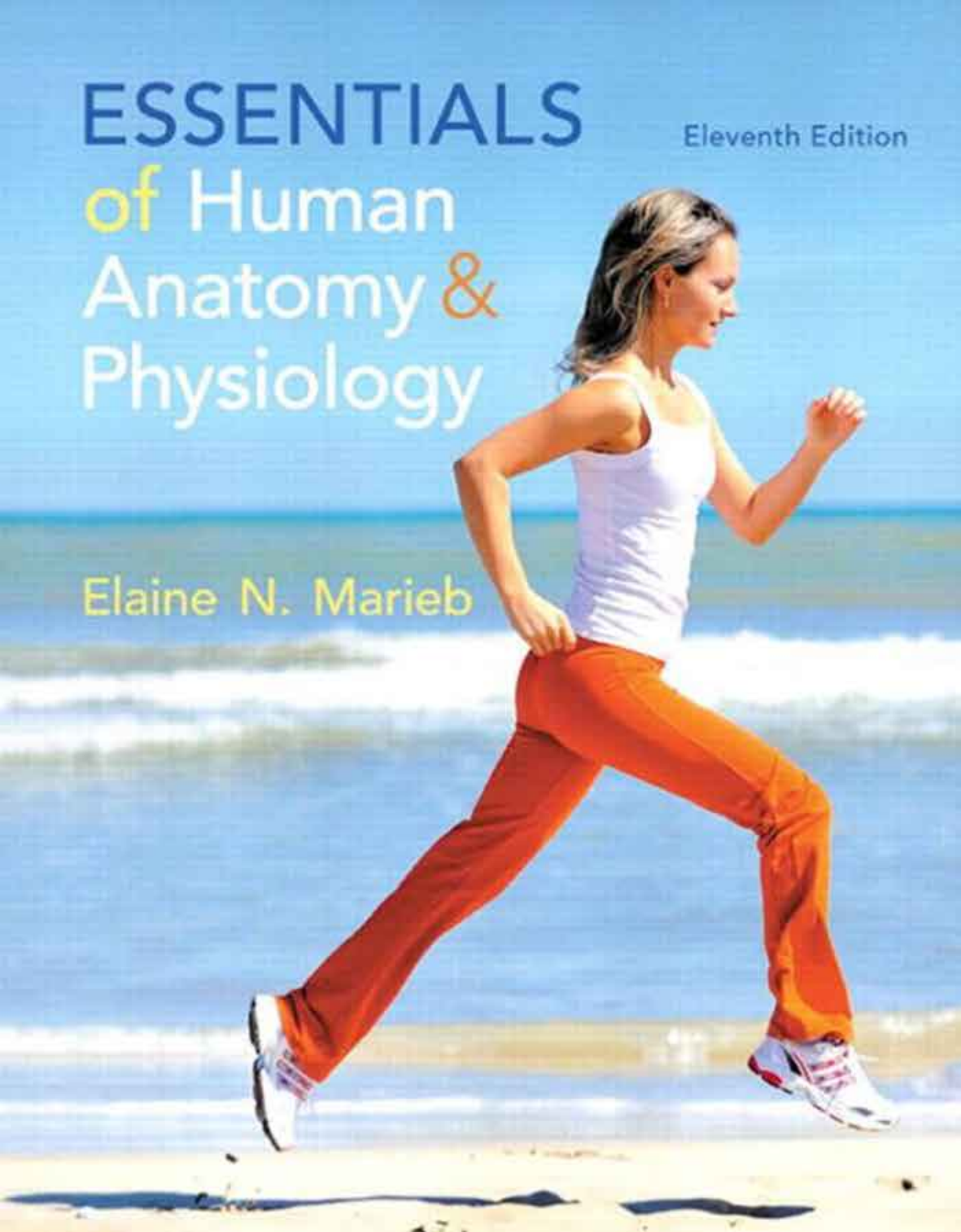
ESSENTIALS of Human Anatomy & Physiology

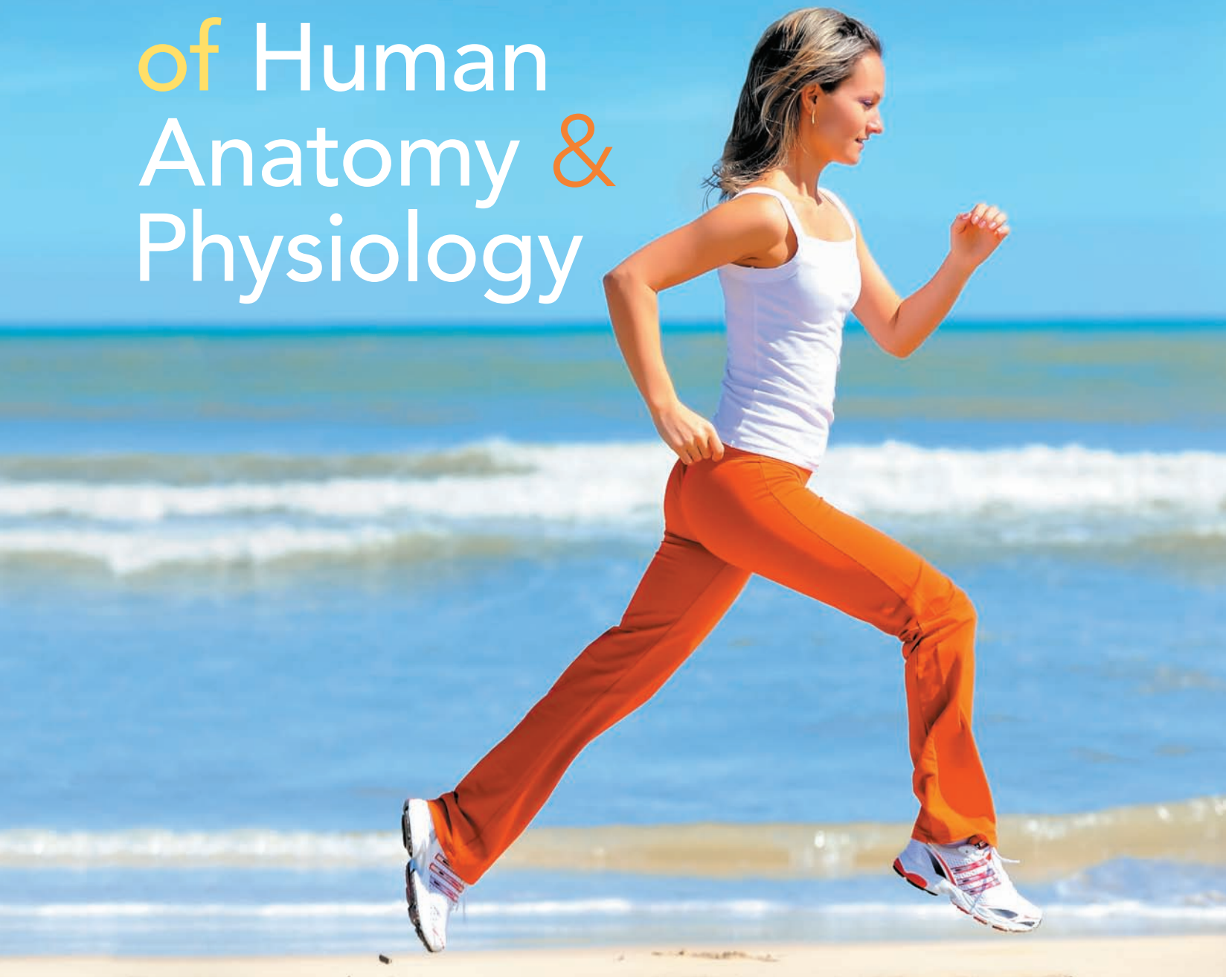
Eleventh Edition



Elaine N. Marieb

ESSENTIALS of Human Anatomy & Physiology

Eleventh Edition



Elaine N. Marieb, R.N., Ph.D.,
Holyoke Community College

PEARSON

Boston Columbus Indianapolis New York San Francisco Upper Saddle River
Amsterdam Cape Town Dubai London Madrid Milan Munich Paris Montréal Toronto
Delhi Mexico City São Paulo Sydney Hong Kong Seoul Singapore Taipei Tokyo

Editor-in-Chief: Serina Beauparlant
Senior Acquisitions Editor: Brooke Suchomel
Associate Project Editor: Shannon Cutt
Director of Development: Barbara Yien
Senior Managing Editor: Michael Early
Production & Design Manager: Michele Mangelli
Production and Art Coordinator: David Novak
Associate Content Producer: Natalie Pettry
Assistant Editor: Ashley Williams
Text and Cover Designer: tani hasegawa
Art House: Imagineering STA Media Services, Inc.
Photo Image Lead: Donna Kalal
Rights & Permissions Project Manager: Jenell Forschler
Copyeditor: Sally Peyrefitte
Proofreader: Betsy Dietrich
Indexer: Kathy Pitcoff
Compositor: Cenveo® Publisher Services
Senior Manufacturing Buyer: Stacey Weinberger
Senior Marketing Manager: Allison Rona
Senior Anatomy & Physiology Specialist: Derek Perrigo

Cover Photo Credit: Mircea Bezergheanu/Shutterstock

Credits and acknowledgments borrowed from other sources and reproduced, with permission, in this textbook appear on the appropriate page within the text or on p. 593.

Library of Congress Cataloging-in-Publication Data

Marieb, Elaine Nicpon
Essentials of human anatomy & physiology / Elaine N. Marieb–Eleventh edition.
pages cm
ISBN 978-0-321-91900-7
1. Human physiology. 2. Human anatomy. I. Title. II. Title:
Essentials of human anatomy and physiology.
QP34.5.M455 2013
612–dc23

2013040834

ISBN 10: 0-321-91900-9 (Student edition)
ISBN 13: 978-0-321-91900-7 (Student edition)
ISBN 10: 0-321-94361-9 (Professional copy)
ISBN 13: 978-0-321-94361-3 (Professional copy)

PEARSON www.pearsonhighered.com

2 3 4 5 6 7 8 9 10—RRD—17 16 15 14 13

About the Author

For **Elaine N. Marieb**, R.N., Ph.D., taking the needs of nursing and other allied health students into account has always been an integral part of her teaching style. Dr. Marieb began her teaching career at Springfield College, where she taught anatomy and physiology to physical education majors. She then joined the faculty of the Biological Science Division of Holyoke Community College in 1969 after receiving her Ph.D. in zoology from the University of Massachusetts at Amherst. While teaching at Holyoke Community College, Dr. Marieb pursued her nursing education, which culminated in a Master of Science degree with a clinical specialization in gerontology from the University of Massachusetts. This experience, along with continual feedback from health care professionals (including generations of former students taught by Dr. Marieb), has inspired the unique perspective and accessibility for which this book is known.

Dr. Marieb's commitment to students extends beyond teaching and writing. Recognizing the challenges students face, Dr. Marieb contributes to the New Directions—Pathways Program at Holyoke Community College by funding a staffed drop-in center and by providing several full-tuition scholarships each year for women who are returning to college after a hiatus or attending college for the first time. She also funds the E. N. Marieb Science Research Awards at Mount Holyoke College (which promotes research by undergraduate science majors) and has underwritten renovation and updating of one of the biology labs in Mount Holyoke's Clapp Laboratory. Recognizing the severe national shortage of nursing faculty, Dr. Marieb also underwrites the Nursing Scholars of the Future Grant Program at the University of Massachusetts at Amherst.

In 1994, Dr. Marieb received the Benefactor Award from the National Council for Resource Development, American Association of Community Colleges, which recognizes her ongoing sponsorship of student scholarships, faculty teaching awards, and other academic contributions to Holyoke Community College. In May 2000, the science building at Holyoke Community College was named in her honor.

In January 2012, Florida Gulf Coast University named a new health professions facility: the Dr. Elaine Nicpon Marieb Hall. This facility contains laboratories in the School of Nursing that simulate an operating room, intensive-care unit, a labor and delivery room, and general medical surgical suites. She has also established a scholarship endowment for nontraditional students in the health professions and an endowment to enhance the activities of faculty, students, and staff within the health professions to support education, research, and community outreach.

Dr. Marieb is an active member of the Human Anatomy and Physiology Society (HAPS) and the American Association for the Advancement of Science (AAAS). Additionally, while actively engaged as an author, Dr. Marieb serves as a consultant for the Pearson *Interactive Physiology*® CD-ROM series. This text—*Essentials of Human Anatomy & Physiology,* Eleventh Edition—is the latest expression of her commitment to the needs of students pursuing the study of A&P.

When not involved in academic pursuits, Dr. Marieb is a world traveler and has vowed to visit every country on this planet. Shorter term, she serves on the board of directors of the famed Marie Selby Botanical Gardens and on the scholarship committee of the Women's Resources Center of Sarasota County. She is an enthusiastic supporter of the local arts and enjoys a competitive match of doubles tennis.

New to the Eleventh Edition

This edition has been thoroughly updated. Specific chapter-by-chapter changes include:

Chapter 1: The Human Body: An Orientation

- New photos of the anatomical position, planes of the body, and MRI scans (Figure 1.6).
- New photo showing the nine abdominopelvic regions (Figure 1.9).
- New Critical Thinking and Clinical Application Question on carpal tunnel syndrome.

Chapter 2: Basic Chemistry

- New coverage of glycolipids (Table 2.5).
- New photo showing water's high surface tension (Figure 2.9).
- New descriptions of amino acid structures (Figure 2.17).

Chapter 3: Cells and Tissues

- New, illustrated Table 3.1: Parts of the Cell: Structure and Function.
- New Concept Link discussing phospholipids as polar molecules.
- New Concept Link discussing the molecular structure of DNA.
- New Concept Link discussing the joining of amino acids by enzymes into peptide bonds, in relation to translation.
- New clinical photo showing post-burn contracture scars, in Homeostatic Imbalance 3.3.

Chapter 4: Skin and Body Membranes

- New clinical photo showing cradle cap in a newborn baby, in Homeostatic Imbalance 4.4.
- New clinical photos of burns (Figure 4.11); cold sores, impetigo, and psoriasis (Figure 4.12); and skin cancer (Figure 4.13).
- New Concept Link discussing the relationship between mitosis, cell division, and cancer.

Chapter 5: The Skeletal System

- New Concept Link discussing the levels of structural organization, in relation to the gross anatomy of a long bone.
- New clinical photo of a child with rickets, in Homeostatic Imbalance 5.1.
- New Concept Link discussing the relationship between regional body terms and bone names, in relation to the axial skeleton.
- New Concept Link discussing the properties of tissues that form the joints.

Chapter 6: The Muscular System

- New Concept Link comparing ATP to a tightly coiled spring.
- New illustrations showing muscle action (Figure 6.14).
- New clinical photo of a patient with myasthenia gravis, in Homeostatic Imbalance 6.4.

Chapter 7: The Nervous System

- New Concept Link relating the concept of a feedback loop to the nervous system.
- New illustrated Table 7.1: Functions of Major Brain Regions.
- New clinical photo of a patient with cerebral palsy, in Homeostatic Imbalance 7.11.

Chapter 8: Special Senses

- New Concept Link relating the basic functions of the nervous system to each of the special senses.
- New clinical photo of an infant with strabismus, in Homeostatic Imbalance 8.11.

Chapter 9: The Endocrine System

- New Concept Link comparing a hormone's relationship to its target cells with that of an enzyme to its substrate.
- New photo of individuals with disorders of pituitary growth hormones (Figure 9.6).
- New clinical photo of the lips of a patient with the hyperpigmentation of Addison's disease, in Homeostatic Imbalance 9.6.

Chapter 10: Blood

- New Concept Link discussing the structure of globular proteins.
- New Concept Link relating the concept of negative feedback to low blood oxygen levels.
- New clinical photo of a thrombus occluding a small pulmonary blood vessel in a human lung, in Homeostatic Imbalance 10.3.

Chapter 11: The Cardiovascular System

- New clinical photo of a prosthetic aortic heart valve, in Homeostatic Imbalance 11.2.
- New Concept Link relating one-way generation of an action potential to heart rhythm.
- New Concept Link relating the portal circulation that links the hypothalamus of the brain and the anterior pituitary gland to hepatic portal circulation.
- New Concept Link relating the passive process of filtration to blood flow.
- New Concept Link discussing epinephrine.

Chapter 12: The Lymphatic System and Body Defenses

- New Concept Link discussing hydrostatic and osmotic pressures.
- New Concept Link discussing the functions of lymphatic vessels.
- New Concept Link discussing the function of the thymus to produce hormones, in relation to lymphoid organs.
- New clinical photo of an abscess, in Homeostatic Imbalance 12.2.
- New Concept Link relating blood antigens to self-antigens.

Chapter 13: The Respiratory System

- New Concept Link discussing mucous membranes.
- New Concept Link relating pressure changes that drive filtration and blood flow to the mechanics of breathing.
- New clinical photo of a colored chest X-ray film showing a collapsed lung, in Homeostatic Imbalance 13.7.
- New Concept Link discussing blood pH, in relation to gas transport.

Chapter 14: The Digestive System and Body Metabolism

- New Concept Link discussing the function of papillae.
- New Concept Link discussing the basic function of valves.
- New Concept Link discussing hydrolysis reactions.
- New clinical photo of a baby with a cleft lip and palate, in Homeostatic Imbalance 14.15.

Chapter 15: The Urinary System

- New Concept Link discussing filtration as a passive process.
- New Concept Link discussing pH as a measure of hydrogen ion concentration, in relation to tubular secretion.
- New clinical photo of a urogram showing the presence of a kidney stone, in Homeostatic Imbalance 15.3.
- New Concept Link discussing the concept of interrelationships among organ systems, in relation to regulation of water intake and output.

Chapter 16: The Reproductive System

- New clinical photo of abnormal sperm, in Homeostatic Imbalance 16.2.
- New Concept Link discussing the tropic hormone, FSH.
- New Concept Link discussing the concept of the feedback loop.

Introducing *Essentials of Human Anatomy and Physiology*, 11th edition

New! Instructors: Use MasteringA&P to Personalize Your Course

New! Students: Use MasteringA&P to Study Anytime, Anywhere

Bring A&P Concepts to Life

A CLOSER LOOK A Wrinkle Out of Time

When it comes to preventing wrinkles, it helps to have good genes, to not smoke, to use a good sunscreen, and to think pleasant thoughts. Good genes speak for themselves—it's partly the luck of the draw whether you look your age or not. Smoking ages the skin by increasing production of an enzyme that destroys collagen. Collagen supports the skin and provides it with elasticity, so with less of it, wrinkles appear. UV radiation damage from too much unprotected exposure to the sun causes elastic fibers to clump, which results in leathery skin. For those wrinkled by years of smoking and sun damage, a surgical face-lift that removes the excess and sagging skin followed by laser resurfacing or microdermabrasion seems to be the only way to banish the wrinkles.

However, for those who sport frown lines, furrowed brows, or crow's feet due to frequent and repetitive facial expressions, cosmetic injections of Botox may be the answer to regaining younger-looking skin. Botulinum toxin type A, more familiarly called Botox Cosmetic, is a toxin produced by the bacterium that causes botulism, a dreaded form of food poisoning. Used in injectable doses (considerably less than the amount that would induce botulism), the

nerves to muscles.) By inhibiting the underlying muscles' ability to contract, existing lines are smoothed out and nearly invisible in a week.

Botox was approved in 1989 to treat two eye muscle disorders—blepharospasm (uncontrollable blinking) and strabismus (misaligned eyes). The discovery that Botox could be used cosmetically was pure luck—physicians using the toxin to counter abnormal eye contractions noticed that the vertical frown lines between the eyes (which make people look tired, angry, or displeased) had softened.

The recent rise in popularity of Botox "shots" has led to changes in the way it is marketed. Some physicians buy the toxin in bulk and arrange "Botox parties" or "Botox happy hours," get-togethers for 10 to 15 people,

Woman re

which mak
more relax
One by on
called, eac
for about
examining
with Botox
is rarely ne
and numbi
available.
Administra
such gathe
a medical
the potent
as unqualit
dispense t
and other

If too
perso
eyelid
musc
(the e
last 3
battlin
nonin
many
there i
allows

Bring the Real World into the Classroom

FOCUS ON CAREERS

Pharmacy Technician

To recognize how medications affect patients, pharmacy technicians need thorough understanding of anatomy and physiology.

When most people get a new medication, they open up the package and toss out the little pamphlet that goes into detail about how the medication works. Not Chris Green. "I love reading the package inserts," says Green, the lead pharmacy technician at a CVS drugstore in Birmingham, Alabama. Green's enthusiasm for those details is a lifesaver for his customers. Pharmacy technicians are a vital link in the chain between doctor and patient.

Although pharmacy technicians are legally prohibited from talking with patients about their symptoms, they can translate medical jargon, and discuss a medication's side effects and other precautions the patient may need to take. For example, doctors may recommend that patients who are on certain

Green started working as a cashier at a drugstore when he was in high school and gradually became interested in the pharmacy itself.

"I was interested in how drugs work, how they can help people and improve their health," he says.

Having earned a bachelor's degree in biology, Green emphasizes that pharmacy technicians must have a good grasp of the sciences, especially basic chemistry and anatomy and

Pharmacy technicians must have a good grasp of anatomy and physiology to understand each drug's chemical properties.

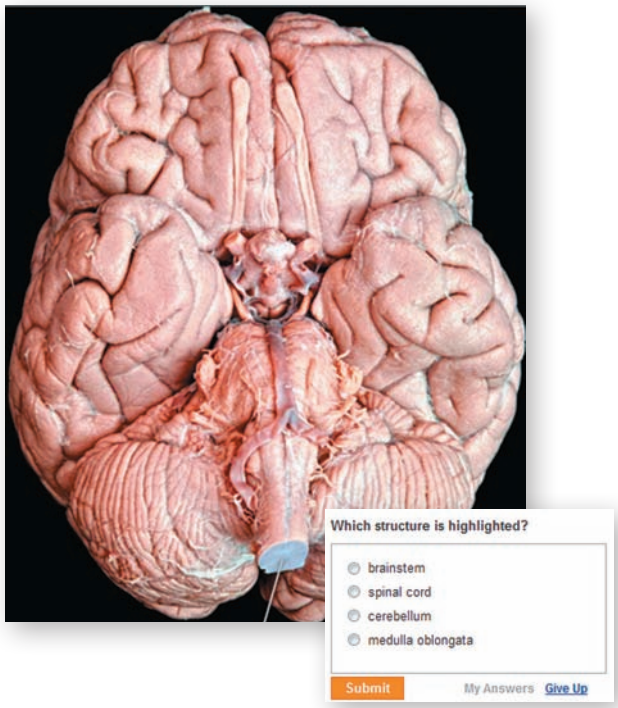
the patient is already taking. Drug interactions happen commonly when you have multiple doctors. "Sometimes, we'll get two ACE inhibitors in the same category from two different doctors [prescribed for the same patient], and that could be lethal," Green says.

Pharmacy technicians work in retail and mail-order pharmacies, hospitals, nursing homes, assisted living facilities, and anywhere else patients have high needs for medication. As the Baby Boom

INSTRUCTORS: Use MasteringA&P® to Personalize Your Course

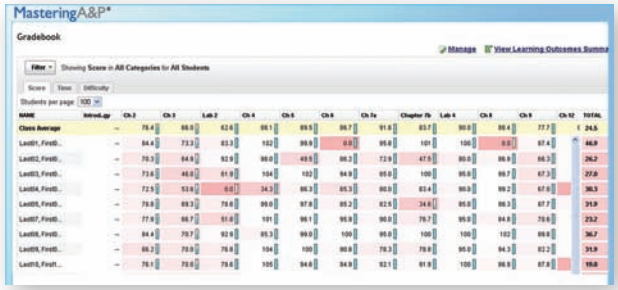
Easily Assess Your Students Using Images from PAL™ 3.0

MasteringA&P allows you to assign multiple choice and open-ended questions using the images from PAL 3.0.



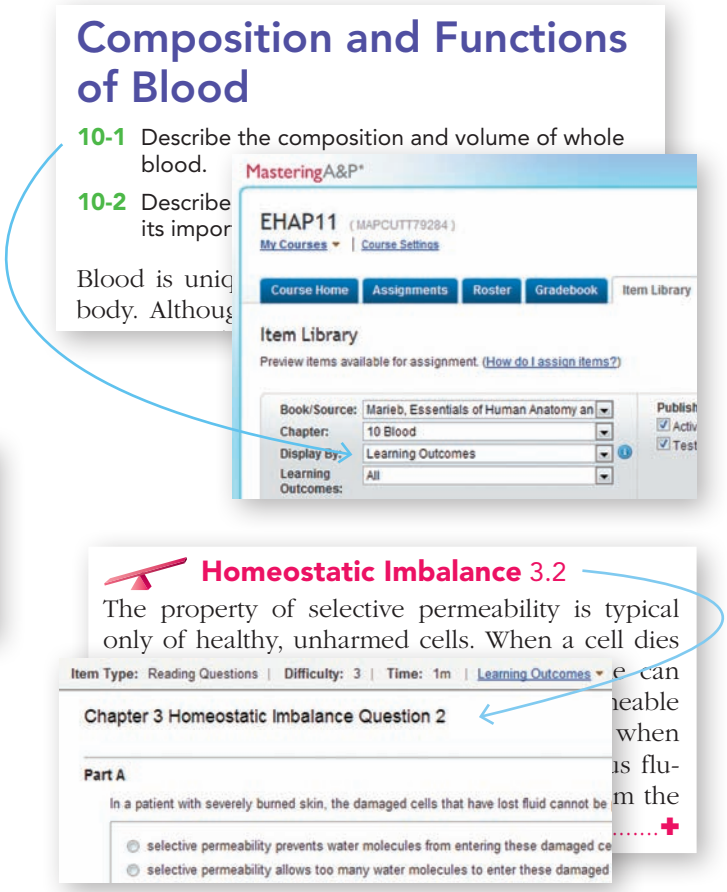
Identify Struggling Students Before It's Too Late

The color-coded gradebook helps you identify vulnerable students at a glance. Assignments are automatically graded, and grades can be easily exported to course management systems or spreadsheets.



New! Assign Learning Objectives and Homeostatic Imbalance Content

The Learning Objectives and Homeostatic Imbalance sections in the book are now numbered, with corresponding assessments in MasteringA&P, making it easy for you to assign them for homework.



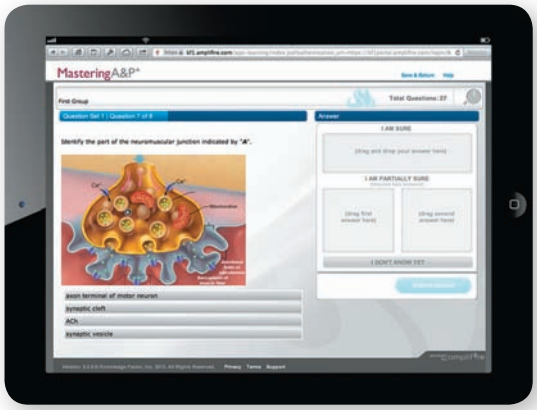
Other Text Features Assignable in MasteringA&P:

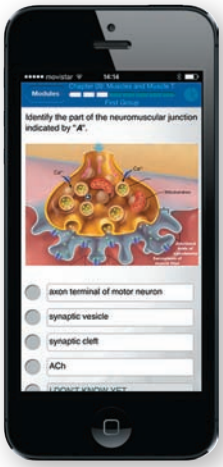
- A&P Flix Coaching Activities offer stunning 3-D visuals of core concepts with in-depth assessments to test student understanding.
- Art-Based Questions gauge students' understanding of concepts illustrated in the book's figures. Wrong-answer feedback provides further guidance.
- Reading Questions keep students on track and are pre-built for easy assignment and grading.
- Test Bank questions are fully revised for the 11th edition, providing an easy way to assess your students.

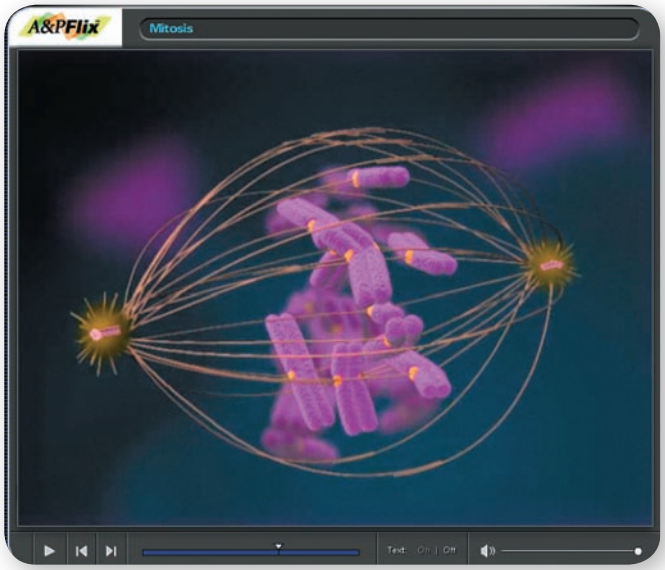
STUDENTS: Use MasteringA&P® to Study Anytime, Anywhere

New! Study on the Go with the Dynamic Study Modules App

Dynamic Study Modules help you learn more information faster, whenever you have a few extra minutes to study.

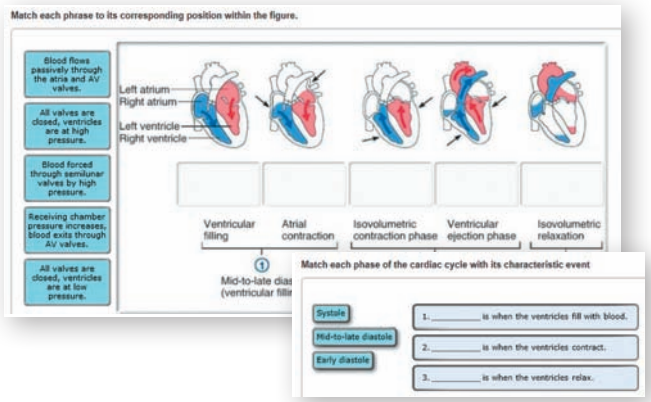






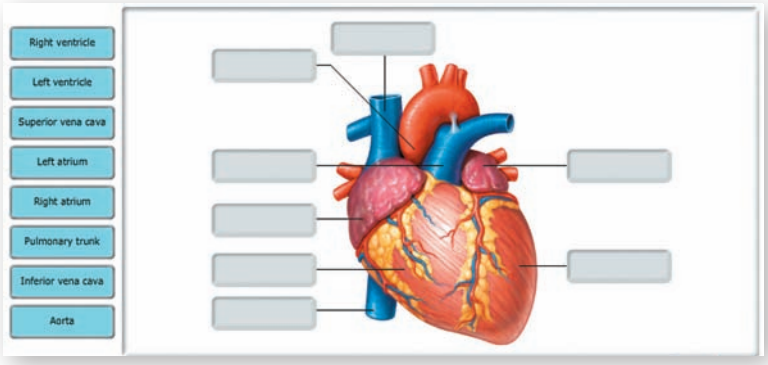
New! Walk Through Key A&P Concepts with New Coaching Activities

Using animations and art from the book, coaching activities are accompanied by questions with specific hints and feedback.



Assess Your Knowledge of Terms and Structures with Art-Labeling Activities

Featuring art from the book, art labeling activities challenge students to identify key terms and structures. Corresponding figures in the book now refer students to these online activities for timely, interactive learning.



Help A&P Students Study & Retain Information

New! Concept Links

appear throughout the book and help students recall previously learned material, apply what they've learned to new material, and make connections across body systems.

Recall that the joining of amino acids by enzymes into peptide bonds is the result of dehydration syn
p. 42). To make
water (H_2O) mu
is removed from
group (OH) is re

Recall that mitosis gone wild is the basis for cancer (Chapter 3, p. 85). In malignant cancers, the stages of mitosis occur so quickly that errors are made. As a result, these cells lack normal control of such processes as mitosis and cell division. Cells experiencing rapid, uncontrolled growth become cancerous.

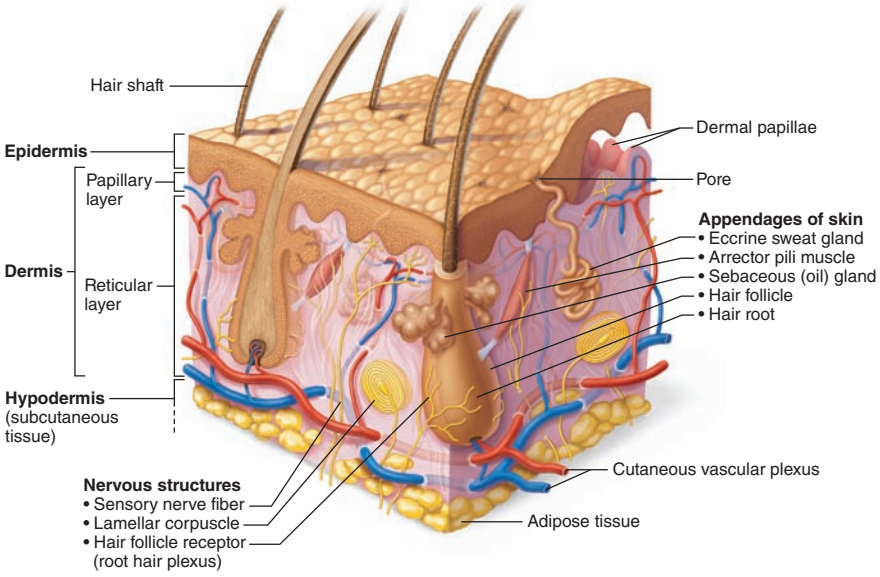


Figure 4.3 Skin structure. Microscopic view of the skin and underlying subcutaneous tissue.

Practice art labeling
MasteringA&P*>Study Area>Chapter 4

New! References to MasteringA&P

appear with relevant figures and show students where to go online for extra practice.

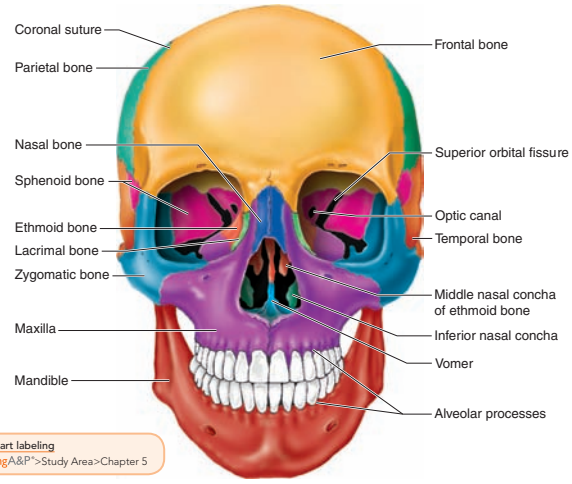
Elaine Marieb's Conversational Writing Style

presents the material without technical jargon, and draws on the author's years of experience as a professor and former nursing student, using meaningful analogies that relate A&P to familiar, everyday concepts.

Many short courses in anatomy and physiology lack the time to consider chemistry as a topic. So why include it here? The answer is simple. The food you eat and the medicines you take when you are ill are composed of chemicals. Indeed, your entire body is made up of chemicals—thousands of them—continuously interacting with one another at an incredible pace.

It is possible to study anatomy without referring much to chemistry, but chemical reactions underlie all body processes—movement, digestion, the pumping of your heart, and even your thoughts. In this chapter we present the basics of

Q: *What bone articulates with every other facial bone?*



Practice art labeling
MasteringA&P®>Study Area>Chapter 5

Figure 5.12 **Human skull, anterior view.**

Homeostatic Imbalance 5.3

The paranasal sinuses also cause many people a great deal of misery. Because the mucosa lining these sinuses is continuous with that in the nose and throat, infections in these areas tend to migrate into the sinuses, causing *sinusitis*. Depending on which sinuses are infected, a headache or upper jaw pain is the usual result.

Palatine Bones The paired palatine bones lie posterior to the palatine processes of the maxillae. They form the posterior part of the hard palate (see Figure 5.11). Failure of these or the palatine processes to fuse medially results in *cleft palate*.

Zygomatic Bones The zygomatic bones are commonly referred to as the cheekbones. They also form a good-sized portion of the lateral walls of the orbits, or eye sockets.

Lacrimal Bones The lacrimal (lak′rĭ-mal) bones are fingernail-sized bones forming part of the medial walls of each orbit. Each lacrimal bone has a groove that serves as a passageway for tears (*lacrima* = tear).

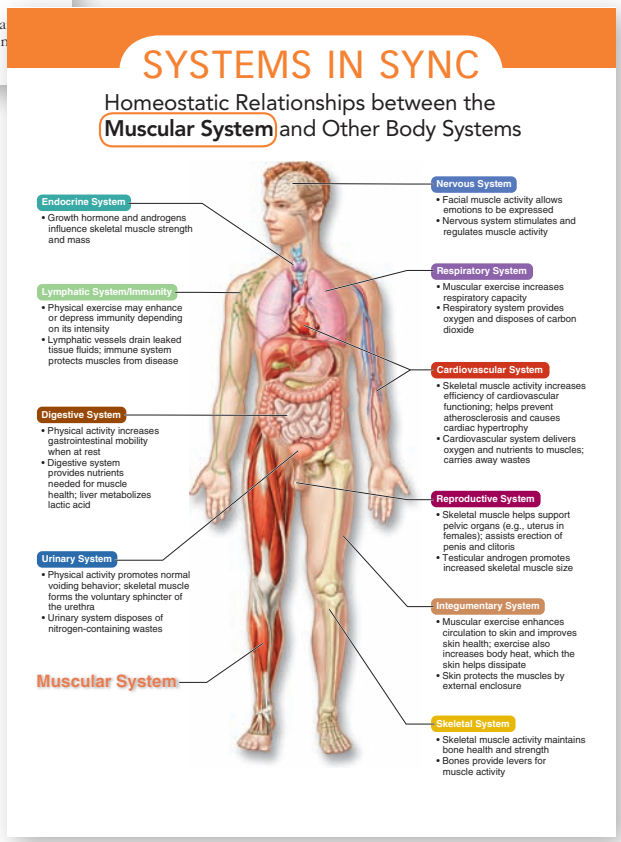
Nasal Bones The small rectangular bones forming the bridge of the nose are the nasal bones. (The lower part of the skeleton of the nose is made up of cartilage.)

Vomer Bone The single bone in the media line of the nasal cavity is the vomer. (*Vomer* mean

A: *The maxilla.*

Figure Questions help students develop a more meaningful understanding of the illustrated concepts and processes and accompany many figures. Answers are found at the bottom of each page.

Systems in Sync Figures summarize, illustrate, and explain the interrelationships of all body systems.



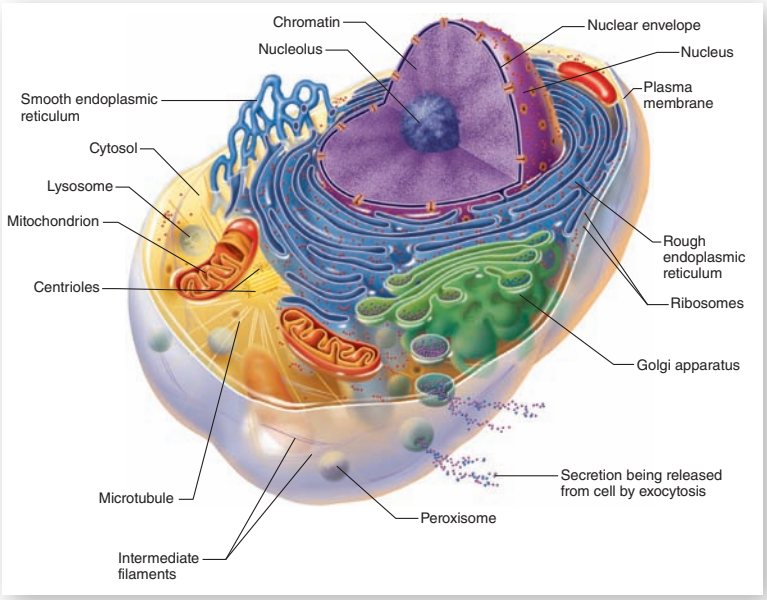
Did You Get It? Questions challenge students to stop, think, and answer concept check questions before moving forward.

Did You Get It?

12. *Gary is trying with all his might to pull a tree stump out of the ground. It does not budge. Which type of contraction are his muscles undergoing?*
13. *What is meant by the term* oxygen deficit?
14. *To develop big, beautiful skeletal muscles, you should focus on which type of exercise: aerobic or resistance exercise?*

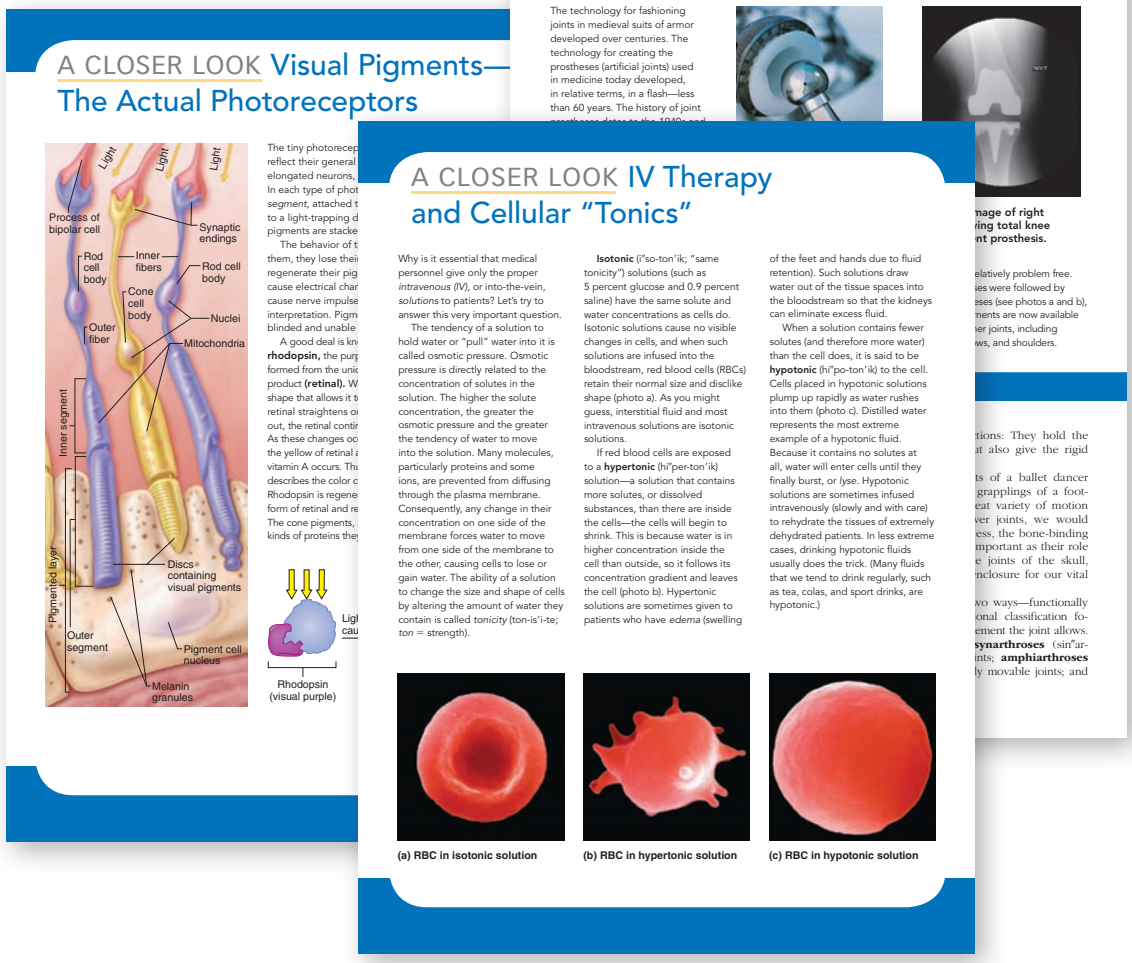
(For answers, see Appendix D.)

Bring A&P Concepts to Life



3-D Anatomy Illustrations are dramatically dynamic and realistic, featuring vibrant, saturated colors to help students visualize key anatomical structures.

A Closer Look boxes discuss new advances in science and topics you may hear about in the news, and describe how they relate to the study of A&P.



A CLOSER LOOK Joint Ventures

The technology for fashioning joints in medieval suits of armor developed over centuries. The technology for creating the prostheses (artificial joints) used in medicine today developed, in relative terms, in a flash—less than 60 years. The history of joint

A CLOSER LOOK Visual Pigments—The Actual Photoreceptors

Light
Process of bipolar cell
Synaptic endings
Rod cell body
Inner fibers
Rod cell body
Cone cell body
Nuclei
Outer fiber
Mitochondria
Inner segment
Discs containing visual pigments
Pigmented layer
Outer segment
Pigment cell nucleus
Melanin granules
Rhodopsin (visual purple)

A CLOSER LOOK IV Therapy and Cellular "Tonics"

Why is it essential that medical personnel give only the proper *intravenous (IV)*, or into-the-vein, *solutions* to patients? Let's try to answer this very important question.

The tendency of a solution to hold water or "pull" water into it is called osmotic pressure. Osmotic pressure is directly related to the concentration of solutes in the solution. The higher the solute concentration, the greater the osmotic pressure and the greater the tendency of water to move into the solution. Many molecules, particularly proteins and some ions, are prevented from diffusing through the plasma membrane. Consequently, any change in their concentration on one side of the membrane forces water to move from one side of the membrane to the other, causing cells to lose or gain water. The ability of a solution to change the size and shape of cells by altering the amount of water they contain is called *tonicity* (ton-is'i-te; *ton* = strength).

Isotonic (i"so-ton'ik; "same tonicity") solutions (such as 5 percent glucose and 0.9 percent saline) have the same solute and water concentrations as cells do. Isotonic solutions cause no visible changes in cells, and when such solutions are infused into the bloodstream, red blood cells (RBCs) retain their normal size and disclike shape (photo a). As you might guess, interstitial fluid and most intravenous solutions are isotonic solutions.

If red blood cells are exposed to a **hypertonic** (hi"per-ton'ik) solution—a solution that contains more solutes, or dissolved substances, than there are inside the cells—the cells will begin to shrink. This is because water is in higher concentration inside the cell than outside, so it follows its concentration gradient and leaves the cell (photo b). Hypertonic solutions are sometimes given to patients who have *edema* (swelling of the feet and hands due to fluid retention). Such solutions draw water out of the tissue spaces into the bloodstream so that the kidneys can eliminate excess fluid.

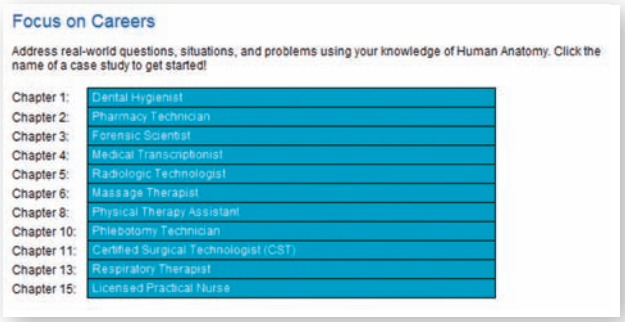
When a solution contains fewer solutes (and therefore more water) than the cell does, it is said to be **hypotonic** (hi"po-ton'ik) to the cell. Cells placed in hypotonic solutions plump up rapidly as water rushes into them (photo c). Distilled water represents the most extreme example of a hypotonic fluid. Because it contains no solutes at all, water will enter cells until they finally burst, or *lyse*. Hypotonic solutions are sometimes infused intravenously (slowly and with care) to rehydrate the tissues of extremely dehydrated patients. In less extreme cases, drinking hypotonic fluids usually does the trick. (Many fluids that we tend to drink regularly, such as tea, colas, and sport drinks, are hypotonic.)

(a) RBC in isotonic solution
(b) RBC in hypertonic solution
(c) RBC in hypotonic solution

Bring the Real World into the Classroom

Focus on Careers boxes feature interviews with working professionals to show the relevance of anatomy and physiology across a wide range of allied health careers. Additional Focus on Careers content is available in the MasteringA&P Study Area.

Available in MasteringA&P®



New! Clinical Photos now accompany Homeostatic Imbalance sections, to help students visualize diseases they may encounter in their future careers. These sections stress the concept that loss of homeostasis leads to pathology or disease.

Homeostatic Imbalance 3.3

Scar tissue is strong, but it lacks the flexibility of most normal tissues. Perhaps even more important is its inability to perform the normal functions of the tissue it replaces. Thus, if scar tissue forms in the wall of the bladder, heart, or another muscular organ, it may severely hamper the functioning of that organ.

Photo showing post-burn contracture scars on the neck. A contracture is a permanent tightening of the skin affecting the underlying tendons or muscles. Contractures develop during the healing process as inelastic fibrous tissue replaces the normal elastic connective tissues. Because fibrous tissue resists stretching, movement of the affected area may be limited.

Resources for Students and Instructors

STUDENT **Supplements**

Anatomy and Physiology Coloring Workbook: A Complete Study Guide, 11th edition

9780321960771 / 0321960777

Learn the structures and functions of the human body from a microscopic to macroscopic level using a wide variety of visual and written exercises and activities.

Essentials of Human Anatomy and Physiology Laboratory Manual, 6th edition

9780321947918 / 0321947916

This brief hands-on lab manual includes 27 exercises featuring a wide range of activities and a four-color Histology Atlas with 55 photomicrographs. Each exercise includes a Pre-Lab Quiz, a materials list, background information, integrated objectives for focused learning, summaries of key concepts, a variety of hands-on activities, and challenging review sheets.

Essentials of Interactive Physiology CD-ROM

9780321949196 / 0321949196

This brief version of the award-winning Interactive Physiology®10-System Suite is specifically adapted for the one-semester course, covering A&P concepts at just the right level and depth. Students benefit from animated tutorials that give insight into the following body systems: muscular, nervous, cardiovascular, respiratory, urinary, endocrine, digestive, and immune, plus coverage of fluids and electrolytes.

INSTRUCTOR **Supplements**

Also available in MasteringA&P®

Instructor's Guide/Test Bank

9780321957313 / 0321957318

This fully updated all-in-one volume provides a wealth of resources for instructors. The Instructor's Guide includes chapter summaries, suggested lecture outlines, teaching and media tips, chapter learning objectives, resources for teaching online, lecture hints, classroom demonstrations and student activities, relevant multimedia and software resources, and a new list of chapter objectives. The Test Bank includes multiple choice, true/false, matching, and essay questions. Test Bank questions are also assignable in MasteringA&P, where they are correlated to book learning objectives and sections, Global Science outcomes, and Bloom's taxonomy.

Instructor's Resource DVD

9780321957290 / 0321957296

The Instructor's Resource DVD (IR-DVD) organizes all instructor media resources into one convenient location. The IR-DVD includes all of the figures and tables from the text in JPEG and PowerPoint® format; label-edit art with editable labels and leader lines; step-edit art that walks students progressively through multistep figures; Clicker Questions and Quiz Show Game questions to encourage student interaction; A&P Flix™ animations; PowerPoint® lecture outlines, the Instructor's Guide/Test Bank in Microsoft® Word and PDF format; the TestGen® electronic test bank; and answers to Worksheets for *Essentials of Interactive Physiology*.

MasteringA&P with Pearson eText – Instant Access

9780321957108 / 0321957105

MasteringA&P for *Essentials of Human Anatomy & Physiology* is an online learning and assessment system proven to help students learn. It helps instructors maximize class time with customizable, easy-to-assign, automatically graded assessments that motivate students to learn outside of class and arrive prepared. The powerful gradebook provides unique insight into student and class performance, even before the first exam. As a result, instructors can spend valuable class time where students need it most. The Mastering system empowers students to take charge of their learning through activities aimed at different learning styles and engages them through practice and step-by-step guidance—at their convenience, 24/7.

Blackboard for Essentials of Human Anatomy & Physiology

9780321957283 / 0321957288

This open-access cartridge contains pre-loaded content for students, including reading quizzes, crossword puzzles, art-labeling activities, and chapter practice tests. Content for instructors includes the Test Bank, *Essentials of Interactive Physiology*® quizzes, A&P Flix™ quizzes, and instructor versions of the reading quizzes and chapter practice tests for creating assessments.

Acknowledgments

Many people contributed to my efforts in the creation of this eleventh edition.

First, I would like to thank the following reviewers for their thoughtful critiques, which helped me with this revision: Carmen Carpenter, South University; Steven D. Collins, Niagara College; Janie Corbitt, Central Georgia Technical College–Milledgeville Campus; Eric D. Forman, Sauk Valley Community College; Andrew Goliszek, North Carolina A&T State University; Amy Goode, Illinois Central College; Jeannette Hafey, Springfield College; Ashley Hagler, Gaston College; Frances Miles, Lake Michigan College–Napier Avenue Campus; Margaret Ott, Tyler Junior College; Heidi Peterson, Indian Hills Community College–Ottumwa Campus; Laura Ritt, Burlington County College; Holly Sanders, Gwinnett Technical College; Leba Sarkis, Aims Community College; Gustavo A. Solis, Forsyth Technical Community College; Ginny Stokes, Nash Community College; Robert Suddith, Cape Fear Community College; John F. Tarpey, City College of San Francisco; Deborah S. Temperly, Delta College; Claudia Williams, Campbell University.

A very special thank you goes to Suzanne Keller of Indian Hills Community College–Ottumwa for her significant contributions to this edition, in the form of the new Concept Link feature.

The staff at Pearson contributed immensely in the form of support and guidance and deserve a hearty round of applause, one and all. Special thanks to Brooke Suchomel, Sr. Acquisitions Editor, and Shannon Cutt, my devoted Project Editor. Thanks also to Ashley Williams, Assistant Editor, for handling all administrative tasks necessary to set-up the project, and for overseeing revision of the Coloring Workbook. Thank you Natalie Pettry, Associate Content Producer, for supervising an impressive variety of media content that will benefit both students and instructors.

A special thank you to tani hasegawa for the book's beautiful and creative new interior and cover design. The work of Kristin Piljay, Photo Researcher, resulted in an array of striking new photos for this edition; and Sally Peyrefitte, my excellent and diligent copyeditor, ensured a consistent style throughout the book. Proofreader Betsy Dietrich skillfully reviewed every page proof, and Kathy Pitcoff provided a thorough and accurate index.

Thank you Donna Kalal, Photo Image Lead, and Jenell Forschler, Rights & Permissions Project Manager, for your resourcefulness in clearing the photo and text permissions in a timely manner. My talented art house, Imagineering STA Media Services, Inc. and compositor, Cenveo® Publisher Services worked tirelessly to provide stunning artwork and student-friendly page layout. Stacey Weinberger, Senior Manufacturing Buyer and Allison Rona, Senior Marketing Manager deserve special thanks for their expertise in delivering and presenting the final product to the market. Last, an emphatic thank you goes to David Novak, my production and art coordinator, for taking on the role of two people during this edition and flawlessly handling every text and art-related production detail—David made the whole process smooth and successful. Michele Mangelli—a tremendous thank you for your skillful oversight of all aspects of the 11th edition...you've never let me down.

Elaine N. Marieb

Anatomy and Physiology
Pearson Education
1301 Sansome Street
San Francisco, CA 94111

Brief Contents

1 The Human Body: An Orientation 1

2 Basic Chemistry 24

3 Cells and Tissues 62

4 Skin and Body Membranes 109

5 The Skeletal System 134

6 The Muscular System 181

7 The Nervous System 225

8 Special Senses 278

9 The Endocrine System 308

10 Blood 337

11 The Cardiovascular System 356

12 The Lymphatic System and Body Defenses 398

13 The Respiratory System 436

14 The Digestive System and Body Metabolism 463

15 The Urinary System 511

16 The Reproductive System 538

Contents

1 The Human Body: An Orientation 1

An Overview of Anatomy and Physiology 1

Anatomy 1

Physiology 2

Relationship between Anatomy and Physiology 2

Levels of Structural Organization 2

From Atoms to Organisms 2

Organ System Overview 3
Integumentary System • Skeletal System • Muscular System • Nervous System • Endocrine System • Cardiovascular System • Lymphatic System • Respiratory System • Digestive System • Urinary System • Reproductive System

Maintaining Life 7

Necessary Life Functions 7
Maintaining Boundaries • Movement • Responsiveness • Digestion • Metabolism • Excretion • Reproduction • Growth

Survival Needs 9

Homeostasis 12

Homeostatic Controls 12

The Language of Anatomy 14

Anatomical Position 14

Directional Terms 14

Regional Terms 14
Anterior Body Landmarks • Posterior Body Landmarks

Body Planes and Sections 17

Body Cavities 18
Dorsal Body Cavity • Ventral Body Cavity • Other Body Cavities

SUMMARY 21

REVIEW QUESTIONS 22

CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 23

A CLOSER LOOK Medical Imaging: Illuminating the Body 10

2 Basic Chemistry 24

Concepts of Matter and Energy 24

Matter 24

Energy 25
Forms of Energy • Energy Form Conversions

Composition of Matter 26

Elements and Atoms 26

Atomic Structure 26
The Basic Atomic Subparticles • Planetary and Orbital Models of an Atom

Identifying Elements 29
Atomic Number • Atomic Mass • Atomic Weight and Isotopes

Molecules and Compounds 30

Chemical Bonds and Chemical Reactions 32

Bond Formation 32
Role of Electrons • Types of Chemical Bonds

Patterns of Chemical Reactions 37
Synthesis Reactions • Decomposition Reactions • Exchange Reactions • Factors Influencing the Rate of Chemical Reactions

Biochemistry: The Chemical Composition of Living Matter 38

Chapter 2, continued

Inorganic Compounds 39
Water • Salts • Acids and Bases

Organic Compounds 42
Carbohydrates • Lipids • Proteins • Nucleic Acids • Adenosine Triphosphate (ATP)

SUMMARY 57

REVIEW QUESTIONS 59

CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 61

FOCUS ON CAREERS Pharmacy Technician 56

3 Cells and Tissues 62

PART I: CELLS 62

Overview of the Cellular Basis of Life 62

Anatomy of a Generalized Cell 63

The Nucleus 64
Nuclear Envelope • Nucleoli • Chromatin

The Plasma Membrane 64
The Fluid Mosaic Model • Membrane Junctions

The Cytoplasm 66
Cytoplasmic Organelles

Cell Extensions 71
Cilia and Flagella • Microvilli

Cell Diversity 74

Cell Physiology 75

Membrane Transport 75
Passive Processes: Diffusion and Filtration • Active Processes

Cell Division 80
Preparations: DNA Replication • Events of Cell Division

Protein Synthesis 85
Genes: The Blueprint for Protein Structure • The Role of RNA • Transcription • Translation

PART II: BODY TISSUES 87

Epithelial Tissue 88

Special Characteristics of Epithelium 88

Classification of Epithelium 88
Simple Epithelia • Stratified Epithelia • Glandular Epithelium

Connective Tissue 93

Common Characteristics of Connective Tissue 93

Extracellular Matrix 93

Types of Connective Tissue 93
Bone • Cartilage • Dense Connective Tissue • Loose Connective Tissue • Blood

Muscle Tissue 97

Types of Muscle Tissue 97
Skeletal Muscle • Cardiac Muscle • Smooth Muscle

Nervous Tissue 99

Tissue Repair (Wound Healing) 100

PART III: DEVELOPMENTAL ASPECTS OF CELLS AND TISSUES 102

SUMMARY 105

REVIEW QUESTIONS 107

CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 108

A CLOSER LOOK IV Therapy and Cellular "Tonics" 84

A CLOSER LOOK Cancer—The Intimate Enemy 102

4 Skin and Body Membranes 109

Classification of Body Membranes 109

Epithelial Membranes 110
Cutaneous Membrane • Mucous Membranes • Serous Membranes

Connective Tissue Membranes 110

The Integumentary System (Skin) 112

Functions of the Integumentary System 112

Structure of the Skin 113
Epidermis • Dermis

Skin Color 119

Appendages of the Skin 119
Cutaneous Glands • Hair and Hair Follicles • Nails

Homeostatic Imbalances of Skin 124
Burns • Infections and Allergies • Skin Cancer

Developmental Aspects of Skin and Body Membranes 128

SUMMARY 131

REVIEW QUESTIONS 132

CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 133

A CLOSER LOOK A Wrinkle Out of Time 118

FOCUS ON CAREERS Medical Transcriptionist 129

SYSTEMS IN SYNC 130

5 The Skeletal System 134

Bones: An Overview 134

Functions of the Bones 135

Classification of Bones 135

Structure of Bone 137
Gross Anatomy of a Long Bone • Microscopic Anatomy

Bone Formation, Growth, and Remodeling 141
Bone Formation and Growth • Bone Remodeling

Bone Fractures 144

Axial Skeleton 146

Skull 147
Cranium • Facial Bones • The Hyoid Bone • Fetal Skull

Vertebral Column (Spine) 152
Cervical Vertebrae • Thoracic Vertebrae • Lumbar Vertebrae • Sacrum • Coccyx

Thoracic Cage 156
Sternum • Ribs

Appendicular Skeleton 158

Bones of the Shoulder Girdle 158

Bones of the Upper Limbs 158
Arm • Forearm • Hand

Bones of the Pelvic Girdle 162

Bones of the Lower Limbs 164
Thigh • Leg • Foot

Joints 166

Fibrous Joints 167

Cartilaginous Joints 169

Synovial Joints 169

Types of Synovial Joints Based on Shape 170

Developmental Aspects of the Skeleton 173

SUMMARY 177

REVIEW QUESTIONS 178

CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 180

A CLOSER LOOK Joint Ventures 166

FOCUS ON CAREERS Radiologic Technologist 143

SYSTEMS IN SYNC 176

6 The Muscular System 181

Overview of Muscle Tissues 181

Muscle Types 181
Skeletal Muscle • Smooth Muscle • Cardiac Muscle

Chapter 6, continued

Muscle Functions 185
Producing Movement • Maintaining Posture and Body Position • Stabilizing Joints • Generating Heat • Additional Functions

Microscopic Anatomy of Skeletal Muscle 185

Skeletal Muscle Activity 187

Stimulation and Contraction of Single Skeletal Muscle Cells 187
The Nerve Stimulus and the Action Potential • Mechanism of Muscle Contraction: The Sliding Filament Theory

Contraction of a Skeletal Muscle as a Whole 191
Graded Responses • Providing Energy for Muscle Contraction • Muscle Fatigue and Oxygen Deficit • Types of Muscle Contractions—Isotonic and Isometric • Muscle Tone • Effect of Exercise on Muscles

Muscle Movements, Types, and Names 196

Types of Body Movements 196
Special Movements

Interactions of Skeletal Muscles in the Body 200

Naming Skeletal Muscles 202

Arrangement of Fascicles 202

Gross Anatomy of Skeletal Muscles 203

Head and Neck Muscles 203
Facial Muscles • Chewing Muscles • Neck Muscles

Trunk Muscles 207
Anterior Muscles • Posterior Muscles

Muscles of the Upper Limb 208
Muscles of the Humerus That Act on the Forearm

Muscles of the Lower Limb 209
Muscles Causing Movement at the Hip Joint • Muscles Causing Movement at the Knee Joint • Muscles Causing Movement at the Ankle and Foot

Developmental Aspects of the Muscular System 218

SUMMARY 219

REVIEW QUESTIONS 222

CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 223

A CLOSER LOOK Anabolic Steroids: Dying to Win? 205

SYSTEMS IN SYNC 220

7 The Nervous System 225

Organization of the Nervous System 226

Structural Classification 227

Functional Classification 227

Nervous Tissue: Structure and Function 227

Supporting Cells 227

Neurons 229
Anatomy • Classification • Physiology: Nerve Impulses • Physiology: Reflexes

Central Nervous System 239

Functional Anatomy of the Brain 239
Cerebral Hemispheres • Diencephalon • Brain Stem • Cerebellum

Protection of the Central Nervous System 247
Meninges • Cerebrospinal Fluid • The Blood-Brain Barrier

Brain Dysfunctions 251

Spinal Cord 252
Gray Matter of the Spinal Cord and Spinal Roots • White Matter of the Spinal Cord

Peripheral Nervous System 255

Structure of a Nerve 255

Cranial Nerves 257

Spinal Nerves and Nerve Plexuses 257

Autonomic Nervous System 264
Somatic and Autonomic Nervous Systems Compared • Anatomy of the Parasympathetic Division • Anatomy of the Sympathetic Division • Autonomic Functioning

Developmental Aspects of the Nervous System 269

SUMMARY 273

REVIEW QUESTIONS 275

CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 277

A CLOSER LOOK The "Terrible Three" 252

A CLOSER LOOK Tracking Down CNS Problems 270

SYSTEMS IN SYNC 272

8 Special Senses 278

PART I: THE EYE AND VISION 279

Anatomy of the Eye 279

External and Accessory Structures 279

Internal Structures: The Eyeball 280
Layers Forming the Wall of the Eyeball • Lens

Physiology of Vision 287

Pathway of Light through the Eye and Light Refraction 287

Visual Fields and Visual Pathways to the Brain 287

Eye Reflexes 288

PART II: THE EAR: HEARING AND BALANCE 290

Anatomy of the Ear 290

External (Outer) Ear 291

Middle Ear 291

Internal (Inner) Ear 292

Equilibrium 292

Static Equilibrium 293

Dynamic Equilibrium 293

Hearing 296

Hearing and Equilibrium Deficits 297

PART III: CHEMICAL SENSES: SMELL AND TASTE 298

Olfactory Receptors and the Sense of Smell 298

Taste Buds and the Sense of Taste 300

PART IV: DEVELOPMENTAL ASPECTS OF THE SPECIAL SENSES 301

SUMMARY 303

REVIEW QUESTIONS 305

CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 306

A CLOSER LOOK Visual Pigments—The Actual Photoreceptors 285

A CLOSER LOOK Bringing Things into Focus 289

FOCUS ON CAREERS Physical Therapy Assistant 295

9 The Endocrine System 308

The Endocrine System and Hormone Function—An Overview 309

The Chemistry of Hormones 309

Chapter 9, continued

Hormone Action 309
Direct Gene Activation • Second-Messenger System

Control of Hormone Release 310
Endocrine Gland Stimuli

The Major Endocrine Organs 312

Pituitary Gland and Hypothalamus 313
Pituitary-Hypothalamus Relationships • Posterior Pituitary and Hypothalamic Hormones • Anterior Pituitary Hormones

Thyroid Gland 317

Parathyroid Glands 319

Adrenal Glands 319
Hormones of the Adrenal Cortex • Hormones of the Adrenal Medulla

Pancreatic Islets 323

Pineal Gland 325

Thymus 327

Gonads 327
Hormones of the Ovaries • Hormones of the Testes

Other Hormone-Producing Tissues and Organs 327

Placenta 330

Developmental Aspects of the Endocrine System 330

SUMMARY 333

REVIEW QUESTIONS 335

CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 336

A CLOSER LOOK Potential Uses for Growth Hormone 316

SYSTEMS IN SYNC 332

10 Blood 337

Composition and Functions of Blood 337

Components 338

Physical Characteristics and Volume 338

Plasma 338

Formed Elements 340
Erythrocytes • Leukocytes • Platelets

Hematopoiesis (Blood Cell Formation) 345
Formation of Red Blood Cells • Formation of White Blood Cells and Platelets

Hemostasis 347

Disorders of Hemostasis 348

Blood Groups and Transfusions 349

Human Blood Groups 349

Blood Typing 352

Developmental Aspects of Blood 352

SUMMARY 353

REVIEW QUESTIONS 354

CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 355

FOCUS ON CAREERS Phlebotomy Technician 350

11 The Cardiovascular System 356

The Heart 357

Anatomy of the Heart 357
Size, Location, and Orientation • Coverings and Walls of the Heart • Chambers and Associated Great Vessels • Heart Valves • Cardiac Circulation

Physiology of the Heart 363
Intrinsic Conduction System of the Heart: Setting the Basic Rhythm • Cardiac Cycle and Heart Sounds • Cardiac Output

Blood Vessels 370

Microscopic Anatomy of Blood Vessels 370
Tunics • Structural Differences in Arteries, Veins, and Capillaries

Gross Anatomy of Blood Vessels 373

Major Arteries of the Systemic Circulation • Major Veins of the Systemic Circulation • Special Circulations

Physiology of Circulation 382
Arterial Pulse • Blood Pressure • Capillary Exchange of Gases and Nutrients • Fluid Movements at Capillary Beds

Developmental Aspects of the Cardiovascular System 390

SUMMARY 392

REVIEW QUESTIONS 394

CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 396

A CLOSER LOOK Electrocardiography: (Don't) Be Still My Heart 367

A CLOSER LOOK Atherosclerosis? Get Out the Cardiovascular Drāno! 387

SYSTEMS IN SYNC 391

12 The Lymphatic System and Body Defenses 398

PART I: THE LYMPHATIC SYSTEM 398

Lymphatic Vessels 399

Lymph Nodes 400

Other Lymphoid Organs 402

PART II: BODY DEFENSES 403

Innate Body Defenses 404

Surface Membrane Barriers 406

Internal Defenses: Cells and Chemicals 406
Natural Killer Cells • Inflammatory Response • Phagocytes • Antimicrobial Proteins • Fever

Adaptive Body Defenses 410

Antigens 412

Cells of the Adaptive Defense System: An Overview 412
Lymphocytes • Antigen-Presenting Cells

Humoral (Antibody-Mediated) Immune Response 415
Active and Passive Humoral Immunity • Antibodies

Cellular (Cell-Mediated) Immune Response 420

Organ Transplants and Rejection 422

Disorders of Immunity 425

PART III: DEVELOPMENTAL ASPECTS OF THE LYMPHATIC SYSTEM AND BODY DEFENSES 429

SUMMARY 431

REVIEW QUESTIONS 433

CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 435

A CLOSER LOOK Aids: The Modern-Day Plague 428

SYSTEMS IN SYNC 430

13 The Respiratory System 436

Functional Anatomy of the Respiratory System 436

The Nose 437

Pharynx 438

Larynx 439

Trachea 440

Main Bronchi 440

Lungs 441
The Respiratory Membrane

Chapter 13, continued

Respiratory Physiology 445

Mechanics of Breathing 445
Inspiration • Expiration

Respiratory Volumes and Capacities 448

Nonrespiratory Air Movements 448

Respiratory Sounds 449

External Respiration, Gas Transport, and Internal Respiration 449
External Respiration • Gas Transport in the Blood • Internal Respiration

Control of Respiration 452
Neural Regulation: Setting the Basic Rhythm • Nonneural Factors Influencing Respiratory Rate and Depth

Respiratory Disorders 454

Developmental Aspects of the Respiratory System 457

SUMMARY 459

REVIEW QUESTIONS 461

CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 462

A CLOSER LOOK Too Clean for Our Own Good? 456

SYSTEMS IN SYNC 458

14 The Digestive System and Body Metabolism 463

PART I: ANATOMY AND PHYSIOLOGY OF THE DIGESTIVE SYSTEM 463

Anatomy of the Digestive System 463

Organs of the Alimentary Canal 464
Mouth • Pharynx • Esophagus • Stomach • Small Intestine • Large Intestine

Accessory Digestive Organs 472
Teeth • Salivary Glands • Pancreas • Liver and Gallbladder

Functions of the Digestive System 476

Overview of Gastrointestinal Processes and Controls 476

Activities Occurring in the Mouth, Pharynx, and Esophagus 478
Food Ingestion and Breakdown • Food Propulsion—Swallowing and Peristalsis

Activities of the Stomach 480
Food Breakdown • Food Propulsion

Activities of the Small Intestine 483
Food Breakdown and Absorption • Food Propulsion

Activities of the Large Intestine 484
Food Breakdown and Absorption • Propulsion of the Residue and Defecation

PART II: NUTRITION AND METABOLISM 487

Nutrition 487

Dietary Sources of the Major Nutrients 488
Carbohydrates • Lipids • Proteins • Vitamins • Minerals

Metabolism 490

Carbohydrate, Fat, and Protein Metabolism in Body Cells 490
Carbohydrate Metabolism • Fat Metabolism • Protein Metabolism

The Central Role of the Liver in Metabolism 494
General Metabolic Functions • Cholesterol Metabolism and Transport

Body Energy Balance 497
Regulation of Food Intake • Metabolic Rate and Body Heat Production • Body Temperature Regulation

PART III: DEVELOPMENTAL ASPECTS OF THE DIGESTIVE SYSTEM AND METABOLISM 501

SUMMARY 506

REVIEW QUESTIONS 508

CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 510

A CLOSER LOOK Peptic Ulcers: "Something Is Eating at Me" 486

A CLOSER LOOK Obesity: Magical Solution Wanted 503

SYSTEMS IN SYNC 505

15 The Urinary System 511

Kidneys 512

Location and Structure 512
Blood Supply

Nephrons 513

Urine Formation 516
Glomerular Filtration • Tubular Reabsorption • Tubular Secretion • Characteristics of Urine

Ureters, Urinary Bladder, and Urethra 520

Ureters 520

Urinary Bladder 521

Urethra 523

Micturition 523

Fluid, Electrolyte, and Acid-Base Balance 524

Maintaining Water and Electrolyte Balance of Blood 524
Body Fluids and Fluid Compartments • The Link between Water and Salt • Regulation of Water Intake and Output

Electrolyte Balance 527

Maintaining Acid-Base Balance of Blood 529
Blood Buffers • Respiratory System Controls • Renal Mechanisms

Developmental Aspects of the Urinary System 531

SUMMARY 535

REVIEW QUESTIONS 536

CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 537

A CLOSER LOOK Renal Failure and the Artificial Kidney 522

FOCUS ON CAREERS Licensed Practical Nurse (LPN) 532

SYSTEMS IN SYNC 534

16 The Reproductive System 538

Anatomy of the Male Reproductive System 539

Testes 539

Duct System 539
Epididymis • Ductus Deferens • Urethra

Accessory Glands and Semen 541
Seminal Glands • Prostate • Bulbo-urethral Glands • Semen

External Genitalia 542

Male Reproductive Functions 543

Spermatogenesis 543

Testosterone Production 545

Anatomy of the Female Reproductive System 547

Ovaries 547

Duct System 547
Uterine (Fallopian) Tubes • Uterus • Vagina

External Genitalia and Female Perineum 550

Female Reproductive Functions and Cycles 551

Oogenesis and the Ovarian Cycle 551

Uterine (Menstrual) Cycle 553

Hormone Production by the Ovaries 555

Mammary Glands 555

Chapter 16, continued

Pregnancy and Embryonic Development 557

Accomplishing Fertilization 558

Events of Embryonic and Fetal Development 559

Effects of Pregnancy on the Mother 561
Anatomical Changes • Physiological Changes

Childbirth 565
Initiation of Labor • Stages of Labor

Developmental Aspects of the Reproductive System 567

SUMMARY 572

REVIEW QUESTIONS 574

CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 576

A CLOSER LOOK Contraception: Preventing Pregnancy 568

SYSTEMS IN SYNC 571

Appendixes

Appendix A: Word Roots, Prefixes, and Suffixes 577

Appendix B: Periodic Table of the Elements 580

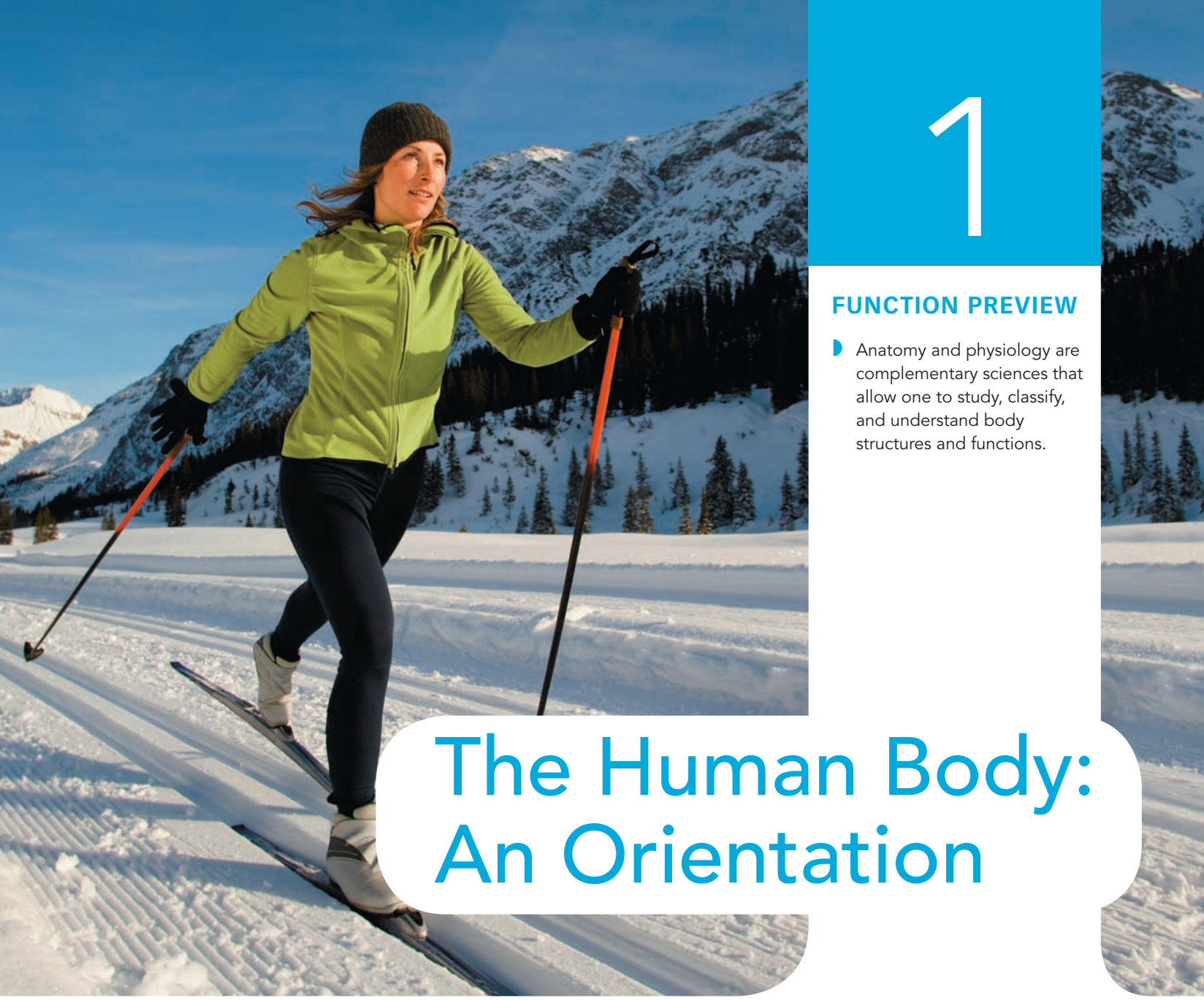
Appendix C: Key Information about Vitamins and Many Essential Minerals 581

Appendix D: Answers to Did You Get It? Questions and Multiple Choice Review Questions 585

Credits 593

Glossary 595

Index 606



1

FUNCTION PREVIEW

- Anatomy and physiology are complementary sciences that allow one to study, classify, and understand body structures and functions.

The Human Body: An Orientation

An Overview of Anatomy and Physiology

1-1 Define *anatomy* and *physiology*.

1-2 Explain how anatomy and physiology are related.

Most of us are naturally curious about our bodies; we want to know what makes us tick. Infants can keep themselves happy for a long time staring at their own hands or pulling their mother's nose. Older children wonder where food goes when they swallow it, and some believe that they will grow a watermelon in their belly if they swallow the seeds. They scream loudly when approached by medical personnel (fearing shots that sting), but they like to play doctor. Adults become upset when their hearts pound, when they have uncontrollable hot flashes, or when they cannot keep their weight down.

Anatomy and physiology, subdivisions of biology, explore many of these topics as they describe how our bodies are put together and how they work.

Anatomy

Anatomy (ah-nat′o-me) is the study of the structure and shape of the body and its parts and their

relationships to one another. Whenever we look at our own body or study large body structures such as the heart or bones, we are observing *gross anatomy;* that is, we are studying large, easily observable structures. Indeed, the term *anatomy,* derived from the Greek words meaning to cut (*tomy*) apart (*ana*), is related most closely to gross anatomical studies because in such studies preserved animals or their organs are dissected (cut up) to be examined. *Microscopic anatomy,* in contrast, is the study of body structures that are too small to be seen with the naked eye. The cells and tissues of the body can only be seen through a microscope.

Physiology

Physiology (fiz″e-ol′o-je) is the study of how the body and its parts work or function (*physio* = nature; *ology* = the study of). Like anatomy, physiology has many subdivisions. For example, *neurophysiology* explains the workings of the nervous system, and *cardiac physiology* studies the function of the heart, which acts as a muscular pump to keep blood flowing throughout the body.

Relationship between Anatomy and Physiology

Anatomy and physiology are always related. The parts of your body form a well-organized unit, and each of those parts has a job to do to make the body operate as a whole. Structure determines what functions can take place. For example, the lungs are not muscular chambers like the heart and cannot pump blood through the body, but because the walls of their air sacs are very thin, they *can* exchange gases and provide oxygen to the body. We stress the intimate relationship between anatomy and physiology throughout this text to make your learning meaningful.

Did You Get It?

1. *Why would you have a hard time learning and understanding physiology if you did not also understand anatomy?*
2. *Kidney function, bone growth, and beating of the heart are all topics of anatomy. True or false?*

(For answers, see Appendix D.)

Throughout this text, Concept Links will highlight links between concepts and/or organ systems. Keep in mind that although discussions of the systems are separated into chapters for detailed study, the overall goal of this text is for you not only to gain an understanding of each individual system, but also to learn how the body systems interact to sustain life.

Levels of Structural Organization

1-3 Name the six levels of structural organization that make up the human body, and explain how they are related.

1-4 Name the organ systems of the body, and briefly state the major functions of each system.

1-5 Identify and classify by organ system all organs discussed.

From Atoms to Organisms

The human body exhibits many levels of structural complexity (Figure 1.1). The simplest level of the structural ladder is the *chemical level* (covered in Chapter 2). At this level, **atoms,** tiny building blocks of matter, combine to form *molecules* such as water, sugar, and proteins. Molecules, in turn, associate in specific ways to form microscopic **cells,** the smallest units of all living things. (We will examine the *cellular level* in Chapter 3). All cells have some common functions, but individual cells vary widely in size and shape, reflecting their particular functions in the body.

The simplest living creatures are composed of single cells, but in complex organisms such as trees or human beings, the structural ladder continues on to the *tissue level.* **Tissues** consist of groups of similar cells that have a common function. Each of the four basic tissue types (epithelial, connective, muscular, and neural) plays a definite but different role in the body. (We discuss tissues in Chapter 3.)

An **organ** is a structure composed of two or more tissue types that performs a specific function for the body. At the *organ level* of organization, extremely complex functions become possible. For example, the small intestine, which digests and absorbs food, is composed of all four tissue types. An **organ system** is a group of organs that

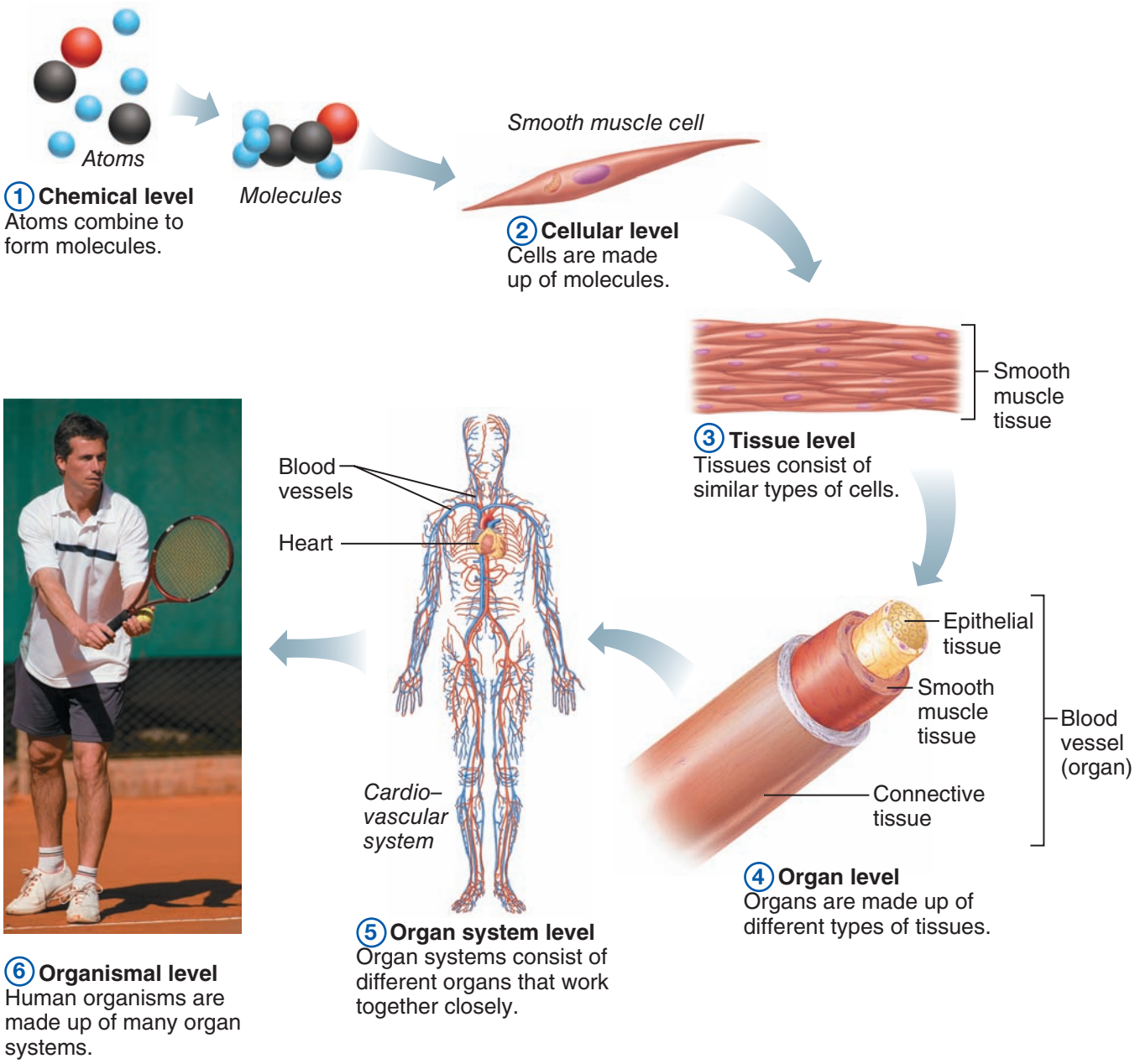


Figure 1.1 Levels of structural organization. In this diagram, components of the cardiovascular system are used to illustrate the levels of structural organization in a human being.

work together to accomplish a common purpose. For example, the heart and blood vessels of the cardiovascular system circulate blood continuously to carry nutrients and oxygen to all body cells.

In all, 11 organ systems make up the living human being, or the **organism,** which represents the highest level of structural organization, the *organismal level*. The organismal level is the sum total of all structural levels working together to keep us alive. (The major organs of each system are shown in Figure 1.2 on pp. 5–6). Refer to the figure as you read through the following descriptions of the organ systems.

Organ System Overview

Integumentary System

The **integumentary** (in-teg″u-men′tar-e) **system** is the external covering of the body, or the skin. It waterproofs the body and cushions and protects

the deeper tissues from injury. It also excretes salts and urea in perspiration and helps regulate body temperature. Temperature, pressure, and pain receptors located in the skin alert us to what is happening at the body surface.

Skeletal System

The **skeletal system** consists of bones, cartilages, ligaments, and joints. It supports the body and provides a framework that the skeletal muscles use to cause movement. It also has a protective function (for example, the skull encloses and protects the brain). *Hematopoiesis* (hem″ah-to-poi-e′sis), or formation of blood cells, takes place within the cavities of the skeleton. The hard substance of bones acts as a storehouse for minerals.

Muscular System

The muscles of the body have only one function—to *contract,* or shorten. When this happens, movement occurs. Hence, muscles can be viewed as the "machines" of the body. The mobility of the body as a whole reflects the activity of *skeletal muscles,* the large, fleshy muscles attached to bones. When these contract, you are able to stand erect, walk, leap, grasp, throw a ball, or smile. The skeletal muscles form the **muscular system.** These muscles are distinct from the muscles of the heart and of other hollow organs, which move fluids (blood, urine) or other substances (such as food) along definite pathways within the body.

Nervous System

The **nervous system** is the body's fast-acting control system. It consists of the brain, spinal cord, nerves, and sensory receptors. The body must be able to respond to irritants or stimuli coming from outside the body (such as light, sound, or changes in temperature) and from inside the body (such as decreases in oxygen or stretching of tissue). The sensory receptors detect these changes and send messages (via electrical signals called *nerve impulses*) to the central nervous system (brain and spinal cord) so that it is constantly informed about what is going on. The central nervous system then assesses this information and responds by activating the appropriate body effectors (muscles or glands).

Endocrine System

Like the nervous system, the **endocrine** (en′do-krin) **system** controls body activities, but it acts much more slowly. The endocrine glands produce chemical molecules called *hormones* and release them into the blood to travel to relatively distant target organs.

The endocrine glands include the pituitary, thyroid, parathyroids, adrenals, thymus, pancreas, pineal, ovaries (in the female), and testes (in the male). The endocrine glands are not connected anatomically in the same way that parts of the other organ systems are. What they have in common is that they all secrete hormones, which regulate other structures. The body functions controlled by hormones are many and varied, involving every cell in the body. Growth, reproduction, and food use by cells are all controlled (at least in part) by hormones.

Cardiovascular System

The primary organs of the **cardiovascular system** are the heart and blood vessels. Using blood as the transporting fluid, the cardiovascular system carries oxygen, nutrients, hormones, and other substances to and from the tissue cells where exchanges are made. White blood cells and chemicals in the blood help to protect the body from such foreign invaders as bacteria, toxins, and tumor cells. The heart acts as the blood pump, propelling blood out of its chambers into the blood vessels to be transported to all body tissues.

Lymphatic System

The role of the **lymphatic system** complements that of the cardiovascular system. Its organs include lymphatic vessels, lymph nodes, and other lymphoid organs such as the spleen and tonsils. The lymphatic vessels return fluid leaked from the blood back to the blood vessels so that blood can be kept continuously circulating through the body. The lymph nodes and other lymphoid organs help to cleanse the blood and house cells involved in immunity.

Respiratory System

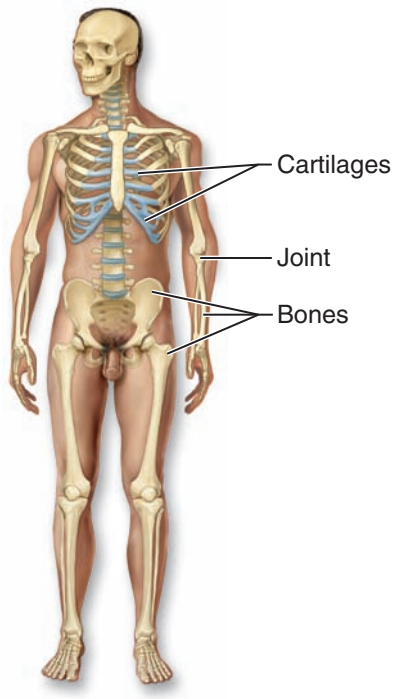
The job of the **respiratory system** is to keep the body constantly supplied with oxygen and to remove carbon dioxide. The respiratory system consists of the nasal passages, pharynx, larynx, trachea, bronchi, and lungs. Within the lungs are tiny air sacs. Gases are transported to and from the blood through the thin walls of these air sacs.

Digestive System

The **digestive system** is basically a tube running through the body from mouth to anus. The organs of

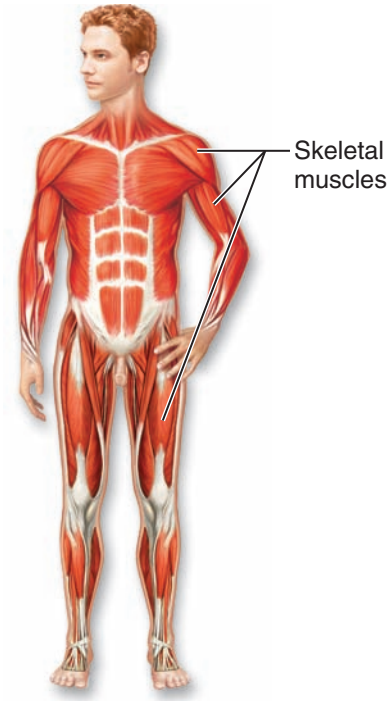
(a) Integumentary System

Forms the external body covering; protects deeper tissue from injury; synthesizes vitamin D; location of cutaneous receptors (pain, pressure, etc.) and sweat and oil glands.



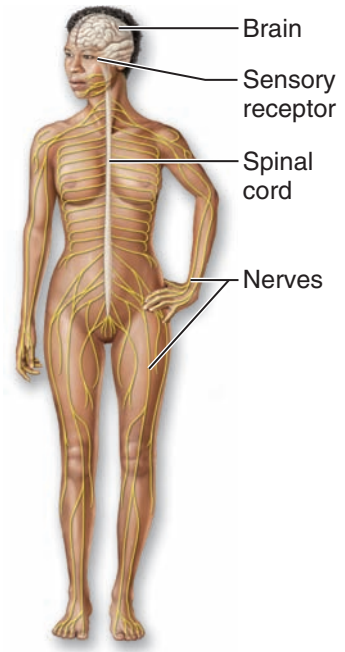
(b) Skeletal System

Protects and supports body organs; provides a framework the muscles use to cause movement; blood cells are formed within bones; stores minerals.



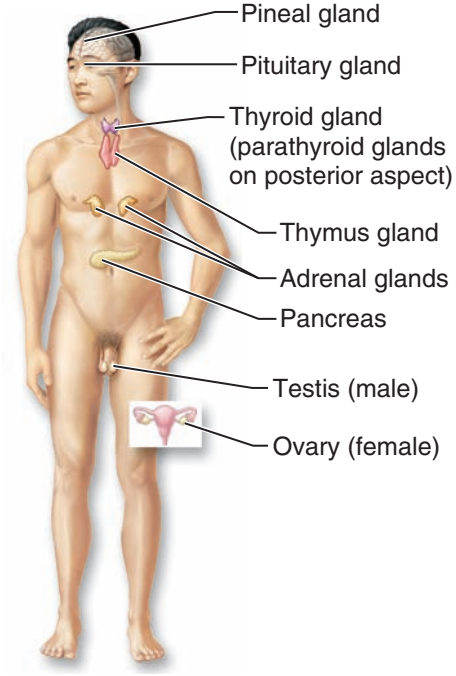
(c) Muscular System

Allows manipulation of the environment, locomotion, and facial expression; maintains posture; produces heat.



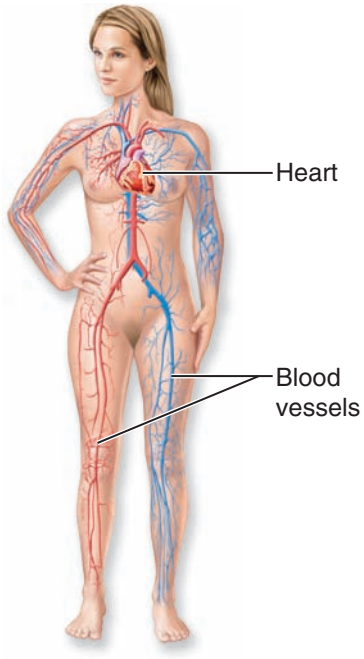
(d) Nervous System

Fast-acting control system of the body; responds to internal and external changes by activating appropriate muscles and glands.



(e) Endocrine System

Glands secrete hormones that regulate processes such as growth, reproduction, and nutrient use by body cells.

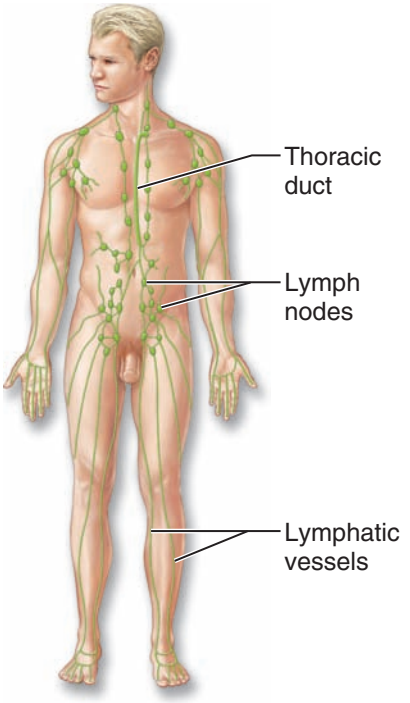


(f) Cardiovascular System

Blood vessels transport blood, which carries oxygen, carbon dioxide, nutrients, wastes, etc.; the heart pumps blood.

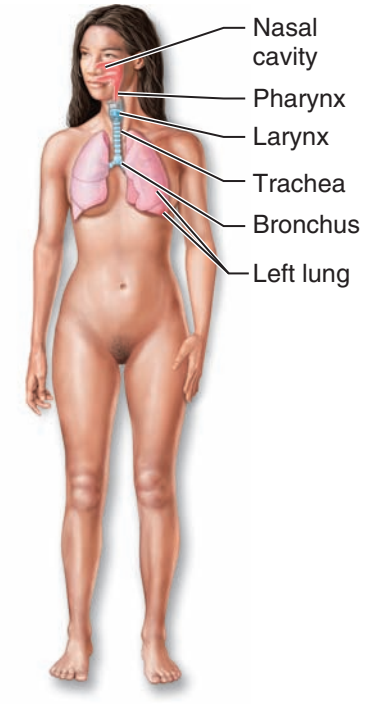
Figure 1.2 The body's organ systems.

(Figure continues on page 6.)



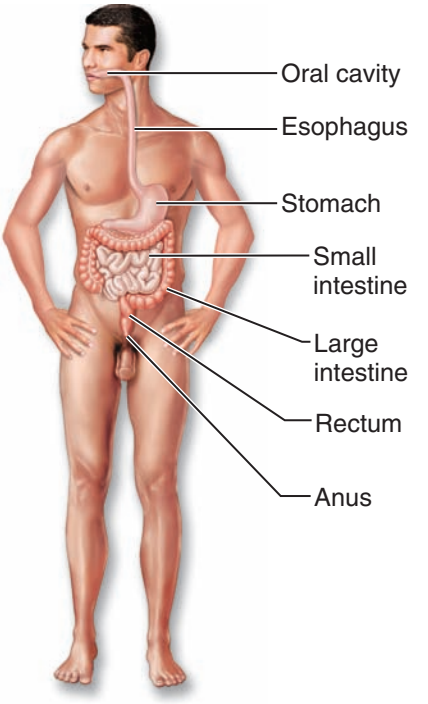
(g) Lymphatic System

Picks up fluid leaked from blood vessels and returns it to blood; disposes of debris in the lymphatic stream; houses white blood cells involved in immunity.



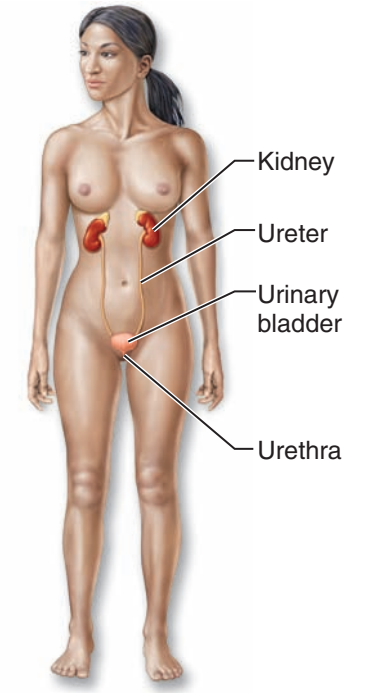
(h) Respiratory System

Keeps blood constantly supplied with oxygen and removes carbon dioxide; the gaseous exchanges occur through the walls of the air sacs of the lungs.



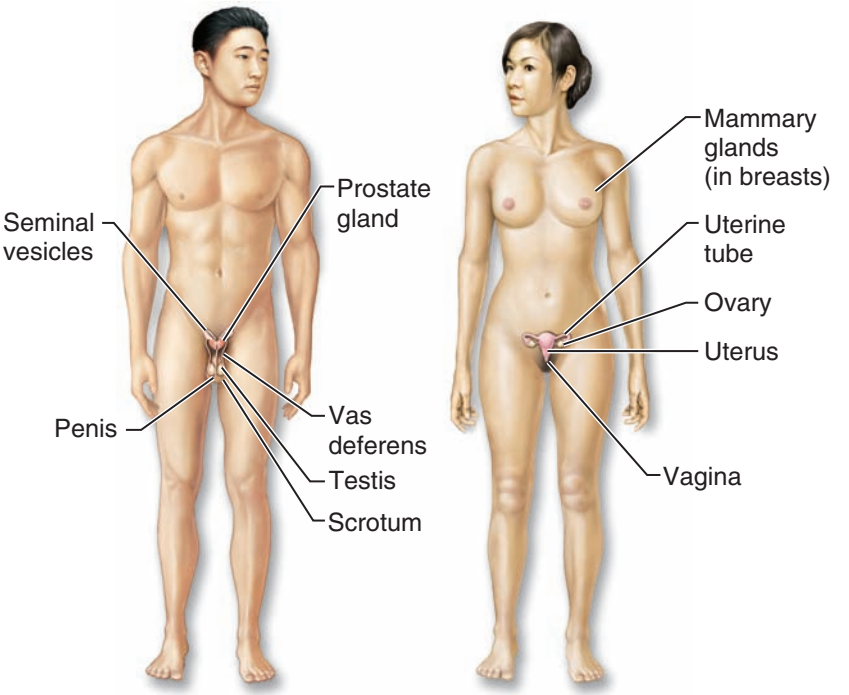
(i) Digestive System

Breaks food down into absorbable units that enter the blood for distribution to body cells; indigestible foodstuffs are eliminated as feces.



(j) Urinary System

Eliminates nitrogen-containing wastes from the body; regulates water, electrolyte, and acid-base balance of the blood.



(k) Male Reproductive System (l) Female Reproductive System

Overall function of the reproductive system is production of offspring. Testes produce sperm and male sex hormone; ducts and glands aid in delivery of viable sperm to the female reproductive tract. Ovaries produce eggs and female sex hormones; remaining structures serve as sites for fertilization and development of the fetus. Mammary glands of female breast produce milk to nourish the newborn.

Figure 1.2 *(continued)* **The body's organ systems.**

the digestive system include the oral cavity (mouth), esophagus, stomach, small and large intestines, and rectum plus a number of accessory organs (liver, salivary glands, pancreas, and others). Their role is to break down food and deliver the products to the blood for dispersal to the body cells. The undigested food that remains in the tract leaves the body through the anus as feces. The breakdown activities that begin in the mouth are completed in the small intestine. From that point on, the major function of the digestive system is to reclaim water. The liver is considered a digestive organ because the bile it produces helps to break down fats. The pancreas, which delivers digestive enzymes to the small intestine, also is functionally a digestive organ.

Urinary System

The body produces wastes as by-products of its normal functions, and these wastes must be disposed of. One type of waste contains nitrogen (examples are urea and uric acid), which results when the body cells break down proteins and nucleic acids. The **urinary system** removes the nitrogen-containing wastes from the blood and flushes them from the body in urine. This system, often called the *excretory system,* is composed of the kidneys, ureters, bladder, and urethra. Other important functions of this system include maintaining the body's water and salt (electrolyte) balance and regulating the acid-base balance of the blood.

Reproductive System

The **reproductive system** exists primarily to produce offspring. The testes of the male produce sperm. Other male reproductive system structures are the scrotum, penis, accessory glands, and the duct system, which carries sperm to the outside of the body. The ovaries of the female produce eggs, or ova; the female duct system consists of the uterine tubes, uterus, and vagina. The uterus provides the site for the development of the fetus (immature infant) once fertilization has occurred.

Did You Get It?

3. *At which level of structural organization is the stomach? At which level is a glucose molecule?*
4. *Which organ system includes the trachea, lungs, nasal cavity, and bronchi?*

(For answers, see Appendix D.)

Maintaining Life

1-6 List eight functions that humans must perform to maintain life.

1-7 List the five survival needs of the human body.

Necessary Life Functions

Now that we have introduced the structural levels composing the human body, a question naturally follows: What does this highly organized human body do? Like all complex animals, human beings maintain their boundaries, move, respond to environmental changes, take in and digest nutrients, carry out metabolism, dispose of wastes, reproduce themselves, and grow. We will discuss each of these necessary life functions briefly here and in more detail in later chapters.

Organ systems do not work in isolation; instead, they work together to promote the well-being of the entire body (**Figure 1.3**, p. 8). Because this theme is emphasized throughout this text, it is worthwhile to identify the most important organ systems contributing to each of the necessary life functions. Also, as you study this figure, you may want to refer back to the more detailed descriptions of the organ systems just provided (pp. 3–7 and in Figure 1.2).

Maintaining Boundaries

Every living organism must be able to maintain its boundaries so that its "inside" remains distinct from its "outside." Every cell of the human body is surrounded by an external membrane that contains its contents and allows needed substances in while generally preventing entry of potentially damaging or unnecessary substances. The body as a whole is also enclosed by the integumentary system, or skin. The integumentary system protects internal organs from drying out (which would be fatal), from bacteria, and from the damaging effects of heat, sunlight, and an unbelievable number of chemical substances in the external environment.

Movement

Movement includes all the activities promoted by the muscular system, such as propelling ourselves from one place to another (by walking, swimming, and so forth) and manipulating the external environment with our fingers. The skeletal system provides the bones that the muscles pull on as they

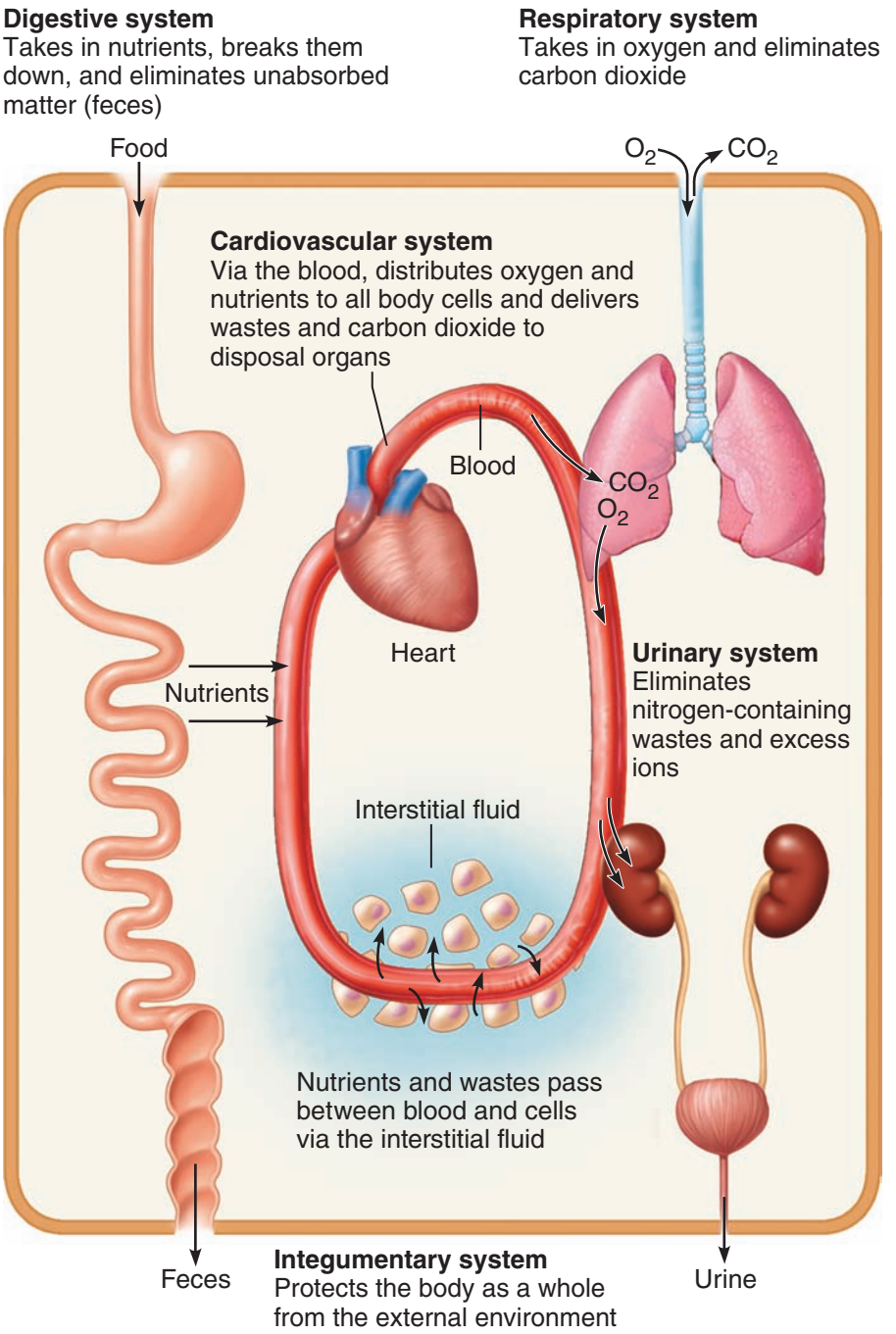


Figure 1.3 **Examples of selected interrelationships among body organ systems.**

work. Movement also occurs when substances such as blood, foodstuffs, and urine are propelled through the internal organs of the cardiovascular, digestive, and urinary systems, respectively.

Responsiveness

Responsiveness, or **irritability,** is the ability to sense changes (stimuli) in the environment and then to react to them. For example, if you cut your hand on broken glass, you involuntarily pull your hand away from the painful stimulus (the broken glass). You do not need to think about it—it just happens! Likewise, when the amount of carbon dioxide in your blood rises to dangerously high levels, your breathing rate speeds up to blow off the excess carbon dioxide.

Because nerve cells are highly irritable and can communicate rapidly with each other via electrical impulses, the nervous system bears the major responsibility for responsiveness. However, all body cells are irritable to some extent.

Digestion

Digestion is the process of breaking down ingested food into simple molecules that can then be absorbed into the blood. The nutrient-rich blood is then distributed to all body cells by the cardiovascular system. In a simple, one-celled organism such as an amoeba, the cell itself is the "digestion factory," but in the complex, multicellular human body, the digestive system performs this function for the entire body.

Metabolism

Metabolism is a broad term that refers to all chemical reactions that occur within body cells. It includes breaking down complex substances into simpler building blocks, making larger structures from smaller ones, and using nutrients and oxygen to produce molecules of adenosine triphosphate (ATP), the energy-rich molecules that power cellular activities. Metabolism depends on the digestive and respiratory systems to make nutrients and oxygen available to the blood and on the cardiovascular system to distribute these needed substances throughout the body. Metabolism is regulated chiefly by hormones secreted by the glands of the endocrine system.

Excretion

Excretion is the process of removing *excreta* (ekskre′tah), or wastes, from the body. If the body is to continue to operate as we expect it to, it must get rid of the nonuseful substances produced during digestion and metabolism. Several organ systems participate in excretion. For example, the digestive system rids the body of indigestible food residues in feces, and the urinary system disposes of nitrogen-containing metabolic wastes in urine.

Reproduction

Reproduction, the production of offspring, can occur on the cellular or organismal level. In cellular reproduction, the original cell divides, producing two identical daughter cells that may then be used for body growth or repair. Reproduction of the human organism, or making a whole new person, is the task of the organs of the reproductive system, which produce sperm and eggs. When a sperm unites with an egg, a fertilized egg forms, which then develops into a baby within the mother's body. The function of the reproductive system is regulated very precisely by hormones of the endocrine system.

Growth

Growth is an increase in size, usually accomplished by an increase in the number of cells. For growth to occur, cell-constructing activities must occur at a faster rate than cell-destroying ones. Hormones released by the endocrine system play a major role in directing growth.

Survival Needs

The goal of nearly all body systems is to maintain life. However, life is extraordinarily fragile and requires that several factors be available. These factors, which we will call *survival needs,* include nutrients (food), oxygen, water, and appropriate temperature and atmospheric pressure.

Nutrients, which the body takes in through food, contain the chemicals used for energy and cell building. Carbohydrates are the major energy-providing fuel for body cells. Proteins and, to a lesser extent, fats are essential for building cell structures. Fats also cushion body organs and provide reserve fuel. Minerals and vitamins are required for the chemical reactions that go on in cells and for oxygen transport in the blood.

All the nutrients in the world are useless unless **oxygen** is also available. Because the chemical reactions that release energy from foods require oxygen, human cells can survive for only a few minutes without it. Approximately 20 percent of the air we breathe is oxygen. It is made available to the blood and body cells by the cooperative efforts of the respiratory and cardiovascular systems.

Water accounts for 60 to 80 percent of body weight. It is the single most abundant chemical substance in the body and provides the fluid base for body secretions and excretions. We obtain water chiefly from ingested foods or liquids, and we lose it by evaporation from the lungs and skin and in body excretions.

If chemical reactions are to continue at life-sustaining levels, **normal body temperature** must be maintained. As body temperature drops below 37°C (98°F), metabolic reactions become

(Text continues on page 12.)