioned side by side on bone surfaces. Active osteoblasts exhibit a somewhat cuboidal shape and have abundant rough endoplasmic reticulum and Golgi apparatus, reflecting the activity of

INTEGRATE

CONCEPT CONNECTION

In section 5.6b (See Clinical View: "Stem Cells"), we discussed the role of stem cells in potential treatments of disease. Osteoprogenitor cells are one type of adult stem cell that is specific to the skeletal system, and researchers are examining their medical treatment potential.

Osteoprogenitor cells develop into osteoblasts.
Osteoblast (forms bone matrix)
Some osteoblasts differentiate into osteocytes.
Osteocyte (maintains bone matrix)
(a) Bone cells
Nuclei
Lysosomes
Ruffled border
(b) Osteoclast
LM 160×
(c) Bone tissue

Figure 7.6 Types of Cells in Bone Connective Tissue. Four different types of cells are found in b
(*a*) Osteoprogenitor cells develop into osteoblasts, many of which differentiate to become osteocytes. (*b*) Some bo
osteoclasts. (*c*) A photomicrograph shows osteoblasts, osteocytes, and osteoclasts. AP R

Chapter Seven Skeletal System:

INTEGRATE

CLINICAL VIEW

Stem Cells

Why all the interest in stem cells?

Stem cells are immature, undifferentiated cells. These cells are able to divide into two cells, the first of which is another stem cell, and the other a cell that could differentiate into a specialized, mature cell with a unique function. Stem cells have generated interest in the scientific and medical communities because of their potential for repair or replacement of damaged or dying tissue.

What are the two basic characteristics of stem cells?

All stem cells exhibit two characteristics: self-renewal and potency. **Self-renewal** refers to their ability to divide repeatedly to produce both new cells for maturation and new stem cells. **Potency** is the potential for differentiation: Different stem cells have varying ability to differentiate into almost any type of cell. Stem cells exhibit the following four levels of potency: totipotency, pluripotency, multipotency, and unipotency:

- **Totipotent** stem cells have a "total potential," meaning that they exhibit the ability to differentiate into any cell type within an organism. A totipotent cell is produced when a secondary oocyte is fertilized by a sperm, giving rise to a zygote. The first few cell divisions of the zygote result in equally totipotent cells. Thus, only embryonic (and not adult) stem cells have the potential to be totipotent.
- **Pluripotent** stem cells are derived from totipotent stem cells. These stem cells are formed from the embryoblast portion (inner cell mass) of the **blastocyst.** The blastocyst is a ball of cells that develops during the first week of development from the zygote. The embryoblast is the portion of the blastocyst that will eventually become an embryo and then a fetus. Pluripotent stem cells can form cells in any of the tissue layers of the embryo, but they cannot form structures such as the placenta. Again, only embryonic stem cells have the potential to be pluripotent.
- **Multipotent** stem cells are derived from pluripotent stem cells. They have the capability to differentiate into a restricted number of some cell types and not others. For example, stem cells in the bone marrow may be stimulated to mature and differentiate into different types of blood cells, but not into some other types of cells. Some adult stem cells have the potential to be multipotent.
- **Unipotent** stem cells have the ability to differentiate into a single type of cell, yet these cells still retain the ability to renew themselves. Epithelial stem cells (discussed previously) are examples of unipotent stem cells. Many adult stem cells are unipotent.

What are the differences between embryonic and adult stem cells?

Stem cells may be categorized as either **embryonic stem cells** or **adult stem cells.** Embryonic stem cells include those that have begun to divide in the zygote and the cells in the blastocyst. Embryonic stem cells exhibit the greatest degree of potency—and thus, the greatest potential to differentiate into multiple cell types. In contrast, adult stem cells are the immature cells found in postnatal (already born) organisms. Adult stem cells typically are multipotent or unipotent, and thus they exhibit less potency than embryonic stem cells.

How are stem cells harvested?

Most embryonic stem cells must be harvested from a structure no more differentiated than a blastocyst. Most of these blastocysts were donated by families undergoing in vitro fertilization who had stored more blastocysts than needed for a successful pregnancy. If these blastocysts were not used by the family and not donated for research, they typically would be destroyed. Note that opponents of embryonic stem cell research counter that these blastocysts could be implanted and lead to viable infants who could be adopted, and any medical benefit from embryonic stem cells does not justify using them in research. Opponents also maintain that adult stem cell research should be explored instead.

Adult stem cells may be extracted from the bone marrow or tissue of an individual. These adult stem cells have been used to successfully treat certain blood and bone cancers, and research is ongoing about their effectiveness for diseases such as lung inflammation, stroke, and Parkinson disease. The main problem with adult stem cells is their limited potency, which suggests that their use for treatment in diseases is limited. Embryonic stem cells exhibit greater promise for treatment because of their greater potency.

Embryonic Stem Cells		Adult Stem Cells	
Embryonic stem cells originate from the dividing cells of the zygote or embryoblast portion of the blastocyst. They may be totipotent or pluripotent.		Adult stem cells are the undifferentiated stem cells in the body after birth. They may be multipotent or unipotent.	
Totipotent stem cells are those cells formed from the zygote, and can give rise to every differentiated cell in the organism and the placenta.	**Pluripotent** stem cells are derived from the embryoblast portion of the blastocyst. This type of stem cell has the capability to mature and specialize into a cell within any tissue in the body (except the placenta).	**Multipotent** stem cells (as in bone marrow) are capable of differentiating into a restricted number of some cell types and not others.	**Unipotent** stem cells (such as epithelial stem cells) have the ability to differentiate into a single type of cell.
Zygote, Morula	Embryoblast, Blastocyst	Red bone marrow, LM 25×, Red bone marrow cells	Epidermis of skin, Epithelial stem cell

"I think that some of the best parts of this chapter are the Integrate: Clinical View boxes. The author does an excellent job of incorporating relevant clinical examples ...I think the clinical relevance is what truly gets students interested about the material and helps solidify a concept."

—Arlee Dulak, University of Massachusetts, Lowell

INTEGRATE

LEARNING STRATEGY

The cells associated with innate immunity have a "military-like" function:

- **Neutrophils** are the "foot soldiers" that are the first to arrive at the site of infection.
- **Macrophages** are the "big eaters"—the cleanup crew that arrives at the injured or infected scene late and stays longer.
- **Basophils/mast cells** engage in chemical warfare causes inflammation.
- **NK cells** serve as "security guards" that "search destroy" unwanted cells.
- **Eosinophils** are the "heavy artillery" to take on th guys" (parasites).

INTEGRATE

LEARNING STRATEGY

Generally, the role of antibodies as weapons is to "tie up the prisoner" until other help arrives. You can remember the six functions of an antibody with the acronyms NAP and CON: Neutralization, Agglutination, and Precipitation (NAP), as well as Complement, Opsonization, and NK cells (CON). Remember—a NAP can help you CONcentrate.

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

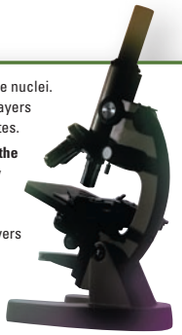
Classroom tried-and-tested learning strategies offer everyday analogies, mnemonics, and useful tips to aid understanding and memory.

INTEGRATE

LEARNING STRATEGY

Integrate lab and lecture material: Follow these steps to help you identify the epidermal strata under the microscope:

1. **Determine if the layer is closer to the free surface or is deeper.** Remember the stratum corneum forms the free surface, whereas the stratum basale forms the deepest epidermal layer.
2. **Examine the shape of the keratinocytes.** The stratum basale contains cuboidal to low columnar keratinocytes, the stratum spinosum contains polygonal keratinocytes, and the stratum lucidum and corneum contain squamous keratinocytes.
3. **See if the keratinocytes have a nucleus or are anucleate.** When they are still alive (as in the strata basale, spinosum, and granulosum), you are able to see nuclei. The stratum lucidum and corneum layers contain dead, anucleate keratinocytes.
4. **Count the layers of keratinocytes in the stratum.** The stratum basale has only one layer of keratinocytes, and the stratum corneum contains 20 to 30 layers of keratinocytes. The other layers contain about two to five layers of keratinocytes.
5. **Determine if the cytoplasm of the keratinocytes contain visible granules.** If the keratinocytes contain visible granules, you likely are looking at the stratum granulosum.



Clinical View

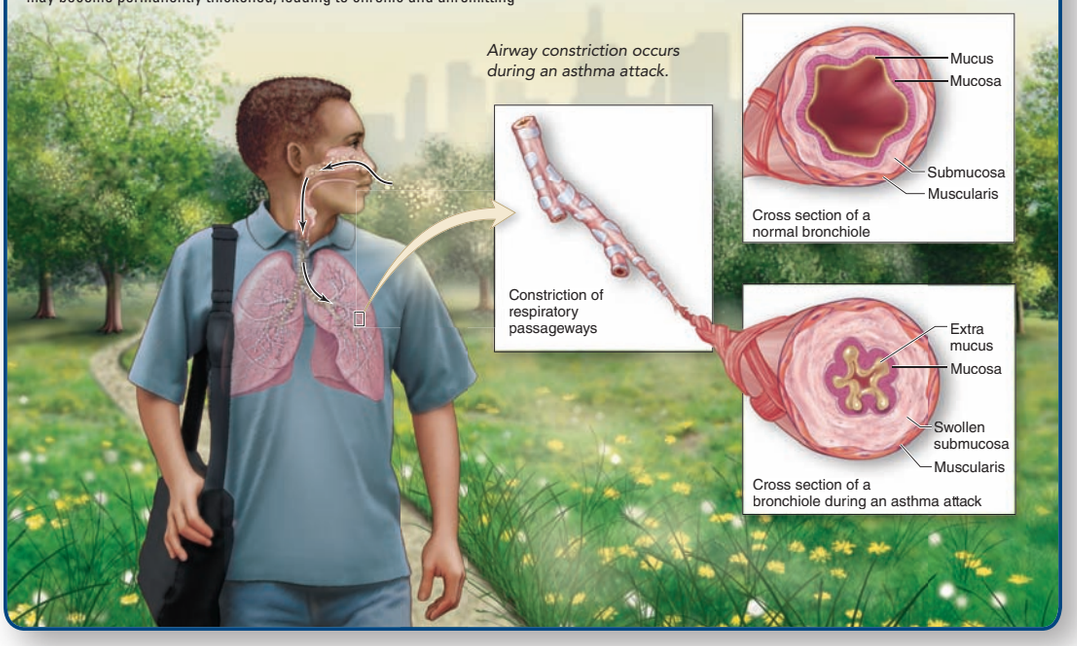
Interesting clinical sidebars reinforce or expand upon the facts discussed within the narrative. The clinical views are adjacent to the facts in the narrative (rather than placed at the end of the chapter) so students may immediately make connections between the narrative and real-life applications.

INTEGRATE

CLINICAL VIEW

Asthma (az'mă) is a chronic condition characterized by episodes of bronchoconstriction coupled with wheezing, coughing, shortness of breath, and excess pulmonary mucus. Typically, the affected person develops sensitivity to an airborne agent, such as pollen, smoke, mold spores, dust mites, or particulate matter. Upon reexposure to this triggering substance, a localized immune reaction occurs in the bronchi and bronchioles, resulting in bronchoconstriction, swollen submucosa, and increased production of mucus. Episodes typically last an hour or two. Continual exposure to the triggering agent increases the severity and frequency of asthma attacks. The walls of the bronchi and bronchioles eventually may become permanently thickened, leading to chronic and unremitting airway narrowing and shortness of breath. If airway narrowing is extreme during a severe asthma attack, death could occur.

The primary treatment for asthma consists of administering inhaled steroids (cortisone-related compounds) to reduce the inflammatory reaction, combined with bronchodilators to alleviate the bronchoconstriction. Allergy shots have proven helpful for some patients. Individuals with severe asthma may need oral doses of steroids to help control the allergic hyper-response and reduce the inflammation. A new treatment called bronchial thermoplasty uses heat to remove some of the outer layers of smooth muscle. This decreases the muscle contractions associated with bronchoconstriction to lessen the severity of asthma.



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?

1. Many times during a long-distance race, water stations are positioned along the side of the road so that runners may rehydrate during the race. Sometimes a runner will take a drink, swirl it around in the mouth, and then spit the water back out instead of swallowing it. Do you think this practice should be encouraged? Explain in terms of the effect on the thirst center and the hydrated state of the body.

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 DID YOU LEARN?

2. Which ions are more prevalent in the intracellular fluid? Which are more prevalent in the extracellular fluid?
3. What is the major distinction in the chemical composition of blood plasma and interstitial fluid?
4. When you are dehydrated, is the net movement of fluid from the blood plasma into the cells or from the cells into the blood plasma?

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. Atoms composed of the same numbers of protons and electrons, but different numbers of neutrons, are called

a. isome
b. ions.

____ 2. Substanc *except*

a. lipids.
b. glucos

____ 3. Tempera propertie

a. cohes
b. capill
c. specif
d. cohes

____ 4. All of th pH *excep*

a. acids contain more H^+ than water.
b. H^+ concentration and pH are inversely relate

Can You Apply What You've Learned?

1. Which property of water is significant in children born prematurely because it causes the air sacs to collapse in the lungs, making breathing difficult?

   a. specific heat
   b. water reactivity
   c. surface tension
   d. capillary action

2. A young boy playing outside on a very hot day has become dehydrated. When he enters the house, he appears lethargic. The mother is a nurse and becomes concerned that he may be experiencing a fluid and electr include all of the following *exc*

   a. sodium ion.
   b. glucose.
   c.
   d.

Can You Synthesize What You've Learned?

1. An individual is exposed to high-energy radiation. Which biomolecule that regulates the process of protein synthesis may have been mutated?
2. The lab results from a diabetic patient show a lower than normal pH (a condition referred to as acidosis). Explain the change in H^+ concentration in the blood, and describe how this change may affect the folding of proteins in the blood plasma (and elsewhere).
3. A patient is given a new drug that decreases blood sugar levels. This drug is regulating which specific molecule?

Challenge Yourself

Assessments at the end of each chapter 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.

Integrated Media and Textbook

Print and Digital Study Tools Connected

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 ANATOMY & PHYSIOLOGY | LEARNSMART® | AP|R

The following study aids may be accessed through Connect.

Concept Overview Interactive Figure 12.23: Events of Neuron Physiology

Clinical Case Study: A Young Man Who Gets Weak When Overheated

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

LearnSmart: Topics and terminology include neurons; synapses; glial cells; axon regeneration; ultrastructure of neurons; neuron physiology; physiologic events in the neuron segments; velocity of a nerve signal; neurotransmitters and neuromodulation; neural integration and neuronal pools of the CNS

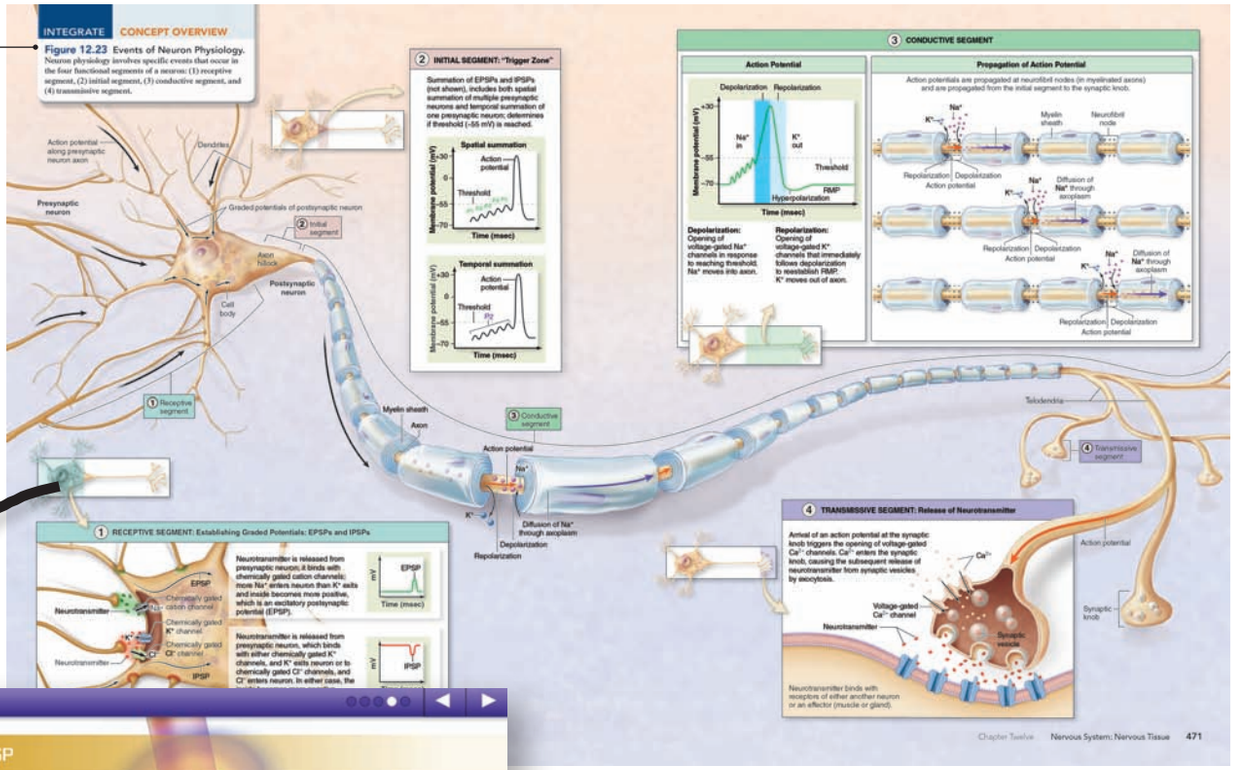
Anatomy & Physiology Revealed: Topics include multipolar neuron; Schwann cell (neurolemmocyte); unmyelinated axon and myelin sheath; action potential generation and propagation; chemical synapse

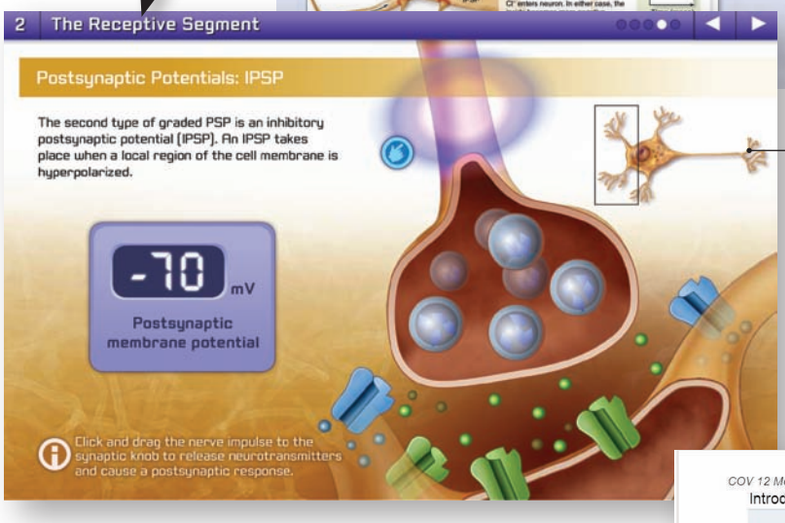
Animations: Topics include PSPs (postsynaptic potentials); action potential propagation; action potential generation; action potential propagation in myelinated neurons

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.

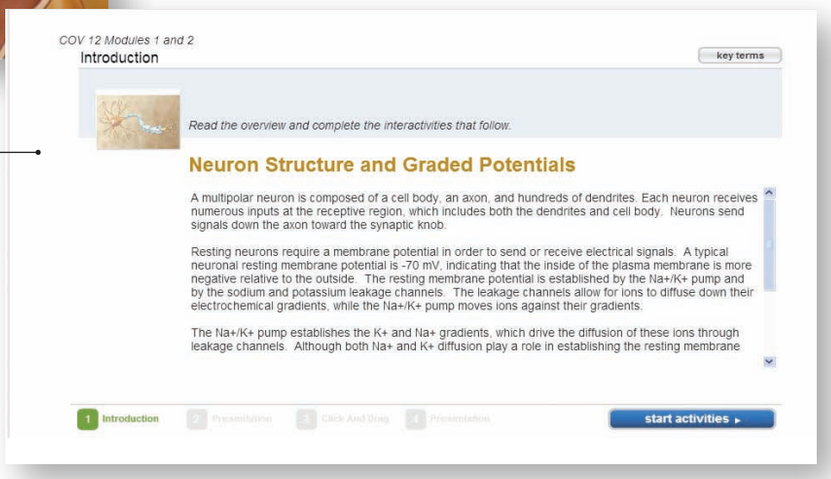
Concept Overview from Textbook





Interactive Presentation Study Tool

Assessable Autograded Activity in Connect

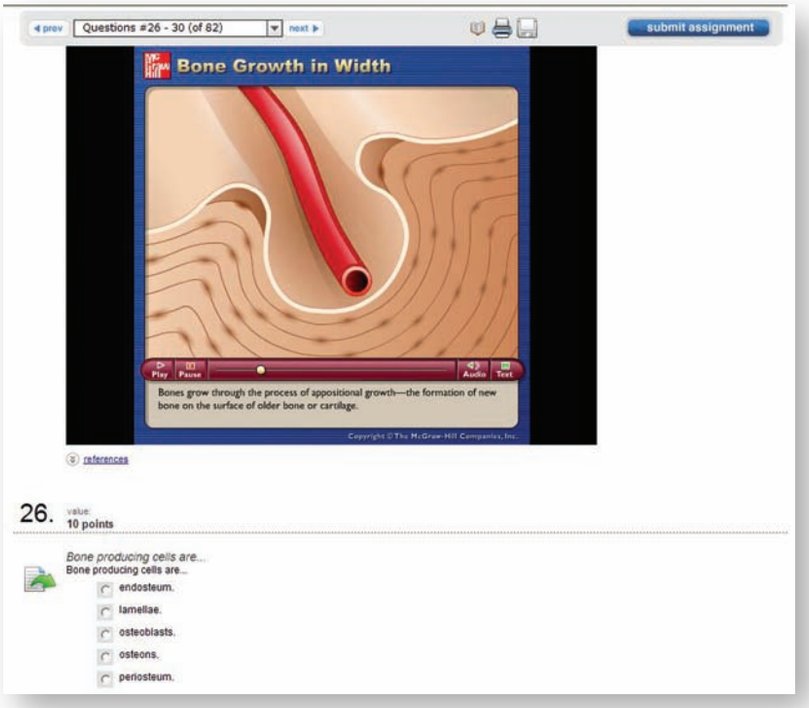


Connect®

McGraw-Hill Connect® interactive learning platform provides:

- Auto-graded assignments
- Adaptive diagnostic tools
- Powerful reporting against learning outcomes and level of difficulty
- An easy-to-use interface
- **McGraw-Hill Tegrity®**, which digitally records and distributes your lectures with a click of a button

Connect includes the full textbook as an integrated, dynamic eBook, which you can also assign. Everything you need . . . in one place!



McGraw-Hill LearnSmart™

Unlike static flashcards or rote memorization, **McGraw-Hill LearnSmart™** ensures your students have mastered course concepts before taking the exam, thereby saving you time and increasing student success.

- The only truly adaptive learning system
- Intelligently identifies course content students have not yet mastered
- Maps out personalized study plans for student success

Learning Objectives and Connect®

Each Learning Objective from the textbook is tied to interactive questions in Connect, to assure that all parts of the chapters have adequate coverage within Connect assignments.

6.1 Composition and Functions of the Integument

The integument is the body's largest organ and is composed of all tissue types that function in concert to protect internal body structures. Its surface is an epithelium that protects underlying body layers. The connective tissue that underlies the epithelium provides strength and resilience to the skin. This connective tissue also contains smooth muscle associated with hair follicles (arrector pili) that alters hair position. Finally, nervous tissue detects and monitors sensory stimuli in the skin, which provide information about touch, pressure, temperature, and pain.

The integument accounts for 7% to 8% of the body weight and covers the entire body surface with an area that varies between about 1.5 and 2.0 square meters (m^2). Its thickness ranges between 1.5 millimeters (mm) and 4 mm or more, depending on body location. (For comparison, a sheet of copier paper is about 0.1 mm thick, so the thickness of the skin would range between 15 and 40 sheets of paper.) The integument consists of two distinct layers: a layer of stratified squamous epithelium called the epidermis, and a deeper layer of primarily dense irregular connective tissue called the dermis (figure 6.1). Deep to the dermis is a layer of areolar and adipose connective tissue called the subcutaneous layer, or hypodermis. The subcutaneous layer is not part of the integumentary system; however, it is described in this chapter because it is closely involved with both the structure and function of the skin.

6.1a Epidermis

LEARNING OBJECTIVES

1. Describe the five layers (strata) of the epidermis.
2. Differentiate between thick skin and thin skin.
3. Explain what causes differences in skin color.

The epithelium of the integument is called the **epidermis** (ep-i-derm′is; *epi* = on, *derma* = skin). It is a keratinized, stratified squamous epithelium (see section 5.1c).

Careful examination of the epidermis, from the basement membrane to its surface, reveals several specific layers, or strata. From deep to superficial, these layers are the stratum basale, stratum spinosum, stratum granulosum, stratum lucidum (found in thick skin only), and the stratum corneum (figure 6.2). The first three strata listed are composed of living keratinocytes, whereas the most superficial two strata contain dead cells.

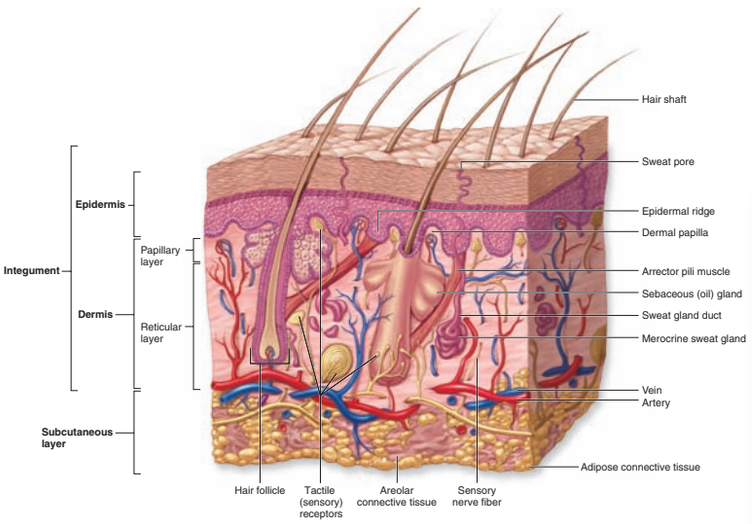
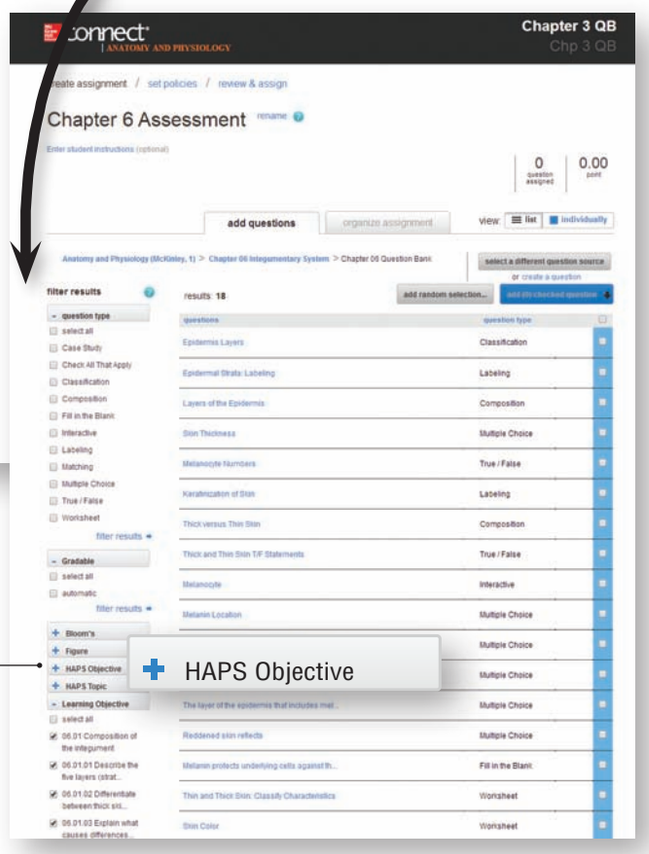


Figure 6.1 Layers of the Integument. A diagrammatic sectional view through the integument shows its relationship to the underlying subcutaneous layer. AP|R

6.1a Epidermis

LEARNING OBJECTIVES

1. Describe the five layers (strata) of the epidermis.
2. Differentiate between thick skin and thin skin.
3. Explain what causes differences in skin color.



Correlated to HAPS Learning Objectives

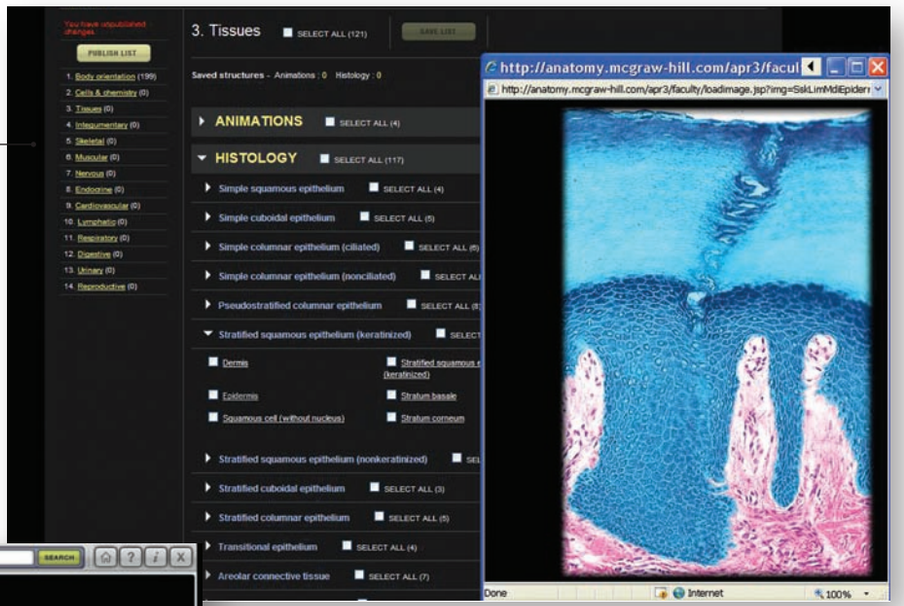
Where appropriate, questions in Connect are now tied to the Human Anatomy and Physiology Society (HAPS) Learning Objectives. Instructors may filter assignable questions by HAPS Learning Objectives and see all the corresponding questions.

Anatomy & Physiology REVEALED®

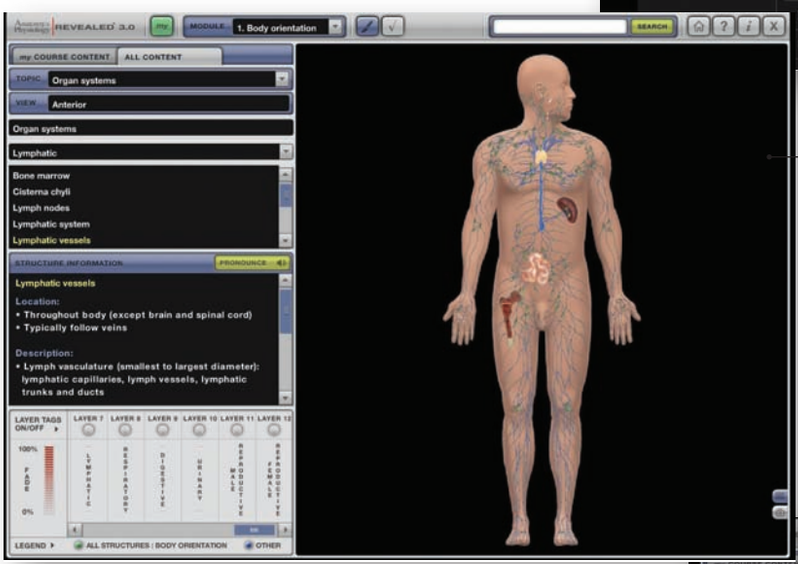
Anatomy & Physiology REVEALED® is an interactive cadaver dissection tool to enhance lecture and lab that students can use anytime, anywhere. Instructors can customize APR 3.0 by indicating the specific content they require in their course through a simple menu selection process. APR 3.0 does the rest. In the course-specific area of the program, students see only the instructor's designated content, and only this content appears in quiz questions.

APR contains all the material covered in an A&P course, including these three modules:

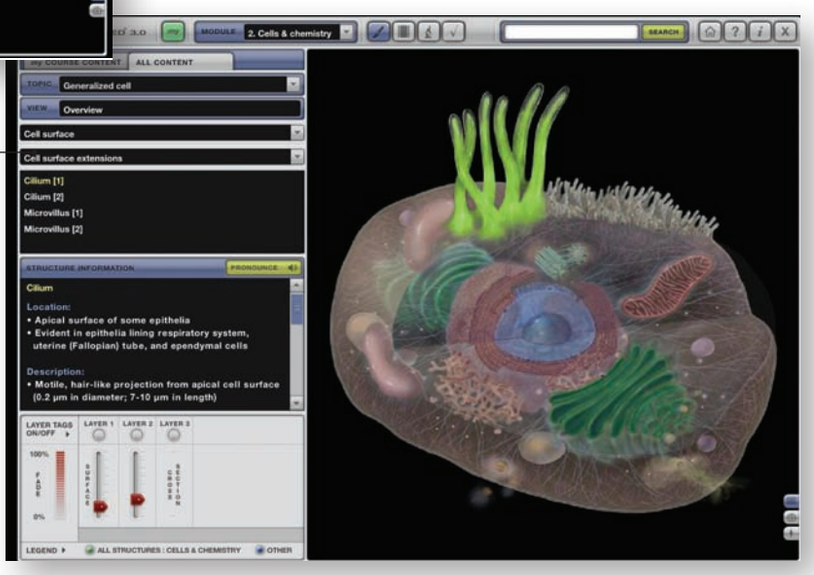
- Body Orientation
- Cells and Chemistry
- Tissues



Tissues Module



Body Orientation Module



Cells and Chemistry Module

Presentation Tools

Accessed from the *Anatomy and Physiology: An Integrated Approach* Connect website, **Presentation Tools** is a collection of digital assets including photos, artwork, animations, and other media that can be used to create customized lectures, visually enhanced tests and quizzes, compelling course websites, or attractive printed support materials. All assets are copyrighted by McGraw-Hill Higher Education, but can be used by instructors for classroom purposes. The visual resources in this collection include the following:

- **Art** Full-color digital files of all illustrations in the book can be readily incorporated into lecture presentations, exams, or custom-made classroom materials. In addition, all files are preinserted into PowerPoint slides for ease of lecture preparation.
- **Photos** The photo collection contains digital files of photographs from the text, which can be reproduced for multiple classroom uses.
- **Tables** Every table that appears in the text has been saved in electronic form for use in classroom presentations and/or quizzes.
- **Animations** Numerous full-color animations illustrating important processes are also provided. Harness the visual impact of concepts in motion by importing these files into classroom presentations or online course materials.
- **PowerPoint Lecture Outlines** Ready-made presentations that combine art and lecture notes are provided for each chapter of the text.
- **PowerPoint Slides** For instructors who prefer to create their lectures from scratch, all illustrations, photos, and tables, are preinserted by chapter into blank PowerPoint slides.

Instructors: To access Connect, request registration information from your McGraw-Hill sales representative.

Digital Lecture Capture: Tegrity McGraw-Hill Tegrity® records and distributes your lecture with just a click of a button. Students can view anytime/anywhere via computer, iPod, or mobile device. Tegrity indexes as it records your slideshow presentations and anything shown on your computer, so students can use keywords to find exactly what they want to study.

Computerized Test Bank Updated by Justin York of Glendale Community College, over 3,600 test questions are served up utilizing EZ Test software to accompany *Anatomy and Physiology: An Integrated Approach*. Diploma's software allows you to quickly create a customized test using McGraw-Hill's supplied questions, or by authoring your own questions. Diploma is a downloadable application that allows you to create your tests without an Internet connection—just download the software and question files directly to your computer.

Content Delivery Flexibility *Anatomy and Physiology: An Integrated Approach* by McKinley/O'Loughlin/Bidle is available in many formats in addition to the traditional textbook to give instructors and students more choices when deciding on the format of their A&P text. Choices include the following:

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- 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.
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chapter 1

The Sciences of Anatomy and Physiology

INTEGRATE

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 image above 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.

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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. Together, these applied sciences provide the basis for understanding health and human performance. The basic vocabulary of these sciences is derived from both Greek and Latin.

If you actively practice the vocabulary and descriptive terminology used in this text, your understanding and appreciation of body structure and function will be enhanced significantly. In this book, you will learn that structure and function are inseparable. You will see how the body functions normally, as well as what happens to body function and structure when injury and disease occur.

INTEGRATE

LEARNING STRATEGY

Boxed elements like this 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.

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 structure and form 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 their functioning 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 outside of the capillary.

Anatomists and physiologists are professionals who use the scientific method to explain and understand the workings of the body. The **scientific method** refers to 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 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 some part of the body and examine these specimens under the microscope. Microscopic anatomy has several subdivisions with two main divisions:

- **Cytology** (sī-tol′ō-jē; *cyto* = cell, *logos* = study) is the study of body cells and their internal structure.
- **Histology** (his-tol′ō-jē; *histos* = web, tissue) is the study of 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 similarities and the 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: "Medical Imaging" at the end of this chapter.)

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. What subdiscipline of anatomy may explore how the lower limb differs between humans and chimpanzees?

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 travel 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).

INTEGRATE

CLINICAL VIEW

Etiology and Pathogenesis of Disease

All health-care professionals must understand not only how organ systems function normally, but also how pathology can affect the physiology of this system. Throughout the chapters in this book, Clinical View boxes provide you with selected pathologies and how these pathologies affect the anatomy and physiology of that system.

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.

1.2 Anatomy and Physiology Integrated

LEARNING OBJECTIVE

1. 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 determines 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 easiest 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 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.

WHAT DID YOU LEARN?

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

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

(*a*) Anatomists 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 system. However, both anatomists and physiologists recognize that form and function are interrelated.

ANATOMISTS

Study the small intestine including its relationship to the rest of the body

(a) Anatomists

Focus on the form and structures of the small intestine

Esophagus
Liver
Stomach
Large intestine
Small intestine

ANATOMISTS

Describe the multiple layers in the wall of the small intestine

ANATOMISTS

Study the tissues of the small intestine and the cells that compose them

Organelles

Villus

Cell

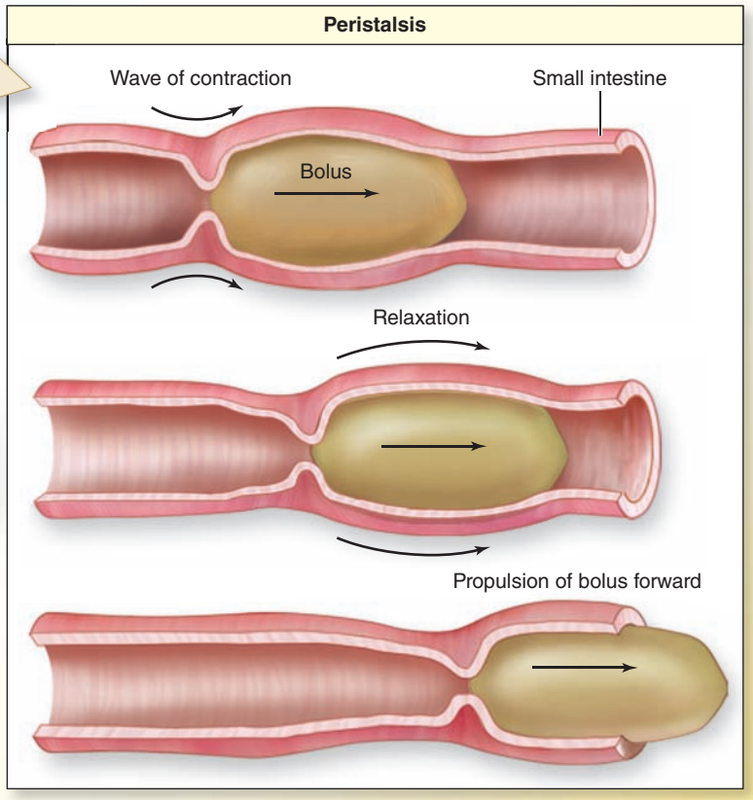
Section of intestinal wall

(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



Anatomists and Physiologists

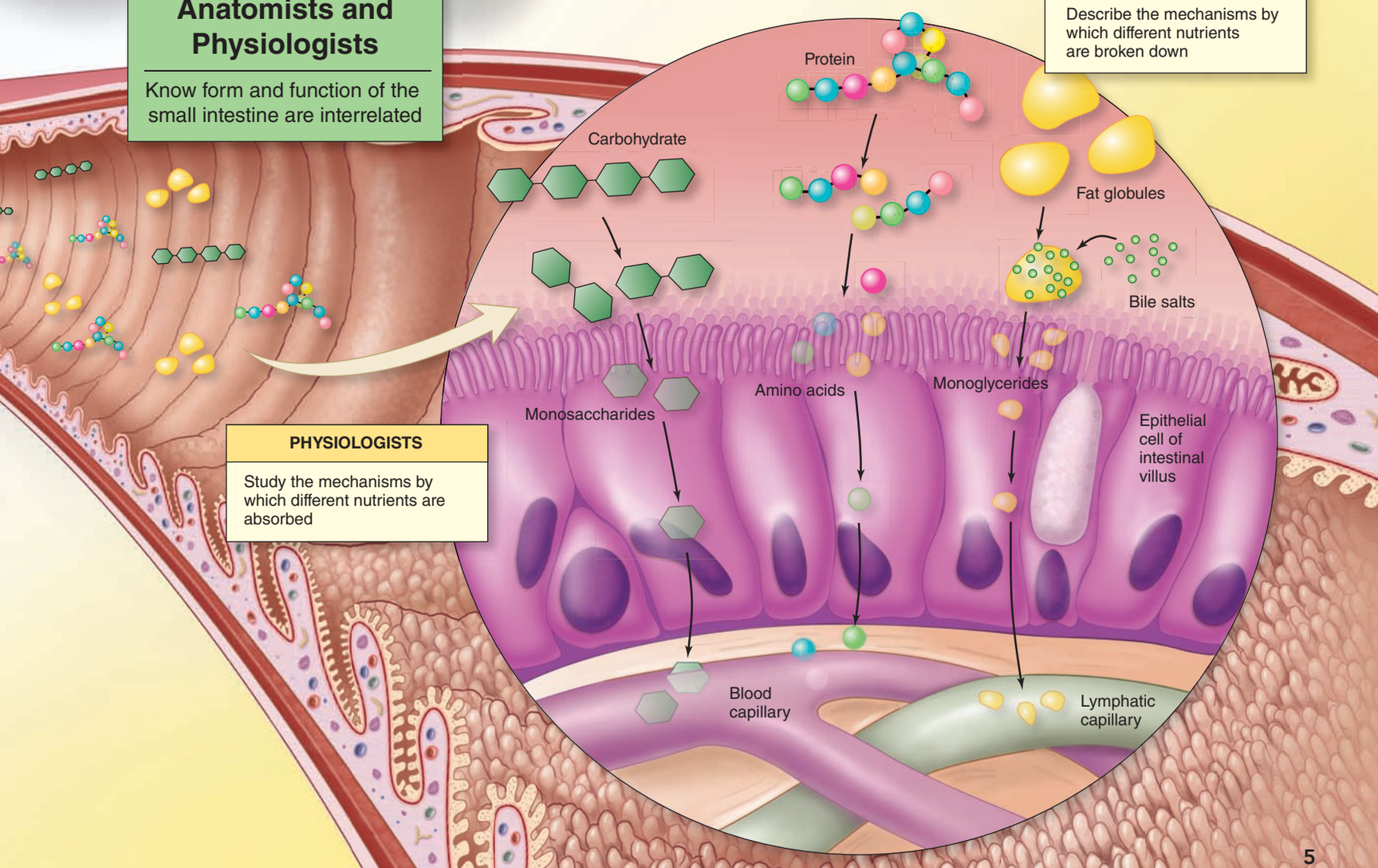
Know form and function of the small intestine are interrelated

PHYSIOLOGISTS

Describe the mechanisms by which different nutrients are broken down

PHYSIOLOGISTS

Study the mechanisms by which different nutrients are absorbed



1.3 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 level supports these characteristics. For example, the organ system concept allows functions to be considered as an interaction between many organs.

1.3a Characteristics That Describe Living Things

LEARNING OBJECTIVE

1. List the characteristics common to all living things.

Several properties are common to all organisms, including humans:

- **Organization.** All organisms exhibit a complex structure and order. In the next section, we note that the human body has several increasingly complex levels of organization.
- **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 2.7) for muscle contraction (see section 10.3).

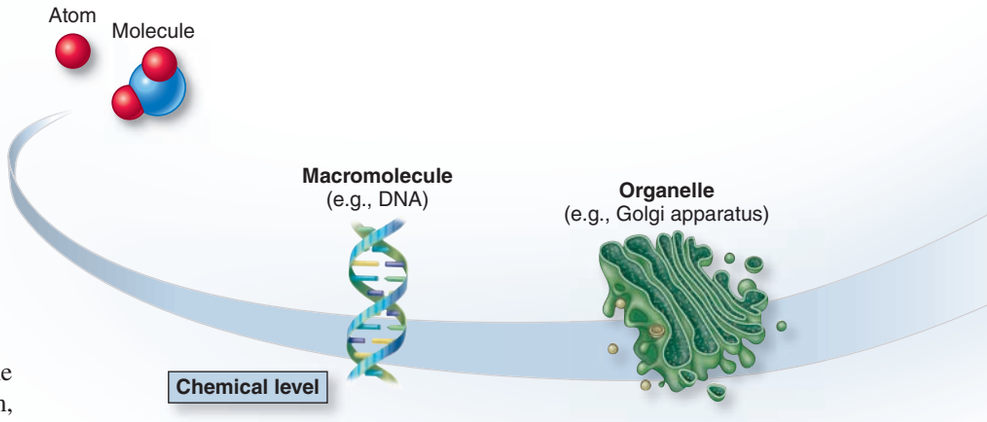
WHAT DO YOU THINK?

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 sophisticated.
- **Responsiveness.** All organisms exhibit **responsiveness,** which is the ability to sense 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 or direct internal bodily function in the face of environmental changes. When body temperature rises, the body regulates this change by circulating more blood near its surface to facilitate heat loss, and thus return the body to within normal range. (The process of maintaining body structures and function is called homeostasis, which is discussed in greater depth in section 1.5)
- **Reproduction.** All organisms produce new cells for growth, maintenance, and repair. The somatic (body) cells divide by a process called mitosis, whereas sex cells (called gametes) are produced by another type of cell division called meiosis. The sex cells, under the right conditions, have the ability to develop into a new living organism.

WHAT DID YOU LEARN?

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



1.3b The View from Simplest to Most Complex

LEARNING OBJECTIVE

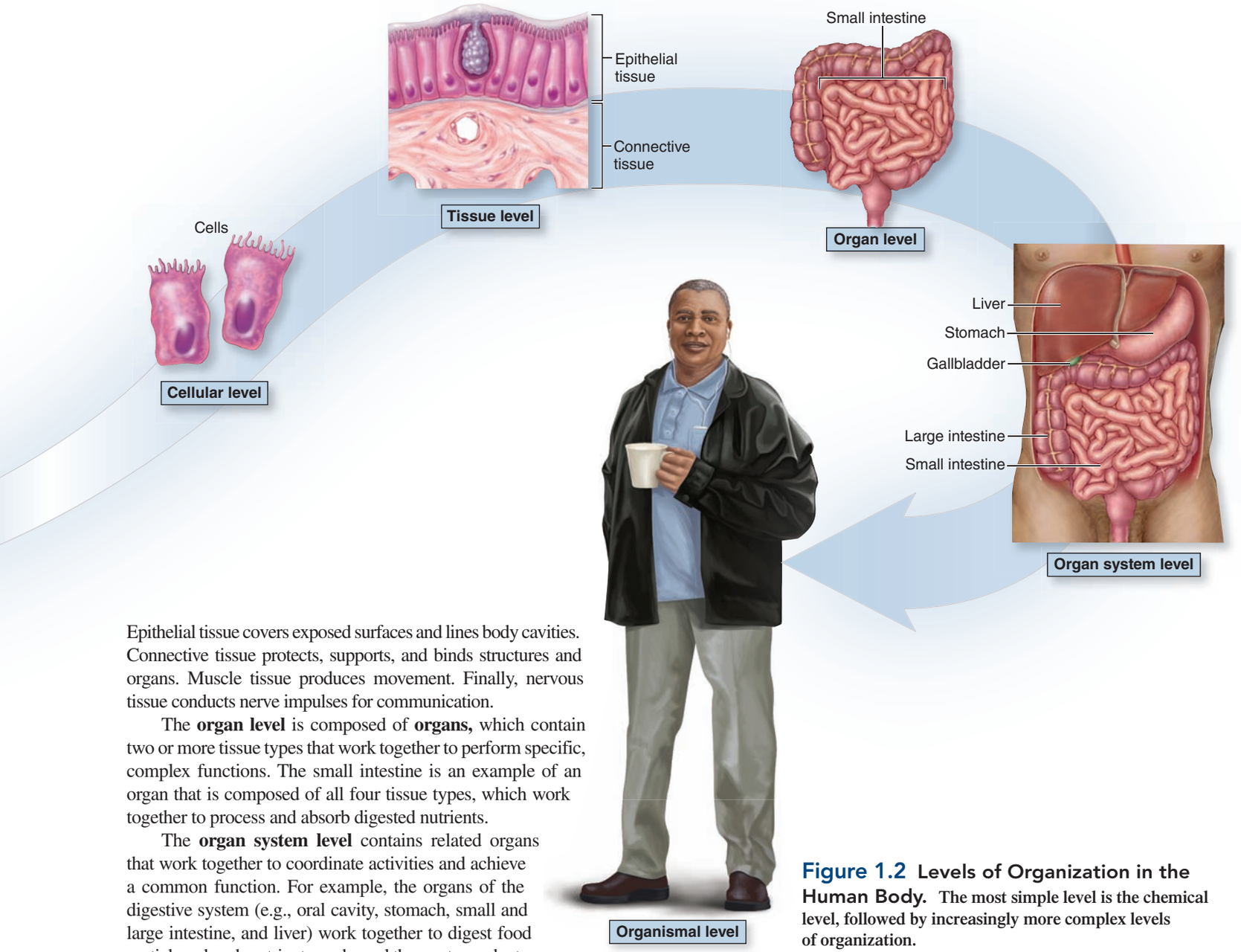
2. Describe the levels of organization in the human body.

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,** which are microscopic structures found within cells.

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

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,** which contain 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 **organ system level** contains 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 highest level of structural organization in the body is the **organismal level.** All body systems function interdependently in an **organism,** which is the living being.

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.

WHAT DID YOU LEARN?

6 Does a higher level of organization contain all the levels beneath it? Explain.

INTEGRATE

CONCEPT CONNECTION

Throughout future chapters, boxes like this one 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.

1.3c Introduction to Organ Systems

LEARNING OBJECTIVE

3. Compare the organ systems of the human body.

All organisms must exchange nutrients, wastes, and gases with their environment to carry on their metabolism. Simple organisms (e.g., bacteria) may exchange these substances directly across their surface membranes. In contrast, complex, multicellular organisms require sophisticated organ systems with specialized structures and functions to perform the myriad of 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?

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

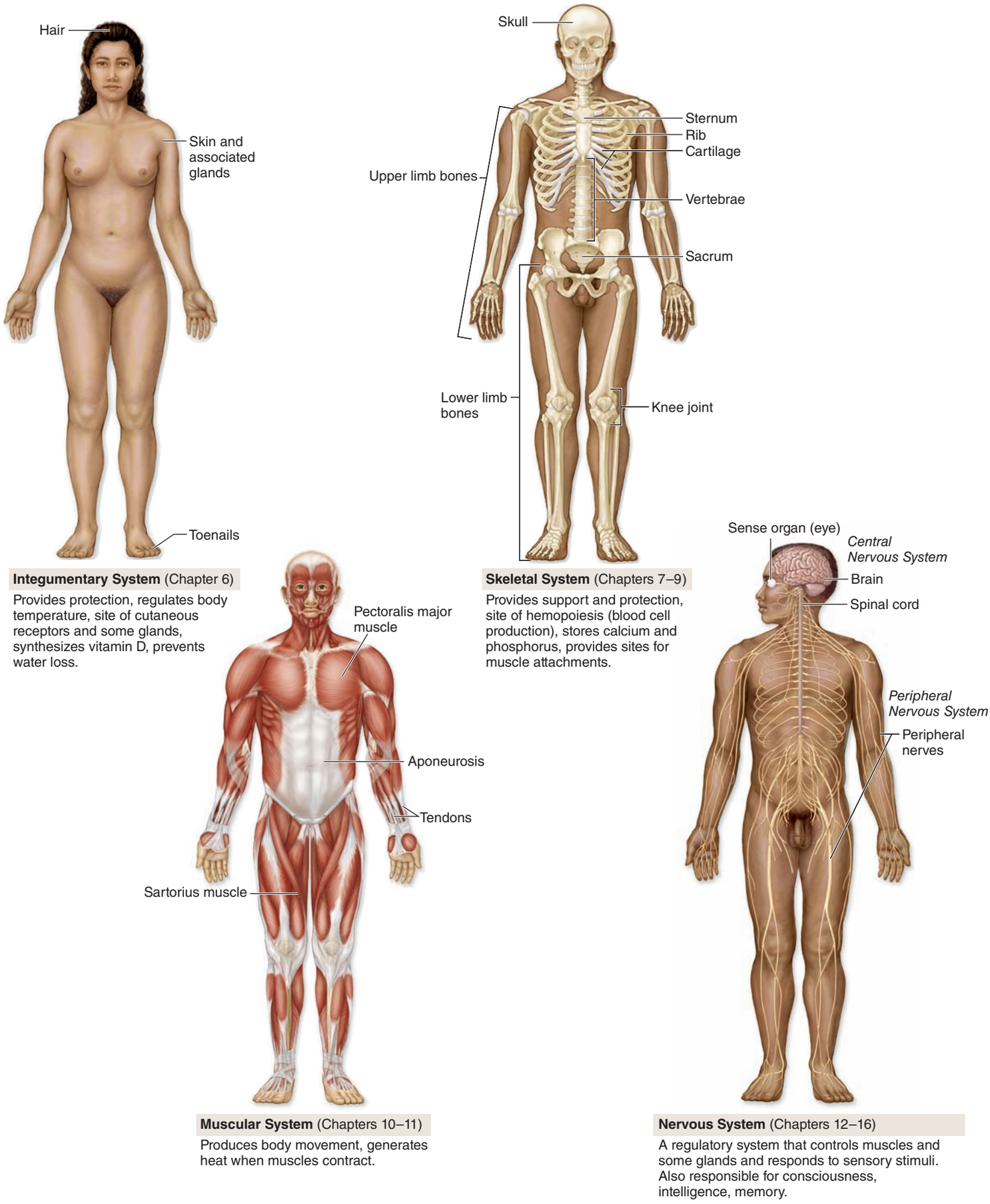
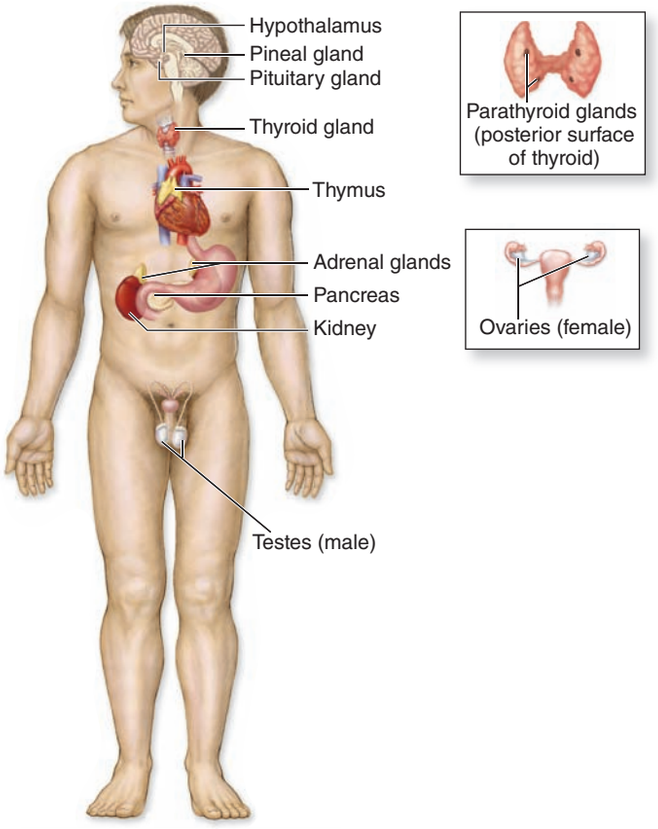
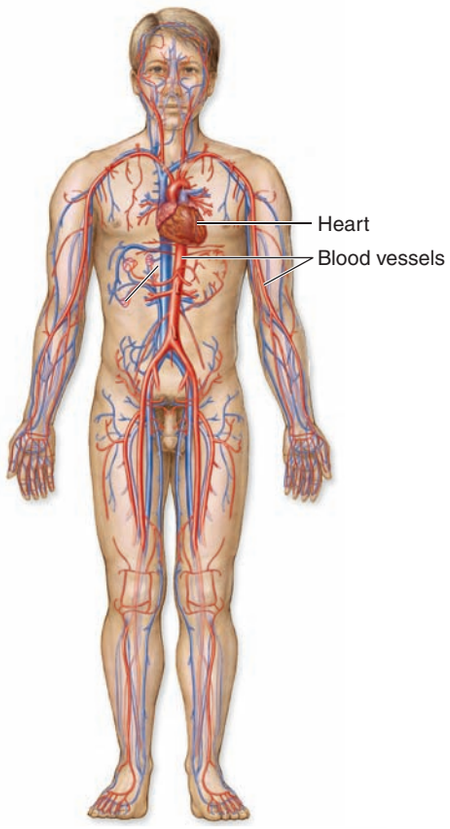


Figure 1.3 Organ Systems. Major components and characteristics of the 11 organ systems of the human body are presented. AP|R



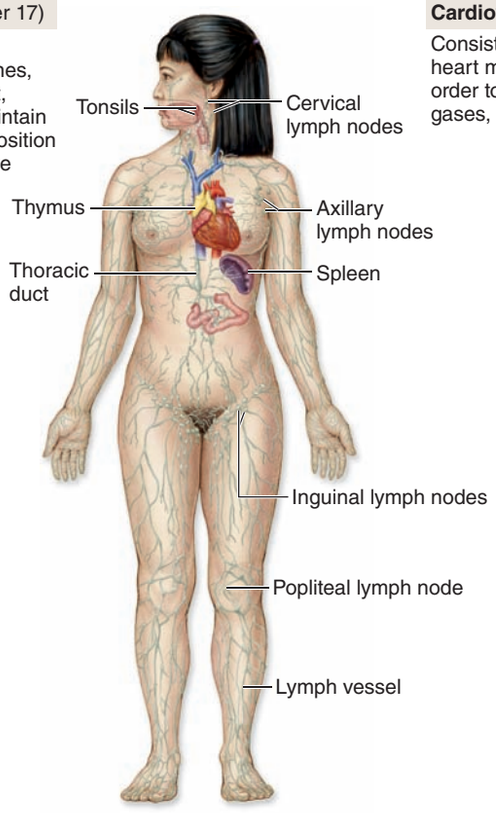
Endocrine System (Chapter 17)

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



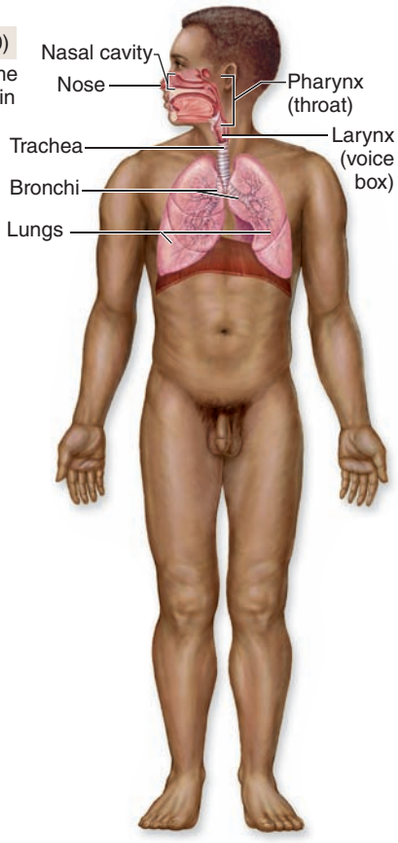
Cardiovascular System (Chapters 18–20)

Consists of the heart 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 transported through lymph vessels) and participates in an immune response when necessary.



Respiratory System (Chapter 23)

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