

GLOBAL  
EDITION



# Fundamentals of Anatomy & Physiology

ELEVENTH EDITION

Martini • Nath • Bartholomew



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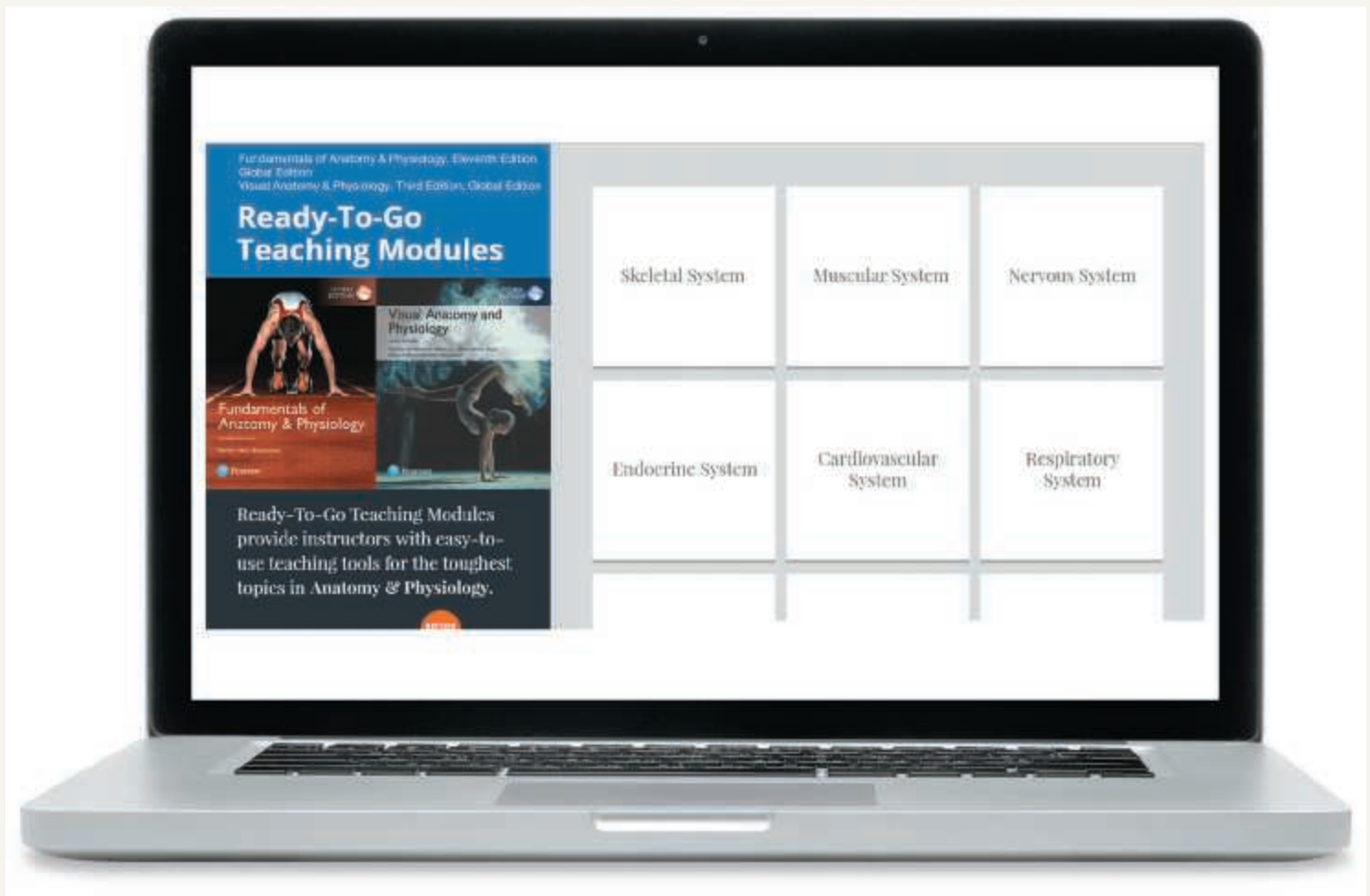
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# Get Ready for a Whole New Mastering Experience

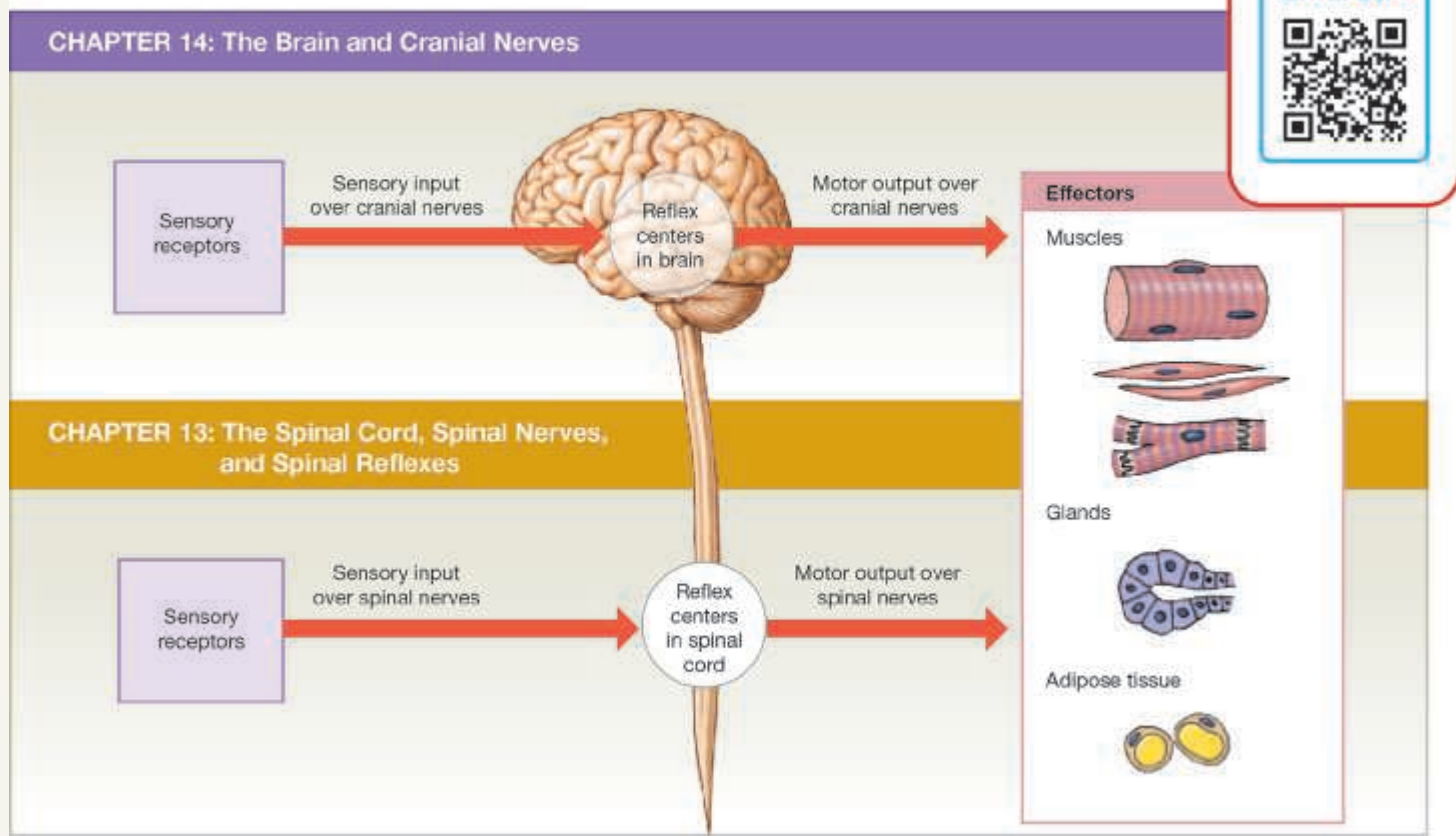
**NEW! Ready-to-Go Teaching Modules** help instructors find the best assets to use before, during, and after class to teach the toughest topics in A&P. Created by teachers for teachers, these curated sets of teaching tools save you time by highlighting the most effective and engaging animations, videos, quizzing, coaching and active learning activities from Pearson Mastering A&P.



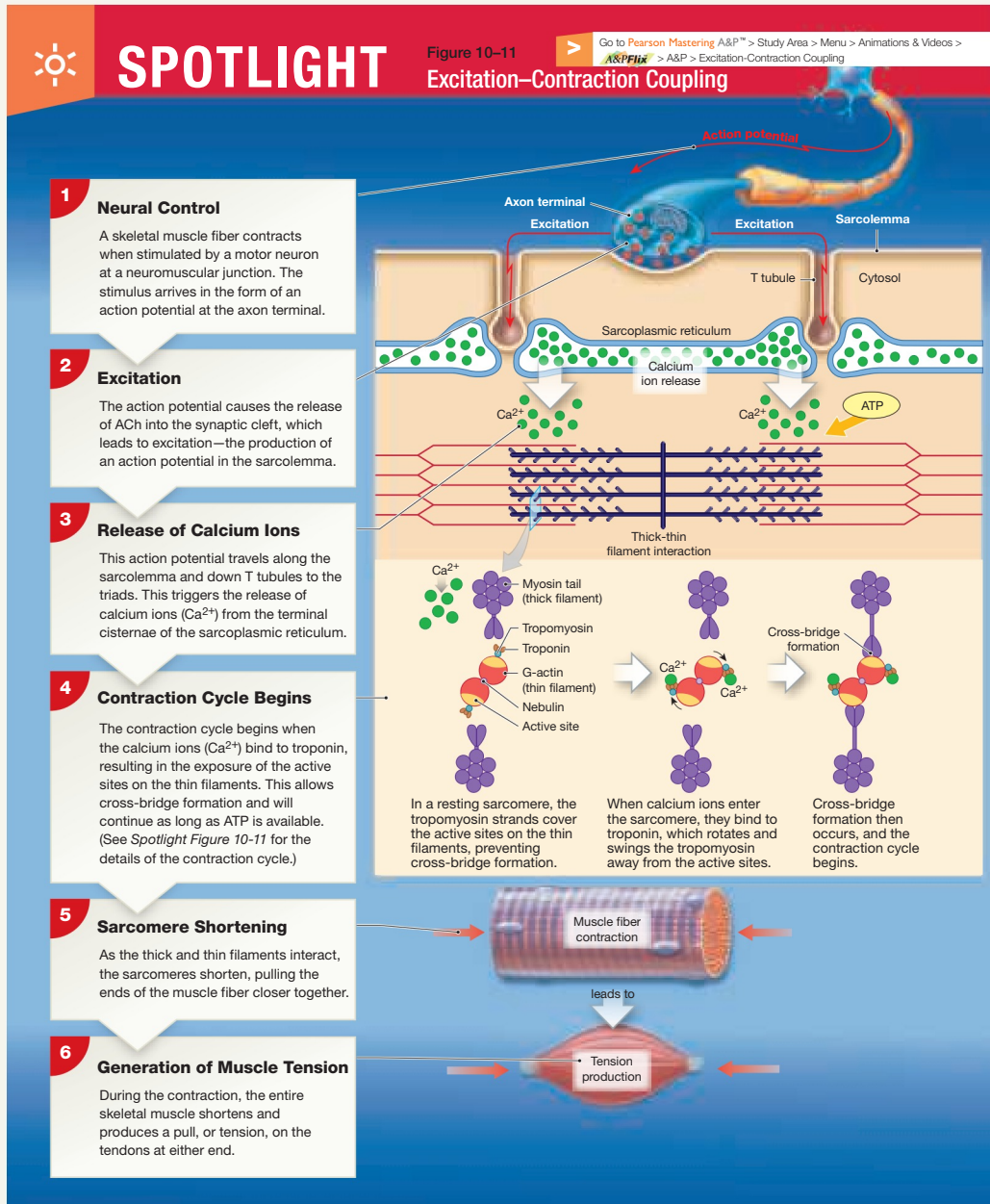
# Help Students Use Art More Effectively

**NEW! SmartArt Videos** help students navigate select, complex pieces of art for some of the toughest topics in A&P. Author Kevin Petti walks students through several figures and provides additional background and detail. The videos can be accessed via QR codes in the book and offer accompanying assignments through Pearson Mastering A&P.

**Figure 13-1** An Overview of Chapters 13 and 14.



**Spotlight Figures** provide highly visual one- and two-page presentations of tough topics in the book, with a particular focus on physiology.



**NEW! Pearson Mastering A&P** references within the chapter direct students to specific digital resources, such as tutorials, animations, and videos, that will help further their understanding of key concepts in the course.

# Systems Integration in the Classroom

**NEW! Build Your Knowledge** features show how each body system influences the others. As students progress through the book, they will build their knowledge about how the body systems work together to maintain homeostasis.



## Build Your Knowledge

**Figure 11-24** Integration of the MUSCULAR system with the other body systems presented so far.

### Integumentary System

- The Integumentary System removes excess body heat, synthesizes vitamin D<sub>3</sub> for calcium and phosphate absorption, and protects underlying muscles.
- The muscular system includes facial muscles that pull on the skin of the face to produce facial expressions.

### Skeletal System

- The Skeletal System provides mineral reserves for maintaining normal calcium and phosphate levels in body fluids, supports skeletal muscles, and provides sites of muscle attachment.
- The muscular system provides skeletal movement and support, and stabilizes bones and joints. Stresses exerted by tendons maintain normal bone structure and bone mass.

### Muscular System

- The muscular system performs these primary functions for the human body:
- It produces skeletal movement
  - It helps maintain posture and body position
  - It supports soft tissues
  - It guards entrances and exits to the body
  - It helps maintain body temperature



# and Beyond

**Clinical Cases** get students motivated for their future careers. Each chapter opens with a story-based Clinical Case related to the chapter content and ends with a Clinical Case Wrap-Up.

## + CLINICAL CASE He Has Fish Skin!

I shook his hand and immediately I knew something was different about him. When Will clasped my hand between both of his, I felt like my hand was sandwiched between two sheets of thick, shaggy sandpaper. There was none of the moistness or warmth of a usual handshake. These hands belonged to Grandpa Will.

Grandpa Will's grandsons adored him, and the feeling was mutual! They lured him into chasing them around the backyard. Because it was a hot summer day, play



lasted all of 15 minutes and then Grandpa brought the gang back to the air-conditioned comfort of the house. He sank back into the recliner. He was flushed and breathing hard, but his shirt stayed dry and crisp—there wasn't a bead of sweat visible on him. The boys climbed onto his lap, laughing, as he encircled them with those coarse hands. "Oh, Grandpa, you feel like a fish!" **What is happening with Grandpa Will's integumentary system? To find out, turn to the Clinical Case Wrap-Up on p. 225.**

## + CLINICAL CASE Wrap-Up He Has Fish Skin!

Grandpa Will has **ichthyosis vulgaris** (ik-THI-oh-sis voo-JAIR-ah). Ichthyosis literally means "fish-like condition," a feature his grandsons noticed right away. Will inherited this skin condition from his parents, who carried a gene mutation for a structural protein. The lack of this protein impairs keratinization. With this condition, skin cells also have fewer desmosomes and tight junctions, so the acorniform papillae and hair-like fish scales.

There is no cure. Every day Grandpa must tend to his skin by applying moisturizers to draw and retain moisture and emollients to soften the scales. He avoids soap, which further dries



his skin, and uses rubber gloves to wash the dishes. In winter, he runs a humidifier in the bedroom. If his skin gets too dry, his skin can break into deep, painful cracks. Because the natural skin barrier is disrupted, secondary infections may arise.

1. Why is ichthyosis called a "disorder of cornification"? Which cells are involved?
2. Grandpa has trouble when it's hot outside. What's wrong?

[See the Clinical Anatomy Key at the back of the book.](#)

### + Clinical Note Abnormal bone development

A variety of endocrine or metabolic problems can result in characteristic skeletal changes. In **pituitary growth failure**, inadequate production of growth hormone leads to reduced epiphyseal cartilage activity and abnormally short bones. This condition is becoming increasingly rare in the United States, because children can be treated with synthetic human growth hormone.

**Gigantism** results from an overproduction of growth hormone before puberty (Photo a). (The world record for height is 272 cm, or 8 ft, 11 in. It was reached by Robert Wadlow, of Alton, Illinois, who died at age 22 in 1940. Wadlow weighed 216 kg, or 475 lb.) If the growth hormone level rises abnormally after epiphyseal cartilages close, the skeleton does not grow longer. Instead, bones get thicker, especially in the face, jaw, and hands. Cartilage growth and alterations in soft-tissue structure lead to changes in physical features, such as the contours of the face. These physical changes take place in the disorder called **acromegaly** (ak-roh-MEG-ah-lee).

Several inherited metabolic conditions that affect many systems influence the growth and development of the skeletal system. These conditions produce characteristic variations in body proportions. For example, many individuals with **Marfan's syndrome** are very tall and have long, slender limbs (Photo b).

The cause is excessive cartilage formation at the epiphyseal cartilages. The underlying mutation affects the structure of connective tissue throughout the body, and commonly causes cardiovascular events such as the sudden death of athletes during strenuous athletic contests.

**a** Gigantism

**b** Marfan's syndrome

**Clinical Notes** appear within every chapter and expand upon topics just discussed. They present diseases and pathologies along with their relationship to normal function.

**Clinical Terms** end every chapter with a list of relevant clinical terms and definitions.

## Related Clinical Terms

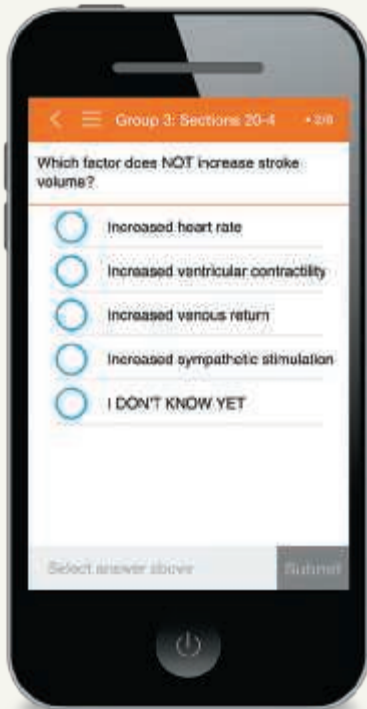
- carbuncle:** A skin infection that often involves a group of hair follicles. The infected material forms a lump, which occurs deep in the skin; the medical term for multiple boils.
- cold sore:** A lesion that typically occurs in or around the mouth and is caused by a dormant herpes simplex virus that may be reactivated by factors such as stress, fever, or sunburn. Also called *fever blister*.
- comedo:** The primary sign of acne consisting of an enlarged pore filled with skin debris, bacteria, and sebum (oil); the medical term for a blackhead.
- dermatology:** The branch of medicine concerned with the diagnosis, treatment, and prevention of diseases of the skin, hair, and nails.
- eczema:** Rash characterized by inflamed, itchy, dry, scaly, or irritated skin.
- frostbite:** Injury to body tissues caused by exposure to below-freezing temperatures, typically affecting the nose, fingers, or toes and sometimes resulting in gangrene.
- furuncle:** A skin infection involving an entire hair follicle and nearby skin tissue; the medical term for a boil.
- gangrene:** A term that describes dead or dying body tissue that occurs because the local blood supply to the tissue is either lost or is inadequate to keep the tissue alive.



# Continuous Learning

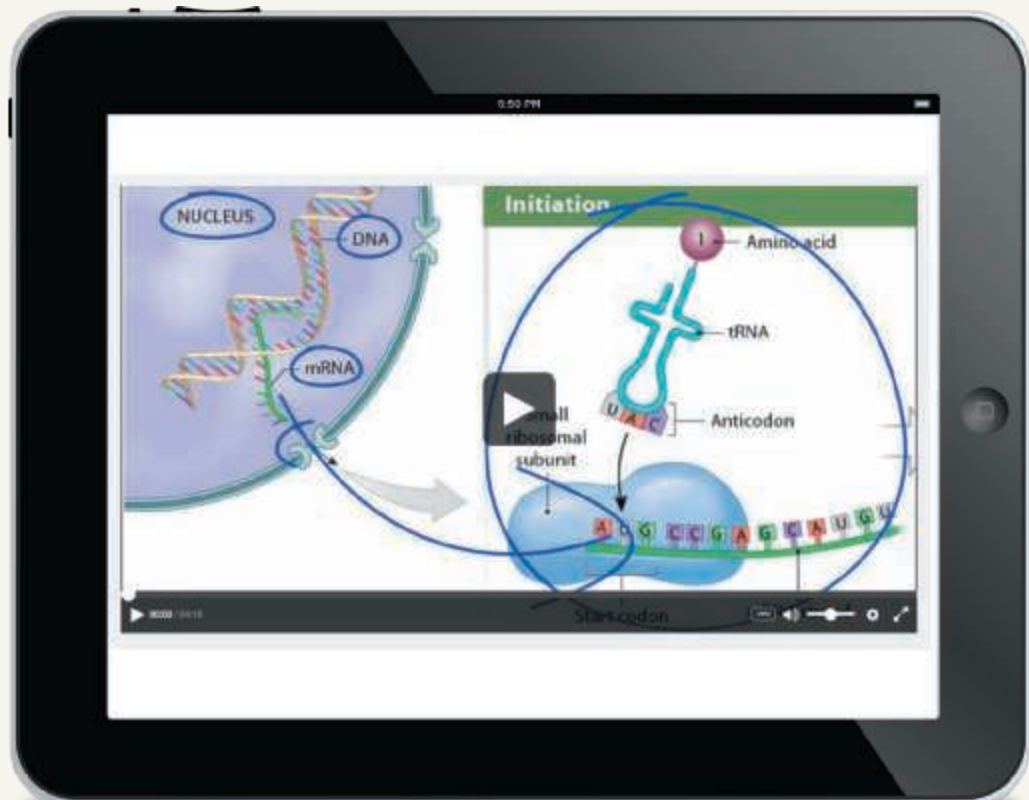
## Before, During, and After Class

**Dynamic Study Modules** enable students to study more effectively on their own. With the Dynamic Study Modules mobile app, students can quickly access and learn the concepts they need to be more successful on quizzes and exams.



**NEW!** Instructors can now select which questions to assign to students.

**NEW!** SmartArt Videos help students navigate some of the complex figures in the text. They are accessible via QR code in the book and are assignable in Pearson Mastering A&P.

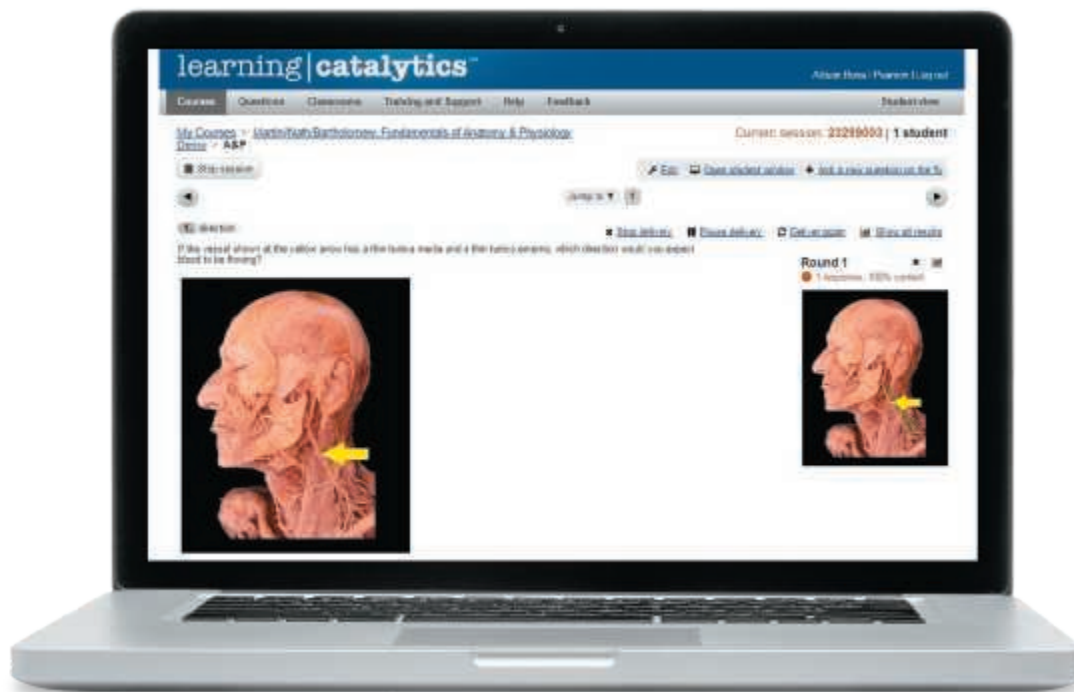


# with

**Learning Catalytics** is a “bring your own device” (laptop, smartphone, or tablet) engagement, assessment, and classroom intelligence system. Students use their device to respond to open-ended questions and then discuss answers in class based on their responses.

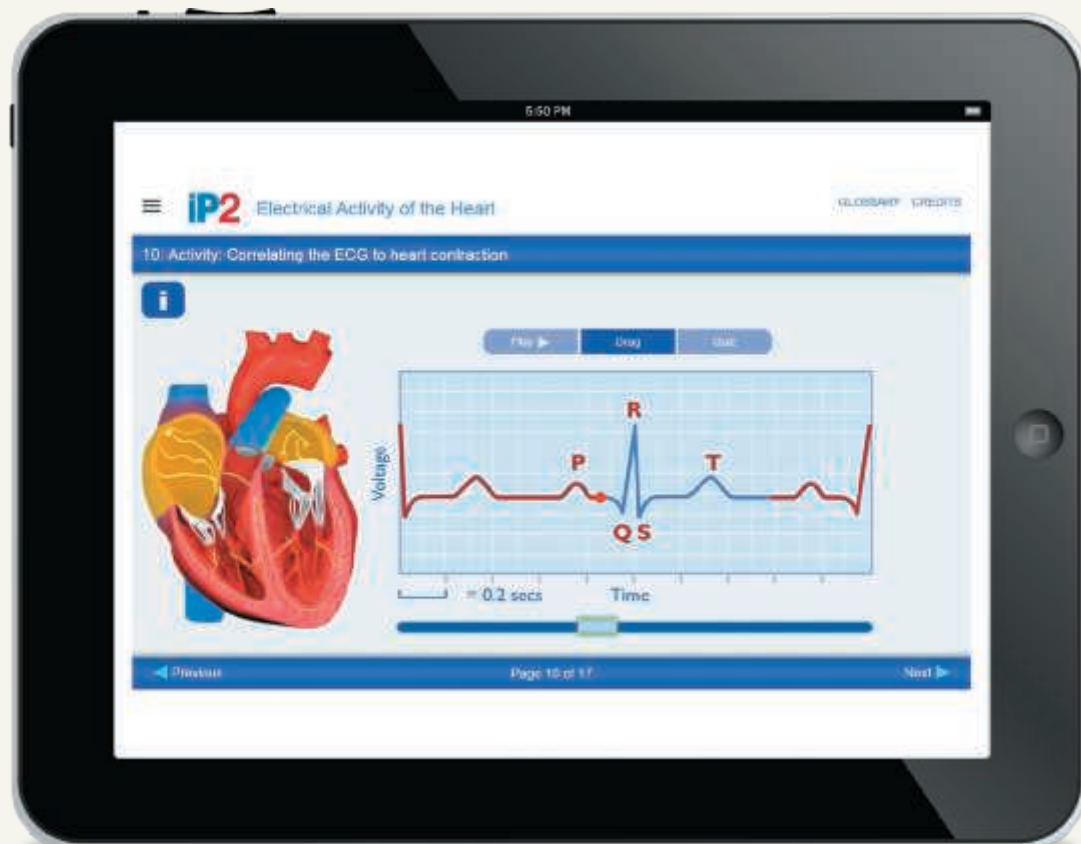
*“My students are so busy and engaged answering Learning Catalytics questions during lecture that they don’t have time for Facebook.”*

*—Declan De Paor, Old Dominion University*



# Pearson Mastering A&P™

**NEW! Interactive Physiology 2.0** helps students advance beyond memorization to a genuine understanding of complex physiological processes. Fun, interactive tutorials, games, and quizzes give students additional explanations to help them grasp difficult concepts. IP 2.0 features brand-new graphics, quicker navigation, and more robust interactivity.



## NEW IP 2.0 modules include:

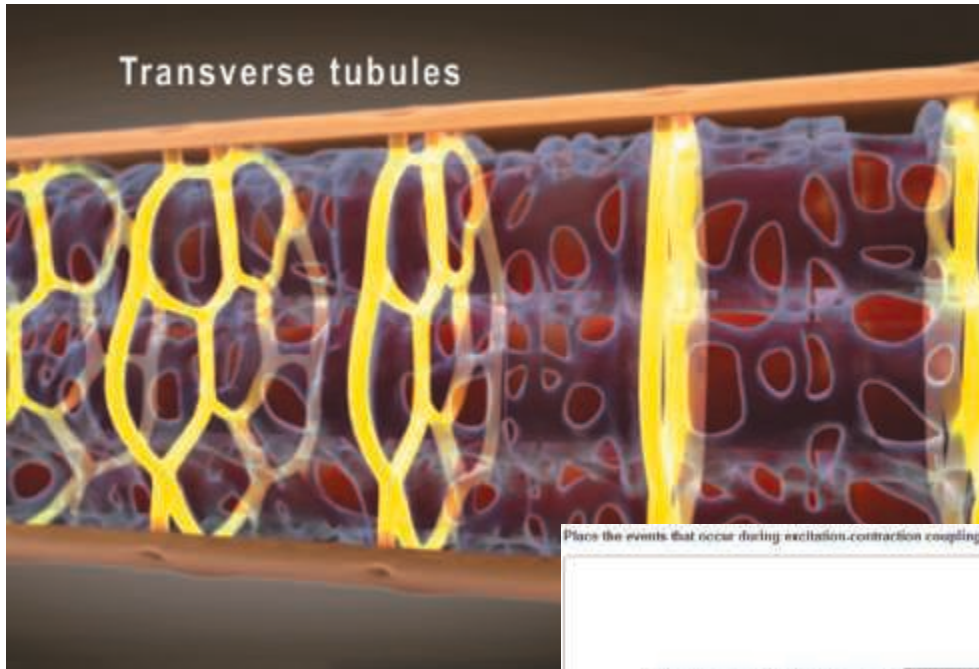
- Resting Membrane Potential
- Electrical Activity of the Heart
- Cardiac Output
- Factors Affecting Blood Pressure
- Generation of an Action Potential

## Coming Soon:

- Cardiac Cycle
- Glomerular Filtration
- Neuromuscular Junction
- Tubular Reabsorption and Secretion
- Excitation Contraction Coupling

# More Learning

**A&P Flix Coaching Activities** bring interactivity to these popular 3D movie-quality animations by asking students to answer questions related to the video.



Place the events that occur during excitation-contraction coupling in the correct order from left to right.

[Reset](#) [Help](#)

AP generated by motor neuron Contraction of skeletal muscle fiber

[Home](#) [My Answers](#) [Give Up](#) [Review Part](#)

**Incorrect; Try Again**  
The AP causes the voltage-sensitive proteins located in the T tubules to change shape.

## Additional assignable Pearson Mastering A&P activities include:

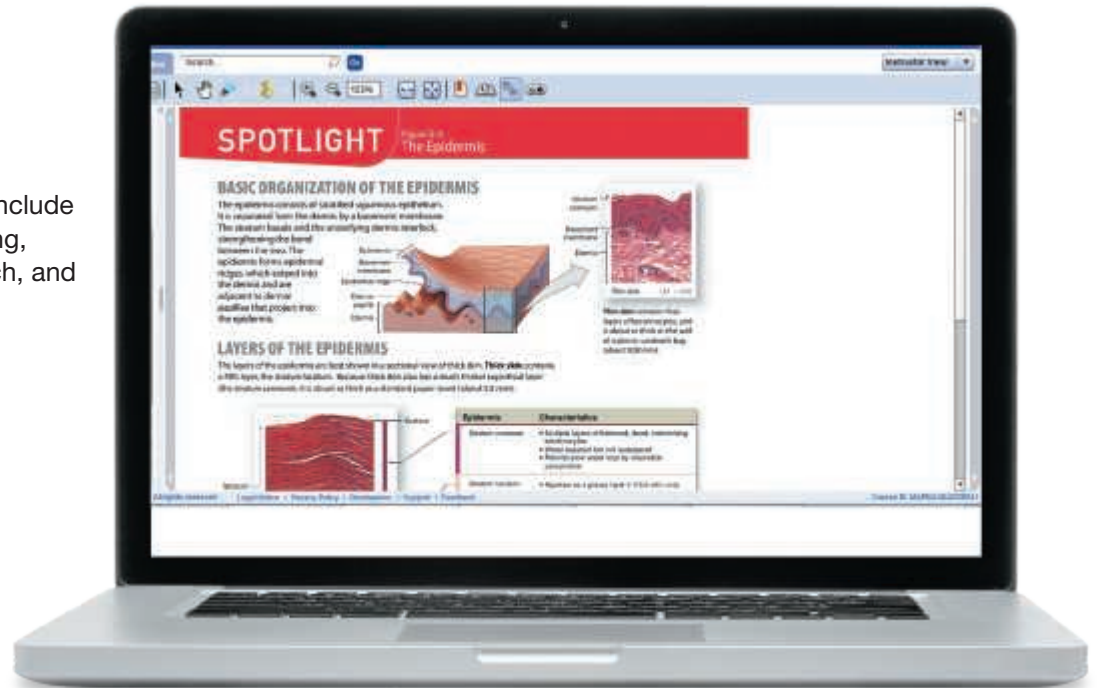
- Spotlight Figure Coaching Activities
- Clinical Case Activities
- Clinical Note Activities
- Bone & Dissection Video Coaching Activities
- And More!

**NEW!** Beginning Fall 2017, all of the assignments from Wood's *Laboratory Manual for A&P featuring Martini Art, 6e* can be accessed in your *Fundamentals of A&P* Mastering course! Only one Pearson Mastering A&P code is needed to access these assignments.

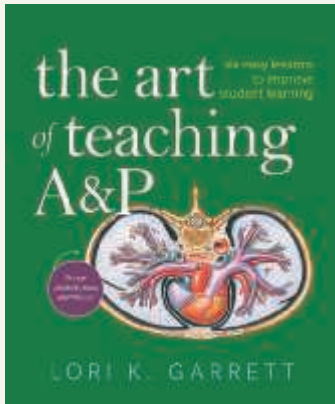


# Online with Pearson eText

**Powerful interactive and customization functions** include instructor and student note-taking, highlighting, bookmarking, search, and links to glossary terms.



# Instructor and Student Support

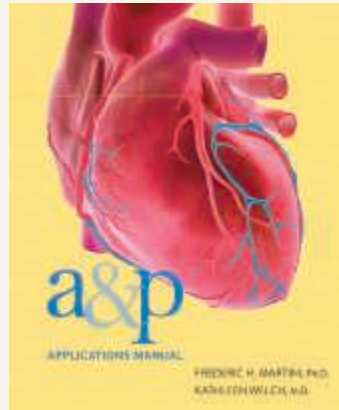


## **NEW! The Art of Teaching A&P: Six Easy Lessons to Improve Student Learning by Lori K. Garrett**

978-0-13-446951-5

0-13-446951-8

Author Lori Garrett (*Get Ready for A&P*) explores some of the most common challenges she's encountered in her classroom when using art to teach anatomy and physiology. From describing the challenge to researching why it occurs and proposing solutions to address it, Lori provides insight into how students look at images. She presents ideas for how educators can best use figures and illustrations to teach complex concepts without overwhelming or discouraging their students.

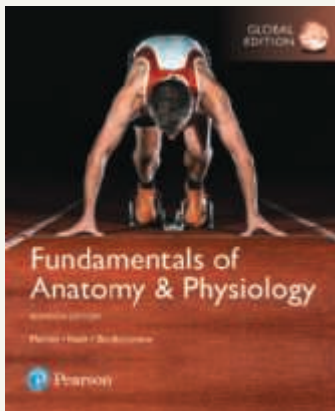


## **A&P Applications Manual by Frederic H. Martini and Kathleen Welch**

978-0-32-194973-8

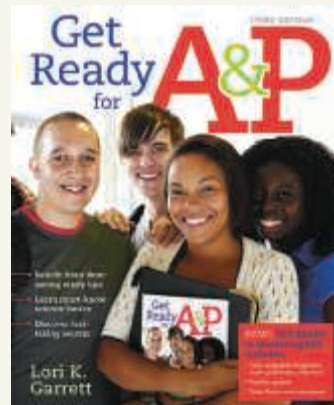
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This manual contains extensive discussions on clinical topics and disorders to help students apply the concepts of anatomy and physiology to daily life and their future health professions.



## **A complete package of instructor resources includes:**

- Customizable PowerPoint slides (with **NEW! Annotations on how to present complex art during lecture**)
- All figures from the book in JPEG format
- A&P Flix 3D movie-quality animations on tough topics (available on Mastering)
- Test Bank
- And more!

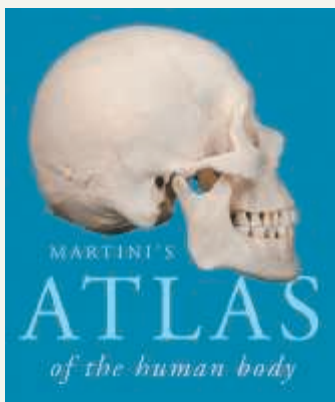


## **Get Ready for A&P by Lori K. Garrett**

978-0-32-181336-7

0-32-181336-7

This book and online component were created to help students be better prepared for their A&P course. Features include pre-tests, guided explanations followed by interactive quizzes and exercises, and end-of-chapter cumulative tests. Also available in the Study Area of Pearson Mastering A&P.



## **Martini's Atlas of the Human Body by Frederic H. Martini**

978-0-32-194072-8

0-32-194072-5

The Atlas offers an abundant collection of anatomy photographs, radiology scans, and embryology summaries, helping students visualize structures and become familiar with the types of images seen in a clinical setting.



## **Study Card for Martini: Body Systems Overview**

978-0-13-460995-9

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A six-panel laminated card showing all body systems and their organs and functions.

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Global Edition

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Dr. Judi Nath is a biology professor and the writer-in-residence at Lourdes University, where she teaches at both the undergraduate and graduate levels. Primary courses include anatomy, physiology, pathophysiology, medical terminology, and science writing. She received her bachelor's and master's degrees from Bowling Green State University, which included study abroad at the University of Salzburg in Austria. Her doctoral work focused on autoimmunity, and she completed her Ph.D. from the University of Toledo. Dr. Nath is devoted to her students and strives to convey the intricacies of science in captivating ways that are meaningful, interactive, and exciting. She has won the Faculty Excellence Award—an accolade recognizing effective teaching, scholarship, and community service—multiple times and in 2013 was named as an Ohio Memorable Educator. She is active in many professional organizations, notably the Human Anatomy and Physiology Society (HAPS), where she has served several terms on the board of directors. Dr. Nath is a coauthor of *Visual Anatomy & Physiology*, *Visual Essentials of Anatomy & Physiology*, *Anatomy & Physiology*, and *Human Anatomy* (published by Pearson), and she is the sole author of *Using Medical Terminology* and *Stedman's Medical Terminology* (published by Wolters Kluwer). Her favorite charities are those that have significantly affected her life, including the local Humane Society, the Cystic Fibrosis Foundation, and the ALS Association. In 2015, she and her husband established the Nath Science Scholarship at Lourdes University to assist students pursuing science-based careers. When not working, days are filled with family life, bicycling, and hanging with the dogs.



## William C. Ober, M.D.

Art Coordinator and Illustrator

Dr. Ober received his undergraduate degree from Washington and Lee University and his M.D. from the University of Virginia. He also studied in the Department of Art as Applied to Medicine at Johns Hopkins University. After graduation, Dr. Ober completed a residency in Family Practice and later was on the faculty at the University of Virginia in the Department of Family Medicine and in the Department of Sports Medicine. He also served as Chief of Medicine of Martha Jefferson Hospital in Charlottesville, Virginia. He is currently a Visiting Professor of Biology at Washington and Lee University, where he has taught several courses and



led student trips to the Galapagos Islands. He was on the Core Faculty at Shoals Marine Laboratory for 24 years, where he taught Biological Illustration every summer. Dr. Ober has collaborated with Dr. Martini on all of his textbooks in every edition.

### Claire E. Ober, R.N.

*Illustrator*

Claire E. Ober, R.N., B.A., practiced family, pediatric, and obstetric nursing before turning to medical illustration as a full-time career. She returned to school at Mary Baldwin College, where she received her degree with distinction in studio art. Following a 5-year apprenticeship, she has worked as Dr. Ober's partner in Medical & Scientific Illustration since 1986. She was on the Core Faculty at Shoals Marine Laboratory and co-taught the Biological Illustration course with Dr. Ober for 24 years. The textbooks illustrated by Medical & Scientific Illustration have won numerous design and illustration awards.



### Kathleen Welch, M.D.

*Clinical Consultant*

Dr. Welch received her B.A. from the University of Wisconsin–Madison, her M.D. from the University of Washington in Seattle, and did her residency in Family Practice at the University of North Carolina in Chapel Hill. Participating in the Seattle WWAMI rural medical education program, she studied in Fairbanks, Anchorage, and Juneau, Alaska, with time in Boise, Idaho, and Anacortes, Washington, as well. For 2 years, she served as Director of Maternal and Child Health at the LBJ Tropical Medical Center in American Samoa and subsequently was a member of the Department of Family Practice at the Kaiser Permanente Clinic in Lahaina, Hawaii, and on the staff at Maui Memorial Hospital. She was in private practice from 1987 until her retirement in 2012. Dr. Welch is a Fellow of the American Academy of Family Practice and a member of the Hawaii Medical Association, the Maui County Medical Association, and the Human Anatomy and Physiology Society (HAPS). With Dr. Martini, she has coauthored both a textbook on anatomy and physiology and the *A&P Applications Manual*. She and Dr. Martini were married in 1979, and they have one son.



### Ralph T. Hutchings

*Biomedical Photographer*

Mr. Hutchings was associated with the Royal College of Surgeons for 20 years. An engineer by training, he has focused for years on photographing the structure of the human body. The result has been a series of color atlases, including the *Color Atlas of Human Anatomy*, the *Color Atlas of Surface Anatomy*, and *The Human Skeleton* (all



published by Mosby-Yearbook Publishing). For his anatomical portrayal of the human body, the International Photographers Association has chosen Mr. Hutchings as the best photographer of humans in the 20th century. He lives in North London, where he tries to balance the demands of his photographic assignments with his hobbies of early motor cars and airplanes.

### Christine Boudrie, M.D.

*Clinical Contributor*

Dr. Boudrie studied at Brown University in Providence, Rhode Island, for her B.S. in biology, and also obtained her M.D. there. After graduation she served in the National Health Service Corps, a program of the U.S. Public Health Service, which sponsored her last 2 years of medical school. She was assigned to provide health education to the rural communities of southeast Michigan with a special focus on seniors. She has had the great pleasure of working with a variety of undergraduate and graduate students in the Northeast and Midwest, earning teaching excellence awards and a nomination for Carnegie Foundation's U.S. Professor of the Year in 2014. Currently, she chairs the Department of Biology and Health Sciences at Lourdes University, a small Franciscan liberal arts school in northwest Ohio.



### Ruth Anne O'Keefe, M.D.

*Clinical Contributor*

Dr. O'Keefe did her undergraduate studies at Marquette University, attended graduate school at the University of Wisconsin, and received her M.D. from George Washington University. She was the first woman to study orthopedics at The Ohio State University during her residency. She did fellowship training in trauma surgery at Loma Linda University in California. She serves on the board of Global Health Partnerships, a group that partners with a clinic serving 35,000 people in remote Kenya. She lives in Albuquerque with her Sweet Ed. She is mother of four, grandmother of nine, and foster mother to many.



### Kevin Petti, PhD

*Smart Art Video Contributor*

Dr. Petti is a professor at San Diego Miramar College, and teaches courses in human anatomy and physiology, human dissection, and health education. He is President Emeritus of the Human Anatomy and Physiology Society (HAPS) and holds a doctorate from the University of San Diego. As a dual U.S./Italian citizen, he also teaches courses in Italy that focus on the genesis of anatomy as a science and its influence on the Renaissance masters.



# Preface

The Eleventh Edition of *Fundamentals of Anatomy & Physiology* is a comprehensive textbook that fulfills the needs of today's students while addressing the concerns of their teachers. We focused our attention on the question "How can we make this information meaningful, manageable, and comprehensible?" During the revision process, we drew upon our content knowledge, research skills, artistic talents, and years of classroom experience to make this edition the best yet.

The broad changes to this edition are presented in the **New to the Eleventh Edition** section below, and the specific changes are presented in the **Chapter-by-Chapter Changes in the Eleventh Edition** section that follows.

## New to the Eleventh Edition

In addition to the many technical changes in this edition, such as updated statistics and anatomy and physiology descriptions, we have made the following key changes:

- **NEW SmartArt Videos** help students better navigate key, complex pieces of art. Author Kevin Petti walks students through select pieces of art from the book, providing additional background and detail.
- **NEW design for homeostasis figures** replaces former Tenth Edition figures in various chapters.
- **NEW Questions have been added to selected figures in all chapters to reinforce text–art integration.**
- **Easier narrative leads to improved clarity of text.** Clearly organized text uses simpler, shorter, more active sentences, with a reading level that makes reading and studying easier for students.
- **Anatomical terms** have been updated based on *Terminologia Anatomica*, *Terminologia Histologica*, and *Terminologia Embryologica*. Eponyms continue to be included within the narrative.

## Hallmark Features of This Text

- **50 Spotlight Figures** provide highly visual one- and two-page presentations of tough topics in the book, with a particular focus on physiology.
- **29 Clinical Cases** get students motivated for their future careers. Each chapter opens with a story-based Clinical Case related to the chapter content and ends with a Clinical Case Wrap-Up.
- **The repetition of the chapter-opening Learning Outcomes below the coordinated section headings within the chapters** underscores the connection between the

HAPS-based Learning Outcomes and the associated teaching points. Author Judi Nath sat on the Human Anatomy and Physiology Society (HAPS) committee that developed the HAPS Learning Outcomes recommended to A&P teachers, and the Learning Outcomes in this book are based on them.

## Chapter-by-Chapter Changes in the Eleventh Edition

This annotated Table of Contents provides examples of revision highlights in each chapter of the Eleventh Edition. For a more complete list of changes, please contact the publisher.

### Chapter 1: An Introduction to Anatomy and Physiology

- Added a new Section 1–1 on using the text and art in tandem.
- New separate section (1–4) on medical terminology.
- Reorganized the chapter to start with simpler anatomical topics and build to more complex physiological ones. Homeostasis and the roles of negative feedback now conclude the chapter as Sections 1–7 and 1–8, respectively.
- NEW Figure 1–1 A Conceptual Framework for Learning
- NEW Clinical Note: *Habeas Corpus* ("You Shall Have the Body")
- NEW Clinical Note: The Sounds of the Body
- Figure 1–8 The Control of Room Temperature (new homeostasis design)
- Figure 1–9 Negative Feedback: Control of Body Temperature (new homeostasis design)
- Former Spotlight Figure 1–10 Diagnostic Imaging Techniques is now a Clinical Note.
- Questions added to Figures 1–3, 1–4, 1–5, 1–6, and 1–9.

### Chapter 2: The Chemical Level of Organization

- Clinical Case: What Is Wrong with My Baby? revised
- Clinical Note: Radiation Sickness revised
- NEW Figure 2–1 Hydrogen Atom with Electron Cloud
- NEW Section 2–9 gathers together coverage of monomers, polymers, and functional groups to provide an overview to the organic compounds.
- Table 2–8. Turnover Times moved to the Appendix as Turnover Times of Organic Components of Four Cell Types.
- NEW Clinical Note: Too Sweet on Sugar?
- Questions added to Figures 2–3, 2–8, 2–9, 2–12, 2–15, 2–17, 2–24, and 2–26.

### Chapter 3: The Cellular Level of Organization

- Clinical Case: The Beat Must Go On! revised (new title)
- Figure 3–2 The Plasma Membrane revised (new added part b)
- Figure 3–8 Lysosome Functions revised
- NEW Clinical Note: Lysosomal Storage Disease
- NEW Clinical Note: Free Radicals
- Figure 3–13 The Process of Translation revised

- NEW Clinical Note: Drugs and the Plasma Membrane
- Figure 3–21 Receptor–Mediated Endocytosis revised
- Spotlight Figure 3–23 Stages of a Cell’s Life Cycle revised
- Questions added to Figures 3–3, 3–9, 3–11, 3–15, 3–17, 3–18, and 3–19.

#### Chapter 4: The Tissue Level of Organization

- NEW Figure 4–1 An Orientation to the Body’s Tissues
- Figure 4–2 Cell Junctions revised (*basal lamina* replaces *clear layer* and *reticular lamina* replaces *dense layer*)
- Table 4–1. Classifying Epithelia revised
- Connective tissue proper has been separated out into its own section, Section 4–5. This section now also includes the discussion of fasciae.
- Figure 4–9 The Cells and Fibers of Connective Tissue Proper revised (added fibrocyte)
- Figure 4–10 Embryonic Connective Tissues revised (now share labels)
- The fluid connective tissues blood and lymph now have their own section, Section 4–6.
- Questions added to Figures 4–3, 4–14, 4–16, 4–18, and 4–19.

#### Chapter 5: The Integumentary System

- NEW Clinical Case: He Has Fish Skin!
- Figure 5–1 The Components of the Integumentary System revised
- The dermis and hypodermis sections have been moved up to become Sections 5–2 and 5–3, respectively, to give students more anatomical background to understand the later physiological sections.
- Spotlight Figure 5–3 The Epidermis revised (matched SEM and art)
- NEW Clinical Note: Nips, Tucks, and Shots
- Figure 5–12 Hair Follicles and Hairs revised (new part b)
- Figure 5–14 Sweat Glands revised (uses *eccrine sweat glands* as primary term)
- NEW Clinical Note: Your Skin, A Mirror of Your Health
- NEW Clinical Note: Burns and Grafts
- NEW Build Your Knowledge Figure 5–15 Integration of the INTEGUMENTARY system with the other body systems presented so far (replaces System Integrator)
- Questions added to Figures 5–1, 5–6, 5–8, 5–10, and 5–13.

#### Chapter 6: Bones and Bone Structure (formerly called Osseous Tissue and Bone Structure)

- NEW Figure 6–4 Bone Lacking a Calcified Matrix
- Figure 6–5 Types of Bone Cells revised (art and layout to parallel text)
- NEW Figure 6–6 Osteons of Compact Bone (former part a removed)
- We now clarify in the section titles that Section 6–5 covers both interstitial and appositional growth, while remodeling is covered in Section 6–6.
- Spotlight Figure 6–17 Types of Fractures and Steps in Repair revised (tibia replaces humerus to better match photograph)
- Questions added to Figures 6–3, 6–5, 6–7, and 6–10.

#### Chapter 7: The Axial Skeleton

- Figure 7–2 Cranial and Facial Subdivisions of the Skull revised

- Figure 7–3 The Adult Skull revised (hyphenates the terms *supra-orbital* and *infra-orbital*)
- Figure 7–9 The Ethmoid revised (*ethmoidal labyrinth* replaces *lateral mass*)
- Spotlight Figure 7–4 Sectional Anatomy of the Skull revised (updated trigeminal nerve [V] terminology)
- Figure 7–14 The Orbital Complex revised (art and photograph now share labels)
- Figure 7–15 The Nasal Complex revised (part b new art)
- Figure 7–17 The Vertebral Column revised (new color-coded vertebral regions)
- Figure 7–22 Sacrum and Coccyx revised (new coccyx label configuration)
- Questions added to Figures 7–16, 7–17, and 7–23.

#### Chapter 8: The Appendicular Skeleton

- NEW Clinical Case: Timber!!
- Figure 8–6 Bones of the Right Wrist and Hand revised (carpal bones separated out into proximal and distal carpals)
- NEW Clinical Note: Shin Splints
- Clinical Note: Carpal Tunnel Syndrome includes new illustration
- Questions added to Figures 8–1, 8–6, 8–8, and 8–12.

#### Chapter 9: Joints

- NEW Clinical Note: Bursitis and Bunions
- NEW Clinical Note: Dislocation
- Spotlight Figure 9–2 Joint Movement revised (headings labeled as parts a, b, and c; *plane joint* replaces *gliding joint*)
- Figure 9–5 Special Movements (part labels added; arrows moved onto photographs in new parts d and e)
- Section 9–5 now covers the hinge joints of the elbow and knee, while Section 9–6 covers the ball-and-socket shoulder and hip joints.
- NEW Build Your Knowledge Figure 9–11 Integration of the SKELETAL system with the other body systems presented so far (replaces System Integrator)
- Questions added to Figures 9–1, 9–3, 9–6, and 9–9.

#### Chapter 10: Muscle Tissue

- NEW Clinical Case: Keep on Keepin’ On
- Figure 10–1 The Organization of Skeletal Muscles revised (added tendon attachment to bone)
- Figure 10–5 Sarcomere Structure, Superficial and Cross-Sectional Views revised (new figure icon)
- Figure 10–6 Levels of Functional Organization in a Skeletal Muscle revised (new grouping of art)
- Figure 10–7 Thin and Thick Filaments revised (new art for parts b, c, and d)
- Spotlight Figure 10–9 Events at the Neuromuscular Junction revised (art now shows Na<sup>+</sup> flow through membrane channels)
- Spotlight Figure 10–11 The Contraction Cycle and Cross-Bridge Formation revised (improved step boxes visibility)
- Figure 10–16 Effects of Repeated Stimulations revised (new art organization and explanatory text)
- Information about tension production at the level of skeletal muscles has been separated out into a new section, Section 10–6.
- Figure 10–20 Muscle Metabolism revised (text and art in bottom box)

- Figure 10–21 Fast versus Slow Fibers revised (micrograph is a TEM not LM)
- Coverage of muscle fatigue has been moved from the muscle metabolism section to the muscle performance section, Section 10–8.
- NEW Clinical Note: Electromyography
- Discussion on the effects of skeletal muscle aging has been moved from Chapter 11 and included with muscle hypertrophy and atrophy in Section 10–8.
- Questions added to Figures 10–3, 10–6, 10–14, and 10–21.

### Chapter 11: The Muscular System

- NEW Clinical Case: Downward-Facing Dog
- Figure 11–1 Muscle Types Based on Pattern of Fascicle Organization revised
- Figure 11–2 The Three Classes of Levers revised (new icons for each lever)
- Spotlight Figure 11–3 Muscle Action revised (new art in part c)
- The introduction to axial and appendicular muscles has been made into a separate section, Section 11–5, to provide an overview before we cover the muscles in detail.
- NEW Clinical Note: Signs of Stroke
- Figure 11–12 Oblique and Rectus Muscles and the Diaphragm revised (added *transversus thoracis* label to part c)
- Figure 11–17 Muscles That Move the Forearm and Hand revised (corrected leader for *triceps brachii*, *medial head*)
- Figure 11–18 Muscles That Move the Hand and Fingers revised
- Figure 11–21 Muscles That Move the Leg revised (*quadriceps femoris* replaces *quadriceps muscles*)
- NEW Build Your Knowledge Figure 11–24 Integration of the MUSCULAR system with the other body systems presented so far (replaces System Integrator)
- Questions added to Figures 11–5, 11–6, 11–10, 11–17, 11–19, and 11–21.

### Chapter 12: Nervous Tissue

- Chapter title changed from Neural Tissue to Nervous Tissue
- Section 12–1 includes discussion of the Enteric Nervous System (ENS) as a third division of the nervous system
- Figure 12–1 A Functional Overview of the Nervous System revised (added a body figure to support text-art integration)
- Moved coverage of synapse structures from Section 12–2 into Section 12–7 so it is now right before students need it to understand synaptic function.
- Figure 12–3 Structural Classification of Neurons revised (moved part labels and text above art)
- Figure 12–5 Neuroglia in the CNS revised (deleted micrograph; label grouping for neuroglia)
- Schwann cell text updated (*neurolemmocytes* replaces *neurilemma cells* and *neurolemma* replaces *neurilemma*).
- Figure 12–7 Peripheral Nerve Regeneration after Injury revised
- Spotlight Figure 12–8 Resting Membrane Potential revised (text revised in first two columns)
- Figure 12–9 Electrochemical Gradients for Potassium and Sodium Ions revised (text revised in part c)
- Figure 12–11 Graded Potentials revised (text in step 2)
- NEW Spotlight Figure 12–13 Generation of an Action Potential revised (text in step boxes)

- Figure 12–14 Propagation of an Action Potential revised (added part labels)
- NEW Figure 12–16 Events in the Functioning of a Cholinergic Synapse revised (now runs across two pages; text in steps revised)
- Table 12–4 Representative Neurotransmitters and Neuromodulators revised (endorphins separated from opioids)
- Figure 12–17 Mechanisms of Neurotransmitter and Receptor Function revised (chemically gated ion channel art now matches that in previous figures)
- Questions added to Figures 12–2, 12–4, and 12–16.

### Chapter 13: The Spinal Cord, Spinal Nerves, and Spinal Reflexes

- Figure 13–1 An Overview of Chapters 13 and 14 revised
- Figure 13–2 Gross Anatomy of the Adult Spinal Cord revised (added new part b)
- Uses the term *posterior* and *anterior* in reference to spinal roots, ganglion, and rami instead of *dorsal* and *ventral* (e.g., Figure 13–3, 13–4, 13–5, and Spotlight Figure 13–8)
- Figure 13–6 A Peripheral Nerve revised (corrected magnified section in part a)
- NEW Figure 13–9 Nerve Plexuses and Peripheral Nerves revised (labels grouped and boxed)
- Figure 13–10 The Cervical Plexus revised (corrected cranial nerve designation, e.g., *accessory nerve [XI]* replaces *accessory nerve [N XI]*)
- Figure 13–12 The Lumbar and Sacral Plexuses revised (removed Clinical Note)
- Spotlight Figure 13–14 Spinal Reflexes revised (added part labels to better coordinate with text)
- Figure 13–15 The Classification of Reflexes revised (reorganized categories within inclusive boxes)
- Figure 13–17 The Plantar Reflex and Babinski Reflex revised (*Babinski reflex* replaces *Babinski sign/positive Babinski reflex* and *plantar reflex* replaces *negative Babinski reflex*)
- Questions added to Figures 13–3, 13–5, 13–9, and 13–15.

### Chapter 14: The Brain and Cranial Nerves

- Figure 14–1 An Introduction to Brain Structures and Functions revised (added part labels a–f to better coordinate with text)
- Figure 14–2 Ventricular System revised (*ventricular system of the brain* replaces *ventricles of the brain*)
- Figure 14–3 The Relationships among the Brain, Cranium, and Cranial Meninges revised (*periosteal cranial dura* replaces *dura mater [periosteal layer]* and *meningeal cranial dura* replaces *dura mater [meningeal layer]*)
- Figure 14–5 The Diencephalon and Brainstem revised (corrected cranial nerve designation, e.g., in Cranial Nerves box, CN replaces N for nerve designations.)
- The sections on the midbrain (now Section 14–5) and cerebellum (now Section 14–6) have been switched, so that we now cover all of the brainstem together.
- Figure 14–10 The Thalamus revised (thalamic nuclei labels now color coded to clarify brain regions that receive thalamic input; *medial geniculate body* and *lateral geniculate body* replace *medial geniculate nucleus* and *lateral geniculate nucleus*)
- Figure 14–18 Origins of the Cranial Nerves revised (new brain cadaver photograph; cranial nerve labels boxed together)
- Questions added to Figures 14–1, 14–3, 14–9, 14–13, 14–15, 14–22, and 14–26.

**Chapter 15: Sensory Pathways and the Somatic Nervous System**

- Figure 15–1 An Overview of Events Occurring Along the Sensory and Motor Pathways revised
- Figure 15–2 Receptors and Receptive Fields revised (different colors for each receptive field and added Epidermis and Free nerve endings labels)
- Figure 15–3 Tonic and Phasic Sensory Receptors revised (new background colors for graphs)
- Figure 15–4 Tactile Receptors in the Skin revised (added *myelin sheath* to afferent nerve fiber in part c; part d, *bulbous corpuscle* replaces *Ruffini corpuscle*; part e, *lamellar [pacinian] corpuscle* replaces *lamellated [pacinian] corpuscle*)
- NEW Figure 15–6 Locations and Functions of Chemoreceptors
- Figure 15–7 Sensory Pathways and Ascending Tracts in the Spinal Cord revised (*gracile fasciculus* replaces *fasciculus gracilis*, *cuneate fasciculus* replaces *fasciculus cuneate*)
- Spotlight Figure 15–8 Somatic Sensory Pathways revised (introduced “somatotopy” in Sensory Homunculus boxed text)
- Questions added to Figures 15–1, 15–2, 15–4, 15–7, and 15–10.

**Chapter 16: The Autonomic Nervous System and Higher-Order Functions**

- NEW Clinical Case: Remember Me?
- NEW Spotlight Figure 16–2 The Autonomic Nervous System (incorporates old Figures 16–4 and 16–6. added Pons and Medulla oblongata labels on the art)
- A new summary Section 16–6 called “The differences in the organization of sympathetic and parasympathetic structures lead to widespread sympathetic effects and specific parasympathetic effects” has been created.
- The sections on memory, states of consciousness, and behavior have been combined into Section 16–9.
- Figure 16–11 The Reticular Activating System (RAS) revised (*CN II* and *CN VIII* replace *N II* and *N VIII*, respectively)
- NEW Build Your Knowledge Figure 16–12 Integration of the NERVOUS system with the other body systems presented so far (replaces System Integrator)
- Questions added to Figures 16–1, 16–3, 16–4, 16–7, and 16–11.

**Chapter 17: The Special Senses**

- Figure 17–1 The Olfactory Organs revised (I replaces N I)
- Spotlight Figure 17–2 Olfaction and Gustation revised (added part a and b labels)
- Figure 17–3 Papillae, Taste Buds, and Gustatory Receptor Cells revised (new figure title; added *Midline groove* label to part a)
- Figure 17–4 External Features and Accessory Structures of the Eye revised (*lateral angle* replaces *lateral canthus*, *medial angle* replaces *medial canthus*, *bulbar conjunctiva* replaces *ocular conjunctiva*, *eyelid* replaces *palpebrae*)
- Figure 17–5 The Sectional Anatomy of the Eye revised (*corneo-scleral junction* replaces *corneal limbus*)
- Figure 17–6 The Pupillary Muscles revised (*dilator pupillae* replaces *pupillary dilator muscles*; *sphincter pupillae* replaces *pupillary constrictor*)
- Figure 17–7 The Organization of the Retina revised (*pigmented layer of retina* replaces *pigmented part of retina*; switched parts b and c to parallel new sequence in the text)
- A new overview section, Section 17–4, called “The focusing of light on the retina leads to the formation of a visual image” has been created in the text.

- Figure 17–10 Factors Affecting Focal Distance revised (clarified text within figure; added Focal point label to all the art)
- Figure 17–11 Accommodation revised (*fovea centralis* replaces *fovea*)
- Figure 17–14 Structure of Rods, Cones, and the Rhodopsin Molecule revised (*pigmented epithelium* replaces *pigment epithelium*)
- Figure 17–23 The Internal Ear revised (*ampullary crest* replaces *crista ampullaris*; clarified position of membranous labyrinth in part a art)
- Figure 17–24 The Semicircular Ducts revised (*ampullary cupula* replaces *cupula*; *vestibular nerve* replaces *vestibular branch* in part a)
- Figure 17–26 Pathways for Equilibrium Sensations revised (*cochlear nerve* replaces *cochlear branch*)
- Figure 17–30 Sound and Hearing revised (added new art to illustrate step 4)
- Figure 17–32 Pathways for Auditory Sensations revised (auditory replaces sound and acoustic in steps 2 and 5)
- Questions added to Figures 17–4, 17–7, 17–21, and 17–28.

**Chapter 18: The Endocrine System**

- Figure 18–1 Organs and Tissues of the Endocrine System revised (clarified hormones in Gonads box)
- Table 18–1 Mechanisms of Intercellular Communication revised (added autocrine communication)
- Spotlight Figure 18–3 G Proteins and Second Messengers revised (added positive feedback involving protein kinase C; clarified calcium ion sources for binding with calmodulin)
- Figure 18–6 Three Mechanisms of Hypothalamic Control over Endocrine Function revised (removed numbers and added color coding to enhance links between hypothalamic structures and functions)
- Figure 18–7 The Hypophyseal Portal System and the Blood Supply to the Pituitary Gland revised (*regulatory hormones* replaces *regulatory factors*)
- Figure 18–8 Feedback Control of Endocrine Secretion revised (added two banners to separate part a from parts b and c; incorporated old part d with a new color-coded table within part a)
- Figure 18–9 Pituitary Hormones and Their Targets revised (added color codes to correlate with Figure 18–6)
- Figure 18–11 Synthesis and Regulation of Thyroid Hormones (added step art to part a that describes synthesis, storage, and secretion of thyroid hormones; added new homeostasis design to part b that illustrates the regulation of thyroid secretion)
- Figure 18–12 Anatomy of the Parathyroid Glands revised (*principal cells* replaces *chief cells*)
- Figure 18–13 Homeostatic Regulation of the Blood Calcium Ion Concentration revised (new homeostasis design)
- Figure 18–14 The Adrenal Gland and Adrenal Hormones revised (added new micrograph and new design for part c)
- Figure 18–17 Homeostatic Regulation of the Blood Glucose Concentration revised (new homeostasis design)
- Figure 18–19 Endocrine Functions of the Kidneys revised (new homeostasis design in part b)
- NEW Build Your Knowledge Figure 18–21 Integration of the ENDOCRINE system with the other body systems presented so far (replaces System Integrator)
- Questions added to Figures 18–6, 18–8, 18–9, 18–14, and 18–17.

**Chapter 19: Blood**

- NEW Clinical Case: Crisis in the Blood
- Section 19–1 now covers the main functions and characteristics of blood, as well as an introduction to both plasma and formed elements (combined with the old Section 19–2).
- Figure 19–4 Stages of RBC Maturation: Erythropoiesis and Figure 19–5 Recycling of Red Blood Cell Components sequence changed because of chapter reorganization.
- Figure 19–6 Blood Types and Cross-Reactions revised (corrected shapes of anti-A and anti-B antibodies)
- Figure 19–7 Blood Type Testing revised (anti-Rh replaces anti-D; added “clumping” or “no clumping” under test results for clarification)
- Figure 19–11 The Phases of Hemostasis (Vascular, Platelet, and Coagulation) and Clot Retraction revised (*clotting factors* replaces *platelet factors* in step 2; new blood clot SEM)
- Table 19–2. Differences in Blood Group Distribution revised
- Questions added to Figures 19–3, 19–5, 19–6, and 19–10.

**Chapter 20: The Heart**

- Figure 20–1 An Overview of the Cardiovascular System revised (new art and boxed labels)
- Figure 20–2 The Location of the Heart in the Thoracic Cavity revised (*parietal layer of serous pericardium* replaces *parietal pericardium*)
- Figure 20–4 The Heart Wall revised (*visceral layer of serous pericardium* replaces *epicardium [visceral pericardium]*)
- Figure 20–5 The Sectional Anatomy of the Heart revised (*tricuspid valve* replaces *right AV [tricuspid] valve*; *mitral valve* replaces *left AV [mitral] valve*)
- Figure 20–7 Valves of the Heart and Blood Flow revised (red arrows replace black arrows in part a; black arrows deleted in part b)
- Figure 20–10 The Conducting System of the Heart and the Pacemaker Potential revised (*pacemaker potential* replaces *prepotential*)
- Figure 20–11 Impulse Conduction through the Heart and Accompanying ECG Tracings revised (added ECG tracings next to the step art)
- Figure 20–12 An Electrocardiogram (ECG) revised (*QRS complex* replaces *QRS interval* in part b)
- Figure 20–14 Cardiac Contractile Cells revised (cardiac contractile cells replaces *cardiac muscle cells*; former Figure 20–5 moved because of chapter reorganization to provide structural information right before functional information)
- Figure 20–15 Action Potentials in Cardiac Contractile Cells and Skeletal Muscle Fibers revised (*ventricular contractile cell* replaces *ventricular muscle cell*)
- Figure 20–16 Phases of the Cardiac Cycle revised (moved labels for Atrial systole, Atrial diastole, Ventricular systole, and Ventricular diastole to perimeter of art for increased correlation)
- Figure 20–17 Pressure and Volume Relationships in the Cardiac Cycle revised (modified colors of banners to match the perimeter art of Figure 20–16 Phases of the Cardiac Cycle for increased correlation)
- Figure 20–19 Factors Affecting Cardiac Output revised (added EDV and ESV)
- Figure 20–23 Factors Affecting Stroke Volume revised (added key)
- Figure 20–24 A Summary of the Factors Affecting Cardiac Output revised (deleted arrow from Preload to End-systolic volume box)
- Table 20–1 Structural and Functional Differences between Cardiac Contractile Cells and Skeletal Muscle Fibers revised (*cardiac contractile cells* replaces *cardiac muscle cells*)
- Questions added to Figures 20–1, 20–5, 20–11, 20–15, 20–21, and 20–24.

**Chapter 21: Blood Vessels and Circulation**

- Figure 21–2 Histological Structures of Blood Vessels revised (added luminal diameters for all vessels)
- Figure 21–4 The Organization of a Capillary Bed revised (deleted metarterioles)
- Figure 21–8 Relationships among Vessel Luminal Diameter, Cross-Sectional Area, Blood Pressure, and Blood Velocity within the Systemic Circuit revised (*vessel luminal diameter* replaces *vessel diameter* in part a; *vessel lumens* replaces *vessels* in part b)
- Figure 21–11 Forces Acting across Capillary Walls revised (added tissue cells background)
- The discussion of vasomotion has been moved from Section 21–1 to Section 21–3, to cover this process with other vessel physiology.
- Figure 21–12 Short-Term and Long-Term Cardiovascular Responses revised (new homeostasis design)
- Figure 21–13 Baroreceptor Reflexes of the Carotid and Aortic Sinuses revised (new homeostasis design)
- Figure 21–14 The Chemoreceptor Reflexes revised (new homeostasis design)
- Figure 21–15 The Hormonal Regulation of Blood Pressure and Blood Volume revised (new homeostasis design)
- Figure 21–16 Cardiovascular Responses to Blood Loss revised (new homeostasis design)
- Figure 21–24 Arteries Supplying the Abdominopelvic Organs revised
- Figure 21–27 Major Veins of the Head, Neck, and Brain revised (added confluence of sinuses to parts a, b and c)
- Figure 21–28 The Venous Drainage of the Abdomen and Chest revised (*median sacral* replaces *medial sacral*; *hemi-azygos* replaces *hemiazgyos*)
- Figure 21–29 Flowchart of Circulation to the Superior and Inferior Venae Cavae revised
- Figure 21–31 The Hepatic Portal System revised
- NEW Build Your Knowledge Figure 21–34 Integration of the CARDIOVASCULAR system with the other body systems presented so far (replaces System Integrator)
- Questions added to Figures 21–2, 21–7, 21–12, 21–15, 21–21, and 21–29.

**Chapter 22: The Lymphatic System and Immunity**

- The coverage of the lymphatic system is now Section 22–1.
- Figure 22–1 The Components of the Lymphatic System revised (Other Lymphoid Tissues and Organs heading replaces Lymphoid Tissues and Organs heading because lymph nodes are organs)
- Figure 22–5 Lymphoid Nodules moved (formerly Figure 22–7, moved due to chapter reorganization)
- Figure 22–6 The Structure of a Lymph Node revised and moved (*cortex* replaces *outer cortex*; *paracortex* replaces *deep cortex*; formerly Figure 22–8, moved due to chapter reorganization)
- Figure 22–7 The Thymus moved (formerly Figure 22–9, moved due to chapter reorganization)
- Figure 22–8 The Spleen moved (formerly Figure 22–10, moved due to chapter reorganization)
- The original Section 22–1 has been moved to become Section 22–2 and adapted so that it is now titled “Lymphocytes are important to the innate (nonspecific) and adaptive (specific) defenses that protect the body.”
- We have broadened the definition of the term “immune response” from a “defense against specific antigens” to “the body’s reaction to infectious agents and abnormal substances.”



- Figure 22–9 The Origin and Distribution of Lymphocytes revised and moved (hemocytoblasts replaces multipotent hemopoietic stem cell; formerly Figure 22–10, moved due to chapter reorganization)
- Figure 22–10 Innate Defenses revised
- Figure 22–11 How Natural Killer Cells Kill Cellular Targets moved (formerly Figure 22–12, moved due to chapter reorganization)
- Figure 22–12 Interferons revised
- NEW Figure 22–13 Pathways of Complement Activation revised (added the Lectin Pathway)
- Figure 22–14 Inflammation and the Steps in Tissue Repair moved (formerly Figure 22–15, moved due to chapter reorganization)
- Figure 22–15 Classes of Lymphocytes revised and moved (*regulatory T cells* replaces *suppressor T cells*; formerly Figure 22–5, moved due to chapter reorganization)
- Figure 22–16 An Overview of Adaptive Immunity revised and moved (former title: An Overview of the Immune Response; formerly Figure 22–17, moved due to chapter reorganization)
- Figure 22–17 Forms of Immunity revised and moved (*acquired* replaces *induced*; formerly Figure 22–16, moved due to chapter reorganization)
- Figure 22–18 Antigens and MHC Proteins revised
- Spotlight Figure 22–21 Cytokines of the Immune System revised and moved (formerly Figure 22–28, moved due to chapter reorganization)
- Figure 22–22 A Summary of the Pathways of T Cell Activation revised and moved (*regulatory T cells* replaces *suppressor T cells*; formerly Figure 22–21, moved due to text reorganization)
- Figure 22–23 The Sensitization and Activation of B Cells moved (formerly Figure 22–22, moved due to chapter reorganization)
- Figure 22–24 Antibody Structure and Function moved (formerly Figure 22–23, moved due to chapter reorganization)
- Figure 22–27 An Integrated Summary of the Immune Response revised and moved (*regulatory T cells* replaces *suppressor T cells*; formerly Figure 22–26, moved due to chapter reorganization)
- NEW Build Your Knowledge Figure 22–30 Integration of the LYMPHATIC system with the other body systems presented so far (replaces System Integrator)
- Questions added to Figures 22–3, 22–8, 22–12, 22–17, 22–25, and 22–26.

### Chapter 23: The Respiratory System

- NEW Clinical Case: No Rest for the Weary
- Figure 23–3 The Structures of the Upper Respiratory System revised (*epithelial surface* replaces *superficial view* in micrograph of part a)
- Figure 23–3 The Structures of the Upper Respiratory System revised (*pharyngeal opening of auditory tube* replaces *nasopharyngeal meatus*)
- Original Sections 23–3 and 23–4 have been combined into a new Section 23–3 on the conducting portion of the lower respiratory system. This section now includes coverage of the bronchial tree.
- Figure 23–6 The Anatomy of the Trachea revised (cross-sectional diagram of trachea and esophagus replaces micrograph to better highlight trachealis)
- NEW Section 23–4 has been added titled “The respiratory portion of the lower respiratory system is where gas exchange occurs.” This covers the respiratory bronchioles, alveolar ducts and alveoli, and the blood air barrier.
- Figure 23–7 The Bronchi, Lobules, and Alveoli of the Lung revised and moved (new art in part c; formerly Figure 23–9, moved due to chapter reorganization)

- Figure 23–8 Alveolar Organization revised and moved (*pneumocyte type I* and *type II* replaces *type I* and *type II pneumocyte*; *blood air barrier* replaces *respiratory membrane*; formerly Figure 23–10, moved due to chapter reorganization)
- Figure 23–9 The Gross Anatomy of the Lungs revised and moved (formerly Figure 23–7, moved due to chapter reorganization)
- Figure 23–10 The Relationship between the Lungs and Heart revised (labeled Anterior border in part b; formerly Figure 23–8, moved due to chapter reorganization)
- Figure 23–11 An Overview of the Key Steps in Respiration revised
- NEW Figure 23–13 Primary and Accessory Respiratory Muscles
- NEW Spotlight Figure 23–14 Pulmonary Ventilation
- Figure 23–15 Pressure and Volume Changes during Inhalation and Exhalation revised and moved (outlined boxes with same color as respective line graphs for better correlation; formerly Figure 23–14, moved due to chapter reorganization)
- Figure 23–16 Pulmonary Volumes and Capacities revised
- Figure 23–18 An Overview of Respiratory Processes and Partial Pressures in Respiration revised (added new icon art)
- Figure 23–23 A Summary of the Primary Gas Transport Mechanisms revised (added oxygen and carbon dioxide partial pressure values)
- Spotlight Figure 23–25 Control of Respiration revised
- Figure 23–26 The Chemoreceptor Response to Changes in  $P_{CO_2}$  revised (new homeostasis design)
- NEW Build Your Knowledge Figure 23–28 Integration of the RESPIRATORY system with the other body systems presented so far (replaces System Integrator)
- Questions added to Figures 23–2, 23–7, 23–8, 23–13, 23–16, 23–20, and 23–26.

### Chapter 24: The Digestive System

- Figure 24–1 Components of the Digestive System revised (*mechanical digestion* replaces *mechanical processing*)
- Figure 24–2 The Mesenteries revised (added Visceral peritoneum label to part d)
- Figure 24–3 Histological Organization of the Digestive Tract revised (*muscular layer* replaces *muscularis externa*; *intestinal glands* replaces *mucosal glands*; *submucosal neural plexus* replaces *submucosal plexus*)
- Figure 24–4 Peristalsis revised (Initial State now step 1)
- Figure 24–6 Anatomy of the Oral Cavity revised (*oral vestibule* replaces *vestibule*; *frenulum of tongue* replaces *lingual frenulum*)
- Figure 24–7 The Teeth moved (formerly Figure 24–8, moved due to chapter reorganization)
- Figure 24–8 Deciduous and Permanent Dentitions revised (new title; *deciduous* replaces *primary*; *permanent* replaces *secondary*; *canine* replaces *cuspid*; formerly Figure 24–9, moved due to chapter reorganization)
- Figure 24–9 Anatomy of the Salivary Glands moved (formerly Figure 24–7, moved due to chapter reorganization)
- Section 24–3, titled “The pharynx and esophagus are passageways that transport the food bolus from the oral cavity to the stomach,” now combines coverage of the pharynx, esophagus, and deglutition.
- Figure 24–12 Gross Anatomy of the Stomach revised (new title; *pyloric part* replaces *pylorus*)
- Figure 24–14 The Secretion of Hydrochloric Acid Ions revised (new title; *anion countertransport mechanism* replaces *countertransport mechanism*; added Dissociation label for clarification)

- Spotlight Figure 24–15 The Regulation of Gastric Activity revised (clarified Key in steps 1 and 2)
- The new Section 24–5 called “Accessory digestive organs, such as the pancreas and liver, produce secretions that aid in chemical digestion” now covers these accessory organs all in one place.
- Figure 24–16 Anatomy of the Pancreas moved (formerly Figure 24–18, moved due to chapter reorganization)
- Figure 24–17 Gross Anatomy of the Liver revised and moved (new title; added Peritoneal cavity label to part a; formerly Figure 24–19, moved due to chapter reorganization)
- Figure 24–18 Histology of the Liver revised and moved (*portal triad* replaces *portal area*; reoriented micrograph to better correlate with art in part b; renamed portal triad structures to *interlobular bile duct*, *interlobular vein*, and *interlobular artery*; *stellate macrophage* replaces *Kupffer cells*; formerly Figure 24–20, moved due to chapter reorganization)
- Figure 24–19 The Anatomy and Physiology of the Gallbladder and Bile Ducts revised (*bile duct* replaces *common bile duct*; formerly Figure 24–21, moved due to chapter reorganization)
- Figure 24–20 Gross Anatomy and Segments of the Intestine moved (new title; formerly Figure 24–16, moved due to chapter reorganization)
- Figure 24–21 Histology of the Intestinal Wall revised (new title; added new part c showing Paneth cells; *intestinal gland* replaces *intestinal crypt*; formerly Figure 24–17, moved due to chapter reorganization)
- Figure 24–22 The Secretion and Effects of Major Duodenal Hormones revised (new title; clarified secretin’s primary effect)
- Figure 24–23 The Secretion and Effects of Major Digestive Tract Hormones revised (new title; added new pancreas art)
- Figure 24–25 Histology of the Colon revised (new title; added two more teniae coli to the icon art to show general positions of all three teniae coli)
- Added coverage of the microbiome under Section 24–7 on the large intestine.
- NEW Figure 24–26 The Defecation Reflex
- Spotlight Figure 24–27 The Chemical Events of Digestion revised
- Figure 24–27 Digestive Secretion and Water Reabsorption in the Digestive Tract revised (added new art next to Dietary Input box)
- NEW Build Your Knowledge Figure 23–28 Integration of the DIGESTIVE system with the other body systems presented so far (replaces System Integrator)
- Questions added to Figures 24–4, 24–9, 24–12, 24–23, and 24–26.

### Chapter 25: Metabolism, Nutrition, and Energetics (title changed to include nutrition)

- NEW Figure 25–1 Metabolism of Organic Nutrients and Nutrient Pools
- We now cover oxidation–reduction reactions in Section 25–1.
- Figure 25–2 Glycolysis moved (formerly Figure 25–3)
- Figure 25–3 The Citric Acid Cycle revised and moved (*electron transport chain* replaces *electron transport system*; formerly Figure 25–4)
- NEW Spotlight Figure 25–4 The Electron Transport Chain and ATP Formation
- Figure 25–5 A Summary of the Energy Yield of Glycolysis and Aerobic Metabolism revised (total ATP yield from a glucose molecule based on new values of ATP yield per NADH [2.5 ATP vs. previous 3 ATP] and FADH<sub>2</sub> [1.5 ATP vs. previous 2 ATP]).

- Figure 25–6 Glycolysis and Gluconeogenesis revised (added NADH → NAD to show pyruvate is reduced to form lactate when oxygen is lacking)
- Figure 25–7 Lipolysis and Beta-Oxidation revised (new title; lowered total ATP yield)
- Figure 25–8 Lipid Transport and Use revised (formerly Figure 25–9)
- Spotlight Figure 25–10 Absorptive and Postabsorptive States revised (*membrane receptor* replaces *carrier protein*; formerly Spotlight Figure 25–11)
- Figure 25–11 MyPlate, MyWins revised (new title)
- Questions added to Figures 25–2, 25–5, 25–7, 25–8, and 25–14.

### Chapter 26: The Urinary System

- Figure 26–6 The Anatomy of a Representative Nephron and the Collecting System revised (new figure title; removed functional anatomy descriptions; *descending thin limb* replaces *thin descending limb* in all relevant figures)
- Figure 26–7 The Functional Anatomy of a Representative Nephron and the Collecting System revised (added *Extraglomerular mesangial cells* label in part a to clarify their distinction from juxtaglomerular cells; *intraglomerular mesangial cell* replaces *mesangial cell*)
- Figure 26–8 The Locations and Structures of Cortical and Juxtamedullary Nephrons moved (formerly Figure 26–7, renumbered because of chapter reorganization)
- Figure 26–9 An Overview of Urine Formation revised (added functional anatomy descriptions from former Figure 26–6)
- Figure 26–11 The Response to a Reduction in the GFR revised (new homeostasis design)
- There is a new section called Principles of Reabsorption and Secretion at the beginning of Section 26–5 to provide an overview of this process before we get into its details.
- Figure 26–12 Transport Activities at the PCT revised (corrected color of cotransport mechanism symbol in the art)
- A new Section 26–6 called “Countercurrent multiplication allows the kidneys to regulate the volume and concentration of urine” has been added to emphasize this content, especially the role of the medullary osmotic gradient. This also includes a more complete kidney function testing section.
- Spotlight Figure 26–16 Summary of Renal Function revised (added new step 8 discussing papillary duct permeability to urea and art showing urea transporter)
- Figure 26–18 Organs for Conducting and Storing Urine revised (deleted “[in urogenital diaphragm]” in part b)
- NEW Figure 26–20 The Control of Urination
- NEW Build Your Knowledge Figure 26–21 Integration of the URINARY system with the other body systems presented so far (replaces System Integrator)
- Questions added to Figures 26–5, 26–6, 26–11, 26–14, and 26–18.

### Chapter 27: Fluid, Electrolyte, and Acid–Base Balance

- Figure 27–5 Homeostatic Regulation of Sodium Ion Concentration in Body Fluids revised (new homeostasis design)
- Figure 27–6 Integration of Fluid Volume Regulation and Sodium Ion Concentration in Body Fluids revised (new homeostasis design)
- Figure 27–7 Major Factors Involved in Disturbances of Potassium Ion Balance revised (new homeostasis design)
- Figure 27–8 Three Classes of Acids Found in the Body revised (*metabolic acids* replaces *organic acids*)

- Figure 27–13 pH Regulation of Tubular Fluid by Kidney Tubule Cells revised (incorporated buffer system type next to relevant chemical reactions for better art–text integration)
- Figure 27–15 Homeostatic Regulation of Acid–Base Balance revised (new homeostasis design)
- Figure 27–16 Responses to Metabolic Acidosis revised (new homeostasis design)
- Figure 27–17 Responses to Metabolic Alkalosis revised (new homeostasis design)
- Questions added to Figures 27–2, 27–7, 27–10, 27–14, and 27–16.

### Chapter 28: The Reproductive System

- NEW Clinical Case: And Baby Makes Three?
- Section 28–2, retitled “The structures of the male reproductive system consist of the testes and scrotum, duct system, accessory glands, and penis,” is now focused on male reproductive anatomy.
- FAP10 Figure 28–2 The Descent of the Testes deleted
- Figure 28–4 Anatomy of the Seminiferous Tubules revised (includes only parts a and b of former Figure 28–5)
- Figure 28–5 Anatomy of the Epididymis revised (former Figure 28–9 moved due to chapter reorganization)
- Figure 28–6 Anatomy of the Ductus Deferens and Accessory Glands revised and reorganized (former Figure 28–10 moved due to chapter reorganization)
- Figure 28–7 Anatomy of the Penis revised and reorganized (former Figure 28–11 moved due to chapter reorganization; new erectile tissue box)
- There is now a Section 28–3 called “Spermatogenesis occurs in the testes, and hormones from the hypothalamus, pituitary gland, and testes control male reproductive functions” that covers male reproductive physiology.
- Section 28–3 now starts with an Overview of Mitosis and Meiosis.
- NEW Figure 28–8 A Comparison of Chromosomes in Mitosis and Meiosis
- Figure 28–9 The Process of Spermatogenesis revised (former Figure 28–7 moved due to chapter reorganization; *sperm* replaces *spermatozoa*)
- Figure 28–10 Spermatogenesis in a Seminiferous Tubule revised (includes only parts c and d of former Figure 28–5; moved due to chapter reorganization)
- Figure 28–11 The Process of Spermiogenesis and Anatomy of a Sperm revised (former Figure 28–8 moved due to chapter reorganization; *sperm* replaces *spermatozoa*)
- The reworked Section 28–4 is now titled “The structures of the female reproductive system consist of the ovaries, uterine tubes, uterus, vagina, and external genitalia” and focuses on presenting the female reproductive anatomy.
- Figure 28–15 Anatomy of the Uterine Tubes revised (former Figure 28–17 moved due to chapter reorganization; new epithelial surface SEM)
- Figure 28–19 Anatomy of the Female External Genitalia revised (former Figure 28–22 moved due to chapter reorganization)
- The reworked Section 28–5 titled “Oogenesis occurs in the ovaries, and hormones from the hypothalamus, pituitary gland, and ovaries control female reproductive functions” presents female reproductive physiology. This section now gathers information on oogenesis, the ovarian cycle, and the uterine cycle, as well as their coordination.

- Figure 28–21 The Process of Oogenesis revised (new title; former Figure 28–15 moved due to chapter reorganization)
- Figure 28–22 Follicle Development and the Ovarian Cycle revised (former Figure 28–16 moved due to chapter reorganization; new ovary art)
- Figure 28–23 A Comparison of the Structure of the Endometrium during the Phases of the Uterine Cycle revised (new title; former Figure 28–20 moved due to chapter reorganization)
- Spotlight Figure 28–24 Hormonal Regulation of Female Reproduction revised (text in Follicle Phase of the Ovarian Cycle box changed to reflect that one tertiary follicle from a group becomes dominant; *Tertiary ovarian follicle development* label replaces *Follicle development* label; temperature ranges changed for both Celsius and Fahrenheit scales; and Menses label changed to Menstrual Phase)
- Under Section 28–6, there are new discussions of contraception and infertility, and sexually transmitted diseases.
- Under Section 28–7, there is a new discussion of development of internal reproductive organs, with a new Figure 28–26 The Development of Male and Female Internal Reproductive Organs.
- NEW Build Your Knowledge Figure 28–27 Integration of the REPRODUCTIVE system with the other body systems presented so far (replaces System Integrator)
- Questions added to Figures 28–7, 28–9, 28–11, 28–22, 28–23, and 28–25.

### Chapter 29: Development and Inheritance

- Figure 29–1 Fertilization revised (changed some titles and text in step art; clarified when DNA synthesis occurs)
- Figure 29–3 Stages in Implantation revised (*cytotrophoblast* replaces *cellular trophoblast*; *syncytiotrophoblast* replaces *syncytial trophoblast*)
- Figure 29–4 The Inner Cell Mass and Gastrulation revised (changed Gastrulation from Day 12 to Day 15)
- Spotlight Figure 29–5 Extra-Embryonic Membranes and Placenta Formation revised (added cervical plug to Week 10/step 5 art)
- Figure 29–6 Anatomy of the Placenta after the First Trimester revised (replaced first sentence of part a text)
- Figure 29–7 The First 12 Weeks of Development revised (new art at 3 weeks of development replaces Week 2 SEM)
- Section 29–5, now called “During the second and third trimesters, fetal development primarily involves growth and organ function,” focuses on the fetal development during this period.
- Section 29–6, called “During gestation, maternal organ systems support the developing fetus; the reproductive system in particular undergoes structural and functional changes” now presents the maternal changes, including hormonal effects.
- Figure 29–12 The Milk Ejection Reflex revised (new title)
- Figure 29–17 Inheritance of an X-Linked Trait revised (former Figure 29–18 moved due to chapter reorganization)
- Figure 29–18 Crossing Over and Recombination revised (clarified text in part b; former Figure 29–17 moved due to chapter reorganization)
- Questions added to Figures 29–2, 29–4, 29–10, 29–14, and 29–15.

### Appendix

- NEW Table 3 Four Common Methods of Reporting Gas Pressure
- NEW Table 4 Turnover Times of Organic Components of Four Cell Types

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To help improve future editions, we encourage you to send any pertinent information, suggestions, or comments about the organization or content of this textbook to us directly, using the e-mail addresses below. We warmly welcome comments and suggestions and will carefully consider them in the preparation of the Twelfth Edition.

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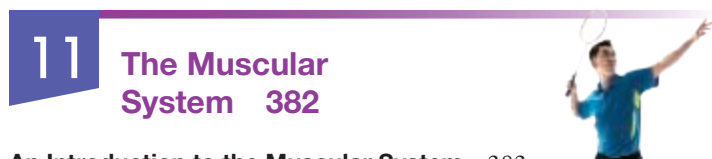
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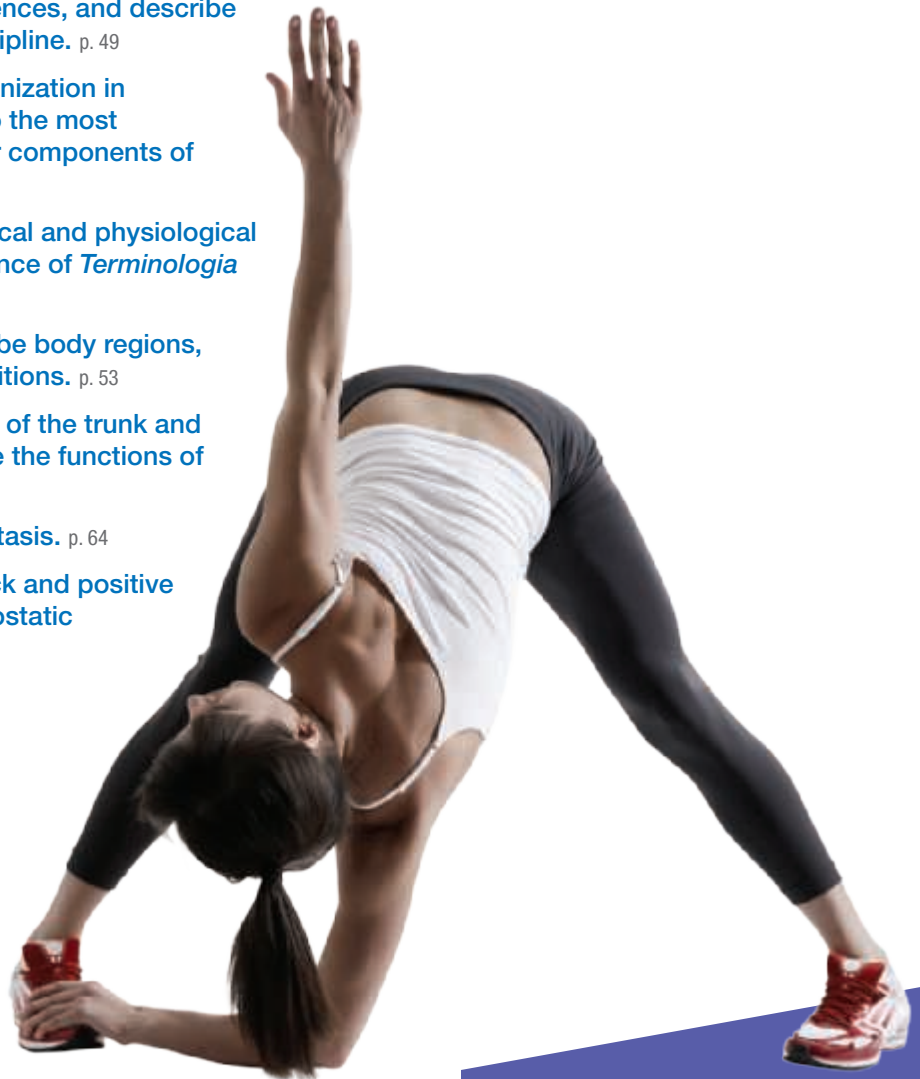
# 1

# An Introduction to Anatomy and Physiology

## Learning Outcomes

These Learning Outcomes correspond by number to this chapter's sections and indicate what you should be able to do after completing the chapter.

- 1-1 ■ Describe how to use the text and art to master learning. p. 48
- 1-2 ■ Define anatomy and physiology, explain the relationship between these sciences, and describe various specialties of each discipline. p. 49
- 1-3 ■ Identify the major levels of organization in organisms, from the simplest to the most complex, and identify the major components of each organ system. p. 52
- 1-4 ■ Describe the origins of anatomical and physiological terms, and explain the significance of *Terminologia Anatomica*. p. 53
- 1-5 ■ Use anatomical terms to describe body regions, body sections, and relative positions. p. 53
- 1-6 ■ Identify the major body cavities of the trunk and their subdivisions, and describe the functions of each. p. 60
- 1-7 ■ Explain the concept of homeostasis. p. 64
- 1-8 ■ Describe how negative feedback and positive feedback are involved in homeostatic regulation. p. 65







## CLINICAL CASE Using A&P to Save a Life

An emergency medical technician (EMT) is on the way to the emergency department with a young victim of street violence. A knife with a 6-inch blade had been found next to the bleeding, unconscious man.

"We have a young male with multiple stab wounds. He has lost a lot of blood and we can barely get a blood pressure," the EMT radios to the triage nurse in the emergency department as the ambulance squeals through traffic. "We started an IV and we are pouring in fluid as fast as we can."

"Where are the wounds?" asks the receiving nurse.

"He has a deep wound in his right upper quadrant, just inferior to the diaphragm. I can see bruising from the hub of the knife around the wound, and there is another wound in his anterior



right thigh. His pulse is 120 and thready (weak). His blood pressure is 60 over 30."

"How long has he been down?" questions the nurse.

"Less than a half hour. We intubated him (inserted a breathing tube) and started a large-bore IV as soon as we got there. We are 10 minutes out now."

"Keep the fluids going wide open, keep pressure on the thigh, and take him directly to Trauma Room 1," come the instructions.

Meanwhile, the nurse orders the trauma team to Trauma Room 1, orders X-Ray to be on standby in the room, and requests 4 units of type O negative whole blood—the universal donor blood—from the blood bank. **Will the team be ready to save this young man?**

**To find out, turn to the Clinical Case Wrap-Up on p. 72.**

## An Introduction to Studying the Human Body

Welcome to the field of human anatomy and physiology—known simply as A&P! In this textbook we will introduce you to the inner workings of the human body, giving information about both its structure (anatomy) and its function (physiology). Many students who use this book are preparing for jobs in health-related fields; but regardless of your career choice, you will find the information within these pages relevant to your future.

We will focus on the human body, but the principles you will learn apply to other living things as well. Our world contains an enormous diversity of living organisms, which vary widely in appearance and lifestyle. One aim of *biology*—the study of life—is to discover the unity and the patterns that underlie this diversity. As we study human anatomy and physiology, three main concepts will emerge: (1) the principle of complementarity of structure and function, (2) the hierarchy of structural relationships, and (3) homeostasis, the tendency toward internal balance. These principles are the foundation for learning about the human organism.

Before we begin with the science of human anatomy and physiology, let's turn our attention to the science of learning and learning strategies. To make the most of your learning experience, apply these strategies, which were collected from academic research.

### 1-1 To make the most of your learning, read the text and view the art together

**Learning Outcome** Describe how to use the text and art to master learning.

## Getting to Know Your Textbook

This first section of the book sets the stage for your success in this course and introduces you to the basic principles of learning. Just as there are three underlying concepts in A&P, there are two basic principles to using your textbook effectively to learn A&P. Practicing these principles will help you throughout your college career.

Let's start. Think back to your first childhood book. You most likely began with a "picture book." Then, as you learned the alphabet and developed speech, you progressed to "word books." The next step was "chapter books." Somewhere along the way, you quit looking at pictures and focused solely on the words (text). Maybe the shift in focus to text-based reading without looking at the pictures happened in high school. You began reading words—paragraph upon paragraph, page upon page of words. Now, you are in college, and we need to realign your focus.

In college, you are faced with lots of new terms, abstract concepts, and unfamiliar images. That's great, because college is intended to increase your knowledge and expand your horizons. However, research has shown that undergraduate students have a tendency to simply read the text (also called the *narrative*), without paying attention to the pictures (referred to as visuals, art, diagrams, illustrations, figures, or images). While you can certainly learn from this approach, further research demonstrates that when students *read the text and then look at the corresponding picture, they actually learn the material better!*

Although this may sound quite intuitive, most students do not do that. So, we wrote a book that truly integrates text with art to help you learn A&P. Please continue reading as we walk you through the process of using a textbook to enhance your learning. Much of what we're about to tell you applies to most

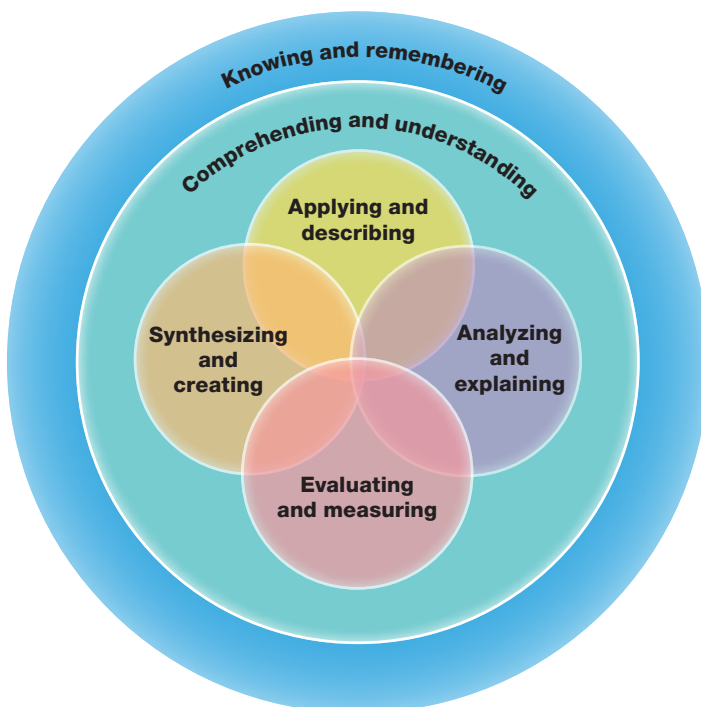
of your college textbooks, but we'll focus on this book, since it was designed for students such as you.

## Anatomy of a Chapter

Your book is broken down into *sections* with *text–art integration*, and specific *learning outcomes* for each section based on a *learning classification scheme*. A **section** is a unit about a topic that continues to build on previously learned topics. The sectional layout promotes logical, efficient navigation through the material, while callouts to figures integrate the text with the art. **Text–art integration** implies that the figures are close to the lines of text and that the figure legends are adjacent to the art. Look at that figure when you see a callout for it. The figure callouts look like this: (Figure 1–1). They are color-coded on purpose so you can stop reading, look at the figure, and then find your place again when you go back to reading the text. So, *strategy #1 is to read the text and then study the image that goes along with the narrative*.

**Learning outcomes** are educational objectives that use key verbs and target specific skills, goals, aims, and achievements. The learning outcomes appear at the beginning of each chapter and within the chapter under the sentence-based headings. *Strategy #2 is to pay attention to these learning outcomes because they are tied directly to testing and tell you what you should be able to do after reading that specific section and studying the images*. These learning outcomes are based on a **learning classification scheme**, which identifies the fundamental levels of learning from lower order skills to those of higher-order skills.

**Figure 1–1** A Conceptual Framework for Learning.



You'll see key verbs in your learning outcomes and you'll notice some overlap among them within the levels of learning. From lower to higher, these levels are (1) knowing and remembering, (2) comprehending and understanding, (3) applying and describing, (4) analyzing and explaining, (5) evaluating and measuring, and (6) synthesizing and creating (Figure 1–1). (Here is where you can practice using what you just learned: Look at that figure, think about it, and then return to this text.) If you practice these basic strategies—(1) read the narrative and study the image and (2) pay attention to the learning outcomes—you are well on your way to success!

### ✓ Checkpoint

1. Describe a learning outcome.
2. Explain how to use your textbook most effectively to enhance your learning.

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

## 1-2 Anatomy (structure) and physiology (function) are closely integrated

**Learning Outcome** Define anatomy and physiology, explain the relationship between these sciences, and describe various specialties of each discipline.

**Anatomy** is the study of internal and external body structures and their physical relationships among other body parts. In contrast, **physiology** is the study of how living organisms perform their vital functions. Someone studying anatomy might, for example, examine where a particular muscle attaches to the skeleton. Someone studying physiology might consider how a muscle contracts or what forces a contracting muscle exerts on the skeleton. You will be studying both anatomy and physiology in this text, so let's look at the relationships between these sciences.

Anatomy and physiology are closely integrated, both in theory and practice. Anatomical information provides clues about functions, and physiological processes can be explained only in terms of the underlying anatomy. This is a very important concept in living systems:

All specific functions are performed by specific structures, and the form of a structure relates to its function. This is known as the *principle of complementarity of structure and function*.

The link between structure and function is always present, but not always understood. For example, the anatomy of the heart was clearly described in the 15th century, but almost 200 years passed before the heart's pumping action was demonstrated.

Anatomists and physiologists approach the relationship between structure and function from different perspectives. To understand the difference, suppose you asked an anatomist and

a physiologist to examine a car and report their findings. The anatomist might begin by measuring and photographing the various parts of the car and, if possible, taking it apart and putting it back together. The anatomist could then explain its key *structural relationships*—for example, how the pistons are seated in the engine cylinders, how the crankshaft is connected to the pistons, and how the transmission links the drive shaft to the axles and, thus, to the wheels. The physiologist also would note the relationships among the car's parts, but he or she would focus mainly on its *functional* characteristics, such as how the combustion of gasoline in the cylinders moves the pistons up and down and makes the drive shaft rotate, and how the transmission conveys this motion to the axles and wheels so that the car moves. Additionally, he or she might also study the amount of power that the engine could generate, the amount of force transmitted to the wheels in different gears, and so forth.

Our basic approach in this textbook will be to start with the descriptive anatomy of body structures (appearance, size, shape, location, weight, and color) before considering the related functions. Sometimes the groups of organs that make up an *organ system* perform very diverse functions, and in those cases we consider the functions of each individual organ separately. A good example is our discussion of the digestive system and its organs. You will learn about the functions of the salivary glands in one section, and the functions of the tongue in another. In other systems, the organs work together so extensively that we present an overall discussion of their physiology, after we describe the system's anatomy. The lymphatic system (which contains a network of vessels) and the cardiovascular system, for example, are treated using this approach.

## Anatomy

When you look at something, how far away you are from it often determines what you see. You get a very different view of your neighborhood from a satellite photo than from your front yard. Similarly, your method of observation has a dramatic effect on your understanding of the structure of the human body. Based on the degree of structural detail being considered, we divide **human anatomy**, the study of the structure of the human body, into *gross (macroscopic) anatomy* and *microscopic anatomy*.

### Gross Anatomy

**Gross anatomy**, or *macroscopic anatomy*, involves examining fairly large structures. Gross anatomy (from the Latin term *grossus*, meaning “thick” or “massive”) can be conducted without using a microscope and can involve the study of anatomy by dissecting a cadaver. There are many different forms of gross anatomy:

- *Surface anatomy*, or superficial anatomy, is the study of the general form of the body's surface, especially in relation to its deeper parts.

- *Regional anatomy* focuses on the anatomical organization of specific areas of the body, such as the head, neck, or trunk. Many advanced courses in anatomy stress a regional approach, because it emphasizes the spatial relationships among structures already familiar to students.
- *Sectional anatomy* is the study of the relationship of the body's structures by examining cross sections of the tissue or organ.
- *Systemic anatomy* is the study of the structure of *organ systems*, which are groups of organs that function together in a coordinated manner. Examples include the *skeletal system*, composed primarily of bones; the *muscular system*, made up of skeletal muscles; and the *cardiovascular system*, consisting of the heart, blood, and vessels. We take a systemic anatomy approach in this book because this format works better to clarify the functional relationships among the component organs. We introduce the 11 organ systems in the human body later in the chapter.
- *Clinical anatomy* includes a number of subspecialties important in clinical practice. Examples include *pathological anatomy* (anatomical features that change during illness), *radiographic anatomy* (anatomical structures seen using specialized imaging techniques), and *surgical anatomy* (anatomical landmarks important in surgery).
- *Developmental anatomy* describes the changes in form that take place between conception and adulthood. The techniques of developmental anatomists are similar to those used in gross anatomy and in microscopic anatomy (discussed next) because developmental anatomy considers anatomical structures over a broad range of sizes—from a single cell to an adult human. The most extensive structural changes take place during the first two months of development. The study of these early developmental processes is called **embryology** (em-brē-OL-ō-jē).

### Microscopic Anatomy

**Microscopic anatomy** deals with structures that we cannot see without magnification. The boundaries of microscopic anatomy are set by the limits of the equipment we use. With a dissecting microscope you can see tissue structure. With a light microscope, you can see basic details of cell structure. And with an electron microscope, you can see individual molecules that are only a few nanometers (billionths of a meter) across.

Microscopic anatomy includes two major subdivisions: cytology and histology. **Cytology** (sī-TOL-ō-jē) is the study of the internal structure of individual *cells*, the simplest units of life. Cells are made up of chemical substances in various combinations, and our lives depend on the chemical processes that take place in the trillions of cells in the body. For this reason, we consider basic chemistry (Chapter 2) before we examine cell structure (Chapter 3). **Histology** (his-TOL-ō-jē)

## + Clinical Note *Habeas Corpus* (“You Shall Have the Body”)

It is the first day of Anatomy. Students await the arrival of their white-coated and gloved professor. Anxiety mounts as a stretcher covered in surgical drapes is wheeled in. This is the cadaver. Who will faint? *Will it be me?* For many students in the health professions, cadaver dissection is a cornerstone of their training. These students are following in a revered tradition that began 2300 years ago with the first examinations of the body after death by Greek royal physicians. The expression “a skeleton in your closet” dates from a later era when medical students had to procure bodies on their own for study (and keep them hidden in the closet). There is much to be learned from death. Cadaver dissections also reveal much about life. After working closely on a cadaver for months,

students develop an attachment to “their” body, often naming it. The intimate revelations of the scalpel, the highly personal variations of human anatomy, the Rubik’s cube of disease, and the stark reality of death combine to leave a deep intellectual and emotional mark on the student.

Students and faculty may end the course with a ceremony to pay their respects to this human body and to this privileged experience.



1

is the examination of *tissues*—groups of specialized cells that work together to perform specific functions (Chapter 4). Tissues combine to form *organs*, such as the heart, kidney, liver, or brain, each with specific functions. Many organs are easy to examine without a microscope, so at the organ level we cross the boundary from microscopic anatomy to gross anatomy. As we proceed through the text, we will consider details at all levels, from microscopic to macroscopic.

### Physiology

**Human physiology** is the study of the functions, or workings, of the human body. These functions are complex processes and much more difficult to examine than most anatomical structures. As a result, there are even more specialties in physiology than in anatomy. Examples include the following:

- *Cell physiology*, the study of the functions of cells, is the cornerstone of human physiology. Cell physiology looks at the chemistry of the cell. It includes both chemical processes within cells and chemical interactions among cells.
- *Organ physiology* is the study of the function of specific organs. An example is *cardiac physiology*, the study of heart function—how the heart works.
- *Systemic physiology* includes all aspects of the functioning of specific organ systems. Cardiovascular physiology, respiratory physiology, and reproductive physiology are examples.
- *Pathological physiology* is the study of the effects of diseases on organ functions or system functions. Modern medicine depends on an understanding of both normal physiology and pathological physiology.

Physicians normally use a combination of anatomical, physiological, chemical, and psychological information when

they evaluate patients. When a patient presents with **signs** (an objective disease indication like a fever) and **symptoms** (a subjective disease indication, such as tiredness), the physician will look at the structures affected (gross anatomy), perhaps collect a fluid or tissue sample (microscopic anatomy) for analysis, and ask questions to find out what changes from normal functioning the patient is experiencing. Think back to your last trip to a doctor’s office. Not only did the physician examine your body, noting any anatomical abnormalities, but he or she also evaluated your physiological processes by asking questions, observing your movements, listening to your body sounds, taking your temperature, and perhaps requesting chemical analyses of fluids such as blood or urine.

In evaluating all these observations to reach a diagnosis, physicians rely on a logical framework based on the scientific method. The **scientific method** is a system of advancing knowledge that begins by proposing a hypothesis to answer a question, and then testing that hypothesis with data collected through observation and experimentation. This method is at the core of all scientific thought, including medical diagnosis.

### ✓ Checkpoint

3. Define *anatomy*.
4. Define *physiology*.
5. Describe how anatomy and physiology are closely related.
6. What is the difference between gross anatomy and microscopic anatomy?
7. Identify several specialties of physiology.
8. Why is it difficult to separate anatomy from physiology?

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

## 1-3 Levels of organization progress from chemicals to a complete organism

**Learning Outcome** Identify the major levels of organization in organisms, from the simplest to the most complex, and identify major components of each organ system.

Our understanding of how the human body works is based on investigations of its different levels of organization. Higher levels of organization are more complex and more variable than lower levels. Chapters 2, 3, and 4 consider the chemical, cellular, and tissue levels of organization of the human body. These levels are the foundations of more complex structures and vital processes, as we describe in Chapters 5–29. The six levels of organization of the human body are shown in **Spotlight Figure 1–2** and include:

- **The Chemical Level.** **Atoms** are the smallest stable units of matter. They can combine to form **molecules** with complex shapes. The atomic components and unique three-dimensional shape of a particular molecule determine its function. For example, complex protein molecules form filaments that produce the contractions of muscle cells in the heart. We explore this level of organization in Chapter 2.
- **The Cellular Level.** **Cells** are the smallest living units in the body. Complex molecules can form various types of larger structures called *organelles*. Each organelle has a specific function in a cell. Energy-producing organelles provide the energy needed for heart muscle cell contractions. We examine the cellular level of organization in Chapter 3.
- **The Tissue Level.** A **tissue** is a group of cells working together to perform one or more specific functions. Heart muscle cells, also called cardiac muscle cells (*cardium*, heart), interact with other types of cells and with materials outside the cell to form cardiac muscle tissue. We consider the tissue level of organization in Chapter 4.
- **The Organ Level.** **Organs** are made of two or more tissues working together to perform specific functions. Layers of cardiac muscle tissue, in combination with another type of tissue called connective tissue, form the bulk of the wall of the heart, which is a hollow, three-dimensional organ.
- **The Organ System Level.** A group of organs interacting to perform a particular function forms an **organ system**. Each time the heart contracts, for example, it pushes blood into a network of blood vessels. Together, the heart, blood, and blood vessels make up the cardiovascular system, one of 11 organ systems in the body. This system functions to distribute oxygen and nutrients throughout the body.
- **The Organism Level.** An individual life form is an **organism**. In our case, an individual human is the highest level of organization that we consider. All of the body's organ systems must work together to maintain the life and health of the organism.

The organization at each level determines not only the structural characteristics but also the functions of higher levels. For example, the arrangement of atoms and molecules at the chemical level creates the protein filaments and organelles at the cellular level that give individual cardiac muscle cells the ability to contract. At the tissue level, these cells are linked, forming cardiac muscle tissue. The structure of the tissue ensures that the contractions are coordinated, producing a powerful heartbeat. When that beat occurs, the internal anatomy of the heart, an organ, enables it to function as a pump. The heart is filled with blood and connected to the blood vessels, and its pumping action circulates blood through the vessels of the cardiovascular system. Through interactions with the respiratory, digestive, urinary, and other systems, the cardiovascular system performs a variety of functions essential to the survival of the organism.

Something that affects a system will ultimately affect each of the system's parts. For example, after massive blood loss, the heart cannot pump blood effectively. When the heart cannot pump and blood cannot flow, oxygen and nutrients cannot be distributed to the heart or around the body. Very soon, the cardiac muscle tissue begins to break down as individual muscle cells die from oxygen and nutrient starvation. These changes will not be restricted to the cardiovascular system. All cells, tissues, and organs in the body will be damaged. **Spotlight Figure 1–2** illustrates the levels of organization and introduces the 11 interdependent, interconnected organ systems in the human body.

The cells, tissues, organs, and organ systems of the body coexist in a relatively small, shared environment, much like the residents of a large city. Just as city dwellers breathe the same air and drink the water supplied by the local water company, cells in the human body absorb oxygen and nutrients from the fluids that surround them. If a city is blanketed in smog or its water supply is contaminated, its inhabitants will become ill. Similarly, if the body fluid composition becomes abnormal, cells will be injured or destroyed. For example, suppose the temperature or salt content of the blood changes. The effect on the heart could range from the need for a minor adjustment (heart muscle tissue contracts more often, raising the heart rate) to a total disaster (the heart stops beating, so the individual dies).



### Checkpoint

9. Identify the major levels of organization of the human body from the simplest to the most complex.
10. Identify the organ systems of the body and cite some major structures of each.
11. At which level of organization does a histologist investigate structures?

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

## 1-4 Medical terminology is important to understanding anatomy and physiology

**Learning Outcome** Describe the origins of anatomical and physiological terms, and explain the significance of *Terminologia Anatomica*.

Early anatomists faced serious problems when trying to communicate. Saying that a bump is “on the back,” for example, does not give very precise information about its location. So anatomists created illustrated maps of the human body and gave each structure a specific name. They used prominent anatomical structures as landmarks, measured distances in centimeters or inches, and discussed these subjects in specialized directional terms. Modern anatomists continue and build on these practices. In effect, anatomy uses a special language that you must learn almost at the start of your study.

That special language, called **medical terminology**, involves using word roots, prefixes, suffixes, and combining forms to build terms related to the body in health and disease. Many of the anatomical and physiological terms you will encounter in this textbook are derived from Greek or Latin roots that originated more than 1500 years ago. In fact, the term *anatomy* is derived from Greek roots that mean “a cutting open”; the term *physiology* also comes from Greek. Learning the word parts used in medical terminology will greatly assist in your study of anatomy and physiology and in your preparation for any health-related career.

There are four basic building blocks—or word parts—of medical terms. *Word roots* are the basic, meaningful parts of a term that cannot be broken down into another term with another definition. *Prefixes* are word elements that are attached to the beginning of words to modify their meaning but cannot stand alone. *Suffixes* are similar to prefixes, except they are word elements or letters added to the end of a word or word part to form another term. *Combining forms* are independent words or word roots that are used in combination with words, prefixes, suffixes, or other combining forms to build a new term. As we introduce new terms, we will provide notes on pronunciation and relevant word parts. In addition, the table inside the back cover of your textbook lists many commonly used word roots, prefixes, suffixes, and combining forms.

To illustrate the building of medical terms, consider the word *pathology* (puh-THOL-ō-jē). Breaking this word into its basic parts reveals its meaning. The prefix *path-* refers to disease (the Greek term for “disease” is *pathos*). The suffix *-ology* means “study of.” So pathology is the study of disease.

Latin and Greek terms are not the only ones that have been imported into the anatomical vocabulary over the centuries, and this vocabulary continues to expand. Many anatomical structures and clinical conditions were first named after either the discoverer or, in the case of diseases, the most famous

victim. During the past 100 years, most of these commemorative names, or **eponyms** (EH-pō-nimz), have been replaced by more precise terms. Where appropriate, we will give both the eponym and the more precise term, because in clinical medicine, both terms may be used.

To avoid the miscommunication that plagued the early anatomists, it is important for scientists throughout the world to use the same name for each body structure. In 1998, two scientific organizations—the Federative Committee on Anatomical Terminology (FCAT) and the International Federation of Associations of Anatomists (IFAA)—published *Terminologia Anatomica* (*TA*). *Terminologia Anatomica* established the worldwide standard for human anatomical terminology. The successor of FCAT is the Federative International Programme on Anatomical Terminologies (FIPAT). In April 2011, FIPAT published *TA* online. Latin continues to be the language of anatomy, but this reference provides an English equivalent term for each anatomical structure. For example, the *tendo calcaneus* (Latin) is also called the calcaneal tendon (English). You may know the structure better by its eponym, the Achilles tendon. Eponyms are not found in *TA*. We have used *TA* as our standard in preparing this textbook.

### ✓ Checkpoint

12. Describe medical terminology.
13. Define *eponym*.
14. Name the book that serves as the international standard for anatomical terms.

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

## 1-5 Anatomical terms describe body regions, anatomical positions and directions, and body sections

**Learning Outcome** Use anatomical terms to describe body regions, body sections, and relative positions.

Anatomists use anatomical terms to describe body regions, relative positions and directions, and body sections, as well as major body cavities and their subdivisions. In the following sections we introduce the terms used in superficial anatomy and sectional anatomy.

### Surface Anatomy

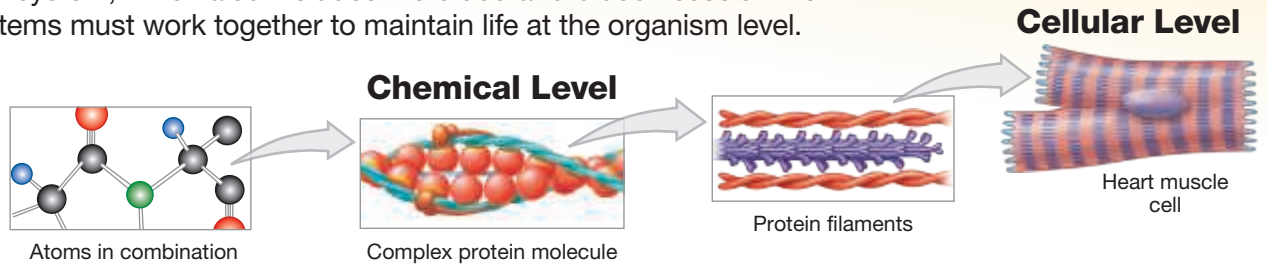
**Surface anatomy** involves locating structures on or near the body surface. A familiarity with anatomical landmarks (structures that can be felt or palpated), anatomical regions (specific areas used for reference purposes), and terms for anatomical directions will make the material in subsequent chapters easier to understand.



# SPOTLIGHT

Figure 1–2  
Levels of Organization

Interacting atoms form molecules that combine to form the protein filaments of a heart muscle cell. Such cells interlock, forming heart muscle tissue, which makes up most of the walls of the heart, a three-dimensional organ. The heart is only one component of the cardiovascular system, which also includes the blood and blood vessels. The various organ systems must work together to maintain life at the organism level.



## THE ORGAN SYSTEMS

Integumentary	Skeletal	Muscular	Nervous	Endocrine	Cardiovascular
<p><b>Major Organs</b></p> <ul style="list-style-type: none"> <li>• Skin</li> <li>• Hair</li> <li>• Sweat glands</li> <li>• Nails</li> </ul> <p><b>Functions</b></p> <ul style="list-style-type: none"> <li>• Protects against environmental hazards</li> <li>• Helps regulate body temperature</li> <li>• Provides sensory information</li> </ul>	<p><b>Major Organs</b></p> <ul style="list-style-type: none"> <li>• Bones</li> <li>• Cartilages</li> <li>• Associated ligaments</li> <li>• Bone marrow</li> </ul> <p><b>Functions</b></p> <ul style="list-style-type: none"> <li>• Provides support and protection for other tissues</li> <li>• Stores calcium and other minerals</li> <li>• Forms blood cells</li> </ul>	<p><b>Major Organs</b></p> <ul style="list-style-type: none"> <li>• Skeletal muscles and associated tendons</li> </ul> <p><b>Functions</b></p> <ul style="list-style-type: none"> <li>• Provides movement</li> <li>• Provides protection and support for other tissues</li> <li>• Generates heat that maintains body temperature</li> </ul>	<p><b>Major Organs</b></p> <ul style="list-style-type: none"> <li>• Brain</li> <li>• Spinal cord</li> <li>• Peripheral nerves</li> <li>• Sense organs</li> </ul> <p><b>Functions</b></p> <ul style="list-style-type: none"> <li>• Directs immediate responses to stimuli</li> <li>• Coordinates or moderates activities of other organ systems</li> <li>• Provides and interprets sensory information about external conditions</li> </ul>	<p><b>Major Organs</b></p> <ul style="list-style-type: none"> <li>• Pituitary gland</li> <li>• Thyroid gland</li> <li>• Pancreas</li> <li>• Adrenal glands</li> <li>• Gonads</li> <li>• Endocrine tissues in other systems</li> </ul> <p><b>Functions</b></p> <ul style="list-style-type: none"> <li>• Directs long-term changes in the activities of other organ systems</li> <li>• Adjusts metabolic activity and energy use by the body</li> <li>• Controls many structural and functional changes during development</li> </ul>	<p><b>Major Organs</b></p> <ul style="list-style-type: none"> <li>• Heart</li> <li>• Blood</li> <li>• Blood vessels</li> </ul> <p><b>Functions</b></p> <ul style="list-style-type: none"> <li>• Distributes blood cells, water, and dissolved materials including nutrients, waste products, oxygen, and carbon dioxide</li> <li>• Distributes heat and assists in control of body temperature</li> </ul>