

FUNDAMENTALS OF  
**Anatomy & Physiology**

Eleventh Edition



MARTINI | NATH | BARTHOLOMEW

<b>1</b> An Introduction to Anatomy and Physiology	<b>SmartArt</b> Homeostatic Regulation	1	Using A&P to Save a Life	2
<b>2</b> The Chemical Level of Organization		27	What Is Wrong with My Baby?	28
<b>3</b> The Cellular Level of Organization	<b>SmartArt</b> Protein Synthesis: Transcription Protein Synthesis: Translation	65	The Beat Must Go On!	66
<b>4</b> The Tissue Level of Organization		114	The Rubber Girl	115
<b>5</b> The Integumentary System		152	He Has Fish Skin!	153
<b>6</b> Bones and Bone Structure	<b>SmartArt</b> Endochondral Ossification The Hormones Regulating Calcium Ion Metabolism	180	A Case of Child Abuse?	181
<b>7</b> The Axial Skeleton		208	Knocked Out	209
<b>8</b> The Appendicular Skeleton		243	Timber!!	244
<b>9</b> Joints		265	What's the Matter with the Birthday Girl?	266
<b>10</b> Muscle Tissue	<b>SmartArt</b> Motor Units and Recruitment Anaerobic vs Aerobic Production of ATP	291	Keep on Keepin' on	292
<b>11</b> The Muscular System		336	Downward-Facing Dog	337
<b>12</b> Nervous Tissue		389	Did President Franklin D. Roosevelt Really Have Polio?	390
<b>13</b> The Spinal Cord, Spinal Nerves, and Spinal Reflexes	<b>SmartArt</b> The Reflex Arc	433	Prom Night	434
<b>14</b> The Brain and Cranial Nerves		465	The Neuroanatomist's Stroke	466
<b>15</b> Sensory Pathways and the Somatic Nervous System		512	Living with Cerebral Palsy	513
<b>16</b> The Autonomic Nervous System and Higher-Order Functions		535	Remember Me?	536
<b>17</b> The Special Senses		565	A Chance to See	566
<b>18</b> The Endocrine System	<b>SmartArt</b> The Pancreas and Regulation of Blood Glucose	610	Stones, Bones, and Groans	611
<b>19</b> Blood		656	Crisis in the Blood	657
<b>20</b> The Heart	<b>SmartArt</b> The Cardiac Cycle The Conducting System of the Heart	688	A Needle to the Chest	689
<b>21</b> Blood Vessels and Circulation		727	Did Ancient Mummies Have Atherosclerosis?	728
<b>22</b> The Lymphatic System and Immunity	<b>SmartArt</b> The Immune Response	785	Isn't There a Vaccine for That?	786
<b>23</b> The Respiratory System	<b>SmartArt</b> Partial Pressures	834	No Rest for the Weary	835
<b>24</b> The Digestive System	<b>SmartArt</b> Structure and Function of the Liver Lobule	884	An Unusual Transplant	885
<b>25</b> Metabolism, Nutrition, and Energetics		939	The Miracle Supplement	940
<b>26</b> The Urinary System	<b>SmartArt</b> Structure of the Nephron	976	A Case of "Hidden" Bleeding	977
<b>27</b> Fluid, Electrolyte, and Acid-Base Balance		1021	When Treatment Makes You Worse	1022
<b>28</b> The Reproductive System		1055	And Baby Makes Three?	1056
<b>29</b> Development and Inheritance		1103	The Twins That Looked Nothing Alike	1104



# Spotlight Figures

1-2 Levels of Organization

2-4 Chemical Notation

3-1 Anatomy of a Model Cell 3-7 Protein Synthesis, Processing, and Packaging 3-22 Overview of Membrane Transport  
3-23 Stages of a Cell's Life Cycle 3-24 DNA Replication

4-21 Inflammation and Regeneration

5-3 The Epidermis

6-11 Endochondral Ossification 6-17 Types of Fractures and Steps in Repair

7-4 Sectional Anatomy of the Skull

8-14 Sex Differences in the Human Skeleton

9-2 Joint Movement

10-10 Events at the Neuromuscular Junction 10-11 Excitation-Contraction Coupling  
10-12 The Contraction Cycle and Cross-Bridge Formation

11-3 Muscle Action

12-8 Processes that Produce the Resting Membrane Potential 12-13 Generation of an Action Potential  
12-14 Propagation of an Action Potential

13-8 Structure, Function, and the Peripheral Distribution of Spinal Nerves ( $T_1 - L_2$ ) 13-14 Spinal Reflexes

14-4 Formation and Circulation of Cerebrospinal Fluid

15-8 Somatic Sensory Pathways

16-2 The Autonomic Nervous System

17-2 Olfaction and Gustation 17-13 Refractive Problems 17-16 Photoreception

18-2 Structural Classification of Hormones 18-3 G Proteins and Second Messengers 18-18 Diabetes Mellitus  
18-20 The General Adaptation Syndrome

19-1 The Composition of Whole Blood 19-8 Hemolytic Disease of the Newborn

20-9 Heart Disease and Heart Attacks 20-13 Cardiac Arrhythmias

21-33 Congenital Heart Problems

22-21 Cytokines of the Immune System

23-13 Pulmonary Ventilation 23-25 Control of Respiration

24-15 The Regulation of Gastric Activity 24-27 The Chemical Events of Digestion

25-4 The Electron Transport Chain and ATP Formation 25-10 Absorptive and Postabsorptive States

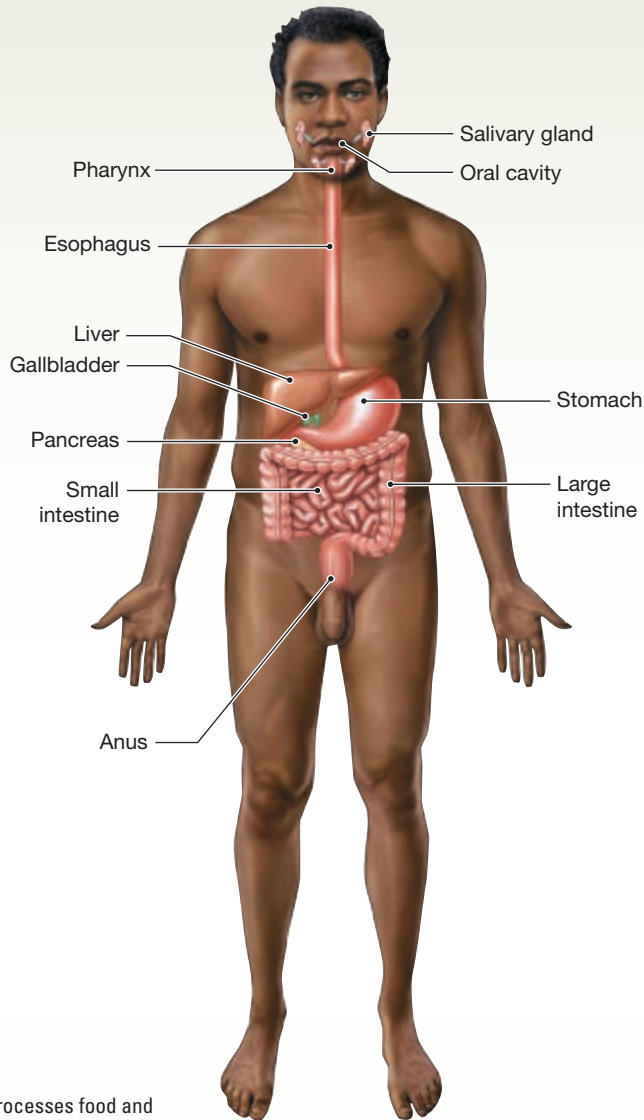
26-16 Summary of Renal Function

27-18 The Diagnosis of Acid-Base Disorders

28-12 Hormonal Regulation of Male Reproduction 28-24 Hormonal Regulation of Female Reproduction

29-5 Extra-embryonic Membranes and Placenta Formation

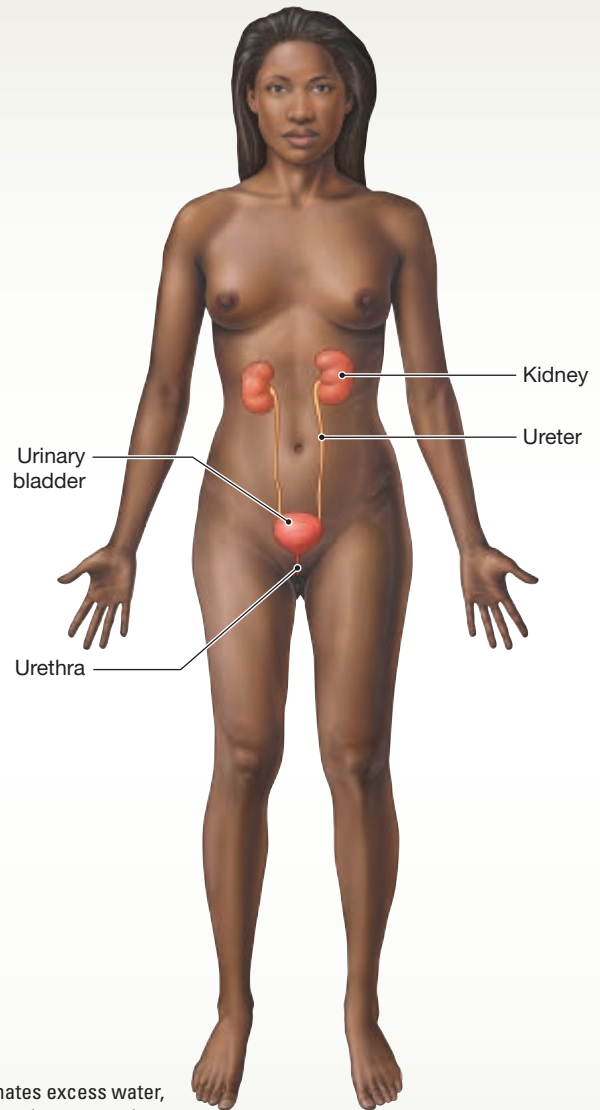
# The Digestive System



Processes food and absorbs nutrients

ORGANS	PRIMARY FUNCTIONS
<b>Salivary Glands</b>	Secrete saliva; provide buffers and lubrication; produce enzymes that begin digestion
<b>Oral Cavity (Mouth)</b>	Cavity for food; works with associated structures (teeth, tongue) to break up food and pass food and liquids to pharynx
<b>Pharynx</b>	Conducts solid food and liquids to esophagus; chamber shared with respiratory tract
<b>Esophagus</b>	Delivers food to stomach
<b>Stomach</b>	Secretes acids and enzymes; mechanically breaks down food
<b>Small Intestine</b>	Secretes digestive enzymes, buffers, and hormones; absorbs nutrients
<b>Liver</b>	Secretes bile; regulates nutrient composition of blood
<b>Gallbladder</b>	Stores bile for release into small intestine
<b>Pancreas</b>	Secretes digestive enzymes and buffers; contains endocrine cells
<b>Large Intestine</b>	Removes water from feces; stores wastes

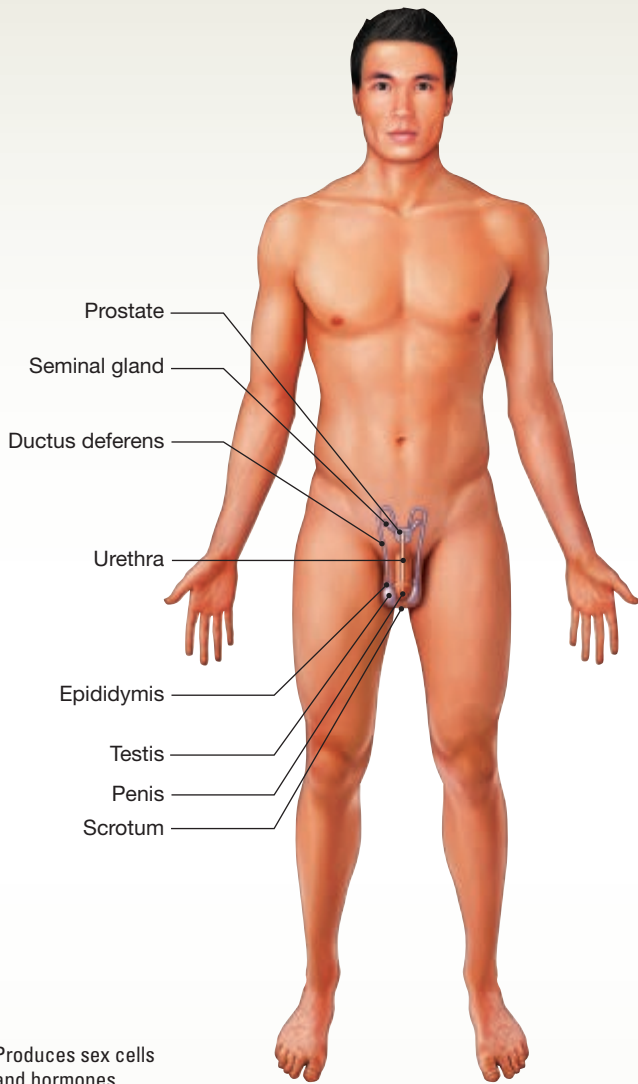
# The Urinary System



Eliminates excess water, salts, and waste products

ORGANS	PRIMARY FUNCTIONS
<b>Kidneys</b>	Form and concentrate urine; regulate blood pH and ion concentrations; perform endocrine functions
<b>Ureters</b>	Conduct urine from kidneys to urinary bladder
<b>Urinary Bladder</b>	Stores urine for eventual elimination
<b>Urethra</b>	Conducts urine to exterior

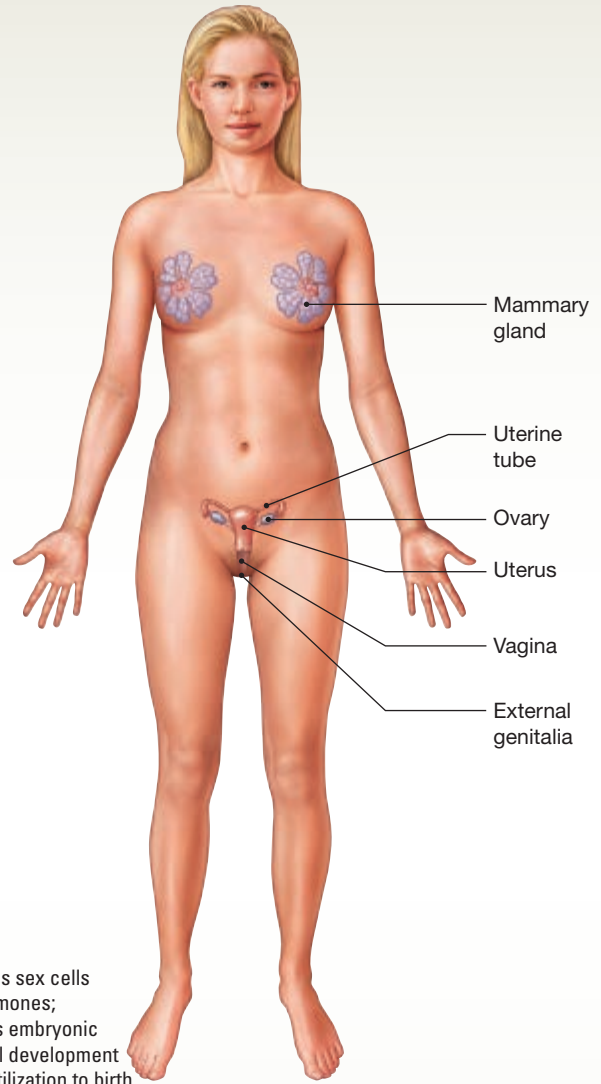
# The Male Reproductive System



Produces sex cells and hormones

ORGANS	PRIMARY FUNCTIONS
<b>Testes</b>	Produce sperm and hormones
Epididymis	Stores, matures, and transports sperm
Ductus Deferens	Conducts sperm between epididymis and prostate
Seminal Glands (Seminal Vesicles)	Secrete fluid that makes up most of the volume of semen
Prostate Gland	Secretes fluid and enzymes
Urethra	Conducts semen to exterior
Penis	Contains erectile tissue; deposits sperm in vagina of female; produces pleasurable sensations during sexual activities
Scrotum	Surrounds the testes and controls their temperature

# The Female Reproductive System



Produces sex cells and hormones; supports embryonic and fetal development from fertilization to birth

ORGANS	PRIMARY FUNCTIONS
<b>Ovaries</b>	Produce oocytes and hormones
<b>Uterine Tubes</b>	Deliver oocyte or embryo to uterus; normal site of fertilization
<b>Uterus</b>	Site of embryonic and fetal development and exchange between maternal and embryonic/fetal bloodstreams; shed lining during menstruation
<b>Vagina</b>	Site of sperm deposition; acts as birth canal during delivery; passageway for fluids during menstruation
Clitoris	Contains erectile tissue; produces pleasurable sensations during sexual activities
Labia	Contain glands that lubricate entrance to vagina
<b>Mammary Glands</b>	Produce milk that nourishes newborn infant



ISBN-13: 978-0-13-460995-9  
ISBN-10: 0-13-460995-6

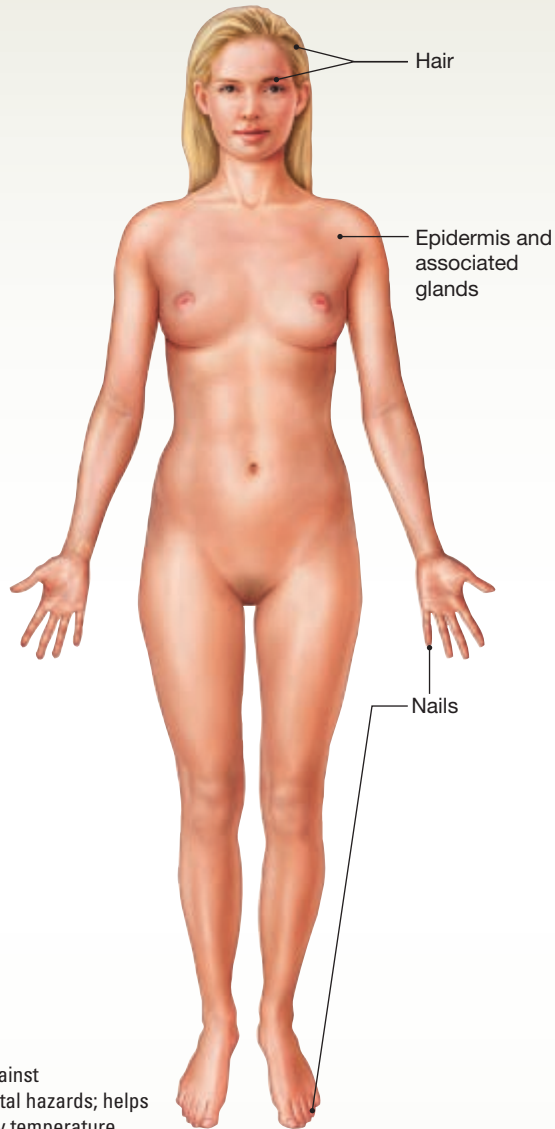




# Frederic H. Martini

## STUDY CARD: BODY SYSTEMS OVERVIEW

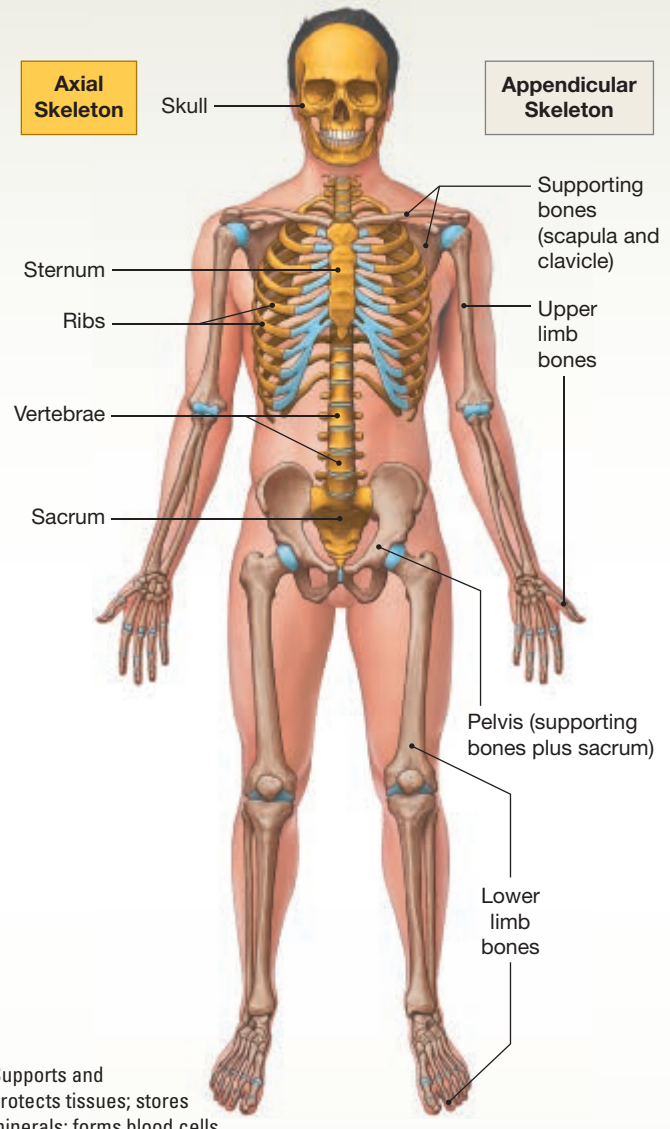
### The Integumentary System



Protects against environmental hazards; helps control body temperature

ORGANS	PRIMARY FUNCTIONS
<b>Cutaneous Membrane</b>	
Epidermis	Covers surface; protects deeper tissues
Dermis	Nourishes epidermis; provides strength; contains glands
<b>Hair Follicles</b>	Produce hair; innervation provides sensation
Hairs	Protect the head
Sebaceous Glands	Secrete lipid coating that lubricates hair shaft and epidermis
<b>Sweat Glands</b>	Produce perspiration for evaporative cooling
<b>Nails</b>	Protect and stiffen distal tips of digits
<b>Sensory Receptors</b>	Provide sensations of touch, pressure, temperature, pain
<b>Subcutaneous Layer</b>	Stores lipids; attaches skin to deeper structures

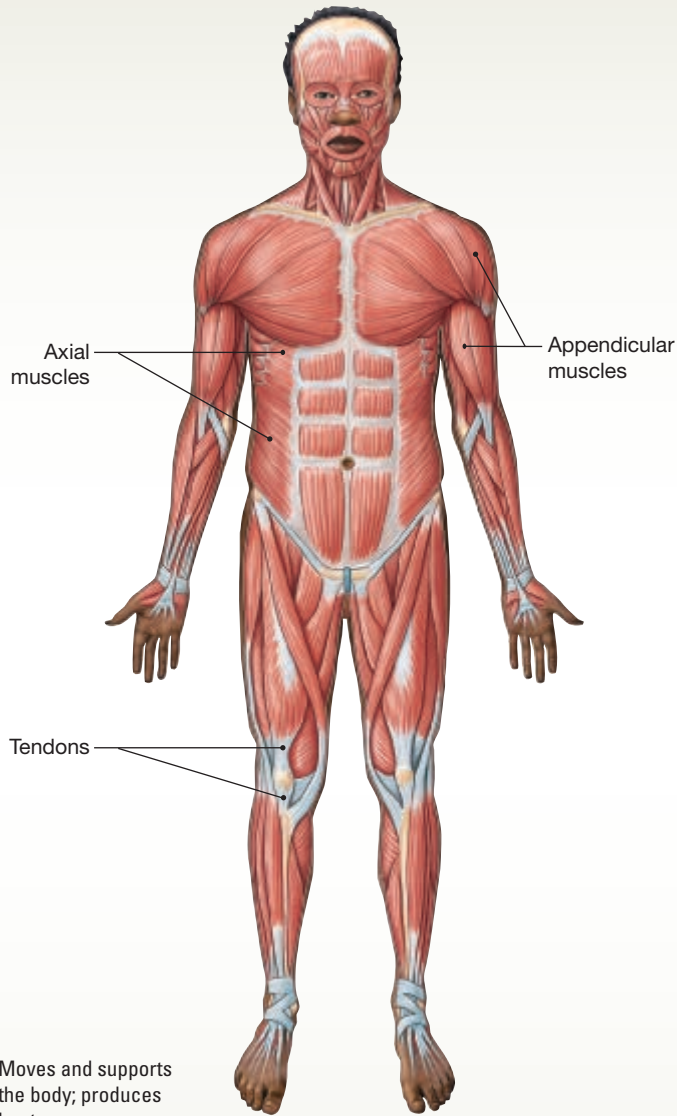
### The Skeletal System



Supports and protects tissues; stores minerals; forms blood cells

ORGANS	PRIMARY FUNCTIONS
<b>Bones, Cartilages, and Joints</b>	Support, protect soft tissues; bones store minerals
<b>Axial Skeleton</b> (skull, vertebrae, ribs, sternum, sacrum, cartilages, and ligaments)	Protects brain, spinal cord, sense organs, and soft tissues of thoracic cavity; supports the body weight over the lower limbs
<b>Appendicular Skeleton</b> (supporting bones, cartilages, and ligaments of the limbs)	Supports and positions the limbs; supports and moves axial skeleton
<b>Bone Marrow</b>	Produces red blood cells and white blood cells; stores lipid reserves

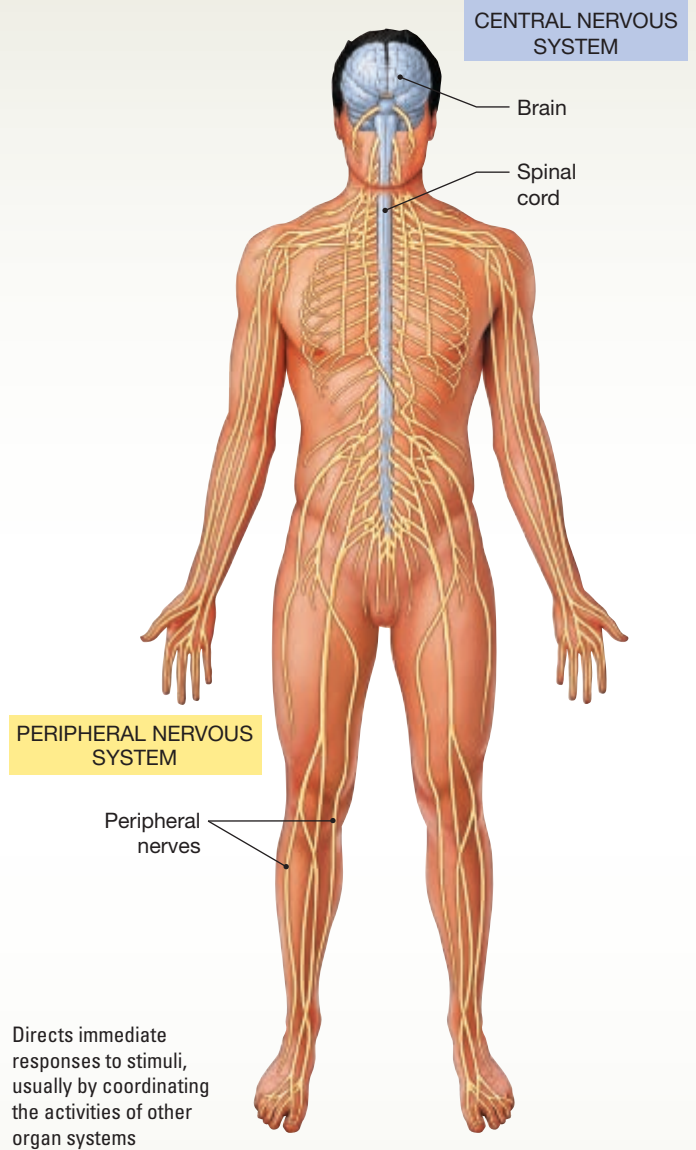
# The Muscular System



Moves and supports the body; produces heat

ORGANS	PRIMARY FUNCTIONS
<b>Skeletal Muscles</b>	Move skeleton; control entrances and exits of digestive tract; contractions generate heat; support skeletal position; protect soft tissues
Axial Muscles	Support and position axial skeleton
Appendicular Muscles	Support, move, and brace limbs
<b>Tendons, Aponeuroses</b>	Harness forces of contraction; attach muscles to bones; assist other muscles

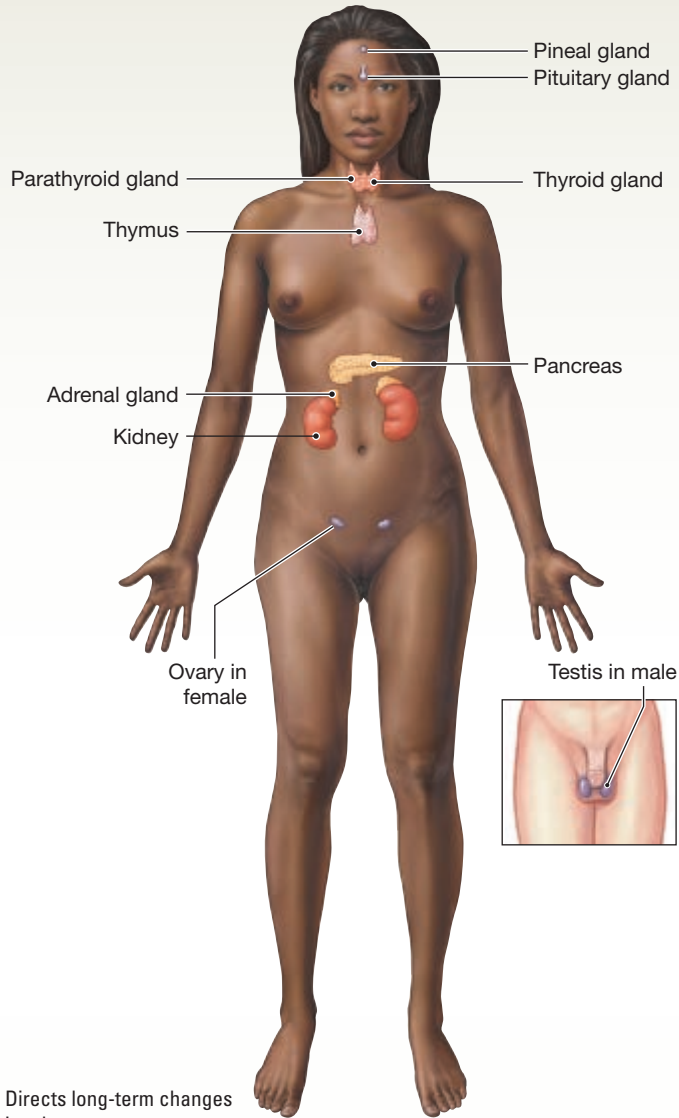
# The Nervous System



Directs immediate responses to stimuli, usually by coordinating the activities of other organ systems

ORGANS	PRIMARY FUNCTIONS
<b>Central Nervous System (CNS)</b>	Acts as control center for nervous system; processes information; provides short-term control over activities of other systems
Brain	Performs complex integrative functions; controls both voluntary and involuntary activities
Spinal Cord	Relays information to and from brain; performs less-complex integrative functions; directs many simple involuntary activities
<b>Peripheral Nervous System (PNS)</b>	Links CNS with other systems and with sense organs

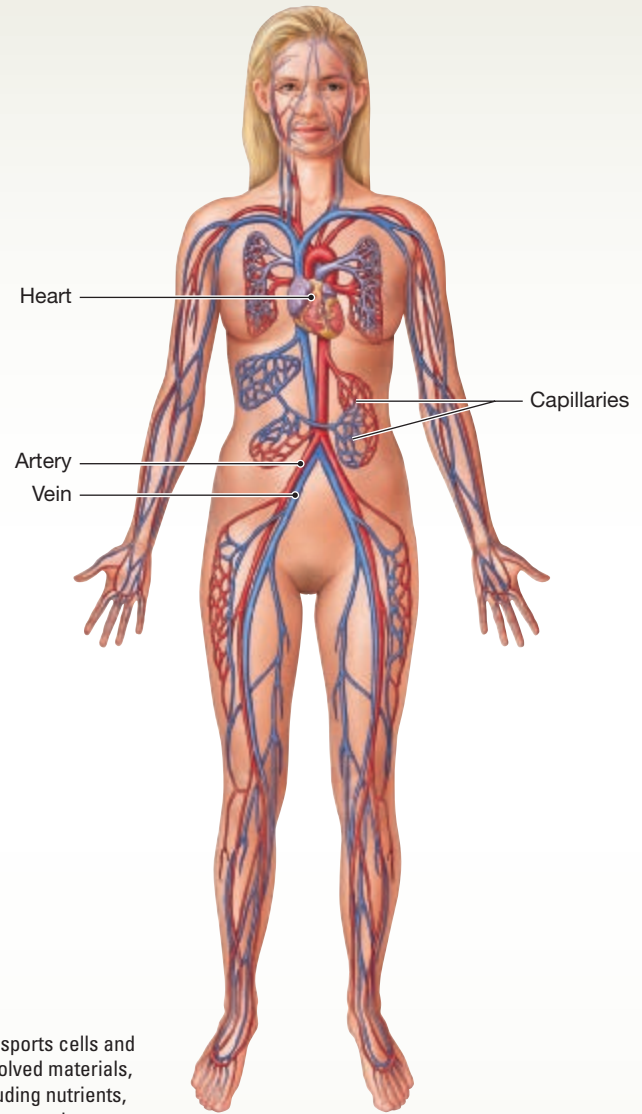
## The Endocrine System



Directs long-term changes in other organ systems

ORGANS	PRIMARY FUNCTIONS
<b>Pineal Gland</b>	May control timing of reproduction and set day-night rhythms
<b>Pituitary Gland</b>	Controls other endocrine glands; regulates growth and fluid balance
<b>Thyroid Gland</b>	Controls tissue metabolic rate; regulates blood calcium levels
<b>Parathyroid Glands</b>	Regulate calcium levels (with thyroid gland)
<b>Thymus</b>	Controls maturation of lymphocytes (T cells)
<b>Adrenal Glands</b>	Adjust water balance and tissue metabolism and regulate cardiovascular and respiratory activity
<b>Kidneys</b>	Control red blood cell production, elevate blood pressure, and assist in calcium homeostasis
<b>Pancreas</b>	Regulates blood glucose levels
<b>Gonads</b>	
Testes	Support male sexual characteristics and reproductive functions
Ovaries	Support female sexual characteristics and reproductive functions

## The Cardiovascular System

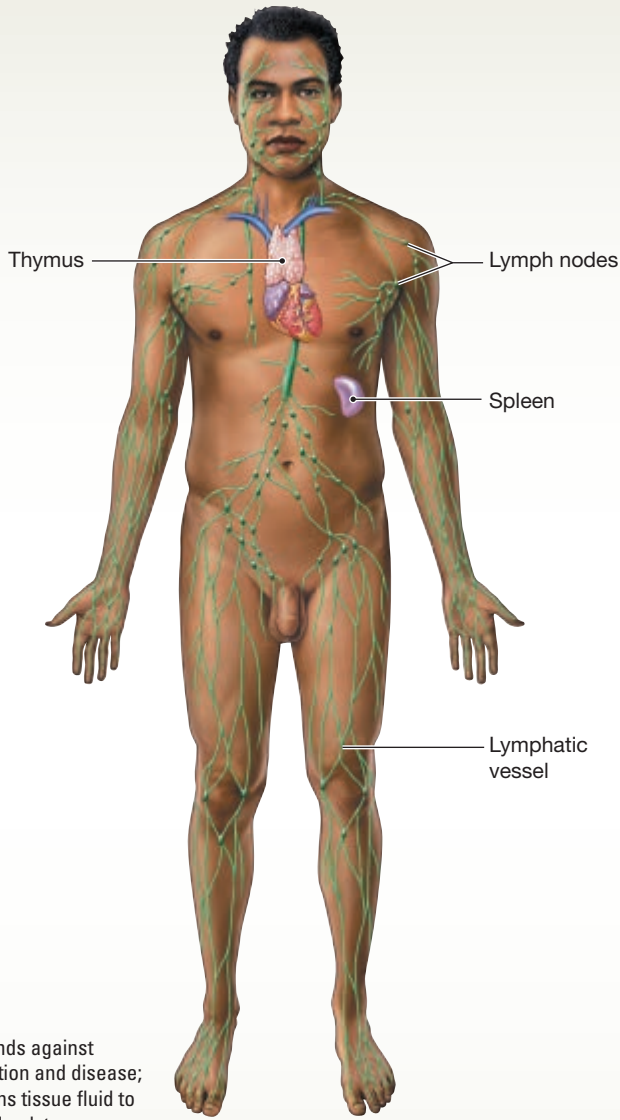


Transports cells and dissolved materials, including nutrients, wastes, and gases

ORGANS	PRIMARY FUNCTIONS
<b>Heart</b>	Propels blood; maintains blood pressure
<b>Blood Vessels</b>	Distribute blood around the body
Arteries	Carry blood from heart to capillaries
Capillaries	Permit diffusion between blood and interstitial fluids
Veins	Return blood from capillaries to the heart
<b>Blood</b>	Transports oxygen, carbon dioxide, and blood cells; delivers nutrients and hormones; removes wastes; regulates temperature; defends against disease



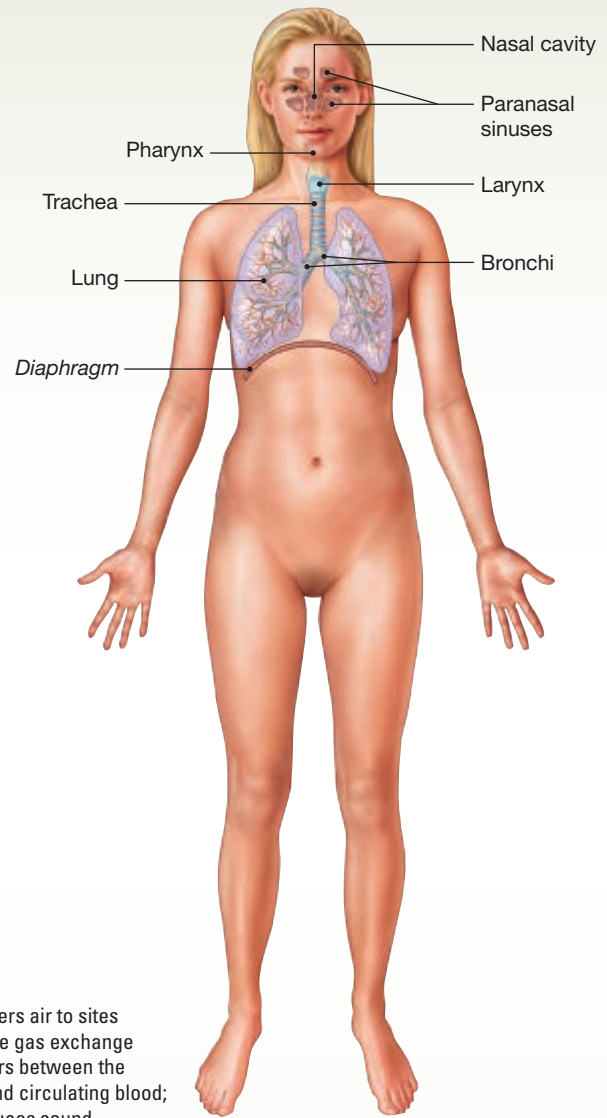
# The Lymphatic System



Defends against infection and disease; returns tissue fluid to the bloodstream

ORGANS	PRIMARY FUNCTIONS
<b>Lymphatic Vessels</b>	Carry lymph (water and proteins) and lymphocytes from peripheral tissues to veins of the cardiovascular system
<b>Lymph Nodes</b>	Monitor the composition of lymph; macrophages engulf pathogens; stimulate immune response
<b>Spleen</b>	Monitors circulating blood; macrophages engulf pathogens; stimulates immune response
<b>Thymus</b>	Controls development and maturation of one class of lymphocytes (T cells)

# The Respiratory System



Delivers air to sites where gas exchange occurs between the air and circulating blood; produces sound

ORGANS	PRIMARY FUNCTIONS
<b>Nasal Cavities, Paranasal Sinuses</b>	Filter, warm, humidify air; detect smells; lessen weight of skull
<b>Pharynx</b>	Conducts air to larynx; is a chamber shared with the digestive tract
<b>Larynx</b>	Protects opening to trachea and contains vocal cords
<b>Trachea</b>	Filters air, traps particles in mucus; cartilages keep airway open
<b>Bronchi</b>	Conducts air between trachea and lungs
<b>Lungs</b>	Move air as a result of thoracic cavity volume changes that occur during breathing
Alveoli	Sites of gas exchange between air and blood

FUNDAMENTALS OF

# Anatomy & Physiology

Eleventh Edition

**Frederic H. Martini, Ph.D.**

University of Hawaii at Manoa

**Judi L. Nath, Ph.D.**

Lourdes University, Sylvania, Ohio

**Edwin F. Bartholomew, M.S.**

**William C. Ober, M.D.**

*Art Coordinator and Illustrator*

**Claire E. Ober, R.N.**

*Illustrator*

**Kathleen Welch, M.D.**

*Clinical Consultant*

**Ralph T. Hutchings**

*Biomedical Photographer*

**Kevin Petti**

San Diego Miramar College  
SmartArt Videos

**Christine Boudrie, M.D.**

Lourdes University, Sylvania, Ohio  
Clinical Cases

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



Editor-in-Chief: *Serina Beauparlant*  
Courseware Portfolio Manager: *Cheryl Cechvala*  
Content Producer: *Jessica Picone*  
Managing Producer: *Nancy Tabor*  
Courseware Director, Content Development: *Barbara Yien*  
Courseware Sr. Analyst: *Suzanne Olivier*  
Courseware Editorial Assistant: *Kimberly Twardochleb*  
Rich Media Content Producer: *Lauren Chen*  
Associate Mastering Producer: *Kristen Sanchez*  
Full-Service Vendor: *Cenveo® Publisher Services*  
Copyeditor: *Lorretta Palagi*

Art Coordinator: *Lisa Torri*  
Design Manager: *Mark Ong*  
Interior Designer: *tani hasegawa*  
Cover Designer: *tani hasegawa*  
Rights & Permissions Project Manager: *Kathleen Zander, Jason Perkins*  
Rights & Permissions Management: *Cenveo® Publisher Services*  
Photo Researcher: *Kristin Piljay*  
Manufacturing Buyer: *Stacey Weinberger*  
Executive Marketing Manager: *Allison Rona*  
Cover Photo Credit: *RGB Ventures/SuperStock/Alamy Stock Photo*

*Notice:* Our knowledge in clinical sciences is constantly changing. The authors and the publisher of this volume have taken care that the information contained herein is accurate and compatible with the standards generally accepted at the time of the publication. Nevertheless, it is difficult to ensure that all information given is entirely accurate for all circumstances. The authors and the publisher disclaim any liability, loss, or damage incurred as a consequence, directly or indirectly, of the use and application of any of the contents of this volume.

Copyright © 2018, 2015, 2012 by Frederic H. Martini, Inc., Judi L. Nath, LLC, and Edwin F. Bartholomew, Inc. Published by Pearson Education, Inc. All Rights Reserved. Printed in the United States of America. This publication is protected by copyright, and permission should be obtained from the publisher prior to any prohibited reproduction, storage in a retrieval system, or transmission in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise. For information regarding permissions, request forms and the appropriate contacts within the Pearson Education Global Rights & Permissions department, please visit [www.pearsoned.com/permissions/](http://www.pearsoned.com/permissions/).

Acknowledgements of third party content appear on page C-1, which constitutes an extension of this copyright page.

PEARSON, ALWAYS LEARNING, MasteringA&P®, A&P Flix®, Practice Anatomy Lab® (PAL®), and Interactive Physiology® are exclusive trademarks in the U.S. and/or other countries owned by Pearson Education, Inc. or its affiliates.

Unless otherwise indicated herein, any third-party trademarks that may appear in this work are the property of their respective owners and any references to third-party trademarks, logos or other trade dress are for demonstrative or descriptive purposes only. Such references are not intended to imply any sponsorship, endorsement, authorization, or promotion of Pearson's products by the owners of such marks, or any relationship between the owner and Pearson Education, Inc. or its affiliates, authors, licensees or distributors.

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

Names: Martini, Frederic, author. | Nath, Judi Lindsley, author. | Bartholomew, Edwin F., author. | Ober, William C., illustrator | Ober, Claire E., illustrator. | Welch, Kathleen (Kathleen Martini), consultant. | Hutchings, R. T., illustrator.

Title: Fundamentals of anatomy & physiology / Frederic H. Martini, Judi L. Nath, Edwin F. Bartholomew; William C. Ober, art coordinator and illustrator; Claire E. Ober, illustrator; Kathleen Welch, clinical consultant; Ralph T. Hutchings, biomedical photographer; clinical cases by Christine Boudrie, Ruth Anne O'Keefe.

Other titles: Fundamentals of anatomy and physiology

Description: Eleventh edition. | New York : Pearson Education, Inc., [2018] | Includes bibliographical references and index.

Identifiers: LCCN 2016041391 | ISBN 9780134396026 (student edition : alk. paper) | ISBN 0134396022 (student edition : alk. paper)

Subjects: | MESH: Anatomy | Physiology

Classification: LCC QP34.5 | NLM QS 4 | DDC 612—dc23 LC record available at <https://lccn.loc.gov/2016041391>



# Text and Illustration Team

## Frederic (Ric) H. Martini, Ph.D.

Author

Dr. Martini received his Ph.D. from Cornell University in comparative and functional anatomy for work on the pathophysiology of stress. In addition to professional publications that include journal articles and contributed chapters, technical reports, and magazine articles, he is the lead author of 10 undergraduate texts on anatomy and physiology. Dr. Martini is currently affiliated with the University of Hawaii at Manoa and has a long-standing bond with the Shoals Marine Laboratory, a joint venture between Cornell University and the University of New Hampshire. He has been active in the Human Anatomy and Physiology Society (HAPS) for over 24 years and was a member of the committee that established the course curriculum guidelines for A&P. He is now a President Emeritus of HAPS after serving as President-Elect, President, and Past-President over 2005–2007. Dr. Martini is also a member of the American Physiological Society, the American Association of Anatomists, the Society for Integrative and Comparative Biology, the Australia/New Zealand Association of Clinical Anatomists, the Hawaii Academy of Science, the American Association for the Advancement of Science, and the International Society of Vertebrate Morphologists.



## Edwin F. Bartholomew, M.S.

Author

Edwin F. Bartholomew received his undergraduate degree from Bowling Green State University and his M.S. from the University of Hawaii. Mr. Bartholomew has taught human anatomy and physiology at both the secondary and undergraduate levels. In addition, he has taught courses ranging from botany to zoology at Maui Community College (now the University of Hawaii Maui College). For many years, he taught at historic Lahainaluna High School, the oldest high school west of the Rockies, where he assisted in establishing a Health Occupations Students of America (HOSA) chapter. He is a coauthor of *Fundamentals of Anatomy & Physiology*, *Visual Anatomy & Physiology*, *Essentials of Anatomy & Physiology*, *Visual Essentials of Anatomy & Physiology*, *Structure and Function of the Human Body*, and *The Human Body in Health and Disease* (all published by Pearson). Mr. Bartholomew is a member of the Human Anatomy and Physiology Society (HAPS), the National Association of Biology Teachers, the National Science Teachers Association, and the American Association for the Advancement of Science.



## Judi L. Nath, Ph.D.

Author

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*

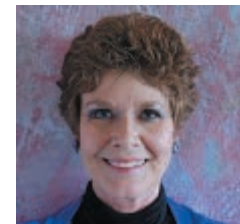
Dr. Boudrie studied at Brown University in Providence, Rhode Island, for her B.S. in biology, and also obtained her M.D. there. After graduation she served in the National Health Service Corps, a program of the U.S. Public Health Service, which sponsored her last 2 years of medical school. She was assigned 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



# Acknowledgments

This textbook represents a group effort, and we would like to acknowledge the people who worked together with us to create this Eleventh Edition.

Foremost on our thank-you list are the instructors who offered invaluable suggestions throughout the revision process. We thank them for their participation and list their names and affiliations below.

**Lois Borek**, *Georgia State University*  
**Angela Bruni**, *Mississippi Gulf Coast Community College*  
**Marien Cendon**, *Miami Dade College, Kendall Campus*  
**Jose Chestnut**, *Essex County College*  
**James E. Clark**, *Manchester Community College*  
**Ferdinand Esser**, *Mercy College*  
**Robert S. Kellar**, *Northern Arizona University*  
**Beth A. Kersten**, *State College of Florida*  
**Mary Katherine Lockwood**, *University of New Hampshire*  
**Naomi Machell**, *Delaware County Community College*  
**Russell Nolan**  
**Amanda R. Pendleton**, *Amarillo College*  
**Louise Petroka**, *Gateway Community College*  
**Courtney B. Ross**, *Gwinnett Technical College*  
**Natalia Schmidt**, *Leeward Community College*  
**Scott L. Simerlein**, *Purdue University North Central*  
**Patricia Steinke**, *San Jacinto College Central*  
**Diane G. Tice**, *Morrisville State College*  
**Pauline Ward**, *Houston Community College*  
**Sarah Ward**, *Colorado Northwestern Community College*  
**Mary Weis**, *Collin College*  
**Colleen Winters**, *Towson University*

The accuracy and currency of the clinical material in this edition reflects the work of our Clinical Case contributors, Christine Boudrie, M.D. and Ruth Anne O’Keefe, M.D., who provided constant, useful feedback on each chapter.

Virtually without exception, reviewers stressed the importance of accurate, integrated, and visually attractive illustrations in helping readers understand essential material. The revision of the art program was directed by Bill Ober, M.D., and Claire E. Ober, R.N. Their suggestions about presentation sequence, topics of clinical importance, and revisions to the proposed art were of incalculable value to us and to the project. The illustration program for this edition was further enhanced by the efforts of several other talented individuals. Jim Gibson designed many of the Spotlight Figures in the art program and consulted on the design and layout of the individual figures. His talents have helped produce an illustration program that is dynamic, cohesive, and easy to understand. Anita Impagliazzo

helped create the photo/art combinations that have resulted in clearer presentations and a greater sense of realism in important anatomical figures. We are also grateful to the talented team at Imagineering ([imagineeringart.com](http://imagineeringart.com)) for their dedicated and detailed illustrative work on key figures. The color micrographs in this edition were provided by Dr. Robert Tallitsch, and his assistance is much appreciated. Many of the striking anatomy photos in the text and in *Martini’s Atlas of the Human Body* are the work of biomedical photographer Ralph Hutchings; his images played a key role in the illustration program.

We also express our appreciation to the editors and support staff at Pearson Science.

We owe special thanks to Senior Acquisitions Editor Cheryl Cechvala for shepherding this project from start to finish. Her ability to manage every detail with such fervor and interest is commendable. She also has an incredible command of the English language coupled with exceptional oratory ability—it’s always fun having candid conversations. Although this was her first year as our editor, she possesses the skills of a seasoned veteran. She is our biggest advocate and is always willing to champion our cause—despite the challenges of working with authors. We are appreciative of all her efforts on our behalf.

Content Producer Jessica Picone was extremely skilled at keeping this project moving forward. Throughout every iteration, she kept track of the files, ensured we were on task, and maintained her high standards. Working with authors can be challenging, and Jessica was up for the task! Editorial Coordinator Kimberly Twardochleb was always available and answered every question we had with speed and accuracy. Having two highly skilled professionals working with us eased our burden. Thanks for not only preparing our material for publication, but making sure it was the best it could possibly be. This past year could not have happened without them.

Suzanne Olivier, our Development Editor, is the absolute best in the business. Suzanne’s ability to look at science material in new ways was astonishing. Moreover, she skillfully encouraged us to think about presenting science information a bit differently, too. She played an essential part in revising this Eleventh Edition. Her unfailing attention to readability, consistency, and quality was indispensable to the authors in meeting our goal of delivering complex A&P content in a more student-friendly, learner-centered way.

We are grateful to Lorretta Palagi for her very careful attention to detail and consistency in her copyedit of the text and art.

This book would not exist without the extraordinary dedication of the Production team who solved many problems under pressure with unfailing good cheer. Norine Strang skillfully

led her excellent team at Cengage to move the book smoothly through composition.

The striking cover and clear, navigable interior design were created by tani hasegawa. Thanks also to Mark Ong, Design Manager, who devised innovative solutions for several complex design challenges.

Thanks to our Photo Researcher, Kristin Piljay, and the permissions team at Cengage for finding, obtaining, and coordinating all the photos in the photo program.

Thanks are also due to Kate Abderholden, Editorial Assistant, who served as project editor for the print supplements for instructors. Thanks also to Stacey Weinberger for handling the physical manufacturing of the book.

We are also grateful to Lauren Chen, Rich Media Content Producer, and Kristin Sanchez, Associate Mastering Producer, for their creative efforts on the media package, most especially MasteringA&P.

We would also like to express our gratitude to the following people at Pearson Science: Paul Corey, President, who continues to support all our texts; Barbara Yien, Director of Development, who kindly kept all phases moving forward under all circumstances; Allison Rona, Executive Marketing Manager; and the dedicated Pearson Science sales representatives for their continuing support of this project. Special thanks to

Editor-in-Chief Serina Beauparlant, who took over the reins and worked closely with our new editor, Cheryl Cechvala, to ensure we had the resources necessary to publish what students need to succeed and what professors want in a textbook. And, a round of applause and a backflip go out to Derek Perrigo, Senior A&P Specialist, our biggest cheerleader.

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.

**Frederic (Ric) H. Martini**

*Haiku, Hawaii*

[martini@pearson.com](mailto:martini@pearson.com)

**Judi L. Nath**

*Sandusky, Ohio*

[nath@pearson.com](mailto:nath@pearson.com)

**Edwin F. Bartholomew**

*Lahaina, Hawaii*

[bartholomew@pearson.com](mailto:bartholomew@pearson.com)

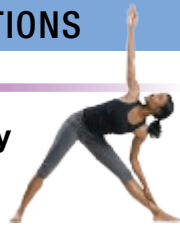


# Contents

Preface v

## UNIT 1 LEVELS OF ORGANIZATIONS

### 1 An Introduction to Anatomy and Physiology 1



An Introduction to Studying the Human Body 2

- 1-1 To make the most of your learning, read the text and view the art together 2**
  - Getting to Know Your Textbook 2
  - Anatomy of a Chapter 3
- 1-2 Anatomy (structure) and physiology (function) are closely integrated 3**
  - Anatomy 4
  - Physiology 5
- 1-3 Levels of organization progress from chemicals to a complete organism 6**
- 1-4 Medical terminology is important to understanding anatomy and physiology 7**
- 1-5 Anatomical terms describe body regions, anatomical positions and directions, and body sections 7**
  - Surface Anatomy 7
  - Sectional Anatomy 13
- 1-6 Body cavities of the trunk protect internal organs and allow them to change shape 14**
  - The Thoracic Cavity 15
  - The Abdominopelvic Cavity 18
- 1-7 Homeostasis, the state of internal balance, is continuously regulated 18**
  - Mechanisms of Homeostatic Regulation 19
  - An Overview of the Process of Homeostatic Regulation 19
- 1-8 Negative feedback opposes variations from normal, whereas positive feedback enhances them 19**
  - The Role of Negative Feedback in Homeostasis 20
  - The Role of Positive Feedback in Homeostasis 22
  - Systems Integration, Equilibrium, and Homeostasis 23

Chapter Review 24

SmartArt Videos

Figure 1–10 Positive Feedback: Blood Clotting. 22

Spotlights

Levels of Organization 8

Clinical Case

Using A&P to Save a Life 2

### Clinical Notes

- Habeas Corpus* (“You Shall Have the Body”) 5
- The Sounds of the Body 13
- Diagnostic Imaging Techniques 16



### 2 The Chemical Level of Organization 27

An Introduction to the Chemical Level of Organization 28

- 2-1 Atoms are the basic particles of matter 28**
  - Atomic Structure 28
  - Elements and Isotopes 29
  - Atomic Weights 30
  - Electrons and Energy Levels 31
- 2-2 Chemical bonds are forces formed by interactions between atoms 32**
  - Ionic Bonds 34
  - Covalent Bonds 35
  - Hydrogen Bonds 36
  - States of Matter 37
- 2-3 Decomposition, synthesis, and exchange reactions are important types of chemical reactions in physiology 37**
  - Basic Energy Concepts 37
  - Types of Chemical Reactions 38
- 2-4 Enzymes speed up reactions by lowering the energy needed to start them 39**
- 2-5 Inorganic compounds lack carbon, and organic compounds contain carbon 40**
- 2-6 Physiological systems depend on water 40**
  - The Properties of Aqueous Solutions 41
  - Colloids and Suspensions 42
- 2-7 Body fluid pH is vital for homeostasis 43**
- 2-8 Acids, bases, and salts have important physiological roles 44**
  - Acids and Bases 44
  - Salts 44
  - Buffers and pH Control 44
- 2-9 Living things contain organic compounds made up of monomers, polymers, and functional groups 45**
- 2-10 Carbohydrates contain carbon, hydrogen, and oxygen in a 1:2:1 ratio 45**
  - Monosaccharides 45
  - Disaccharides and Polysaccharides 46

- 2-11 Lipids often contain a carbon-to-hydrogen ratio of 1:2** 47  
 Fatty Acids 48  
 Eicosanoids 48  
 Glycerides 49  
 Steroids 50  
 Phospholipids and Glycolipids 51
- 2-12 Proteins contain carbon, hydrogen, oxygen, and nitrogen and are formed from amino acids** 51  
 Protein Structure 53  
 Protein Shape 54  
 Enzyme Function 55  
 Glycoproteins and Proteoglycans 57
- 2-13 DNA and RNA are nucleic acids** 57  
 Structure of Nucleic Acids 57  
 Comparison of RNA and DNA 57
- 2-14 ATP is a high-energy compound used by cells** 59
- Chapter Review 61
- Spotlights  
 Chemical Notation 33
- Clinical Case  
 What Is Wrong with My Baby? 28
- Clinical Notes  
 Radiation Sickness 32  
 Too Sweet on Sugar? 49

## 3 The Cellular Level of Organization 65



### An Introduction to Cells 66

- 3-1 The plasma membrane separates the cell from its surrounding environment and performs various functions** 66  
 Membrane Lipids 67  
 Membrane Proteins 67  
 Membrane Carbohydrates 71
- 3-2 Organelles within the cytoplasm perform particular functions** 71  
 The Cytosol 72  
 Nonmembranous Organelles 72  
 Membranous Organelles 76
- 3-3 The nucleus contains DNA and enzymes essential for controlling cellular activities** 83  
 Structure of the Nucleus 83  
 Information Storage in the Nucleus 84
- 3-4 DNA controls protein synthesis, cell structure, and cell function** 85  
 Regulation of Transcription by Gene Activation 85  
 Transcription of DNA into mRNA 85  
 Translation from mRNA into a Polypeptide 87  
 How DNA Controls Cell Structure and Function 89

- 3-5 Diffusion is a passive transport mechanism that assists membrane passage of solutes and water** 90  
 Diffusion 90  
 Osmosis: Diffusion of Water across Selectively Permeable Membranes 93
- 3-6 Carrier-mediated and vesicular transport assist membrane passage of specific substances** 94  
 Carrier-Mediated Transport 95  
 Vesicular Transport 97
- 3-7 The membrane potential of a cell results from the unequal distribution of positive and negative charges across the plasma membrane** 99
- 3-8 Stages of the cell life cycle include interphase, mitosis, and cytokinesis** 102  
 The Cell Life Cycle 102  
 The Mitotic Rate and Energy Use 103
- 3-9 Several factors regulate the cell life cycle** 103
- 3-10 Abnormal cell growth and division characterize tumors and cancers** 107
- 3-11 Cellular differentiation is cellular specialization as a result of gene activation or repression** 109
- Chapter Review 110

### SmartArt Videos

- Figure 3–12 mRNA Transcription. 86  
 Figure 3–13 The Process of Translation. 88

### Spotlights

- Anatomy of a Model Cell 68  
 Protein Synthesis, Processing, and Packaging 78  
 Overview of Membrane Transport 100  
 Stages of a Cell's Life Cycle 104  
 DNA Replication 106

### Clinical Case

- The Beat Must Go On! 66

### Clinical Notes

- Lysosomal Storage Diseases 80  
 Free Radicals 82  
 DNA Fingerprinting 85  
 Mutations 87  
 Drugs and the Plasma Membrane 91  
 Telomerase, Aging, and Cancer 108  
 Breakthroughs with Stem Cells 109

## 4 The Tissue Level of Organization 114



### An Introduction to the Tissue Level of Organization 115

- 4-1 The four tissue types are epithelial, connective, muscle, and nervous** 115
- 4-2 Epithelial tissue covers body surfaces, lines internal surfaces, and serves other essential functions** 115  
 Functions of Epithelial Tissue 116  
 Characteristics of Epithelial Tissue 117

- Specializations of Epithelial Cells 117  
 Maintaining the Integrity of Epithelia 118
- 4-3 Cell shape and number of layers determine the classification of epithelia** 120  
 Classification of Epithelia 120  
 Glandular Epithelia 122
- 4-4 Connective tissue has varied roles in the body that reflect the physical properties of its three main types** 126
- 4-5 Connective tissue proper includes loose connective tissues that fill internal spaces and dense connective tissues that contribute to the internal framework of the body** 128  
 Structure of Connective Tissue Proper 128  
 Loose Connective Tissues 130  
 Dense Connective Tissues 133  
 Fasciae: Layers of Connective Tissue Proper 133
- 4-6 Blood and lymph are fluid connective tissues that transport cells and dissolved materials** 135
- 4-7 The supporting connective tissues cartilage and bone provide a strong framework** 136  
 Cartilage 136  
 Bone 137
- 4-8 Tissue membranes made from epithelia and connective tissue make up four types of physical barriers** 140  
 Mucous Membranes 140  
 Serous Membranes 140  
 The Cutaneous Membrane 141  
 Synovial Membranes 142
- 4-9 The three types of muscle tissue are skeletal, cardiac, and smooth** 142  
 Skeletal Muscle Tissue 142  
 Cardiac Muscle Tissue 144  
 Smooth Muscle Tissue 144
- 4-10 Nervous tissue responds to stimuli and propagates electrical impulses throughout the body** 144
- 4-11 The response to tissue injury involves inflammation and regeneration** 145  
 Inflammation 145  
 Regeneration 146
- 4-12 With advancing age, tissue regeneration decreases and cancer rates increase** 146  
 Aging and Tissue Structure 146  
 Aging and Cancer Incidence 146
- Chapter Review 148
- Spotlights  
 Inflammation and Regeneration 147
- Clinical Case  
 The Rubber Girl 115
- Clinical Notes  
 Exfoliative Cytology 126  
 Marfan Syndrome 131

## UNIT 2 SUPPORT AND MOVEMENT

### 5 The Integumentary System 152



- An Introduction to the Integumentary System 153
- 5-1 The epidermis is a protective covering composed of layers with various functions** 153  
 Cells of the Epidermis: Keratinocytes 154  
 Layers of the Epidermis 154  
 Epidermal Growth Factor 157
- 5-2 The dermis is the tissue layer that supports the epidermis** 158  
 Layers of the Dermis 158  
 Dermal Strength and Elasticity 158  
 Tension Lines 159  
 The Dermal Blood Supply 159  
 Innervation of the Skin 160
- 5-3 The subcutaneous layer connects the dermis to underlying tissues** 160
- 5-4 Epidermal pigmentation and dermal circulation influence skin color** 161  
 The Role of Epidermal Pigmentation 161  
 The Role of Dermal Circulation: Hemoglobin 163  
 Disease-Related Changes in Skin Color 163
- 5-5 Sunlight causes epidermal cells to convert a steroid into vitamin D<sub>3</sub>** 163
- 5-6 Hair is made of keratinized dead cells pushed to the skin surface where it has protecting and insulating roles** 165  
 Hair and Hair Follicle Structure 165  
 Hair Production 166  
 The Hair Growth Cycle 166  
 Types of Hairs 168  
 Hair Color 168
- 5-7 Sebaceous glands and sweat glands are exocrine glands found in the skin** 168  
 Sebaceous Glands 168  
 Sweat Glands 169  
 Other Integumentary Glands 170  
 Control of Glandular Secretions and Thermoregulation 170
- 5-8 Nails are keratinized epidermal cells that protect the tips of fingers and toes** 171
- 5-9 After an injury, the integument is repaired in several phases** 172
- 5-10 Effects of aging on the skin include thinning, wrinkling, and reduced melanocyte activity** 175

**Build Your Knowledge**

Integration of the INTEGUMENTARY system with the other body systems presented so far 176

**Chapter Review** 177

**Spotlights**

The Epidermis 156

**Clinical Case**

He Has Fish Skin! 153

**Clinical Notes**

Nips, Tucks, and Shots 161

Skin Cancer 164

Decubitus Ulcers 166

Your Skin, A Mirror of Your Health 173

Burns and Grafts 174



**6 Bones and Bone Structure 180**

**An Introduction to Bones and Bone Tissue** 181

**6-1 The skeletal system has several major functions** 181

**6-2 Bones are classified according to shape and structure, and they have a variety of bone markings** 182

Bone Shapes 182

Bone Markings 183

Bone Structure 183

**6-3 Bone is composed of matrix and several types of cells: osteogenic cells, osteoblasts, osteocytes, and osteoclasts** 183

Bone Matrix 183

Bone Cells 185

**6-4 Compact bone contains parallel osteons, and spongy bone contains trabeculae** 187

Compact Bone Structure 187

Spongy Bone Structure 188

Coordinated Functions of Compact and Spongy Bone 189

Surface Coverings of Bone 189

**6-5 Bones form through ossification and enlarge through interstitial and appositional growth** 190

Endochondral Ossification 191

Intramembranous Ossification 191

Blood and Nerve Supplies to Bone 194

**6-6 Bone growth and development depend on bone remodeling, which is a balance between bone formation and bone resorption** 194

**6-7 Exercise, nutrition, and hormones affect bone development and the skeletal system** 196

The Effects of Exercise on Bone 196

Nutritional and Hormonal Effects on Bone 197

**6-8 Calcium plays a critical role in bone physiology** 198

The Skeleton as a Calcium Reserve 198

Hormones and Calcium Ion Balance 199

**6-9 A fracture is a crack or break in a bone** 201

**6-10 Osteopenia has widespread effects on aging bones** 204

**Chapter Review** 205

**SmartArt Videos**

Figure 6-11 Endochondral Ossification 192

Figure 6-16 Factors That Increase the Blood Calcium Ion Level. 200

**Spotlights**

Endochondral Ossification 192

Types of Fractures and Steps in Repair 202

**Clinical Case**

A Case of Child Abuse? 181

**Clinical Notes**

Abnormal Bone Development 198

**7 The Axial Skeleton 208**



**An Introduction to the Divisions of the Skeleton** 209

**7-1 The 80 bones of the head and trunk make up the axial skeleton** 209

**7-2 The skull's 8 cranial bones protect the brain, and its 14 facial bones form the mouth, nose, and orbits** 209

Cranial, Facial, and Associated Bones 209

Sutures 211

Sinuses, Foramina, and Fissures 225

**7-3 Each orbital complex contains and protects an eye, and the nasal complex encloses the nasal cavities** 225

The Orbital Complexes 225

The Nasal Complex 226

**7-4 Fontanelles are non-ossified fibrous areas between cranial bones that ease birth and allow for rapid brain growth in infants and children** 226

**7-5 The vertebral column has four flexible and supportive spinal curves** 228

**7-6 The five vertebral regions—cervical, thoracic, lumbar, sacral, and coccygeal—each have characteristic vertebrae** 229

Vertebral Anatomy 229

Characteristics of Regional Vertebrae 230

**7-7 The thoracic cage protects organs in the chest and provides sites for muscle attachment** 237

The Ribs 238

The Sternum 239

**Chapter Review** 239

**Spotlight**

Sectional Anatomy of the Skull 214

**Clinical Case**

Knocked Out 209

**Clinical Notes**

Temporomandibular Joint Syndrome 224

Sinusitis 227

Craniostenosis 228

Kyphosis, Lordosis, and Scoliosis 236



**8****The Appendicular Skeleton 243****An Introduction to the Appendicular Skeleton 244****8-1 The pectoral (shoulder) girdles attach the upper limbs to the axial skeleton 244**

The Clavicles 244

The Scapulae 246

**8-2 The bones of the upper limbs are adapted for free movement 247**

Arm Bone: The Humerus 247

Bones of the Forearm 249

Bones of the Wrist and Hand 250

**8-3 The pelvic girdle (hips) attaches the lower limbs to the axial skeleton 252**

The Pelvic Girdle (Hip Bones) 252

The Pelvis (Pelvic Girdle, Sacrum, and Coccyx) 252

**8-4 The bones of the lower limbs are adapted for movement and support 254**

The Femur (Thighbone) 254

The Patella (Kneecap) 255

Bones of the Leg 257

Bones of the Ankle and Foot 257

**8-5 Differences in sex and age account for individual skeletal variation 260****Chapter Review 262****Spotlights**

Sex Differences in the Human Skeleton 261

**Clinical Case**

Timber!! 244

**Clinical Notes**

Carpal Tunnel Syndrome 251

Hip Fracture 255

Shin Splints 257

Stress Fractures 259

Club Foot 260

**9****Joints 265****An Introduction to Joints 266****9-1 Joints are categorized according to their structure or range of motion 266****9-2 Diarthroses: Synovial joints contain synovial fluid and are surrounded by a joint capsule and stabilizing accessory structures 268**

Articular Cartilage 268

Synovial Fluid 269

Accessory Structures 269

Factors That Stabilize Synovial Joints 270

**9-3 Diarthroses: The different types of synovial joints allow a wide range of skeletal movements 270**

Types of Movements at Synovial Joints 270

Classification of Synovial Joints 276

**9-4 Intervertebral joints contain intervertebral discs and ligaments that allow for vertebral movements 276**

Structure of Intervertebral Joints 276

Vertebral Movements 277

**9-5 The elbow and knee are both hinge joints 278**

The Elbow Joint 278

The Knee Joint 279

**9-6 The shoulder and hip are both ball-and-socket joints 281**

The Shoulder Joint 282

The Hip Joint 283

**9-7 With advancing age, arthritis and other degenerative changes often impair joint mobility 285****9-8 The skeletal system supports and stores energy and minerals for other body systems 286****Build Your Knowledge**

Integration of the SKELETAL system with the other body systems presented so far 287

**Chapter Review 288****Spotlights**

Joint Movement 272

**Clinical Case**

What's the Matter with the Birthday Girl? 266

**Clinical Notes**

Bursitis and Bunions 270

Dislocation 270

Damage to Intervertebral Discs 281

Knee Injuries 282

**10****Muscle Tissue 291****An Introduction to Muscle Tissue 292****10-1 The primary function of muscle tissue is to produce movement 292**

Common Properties of Muscle Tissue 292

Functions of Skeletal Muscle 292

**10-2 Skeletal muscle contains muscle tissue, connective tissues, blood vessels, and nerves 293**

Organization of Connective Tissues and Muscle Tissue 293

Function of Skeletal Muscle Components 293

**10-3 Skeletal muscle fibers are organized into repeating functional units that contain sliding filaments 294**

The Sarcolemma and Transverse Tubules 295

The Sarcoplasmic Reticulum 296

Myofibrils 296

Sarcomeres 297

The Sliding-Filament Theory of Muscle Contraction 301

- 10-4 Motor neurons stimulate skeletal muscle fibers to contract at the neuromuscular junction** 302  
Electrical Impulses and Excitable Membranes 302  
The Control of Skeletal Muscle Activity 303
- 10-5 Muscle fibers produce different amounts of tension depending on sarcomere length and frequency of stimulation** 311  
Length–Tension Relationships 311  
Frequency of Stimulation 312
- 10-6 Skeletal muscles produce increased tension by recruiting additional motor units** 315  
Motor Units 315  
Types of Muscle Contractions 316  
Load and Speed of Contraction 318  
Muscle Relaxation and the Return to Resting Length 319
- 10-7 To maintain regular muscle fiber activity, energy and recovery are required** 319  
ATP Generation and Muscle Fiber Contraction 319  
Muscle Metabolism and Varying Activity Levels 320  
The Recovery Period 322  
Hormones and Muscle Metabolism 323
- 10-8 Muscle performance depends on muscle fiber type and physical conditioning** 323  
Types of Skeletal Muscle Fibers 323  
Muscle Performance and the Distribution of Muscle Fibers 323  
Muscle Hypertrophy, Atrophy, and Effects of Aging 325  
Muscle Fatigue 325  
Physical Conditioning 326
- 10-9 Cardiac muscle tissue, found in the heart, produces coordinated and automatic contractions** 327  
Structural Characteristics of Cardiac Muscle Tissue 327  
Functional Characteristics of Cardiac Muscle Tissue 328
- 10-10 Smooth muscle tissue contracts to move substances within internal passageways** 329  
Structural Characteristics of Smooth Muscle Tissue 329  
Functional Characteristics of Smooth Muscle Tissue 329

## Chapter Review 332

### SmartArt Videos

- Figure 10–17 The Arrangement and Activity of Motor Units in a Skeletal Muscle. 315  
Figure 10–20 Muscle Metabolism. 321

### Spotlights

- Events at the Neuromuscular Junction 304  
Excitation–Contraction Coupling 306  
The Contraction Cycle and Cross-Bridge Formation 308

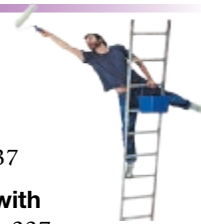
### Clinical Case

- Keep on Keepin' on 292

### Clinical Notes

- Tetanus 307  
Rigor Mortis 307  
Delayed-Onset Muscle Soreness 326  
Electromyography 330

## 11 The Muscular System 336



### An Introduction to the Muscular System 337

- 11-1 Fascicle arrangement is correlated with muscle power and range of motion** 337  
Parallel Muscles 337  
Convergent Muscles 337  
Pennate Muscles 337  
Circular Muscles 338
- 11-2 The use of bones as levers increases muscle efficiency** 339
- 11-3 The origins and insertions of muscles determine their actions** 339  
Origins and Insertions 339  
Actions 341
- 11-4 Descriptive terms are used to name skeletal muscles** 343  
Region of the Body 343  
Position, Direction, or Fascicle Arrangement 346  
Structural Characteristics 346  
Action 346
- 11-5 Axial muscles position the axial skeleton, and appendicular muscles support and move the appendicular skeleton** 346
- 11-6 Axial muscles are muscles of the head and neck, vertebral column, trunk, and pelvic floor** 347  
Muscles of the Head and Neck 347  
Muscles of the Vertebral Column 354  
Oblique and Rectus Muscles and the Diaphragm 358  
Muscles of the Pelvic Floor 361
- 11-7 Appendicular muscles are muscles of the shoulders, upper limbs, pelvis, and lower limbs** 362  
Muscles of the Shoulders and Upper Limbs 363  
Muscles of the Pelvis and Lower Limbs 373
- 11-8 Exercise of the muscular system produces responses in multiple body systems** 383

### Build Your Knowledge

- Integration of the MUSCULAR systems with the other body systems presented so far 384

### Chapter Review 385

### Spotlights

- Muscle Action 342

### Clinical Case

- Downward-Facing Dog 337

### Clinical Notes

- Intramuscular Injections 353  
Signs of Stroke 355  
Hernia 380

**UNIT 3 CONTROL AND REGULATION****12 Nervous Tissue 389****An Introduction to the Nervous System and Nervous Tissue 390**

- 12-1 The nervous system has anatomical and functional divisions 390**  
 The Anatomical Divisions of the Nervous System 390  
 The Functional Divisions of the Nervous System 391
- 12-2 Neurons are nerve cells specialized for intercellular communication 392**  
 Functional Characteristics of Neurons 392  
 The Structure of Neurons 392  
 The Classification of Neurons 394
- 12-3 CNS and PNS neuroglia support and protect neurons 395**  
 Neuroglia of the Central Nervous System 395  
 Neuroglia of the Peripheral Nervous System 399  
 Neural Responses to Injuries 399
- 12-4 The membrane potential of a neuron is determined by differences in ion concentrations and membrane permeability 402**  
 The Resting Membrane Potential 402  
 Changes in the Resting Membrane Potential: Membrane Channels 405  
 Graded Potentials 407
- 12-5 An action potential is an all-or-none electrical event used for long-distance communication 409**  
 Threshold and the All-or-None Principle 409  
 Generation of Action Potentials 409  
 Propagation of Action Potentials 412  
 Axon Diameter and Propagation Speed 416
- 12-6 Synapses transmit signals among neurons or between neurons and other cells 416**  
 Types of Synapses 416  
 Function of Chemical Synapses 417
- 12-7 The effects of neurotransmitters and neuromodulators depend on their receptors 420**  
 Classes of Neurotransmitters and Neuromodulators 420  
 The Functions of Neurotransmitters and Neuromodulators and Their Receptors 421
- 12-8 Individual neurons process information by integrating excitatory and inhibitory stimuli 424**  
 Postsynaptic Potentials 425  
 Presynaptic Regulation: Inhibition and Facilitation 427  
 The Rate of Action Potential Generation 427

**Chapter Review 428****Spotlights**

- Processes That Produce the Resting Membrane Potential 403  
 Generation of an Action Potential 410  
 Propagation of an Action Potential 414

**Clinical Case**

- Did President Franklin D. Roosevelt Really Have Polio? 390

**Clinical Notes**

- Rabies 393  
 CNS Tumors 398  
 Demyelination 399

**13 The Spinal Cord, Spinal Nerves, and Spinal Reflexes 433****An Introduction to the Spinal Cord, Spinal Nerves, and Spinal Reflexes 434**

- 13-1 This text's coverage of the nervous system parallels its simple- to-complex levels of organization 434**
- 13-2 The spinal cord is surrounded by three meninges and has spinal nerve roots 435**  
 Gross Anatomy of the Spinal Cord 435  
 Protection of the Spinal Cord: Spinal Meninges 438
- 13-3 Spinal cord gray matter integrates information and initiates commands, and white matter carries information from place to place 440**  
 Functional Organization of Gray Matter 440  
 Functional Organization of White Matter 440
- 13-4 Spinal nerves extend to form peripheral nerves, sometimes forming plexuses along the way; these nerves carry sensory and motor information 442**  
 Anatomy of Spinal Nerves 442  
 Peripheral Distribution and Function of Spinal Nerves 442  
 Nerve Plexuses 447
- 13-5 Interneurons are organized into functional groups called neuronal pools 452**
- 13-6 The different types of neural reflexes are all rapid, automatic responses to stimuli 453**  
 The Reflex Arc 453  
 Classification of Reflexes 456
- 13-7 Monosynaptic reflexes produce simple responses, while polysynaptic reflexes can produce complex behaviors 457**  
 Monosynaptic Reflexes 457  
 Polysynaptic Reflexes 459
- 13-8 The brain can affect spinal cord-based reflexes 460**  
 Voluntary Movements and Reflex Motor Patterns 460  
 Reinforcement and Inhibition 460

**Chapter Review 461****SmartArt Videos**

- Figure 13–1 An Overview of Chapters 13 and 14. 435

**Spotlights**

- Structure, Function, and the Peripheral Distribution of Spinal Nerves ( $T_1$ – $L_2$ ) 444  
 Spinal Reflexes 454

**Clinical Case**

- Prom Night 434

## Clinical Notes

- Anesthesia 439
- Shingles 443
- Sensory Innervation in the Hand 448
- Sensory Innervation in the Ankle and Foot 451

## 14 The Brain and Cranial Nerves 465



### An Introduction to the Brain and Cranial Nerves 466

#### 14-1 The brain develops four major regions: the cerebrum, cerebellum, diencephalon, and brainstem 466

- Major Brain Regions and Landmarks 466
- Embryology of the Brain 468
- Ventricles of the Brain 468

#### 14-2 The brain is protected and supported by the cranial meninges, cerebrospinal fluid, and the blood brain barrier 469

- The Cranial Meninges 469
- Cerebrospinal Fluid 471
- The Protective Function of the Cranial Meninges and CSF 473
- The Blood Supply to the Brain 473
- The Blood Brain Barrier 473

#### 14-3 Brainstem: The medulla oblongata relays signals between the rest of the brain and the spinal cord 474

#### 14-4 Brainstem: The pons contains nuclei that process and tracts that relay sensory and motor information 477

#### 14-5 Brainstem: The midbrain regulates visual and auditory reflexes and controls alertness 478

#### 14-6 The cerebellum coordinates reflexive and learned patterns of muscular activity at the subconscious level 478

- Structure of the Cerebellum 478
- Functions of the Cerebellum 478

#### 14-7 The diencephalon integrates sensory information with motor output at the subconscious level 481

- The Thalamus 481
- The Hypothalamus 482

#### 14-8 The limbic system is a group of nuclei and tracts that functions in emotion, motivation, and memory 484

#### 14-9 The cerebrum contains motor, sensory, and association areas, allowing for higher mental functions 486

- Structure of the Cerebral Cortex and Cerebral Hemispheres 486
- The White Matter of the Cerebrum 486
- The Basal Nuclei 488
- Motor, Sensory, and Association Areas of the Cortex 490
- Integrative Centers and Higher Mental Functions 492
- Monitoring Brain Activity: The Electroencephalogram 493

#### 14-10 Cranial reflexes are rapid, automatic responses involving sensory and motor fibers of cranial nerves 506

### Chapter Review 507

### Spotlights

- Formation and Circulation of Cerebrospinal Fluid 472

### Clinical Case

- The Neuroanatomist's Stroke 466

### Clinical Notes

- Epidural and Subdural Hemorrhages 471
- Aphasia and Dyslexia 493
- Concussion and Beyond 506

## 15 Sensory Pathways and the Somatic Nervous System 512



### An Introduction to Sensory Pathways and the Somatic Nervous System 513

#### 15-1 Sensory stimuli cause signals to be sent along sensory pathways, and in response motor commands are sent along motor pathways 513

#### 15-2 Sensory receptors connect our internal and external environments with the nervous system 514

- The Detection of Stimuli 515
- The Interpretation of Sensory Information 515

#### 15-3 General sensory receptors can be classified by the type of stimulus that excites them 517

- Nociceptors and Pain 517
- Thermoreceptors 518
- Mechanoreceptors 518
- Chemoreceptors 521

#### 15-4 The afferent division is made up of separate somatic sensory and visceral sensory pathways that deliver sensory information to the CNS 522

- Somatic Sensory Pathways 522
- Visceral Sensory Pathways 527

#### 15-5 The somatic nervous system is an efferent division made up of somatic motor pathways that control skeletal muscles 527

- The Corticospinal Pathway 528
- The Medial and Lateral Pathways 530
- The Monitoring Role of the Basal Nuclei and Cerebellum 530

### Chapter Review 532

### Spotlights

- Somatic Sensory Pathways 524

### Clinical Case

- Living with Cerebral Palsy 513

### Clinical Notes

- Assessment of Tactile Sensitivities 523
- Phantom Limb Syndrome 526
- Amyotrophic Lateral Sclerosis 530



## 16 The Autonomic Nervous System and Higher-Order Functions 535



### An Introduction to the Autonomic Nervous System and Higher-Order Functions 536

- 16-1 The autonomic nervous system, which has sympathetic and parasympathetic divisions, is involved in the unconscious regulation of visceral functions** 536
- Comparison of the Somatic and Autonomic Nervous Systems 536
  - Organization of the ANS 537
  - Divisions of the ANS 538
- 16-2 The sympathetic division has short preganglionic fibers and long postganglionic fibers and is involved in using energy and increasing metabolic rate** 538
- Functional Organization of the Sympathetic Division 538
  - Sympathetic Activation 543
- 16-3 Different types of neurotransmitters and receptors lead to different sympathetic effects** 543
- Effects of Sympathetic Stimulation of Adrenergic Synapses and Receptors 544
  - Effects of Sympathetic Stimulation on Other Types of Synapses 545
- 16-4 The parasympathetic division has long preganglionic fibers and short postganglionic fibers and is involved in conserving energy and lowering metabolic rate** 545
- Functional Organization of the Parasympathetic Division 545
  - Parasympathetic Activation 546
- 16-5 Different types of receptors lead to different parasympathetic effects** 546
- Effects of Parasympathetic Stimulation of Cholinergic Receptors 546
  - Effects of Toxins on Cholinergic Receptors 546
- 16-6 The differences in the organization of sympathetic and parasympathetic structures lead to widespread sympathetic effects and specific parasympathetic effects** 547
- Summary of the Sympathetic Division 548
  - Summary of the Parasympathetic Division 548
- 16-7 Dual innervation of organs allows the sympathetic and parasympathetic divisions to coordinate vital functions** 548
- Anatomy of Dual Innervation 549
  - Autonomic Tone 551
- 16-8 Various levels of autonomic regulation allow for the integration and control of autonomic functions** 551
- Visceral Reflexes 551
  - Higher Levels of Autonomic Control 552
  - The Integration of ANS and SNS Activities 552

### 16-9 Higher-order functions include memory and states of consciousness, and neurotransmitters influence behavior

 553

- Memory 554
- States of Consciousness 556
- Influence of Neurotransmitters on Brain Chemistry and Behavior 558

### 16-10 Aging produces various structural and functional changes in the nervous system

 558

#### Build Your Knowledge

- Integration of the NERVOUS system with the other body systems presented so far 560

#### Chapter Review

 561

#### Spotlights

- The Autonomic Nervous System 540

#### Clinical Case

- Remember Me? 536

#### Clinical Notes

- Insomnia 556
- Summary of Nervous System Disorders 558
- Fainting 559

## 17 The Special Senses 565



### An Introduction to the Special Senses

 566

- 17-1 Olfaction, the sense of smell, involves olfactory receptors responding to airborne chemical stimuli** 566
- Anatomy of the Olfactory Organs 566
  - Olfactory Receptors and the Physiology of Olfaction 567
  - Olfactory Pathways 567
  - Olfactory Discrimination 570
- 17-2 Gustation, the sense of taste, involves gustatory receptors responding to dissolved chemical stimuli** 570
- Anatomy of Papillae and Taste Buds 570
  - Gustatory Receptors 570
  - Gustatory Pathways 570
  - Gustatory Discrimination and Physiology of Gustation 571
- 17-3 Internal eye structures contribute to vision, while accessory eye structures provide protection** 572
- Accessory Structures of the Eye 572
  - Anatomy of the Eyeball 574
- 17-4 The focusing of light on the retina leads to the formation of a visual image** 581
- An Introduction to Light 581
  - Image Formation and Reversal 582
  - Visual Acuity 582
- 17-5 Photoreceptors transduce light into electrical signals that are then processed in the visual cortex** 583
- Physiology of Vision 583
  - The Visual Pathways 589

**17-6 Equilibrium sensations monitor head position and movement, while hearing involves the detection and interpretation of sound waves** 592

Anatomy of the Ear 592

Equilibrium 595

Hearing 598

**Chapter Review** 606**Spotlights**

Olfaction and Gustation 568

Refractive Problems 584

Photoreception 586

**Clinical Case**

A Chance to See 566

**Clinical Notes**

Diabetic Retinopathy 577

Detached Retina 579

Glaucoma 580

Motion Sickness 599

**18 The Endocrine System** 610**An Introduction to the Endocrine System** 611**18-1 Homeostasis is preserved through intercellular communication by the nervous and endocrine systems** 611

Mechanisms of Intercellular Communication 611

Comparison of Endocrine and Nervous Communication 612

**18-2 The endocrine system regulates physiological processes by releasing bloodborne hormones that bind to receptors on remote target organs** 613

Overview of Endocrine Organs and Tissues 613

Classes of Hormones 613

Transport and Inactivation of Hormones 613

Mechanisms of Hormone Action 614

Control of Hormone Secretion 618

**18-3 The anterior lobe of the pituitary gland produces and releases hormones under hypothalamic control, while the posterior lobe releases hypothalamic hormones** 619

Anatomy of the Hypothalamus and Pituitary Gland 619

Control of Pituitary Activity by the Hypothalamus 620

The Anterior Lobe of the Pituitary Gland 621

The Posterior Lobe of the Pituitary Gland 625

Summary: The Hormones of the Pituitary Gland 626

**18-4 The thyroid gland synthesizes thyroid hormones that affect the rate of metabolism** 627

Anatomy of the Thyroid Gland 628

Synthesis and Regulation of Thyroid Hormones 628

Functions of Thyroid Hormones 631

Synthesis and Functions of Calcitonin 631

**18-5 The four parathyroid glands secrete parathyroid hormone, which increases the blood calcium ion level** 632**18-6 The paired adrenal glands secrete several hormones that affect electrolyte balance and stress responses** 634

Anatomy of the Adrenal Glands 634

Corticosteroids of the Adrenal Cortex 634

Catecholamines of the Adrenal Medulla 636

**18-7 The pineal gland secretes melatonin, which affects the circadian rhythm** 637**18-8 The pancreas is both an exocrine organ and an endocrine gland that produces hormones affecting the blood glucose level** 637

Anatomy of the Pancreas 638

Functions of Pancreatic Islet Cells 638

Hormones That Regulate the Blood Glucose Level 638

Diabetes Mellitus 641

**18-9 Many organs have secondary endocrine functions** 641

The Intestines 641

The Kidneys 641

The Heart 644

The Thymus 644

The Gonads 644

Adipose Tissue 646

**18-10 Hormones interact over our lifetime to produce coordinated physiological responses** 646

Role of Hormones in Growth 647

The Hormonal Responses to Stress 647

The Effects of Hormones on Behavior 647

Aging and Hormone Production 647

**Build Your Knowledge**

Integration of the ENDOCRINE system with the other body systems presented so far 650

**Chapter Review** 651**SmartArt Videos**

Figure 18–16 Anatomy of the Pancreas. 638

**Spotlights**

Structural Classification of Hormones 615

G Proteins and Second Messengers 617

Diabetes Mellitus 642

The General Adaptation Syndrome 648

**Clinical Case**

Stones, Bones, and Groans 611

**Clinical Notes**

Diabetes Insipidus 625

Endocrine Disorders 645

Hormones and Athletic Performance 649

**UNIT 4 FLUIDS AND TRANSPORT****19 Blood 656****An Introduction to Blood and the Cardiovascular System 657****19-1 Blood, composed of plasma and formed elements, provides transport, regulation, and protective services to the body 657**

Functions of Blood 657

Characteristics of Blood 658

Components of Blood 658

**19-2 Red blood cells, formed by erythropoiesis, contain hemoglobin that transports respiratory gases 659**

Abundance of RBCs: The Hematocrit 659

Relationship of RBC Structure to RBC Function 659

Hemoglobin 662

RBC Formation and Turnover 664

**19-3 The ABO and Rh blood groups are based on antigen–antibody responses 666**

ABO and Rh Blood Groups 666

Transfusions 669

**19-4 The various types of white blood cells contribute to the body's defenses 670**

WBC Characteristics and Functions 671

Types of WBCs 671

The Differential Count and Changes in WBC Profiles 675

WBC Production: Leukopoiesis 675

Regulation of WBC Production 676

**19-5 Platelets, disc-shaped cell fragments, function in the clotting process 678**

Platelet Functions 678

Platelet Production 678

**19-6 The process of blood clotting, or hemostasis, stops blood loss 678**

The Vascular Phase 679

The Platelet Phase 679

The Coagulation Phase 679

Clot Retraction 683

Fibrinolysis 683

**Chapter Review 683****Spotlights**

The Composition of Whole Blood 660

Hemolytic Disease of the Newborn 672

**Clinical Case**

Crisis in the Blood 657

**Clinical Notes**

Plasma Expanders 658

Collecting Blood for Analysis 659

Bleeding and Clotting Extremes 682

**20 The Heart 688****An Introduction to the Heart as Part of the Cardiovascular System 689****20-1 The heart is a four-chambered organ that pumps blood through the systemic and pulmonary circuits 689**

Overview of Heart Function: The Pulmonary and Systemic Circuits 689

Heart Location and Position 690

Heart Superficial Anatomy, Heart Wall, and Cardiac Skeleton 690

Heart Chambers, Valves, and Great Vessels 694

Blood Flow through the Heart Valves 697

The Blood Supply to the Heart 697

**20-2 The cells of the conducting system distribute electrical impulses through the heart, causing cardiac contractile cells to contract 702**

Cardiac Physiology: Electrical Impulses Leading to the Contractions Making Up a Heartbeat 702

The Conducting System: Pacemaker and Conducting Cells 702

The Electrocardiogram (ECG) 705

Cardiac Contractions: Contractile Cells 707

**20-3 The contraction–relaxation events that occur during a complete heartbeat make up a cardiac cycle 711**

An Introduction to Pressure and Flow in the Heart 711

Phases of the Cardiac Cycle 712

Pressure and Volume Changes in the Cardiac Cycle 713

Heart Sounds 715

**20-4 Cardiac output is determined by heart rate and stroke volume 716**

Factors Affecting the Heart Rate 716

Factors Affecting the Stroke Volume 719

Summary: The Control of Cardiac Output 721

The Heart and the Vessels of the Cardiovascular System 722

**Chapter Review 723****SmartArt Videos**

Figure 20–16 Phases of the Cardiac Cycle. 712

Figure 20–19 Factors Affecting Cardiac Output. 716

**Spotlights**

Heart Disease and Heart Attacks 700

Cardiac Arrhythmias 708

**Clinical Case**

A Needle to the Chest 689

**Clinical Notes**

Faulty Heart Valves 697

Broken-Heart Syndrome 702

## 21 Blood Vessels and Circulation 727



### An Introduction to Blood Vessels and Circulation 728

#### 21-1 Arteries, which are elastic or muscular, and veins, which contain valves, have three-layered walls; capillaries have thin walls with only one layer 728

Vessel Wall Structure in Arteries and Veins 728

Differences between Arteries and Veins 729

Arteries 730

Capillaries 733

Veins 735

The Distribution of Blood 736

#### 21-2 Pressure and resistance determine blood flow and affect rates of capillary exchange 737

Introduction to Pressure and Flow in Blood Vessels 737

Pressures Affecting Blood Flow 737

Total Peripheral Resistance 737

An Overview of Cardiovascular Pressures 739

Capillary Exchange and Capillary Pressures 742

#### 21-3 Blood flow and pressure in tissues are controlled by both autoregulation and central regulation 745

Vasomotion 745

Overview of Autoregulation and Central Regulation 745

Autoregulation of Blood Flow within Tissues 745

Central Regulation: Neural Mechanisms 747

Central Regulation: Endocrine Mechanisms 750

#### 21-4 The cardiovascular system adapts to physiological stress while maintaining a special vascular supply to the brain, heart, and lungs 752

Vascular Supply to Special Regions 752

The Cardiovascular Response to Exercise 753

The Cardiovascular Response to Hemorrhaging and Shock 755

#### 21-5 The vessels of the cardiovascular system make up both pulmonary and systemic circuits 756

#### 21-6 In the pulmonary circuit, deoxygenated blood enters the lungs in arteries, and oxygenated blood leaves the lungs by veins 757

#### 21-7 The systemic circuit carries oxygenated blood from the left ventricle to tissues and organs other than the lungs, and returns deoxygenated blood to the right atrium 758

Systemic Arteries 758

The Ascending Aorta 758

The Aortic Arch 758

Systemic Veins 766

#### 21-8 Modifications of fetal and maternal cardiovascular systems promote the exchange of materials; the fetal cardiovascular system changes to function independently after birth 775

Fetal Circulatory Route and Placental Blood Supply 775

Fetal Heart and Great Vessels 775

Cardiovascular Changes at Birth 776

### 21-9 Aging affects the blood, heart, and blood vessels 778

#### Build Your Knowledge

Integration of the CARDIOVASCULAR system with the other body systems presented so far 779

#### Chapter Review 780

#### Spotlights

Congenital Heart Problems 777

#### Clinical Case

Did Ancient Mummies Have Atherosclerosis? 728

#### Clinical Notes

Arteriosclerosis 732

Varicose Veins 736

Edema 744

Aortic Aneurysm 763

Preparing the Circulation for Dialysis 770

## 22 The Lymphatic System and Immunity 785



### An Introduction to the Lymphatic System and Immunity 786

#### 22-1 The vessels, tissues, and organs of the lymphatic system maintain fluid volume and function in body defenses 786

Functions of the Lymphatic System 787

Lymphatic Vessels and Circulation of Lymph 787

Lymphoid Cells 790

Lymphoid Tissues 790

Lymphoid Organs 792

#### 22-2 Lymphocytes are important to innate (nonspecific) and adaptive (specific) immunity 796

Types of Immunity 796

Lymphocytes 797

#### 22-3 Innate defenses respond the same regardless of the invader 797

Physical Barriers 797

Phagocytes 800

Immune Surveillance 801

Interferons 802

Complement System 802

Inflammation 802

Fever 805

#### 22-4 Adaptive (specific) defenses respond to particular threats and are either cell mediated or antibody mediated 805

Lymphocytes of Adaptive Immunity 805

Types of Adaptive Immunity 805

An Introduction to Adaptive Immunity 806

Forms of Adaptive Immunity 807

Properties of Adaptive Immunity 807



- 22-5 In cell-mediated adaptive immunity, presented antigens activate T cells, which respond by producing cytotoxic and helper T cells** 809  
 Activation and Clonal Selection of T Cells 809  
 Functions of Activated CD8 T Cells 812  
 Functions of Activated CD4 T Cells: Helper T (T<sub>H</sub>) and Memory T<sub>H</sub> Cells 813  
 Cytokines of Adaptive Defenses 813  
 Summary of Cell-Mediated Adaptive Immunity 813
- 22-6 In antibody-mediated adaptive immunity, sensitized B cells respond to antigens by producing specific antibodies** 816  
 B Cell Sensitization and Activation 816  
 Antibody Structure and Function 817  
 Primary and Secondary Responses to Antigen Exposure 820
- 22-7 Immunocompetence enables a normal immune response; abnormal responses result in immune disorders** 821  
 Summary of Innate and Adaptive Immunity 821  
 The Development of Immunocompetence 822  
 Stress and the Immune Response 825  
 Immune Disorders 825
- 22-8 The immune response diminishes as we age** 827
- 22-9 The nervous and endocrine systems influence the immune response** 829
- Build Your Knowledge**  
 Integration of the LYMPHATIC system with the other body systems presented so far 828
- Chapter Review** 829
- SmartArt Videos**  
 Figure 22–17 Forms of Immunity. 808
- Spotlights**  
 Cytokines of the Immune System 814
- Clinical Case**  
 Isn't There a Vaccine for That? 786
- Clinical Notes**  
 Lymphadenopathy 793  
 Lab Tests for Organ Donation 809  
 Organ Donation 811  
 AIDS 827
- 23-1 In gas transport, most oxygen is transported bound to hemoglobin, whereas carbon dioxide is transported in three ways** 864  
 Oxygen Transport 864  
 Carbon Dioxide Transport 867  
 Summary of Gas Transport 868
- 23-2 The conducting portion of the upper respiratory system filters, warms, and humidifies air** 838  
 The Nose and Nasal Cavity 838  
 The Pharynx 839
- 23-3 The conducting portion of the lower respiratory system conducts air to the respiratory portion and produces sound** 841  
 The Larynx 841  
 Sound Production 843  
 The Trachea 843  
 The Bronchial Tree 844
- 23-4 The respiratory portion of the lower respiratory system is where gas exchange occurs** 846  
 The Respiratory Bronchioles 846  
 Alveolar Ducts and Alveoli 846  
 The Blood Air Barrier 848
- 23-5 Enclosed by pleural cavities, the lungs are paired organs made up of multiple lobes** 848  
 Anatomy of the Lungs 848  
 Blood Supply to the Lungs 850  
 Pleural Cavities and Pleural Membranes 850
- 23-6 External respiration and internal respiration allow gas exchange within the body** 851
- 23-7 Pulmonary ventilation—air exchange between the atmosphere and the lungs—involves muscle actions and volume changes that cause pressure changes** 852  
 An Introduction to Airflow 852  
 Overview of Pulmonary Ventilation: Volume Changes and Pressure Gradients 853  
 Actions of the Respiratory Muscles 853  
 Volume Changes in Pulmonary Ventilation 855  
 Pressure Gradients in Pulmonary Ventilation 855  
 Summary of Volume Changes and Pressure Gradients during a Respiratory Cycle 857  
 Physical Factors Affecting Pulmonary Ventilation 857  
 Measuring Respiratory Rates and Volumes 857
- 23-8 Gas exchange depends on the partial pressures of gases and the diffusion of gas molecules** 860  
 An Introduction to the Diffusion of Gases 860  
 Diffusion of Gases across the Blood Air Barrier 861  
 Summary of Gas Exchange 862  
 Internal Respiration 863
- 23-9 In gas transport, most oxygen is transported bound to hemoglobin, whereas carbon dioxide is transported in three ways** 864  
 Oxygen Transport 864  
 Carbon Dioxide Transport 867  
 Summary of Gas Transport 868
- Organization of the Respiratory System** 835  
**The Respiratory Mucosa and the Respiratory Defense System** 836

## UNIT 5 ENVIRONMENTAL EXCHANGE

### 23 The Respiratory System 834



**An Introduction to the Respiratory System** 835

- 23-1 The respiratory system, organized into an upper respiratory system and a lower respiratory system, functions primarily to aid gas exchange** 835  
 Functions of the Respiratory System 835

- 23-10 Respiratory centers in the brainstem, along with respiratory reflexes, control respiration** 868  
 Local Regulation of Oxygen Delivery and Ventilation-to-Perfusion Ratio 868  
 Neural Control of Respiration 869
- 23-11 Respiratory performance changes over the life span** 876  
 Changes in the Respiratory System in Newborns 876  
 Changes in the Respiratory System in Elderly Individuals 876
- 23-12 The respiratory system provides oxygen to, and eliminates carbon dioxide from, other organ systems** 877
- Build Your Knowledge**  
 Integration of the RESPIRATORY system with the other body systems presented so far 878
- Chapter Review** 879
- SmartArt Videos**  
 Figure 23–18 A Summary of Respiratory Processes and Partial Pressures in Respiration. 863
- Spotlights**  
 Pulmonary Ventilation 854  
 Control of Respiration 872
- Clinical Case**  
 No Rest for the Weary 835
- Clinical Notes**  
 Breakdown of the Respiratory Defense System 838  
 Pneumothorax 856  
 Decompression Sickness 862  
 Blood Gas Analysis 862  
 Carbon Monoxide Poisoning 867  
 Smoking and the Lungs 877

## 24 The Digestive System 884



### An Introduction to the Digestive System 885

- 24-1 The digestive system, consisting of the digestive tract and accessory organs, functions primarily to break down and absorb nutrients from food and to eliminate wastes** 885  
 Functions and Processes of the Digestive System 885  
 Relationship between the Digestive Organs and the Peritoneum: The Mesenteries 887  
 Histology of the Digestive Tract 889  
 Motility of the Digestive Tract 890  
 Regulation of Digestive Functions 891
- 24-2 The oral cavity, which contains the tongue, teeth, and salivary glands, functions in the ingestion and mechanical digestion of food** 893  
 The Oral Cavity 893  
 The Tongue 894  
 The Teeth 894  
 The Salivary Glands 896  
 Mechanical Digestion: Mastication (Chewing) 898

- 24-3 The pharynx and esophagus are passageways that transport the food bolus from the oral cavity to the stomach** 898  
 The Pharynx 898  
 The Esophagus 898  
 Ingestion: Deglutition (Swallowing) 900
- 24-4 The stomach is a J-shaped organ that receives the bolus and aids in its chemical and mechanical digestion** 901  
 Gross Anatomy of the Stomach 901  
 Histology of the Stomach 901  
 Secretory Glands and Gastric Secretions 903  
 Physiology of the Stomach: Chemical Digestion 905  
 Regulation of Gastric Activity in Phases of Digestion 905
- 24-5 Accessory digestive organs, such as the pancreas and liver, produce secretions that aid in chemical digestion** 905  
 The Pancreas 908  
 The Liver 909  
 The Gallbladder 914
- 24-6 The small intestine primarily functions in the chemical digestion and absorption of nutrients** 915  
 Gross Anatomy of the Small Intestine 915  
 Histology of the Small Intestine 915  
 Physiology of the Small Intestine 918  
 Regulation: Coordination of Secretion and Absorption in the Digestive Tract 918
- 24-7 The large intestine, which is divided into three parts, absorbs water from digestive materials and eliminates the remaining waste as feces** 921  
 Gross Anatomy and Segments of the Large Intestine 921  
 Histology of the Large Intestine 923  
 Physiology of the Large Intestine 923
- 24-8 Chemical digestion is the enzyme-mediated hydrolysis of food into nutrients that can be absorbed and used by the body** 926  
 Hydrolysis of Nutrients by Enzymes 926  
 Carbohydrate Digestion and Absorption 927  
 Lipid Digestion and Absorption 929  
 Protein Digestion and Absorption 930  
 Nucleic Acid Digestion and Absorption 930  
 Absorption of Water, Ions, and Vitamins 930
- 24-9 Many age-related changes affect digestion and absorption** 931
- 24-10 The digestive system is extensively integrated with other body systems** 932
- Build Your Knowledge**  
 Integration of the DIGESTIVE system with the other body systems presented so far 933
- Chapter Review** 934
- SmartArt Videos**  
 Figure 24–18 Histology of the Liver. 911

**Spotlights**

- The Regulation of Gastric Activity 906
- The Chemical Events of Digestion 928

**Clinical Case**

- An Unusual Transplant 885

**Clinical Notes**

- Peritonitis 887
- Epithelial Renewal and Repair 890
- Mumps 897
- Gastritis and Peptic Ulcers 903
- Pancreatitis 909
- Cirrhosis 910
- Colorectal Cancer 923
- Colonoscopy 926

## 25 Metabolism, Nutrition, and Energetics 939



### An Introduction to Metabolism, Nutrition, and Energetics 940

#### 25-1 Metabolism is the sum of all the catabolic and anabolic reactions in the body, and energetics is the flow and transformation of energy 940

- Metabolism 940
- Energetics 942
- Oxidation and Reduction 942

#### 25-2 Carbohydrate metabolism generates ATP by glucose catabolism and forms glucose by gluconeogenesis 943

- Overview of Glucose Catabolism 943
- Glucose Catabolism: Glycolysis 943
- Glucose Catabolism: Fate of Pyruvate 943
- Glucose Catabolism: Aerobic Metabolism 944
- Glucose Catabolism: Energy Yield of Glycolysis and Aerobic Metabolism 948
- Glucose Anabolism: Gluconeogenesis 950

#### 25-3 Lipid metabolism provides long-term storage and release of energy 951

- Lipid Catabolism: Lipolysis 951
- Lipid Anabolism: Lipogenesis 953
- Lipid Storage and Energy Release 953
- Lipid Transport and Distribution 953

#### 25-4 Protein metabolism provides amino acids and synthesizes proteins 956

- Amino Acid Catabolism 956
- Protein Synthesis 956

#### 25-5 The body experiences two patterns of metabolic activity: energy storage in the absorptive state and energy release in the postabsorptive state 957

#### 25-6 Adequate nutrition allows normal physiological functioning 959

- Food Groups and a Balanced Diet 959
- Nitrogen Balance 962
- The Role of Minerals and Vitamins 962

#### 25-7 Metabolic rate is the average caloric expenditure, and thermoregulation involves balancing heat-producing and heat-losing mechanisms 966

- Energy Gains and Losses 966
- Thermoregulation 967

**Chapter Review 972****Spotlights**

- The Electron Transport Chain and ATP Formation 947
- Absorptive and Postabsorptive States 960

**Clinical Case**

- The Miracle Supplement 940

**Clinical Notes**

- Carbohydrate Loading 951
- Dietary Fats and Cholesterol 955
- Blood Testing for Fat 955
- Vitamins 965
- Alcohol by the Numbers 965
- Alcohol and Disease 965
- Anorexia 966
- Superfoods 966
- Hypothermia in the Operating Room 970
- Excess Body Heat 971
- Deficient Body Heat 971

## 26 The Urinary System 976



### An Introduction to the Urinary System 977

#### 26-1 The organs of the urinary system function in excreting wastes and regulating body fluids 977

- Organs of the Urinary System 977
- Urinary System Functions 978

#### 26-2 Kidneys are highly vascular organs containing functional units called nephrons 978

- Position and Associated Structures of the Kidneys 978
- Gross Anatomy of the Kidneys 979
- Blood Supply and Innervation of the Kidneys 980
- Microscopic Anatomy of the Kidneys: The Nephron and Collecting System 982

#### 26-3 Different segments of the nephron form urine by filtration, reabsorption, and secretion 987

- Metabolic Wastes 987
- Basic Processes of Urine Formation 987

#### 26-4 The glomerulus filters blood through the filtration membrane to produce filtrate; several pressures determine the glomerular filtration rate 989

- Function of the Filtration Membrane 989
- Filtration Pressures 989
- The Glomerular Filtration Rate (GFR) 990
- Regulation of the GFR 991

- 26-5 The renal tubule reabsorbs nutrients, ions, and water and secretes ions and wastes; the collecting system reabsorbs ions and water** 993  
 Principles of Reabsorption and Secretion 993  
 An Overview of Reabsorbed and Secreted Substances 994  
 Reabsorption and Secretion along the PCT 995  
 Reabsorption and Secretion along the Nephron Loop 995  
 Reabsorption and Secretion along the DCT 997  
 Reabsorption and Secretion along the Collecting System 1000
- 26-6 Countercurrent multiplication allows the kidneys to regulate the volume and concentration of urine** 1001  
 The Nephron Loop and Countercurrent Multiplication 1001  
 Regulation of Urine Volume and Osmotic Concentration: Production of Dilute and Concentrated Urine 1003  
 The Function of the Vasa Recta: Countercurrent Exchange 1005  
 Urine Composition and Analysis 1005
- 26-7 Urine is transported by the ureters, stored in the bladder, and eliminated through the urethra by urinary reflexes** 1009  
 The Ureters 1009  
 The Urinary Bladder 1010  
 The Urethra 1011  
 Urinary Reflexes: Urine Storage and Urine Voiding 1012
- 26-8 Age-related changes affect kidney function and urination** 1013
- 26-9 The urinary system is one of several body systems involved in waste excretion** 1014
- Build Your Knowledge**  
 Integration of the URINARY system with the other body systems presented so far 1015
- Chapter Review** 1016
- SmartArt Videos**  
 Figure 26–8 The Locations and Structures of Cortical and Juxtamedullary Nephrons. 985
- Spotlights**  
 Summary of Renal Function 1006
- Clinical Case**  
 A Case of “Hidden” Bleeding 977
- Clinical Notes**  
 Glomerulonephritis 984  
 Diuretics 1000  
 Urinary Obstruction 1013  
 Renal Failure and Kidney Transplant 1014

## 27

## Fluid, Electrolyte, and Acid-Base Balance 1021



- An Introduction to Fluid, Electrolyte, and Acid-Base Balance** 1022
- 27-1 Fluid balance, electrolyte balance, and acid-base balance are interrelated and essential to homeostasis** 1022
- 27-2 Extracellular fluid (ECF) and intracellular fluid (ICF) are fluid compartments with differing solute concentrations that are closely regulated** 1023  
 Body Water Content 1023  
 The Fluid Compartments of the ECF and ICF 1023  
 Solute Exchanges between the ECF and the ICF 1024  
 An Overview of the Regulation of Fluid and Electrolyte Balance 1025
- 27-3 Fluid balance involves the regulation and distribution of water gains and losses** 1027  
 Fluid Gains and Losses 1027  
 Water Movement between Fluid Compartments 1028  
 Fluid Shifts between the ECF and ICF 1028
- 27-4 In electrolyte balance, the concentrations of sodium, potassium, calcium, magnesium, phosphate, and chloride ions in body fluids are tightly regulated** 1030  
 Sodium Balance 1030  
 Potassium Balance 1033  
 Balance of Other Electrolytes 1034
- 27-5 In acid-base balance, buffer systems as well as respiratory and renal compensation regulate pH changes in body fluids** 1036  
 Types of Acids in the Body 1036  
 Mechanisms of pH Control: Buffer Systems 1036  
 Regulation of Acid-Base Balance 1041
- 27-6 Disorders of acid-base balance can be classified as respiratory or metabolic** 1042  
 Respiratory Acid-Base Disorders 1045  
 Metabolic Acid-Base Disorders 1046  
 Combined Respiratory and Metabolic Acidosis 1049  
 The Detection of Acidosis and Alkalosis 1049
- 27-7 Aging affects fluid, electrolyte, and acid-base balance** 1049
- Chapter Review** 1051
- Spotlights**  
 The Diagnosis of Acid-Base Disorders 1050
- Clinical Case**  
 When Treatment Makes You Worse 1022
- Clinical Notes**  
 Water and Weight Loss 1029  
 Athletes and Salt Loss 1033  
 Sports Drinks 1033



**UNIT 6 CONTINUITY OF LIFE****28 The Reproductive System 1055****An Introduction to the Reproductive System 1056**

**28-1 Male and female reproductive system structures produce gametes that combine to form a new individual 1056**

**28-2 The structures of the male reproductive system consist of the testes, duct system, accessory glands, and penis 1057**

The Testes and Associated Structures 1057

Functional Anatomy of the Male Reproductive Duct System 1059

The Accessory Glands 1061

Semen 1063

The Penis 1063

**28-3 Spermatogenesis occurs in the testes, and hormones from the hypothalamus, pituitary gland, and testes control male reproductive functions 1065**

Overview of Mitosis and Meiosis 1065

Spermatogenesis 1067

Maturation of Sperm 1070

The Anatomy of a Sperm 1070

Hormonal Regulation of Male Reproductive Function 1070

**28-4 The structures of the female reproductive system consist of the ovaries, uterine tubes, uterus, vagina, and external genitalia 1072**

The Ovaries 1073

The Uterine Tubes 1074

The Uterus 1075

The Vagina 1078

The Female External Genitalia 1080

The Breasts 1080

**28-5 Oogenesis occurs in the ovaries, and hormones from the hypothalamus, pituitary gland, and ovaries control female reproductive functions 1082**

Oogenesis 1082

The Ovarian Cycle 1085

The Uterine (Menstrual) Cycle 1086

Hormonal Coordination of the Ovarian and Uterine Cycles 1087

**28-6 The autonomic nervous system influences male and female sexual function 1091**

Human Sexual Function 1091

Contraception and Infertility 1092

Sexually Transmitted Diseases (STDs) 1093

**28-7 Changes in levels of reproductive hormones cause functional changes throughout the life span 1093**

Development of the Genitalia 1093

Effects of Aging 1094

**28-8 The reproductive system secretes hormones affecting growth and metabolism of all body systems 1096**

**Build Your Knowledge**

Integration of the REPRODUCTIVE system with the other body systems presented so far 1097

**Chapter Review 1098****Spotlights**

Hormonal Regulation of Male Reproduction 1071

Hormonal Regulation of Female Reproduction 1088

**Clinical Case**

And Baby Makes Three? 1056

**Clinical Notes**

Circumcision 1065

Dehydroepiandrosterone (DHEA) 1070

Enlarged Prostate 1072

Prostate Cancer 1072

Prostate-Specific Antigen (PSA) Testing 1072

Ovarian Cancer 1075

Pap Smear 1077

Fibrocystic Disease and Breast Cancer 1081

Laparoscopy 1082

Mammoplasty 1082

**29 Development and Inheritance 1103****An Introduction to Development and Inheritance 1104**

**29-1 Directed by inherited genes, a fertilized ovum differentiates during prenatal development to form an individual; postnatal development brings that individual to maturity 1104**

**29-2 Fertilization—the fusion of a secondary oocyte and a sperm—forms a zygote 1105**

The Secondary Oocyte and Sperm before Fertilization 1105

The Process of Fertilization 1105

Events after Fertilization 1106

**29-3 Gestation consists of three stages of prenatal development: the first, second, and third trimesters 1107**

**29-4 The first trimester includes pre-embryonic and embryonic development, involving the processes of cleavage, implantation, placentation, and embryogenesis 1107**

The Pre-Embryonic Period 1108

The Embryonic Period 1109

<b>29-5</b>	<b>During the second and third trimesters, fetal development involves growth and organ function</b>	1115
<b>29-6</b>	<b>During gestation, maternal organ systems support the developing fetus; the reproductive system undergoes structural and functional changes</b>	1117
	Hormonal Regulation during Gestation	1120
	Changes in Maternal Organ Systems	1121
<b>29-7</b>	<b>Childbirth occurs through the process of labor, which consists of the dilation, expulsion, and placental stages</b>	1123
	Initiation of Labor	1123
	The Stages of Labor	1123
	Difficulties of Labor and Delivery and Multiple Births	1124
<b>29-8</b>	<b>Postnatal stages are the neonatal period, infancy, childhood, adolescence, and maturity, followed by senescence and death</b>	1126
	The Neonatal Period, Infancy, and Childhood	1127
	Adolescence and Maturity	1130
	Senescence and Death	1131
<b>29-9</b>	<b>Genes and chromosomes determine patterns of inheritance</b>	1131
	Genotype and Phenotype	1131
	Homologous Chromosomes and Alleles	1132
	Autosomal Patterns of Inheritance	1132
	Sex-Linked Patterns of Inheritance	1135
	Sources of Individual Variation	1136

Effect of Environmental Factors: Penetrance and Expressivity 1138

The Human Genome 1138

**Chapter Review** 1140

**Spotlights**

Extra-Embryonic Membranes and Placenta Formation 1112

**Clinical Case**

The Twins That Looked Nothing Alike 1104

**Clinical Notes**

Abortion 1123

C-Section 1126

Chromosomal Abnormalities 1137

Amniocentesis 1137

**Answers to Checkpoints, Review Questions, and Clinical Case**

**Wrap-Ups** AN-1

**Appendices**

Appendix A Normal Physiological Values A-1

Appendix B Gas Pressure Measurements and Cell Turnover Times A-3

Appendix C Codon Chart A-4

Appendix D Periodic Table of the Elements A-5

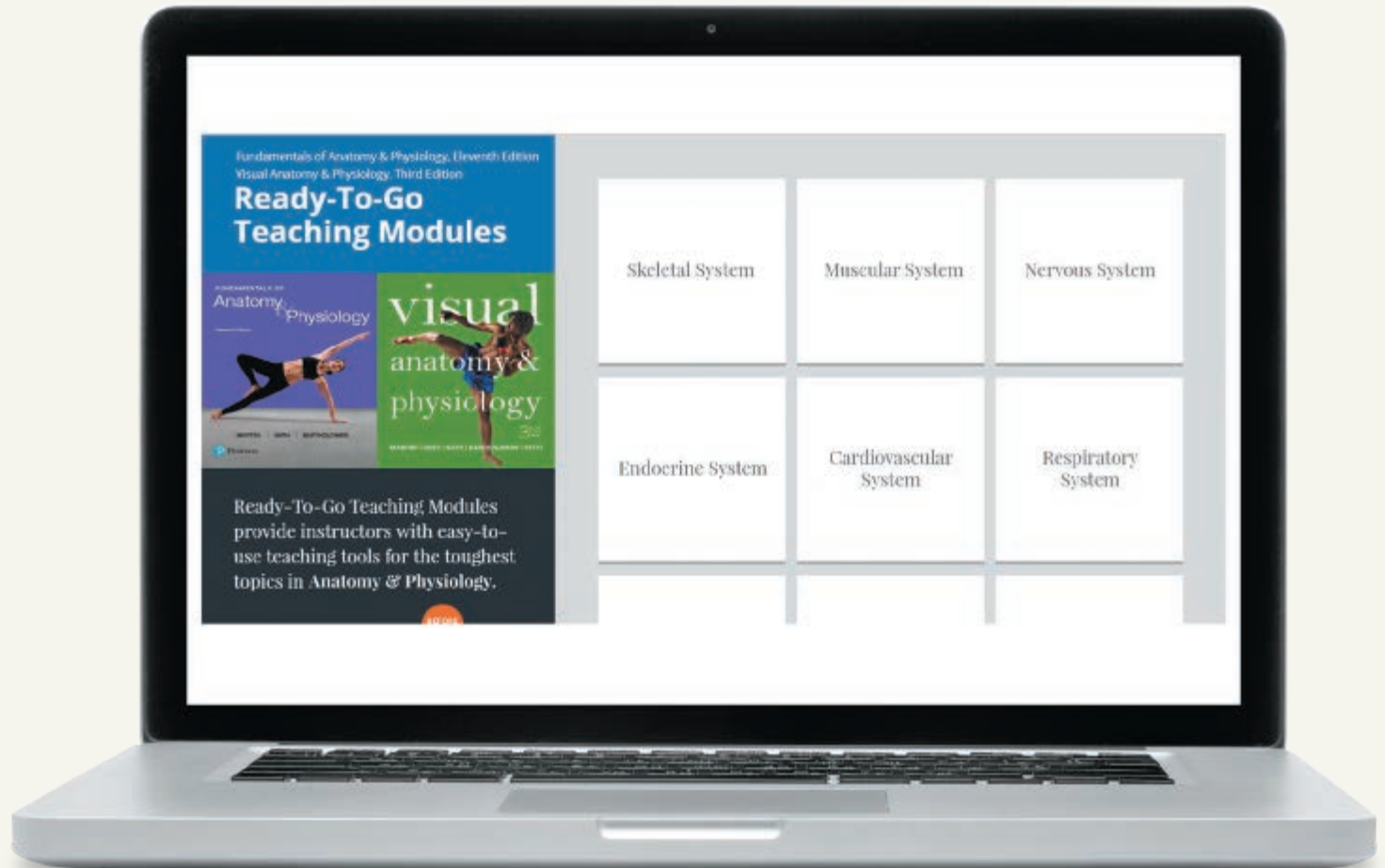
**Glossary** G-1

**Credits** C-1

**Index** I-1

# Get Ready for a Whole New Mastering Experience

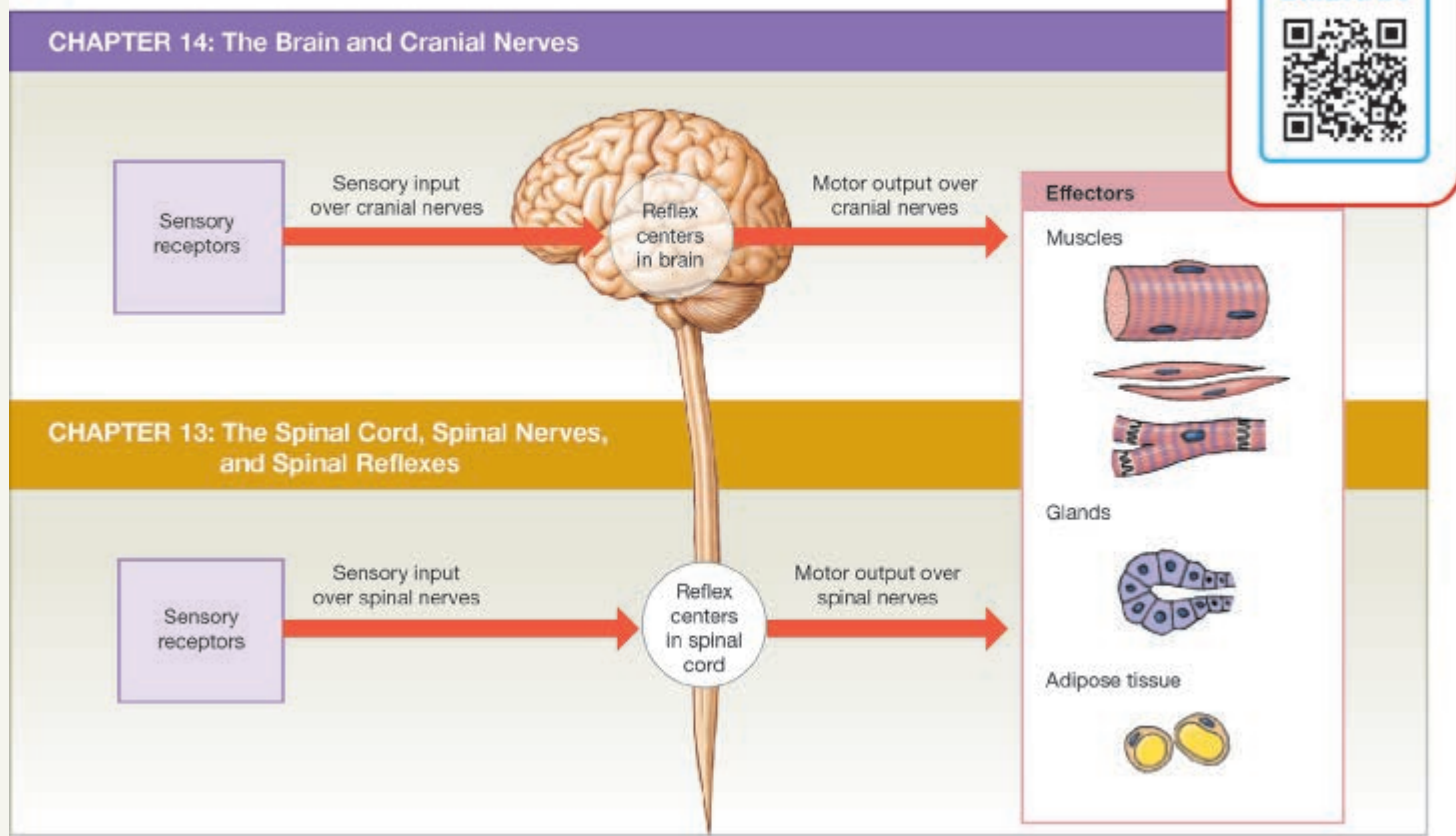
**NEW! Ready-to-Go Teaching Modules** help instructors find the best assets to use before, during, and after class to teach the toughest topics in A&P. Created by teachers for teachers, these curated sets of teaching tools save you time by highlighting the most effective and engaging animations, videos,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



# Help Students Use Art More Effectively

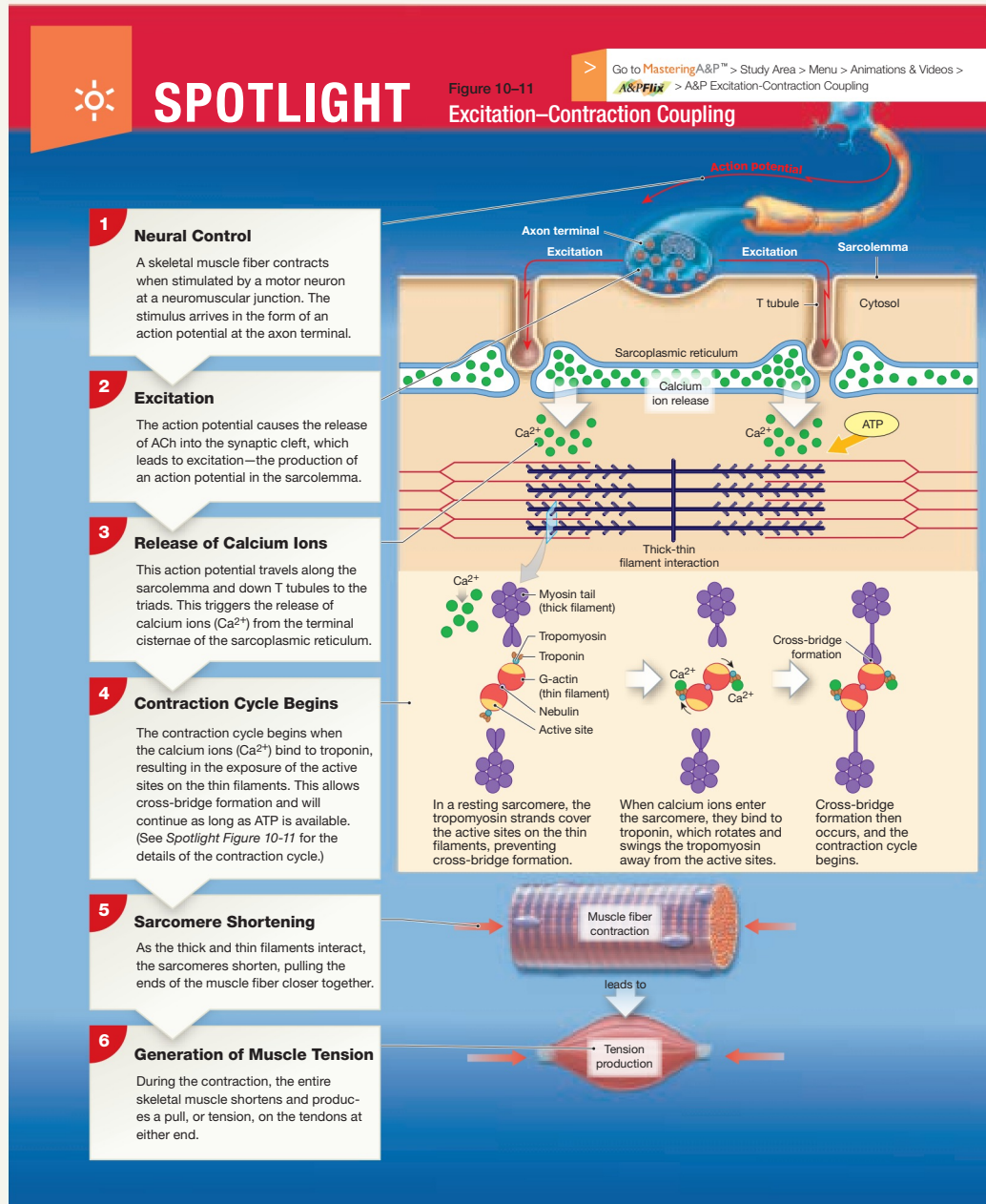
**NEW! SmartArt Videos** help students navigate select, complex pieces of art for some of the toughest topics in A&P. Author Kevin Petti walks students through several figures and provides additional background and detail. The videos can be accessed via QR codes in the book and offer accompanying assignments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

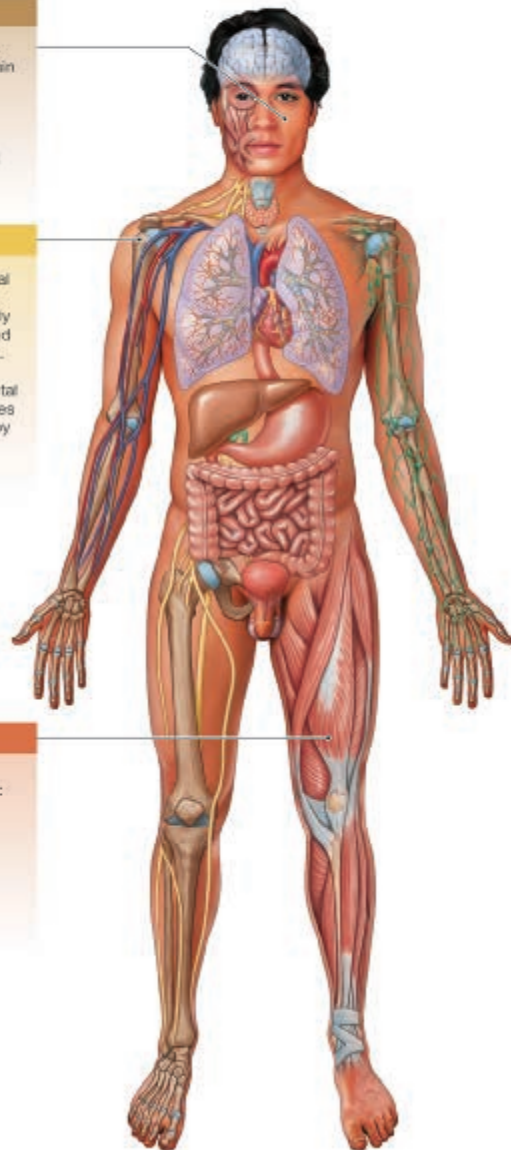
- The Integumentary System removes excess body heat, synthesizes vitamin D<sub>3</sub> for calcium and phosphate absorption, and protects underlying muscles.
- The muscular system includes facial muscles that pull on the skin of the face to produce facial expressions

### 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. 179.**

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

Grandpa Will has ichthyosis vulgaris (IK-thé-oh-sis vû-GAR-is). 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 epidermis becomes flaky and resembles 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 care gets lax, his skin can break into deep, painful cracks. Because the natural skin barrier is disrupted, secondary infection can move in.

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 Skin Answers Up 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.

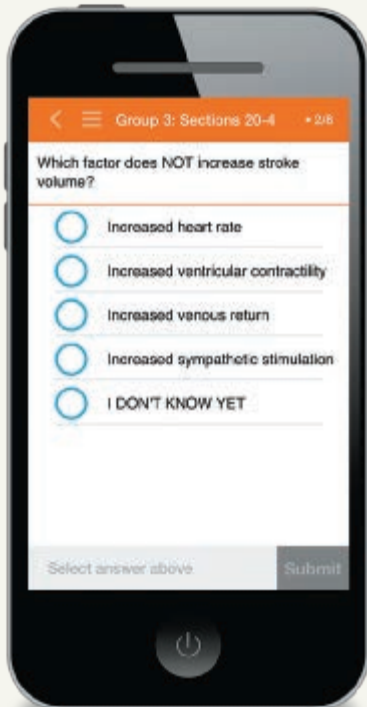
## Related Clinical Terms

- 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

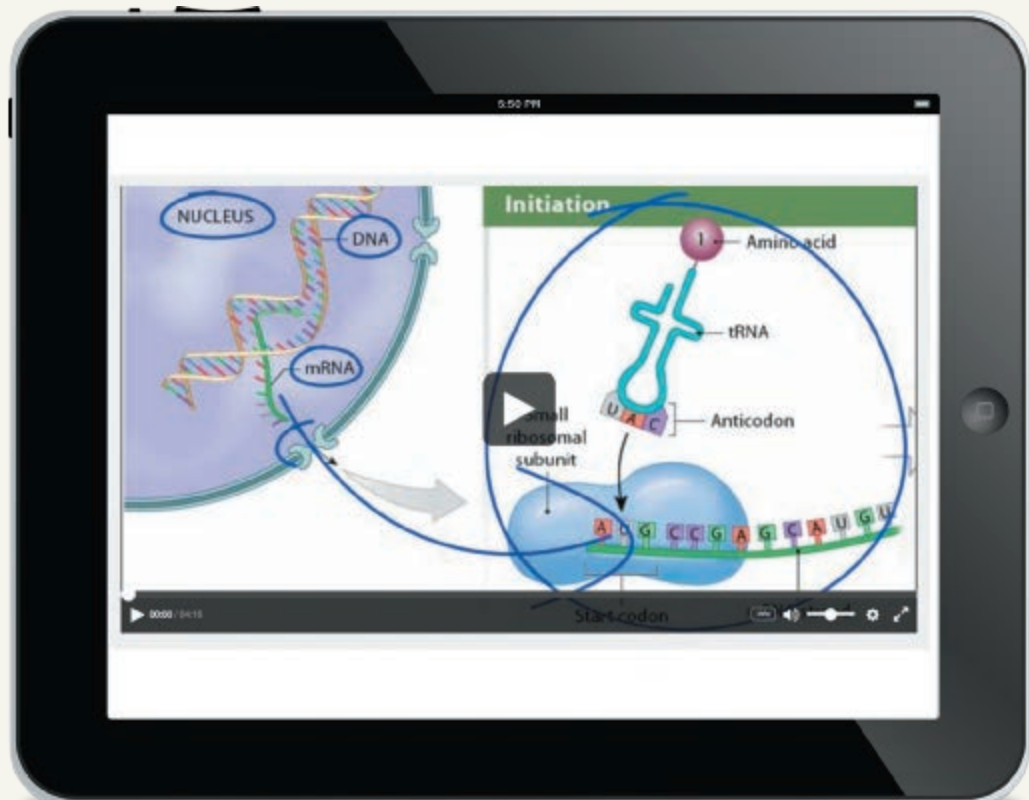
## Before, During, and After Class

**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 MasteringA&P.



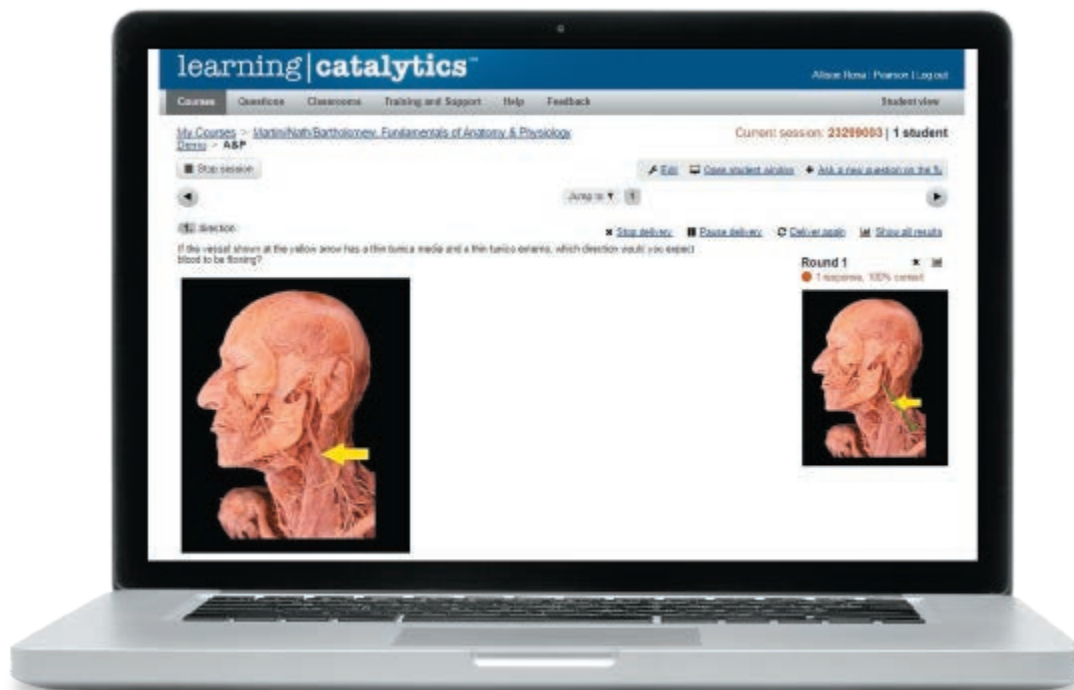


# with

**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.

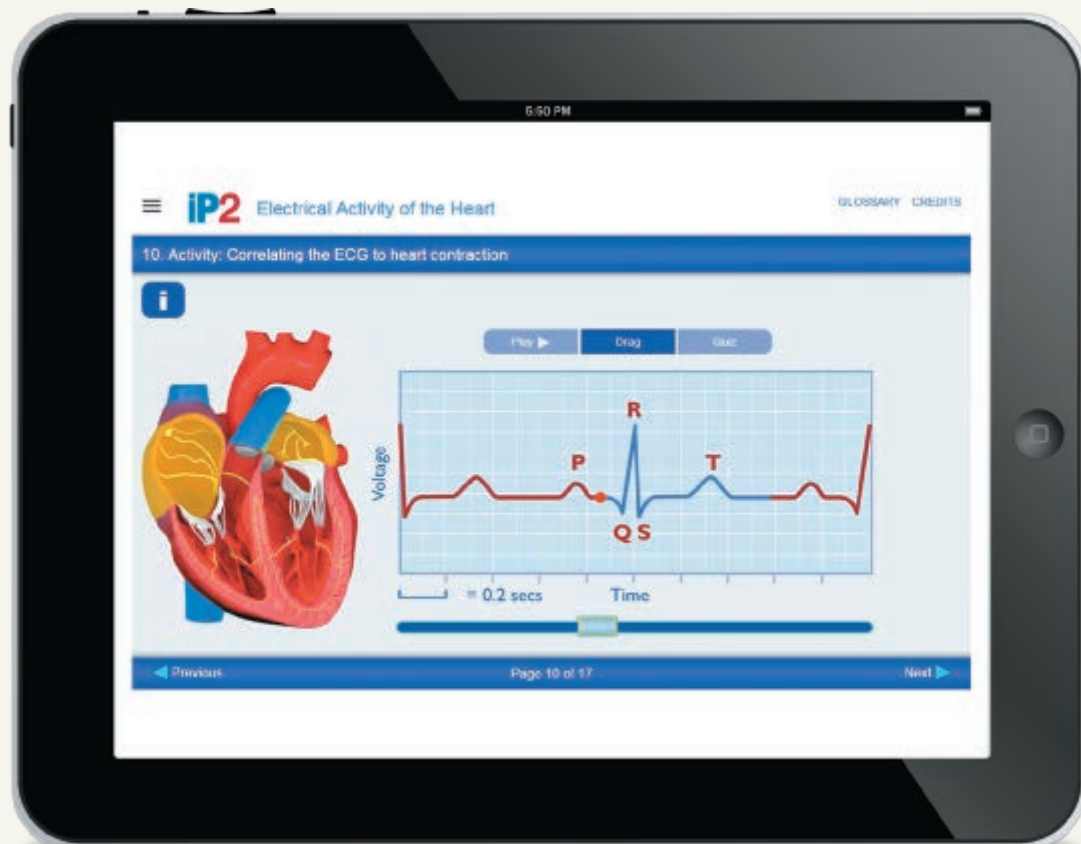
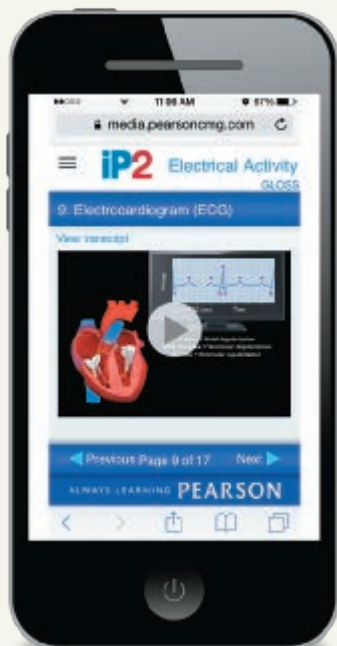
*“My students are so busy and engaged answering Learning Catalytics questions during lecture that they don’t have time for Facebook.”*

*—Declan De Paor, Old Dominion University*



# MasteringA&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:

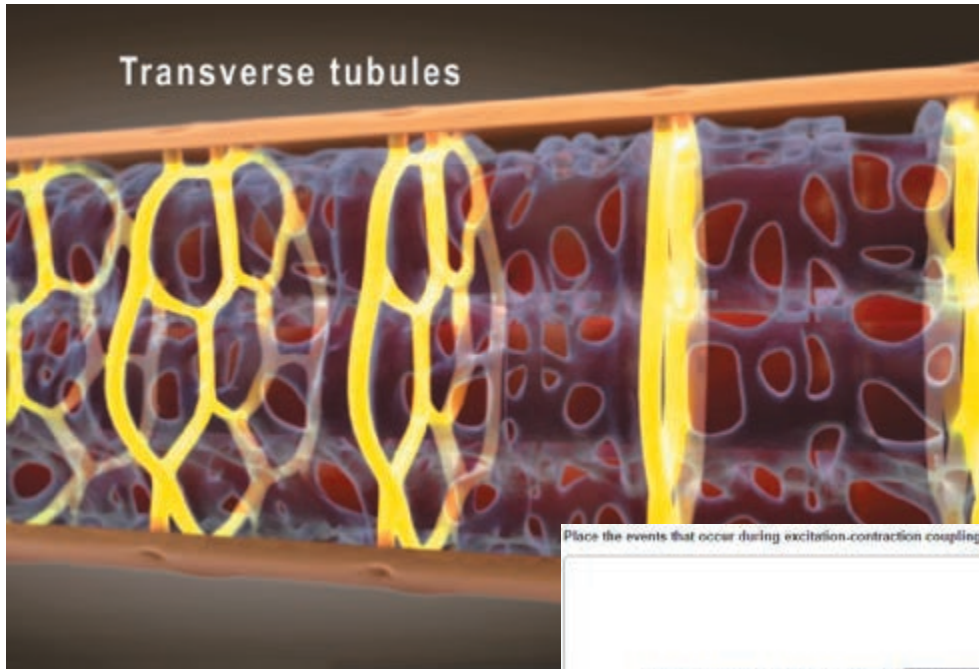
- Resting Membrane Potential
- Electrical Activity of the Heart
- Cardiac Output
- Factors Affecting Blood Pressure
- Generation of an Action Potential

## 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 travels down T tubules to triads    AP propagates along sarcolemma     $\text{Ca}^{2+}$  levels in sarcoplasm increase    Sarcoplasmic reticulum releases  $\text{Ca}^{2+}$     Voltage-sensitive proteins open  $\text{Ca}^{2+}$  channels

AP generated by motor neuron    Contraction of skeletal muscle fiber

[Submit](#)   [Hints](#)   [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 MasteringA&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 MasteringA&P code is needed to access these assignments.

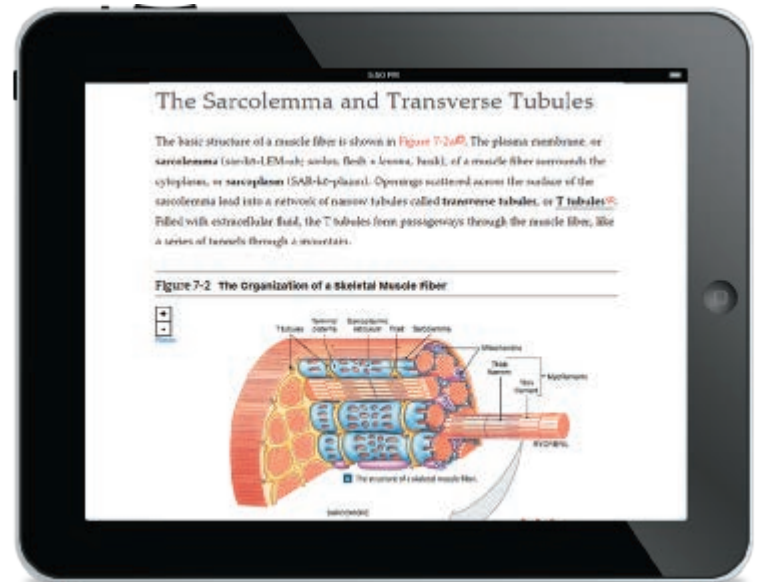
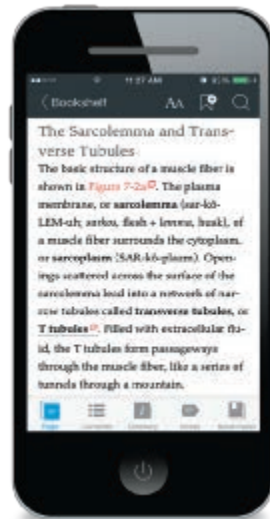




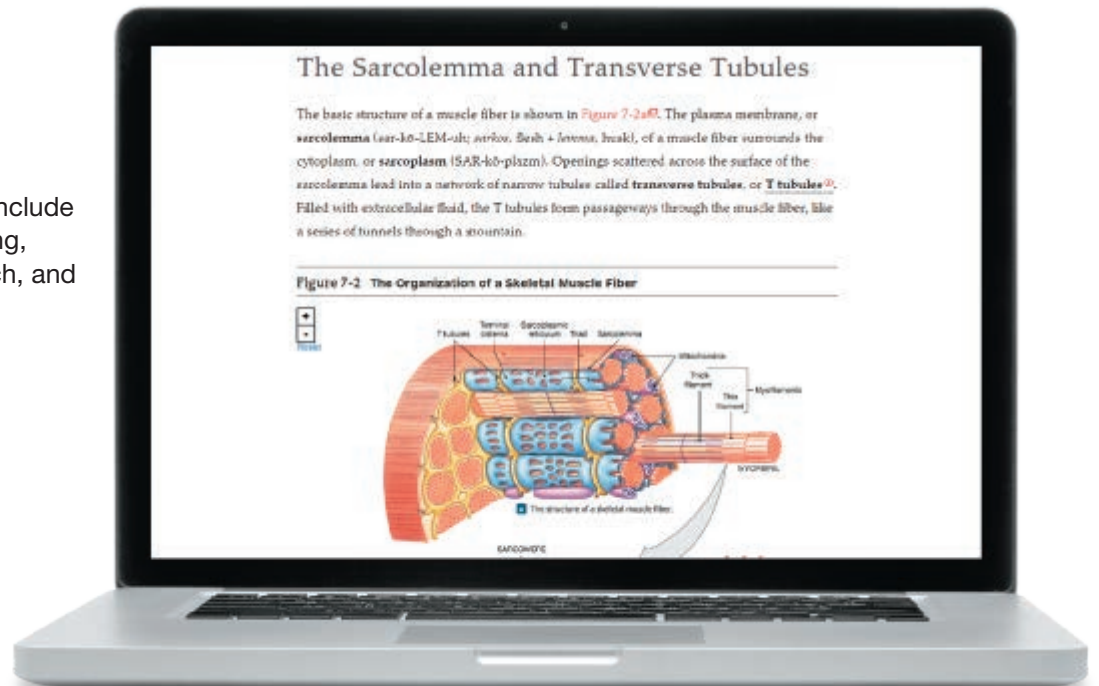
# On or Offline with eText 2.0

**NEW!** The **Eleventh Edition** is available in Pearson's fully-accessible eText 2.0 platform.\*

**NEW!** The **eText 2.0 mobile app** offers offline access and can be downloaded for most iOS and Android phones and tablets from the iTunes or Google Play stores.

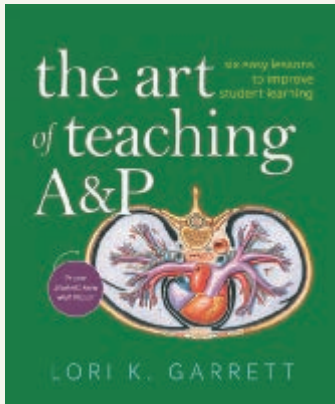


**Powerful interactive and customization functions** include instructor and student note-taking, highlighting, bookmarking, search, and links to glossary terms.



\*The eText 2.0 edition will be live for Fall 2017 classes.

# Instructor and Student Support

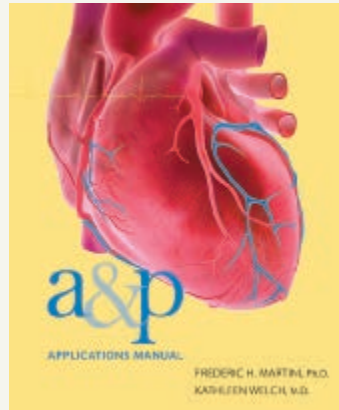


## **NEW!** The Art of Teaching A&P: Six Easy Lessons to Improve Student Learning by Lori K. Garrett

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.

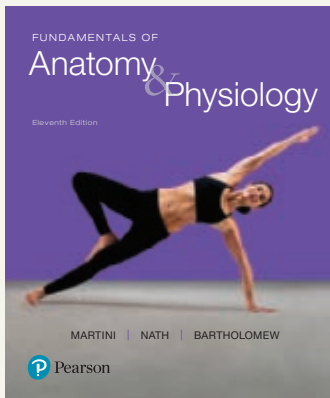


## **A&P Applications Manual by Frederic H. Martini and Kathleen Welch**

978-0-32-194973-8

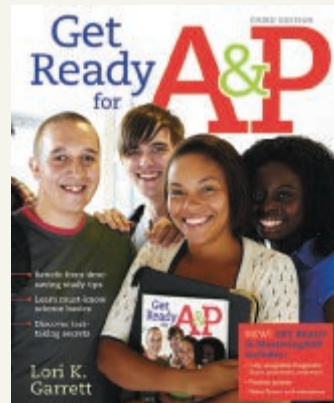
0-32-194973-0

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. Free when packaged with the textbook.



## **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
- Test Bank
- And more!

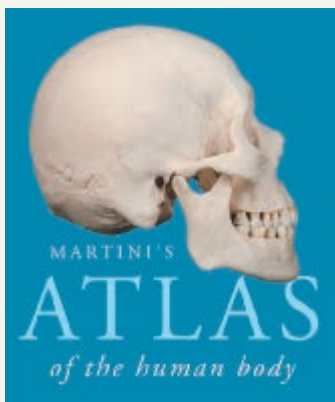


## **Get Ready for A&P by Lori K. Garrett**

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 MasteringA&P. Free when packaged with the textbook.

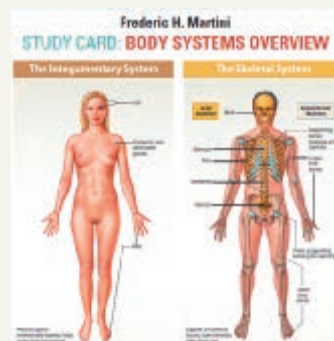


## **Martini's Atlas of the Human Body by Frederic H. Martini**

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. Free when packaged with the textbook.



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

978-0-13-460995-9

0-13-460995-6

A six-panel laminated card showing all body systems and their organs and functions. Free when packaged with the textbook.

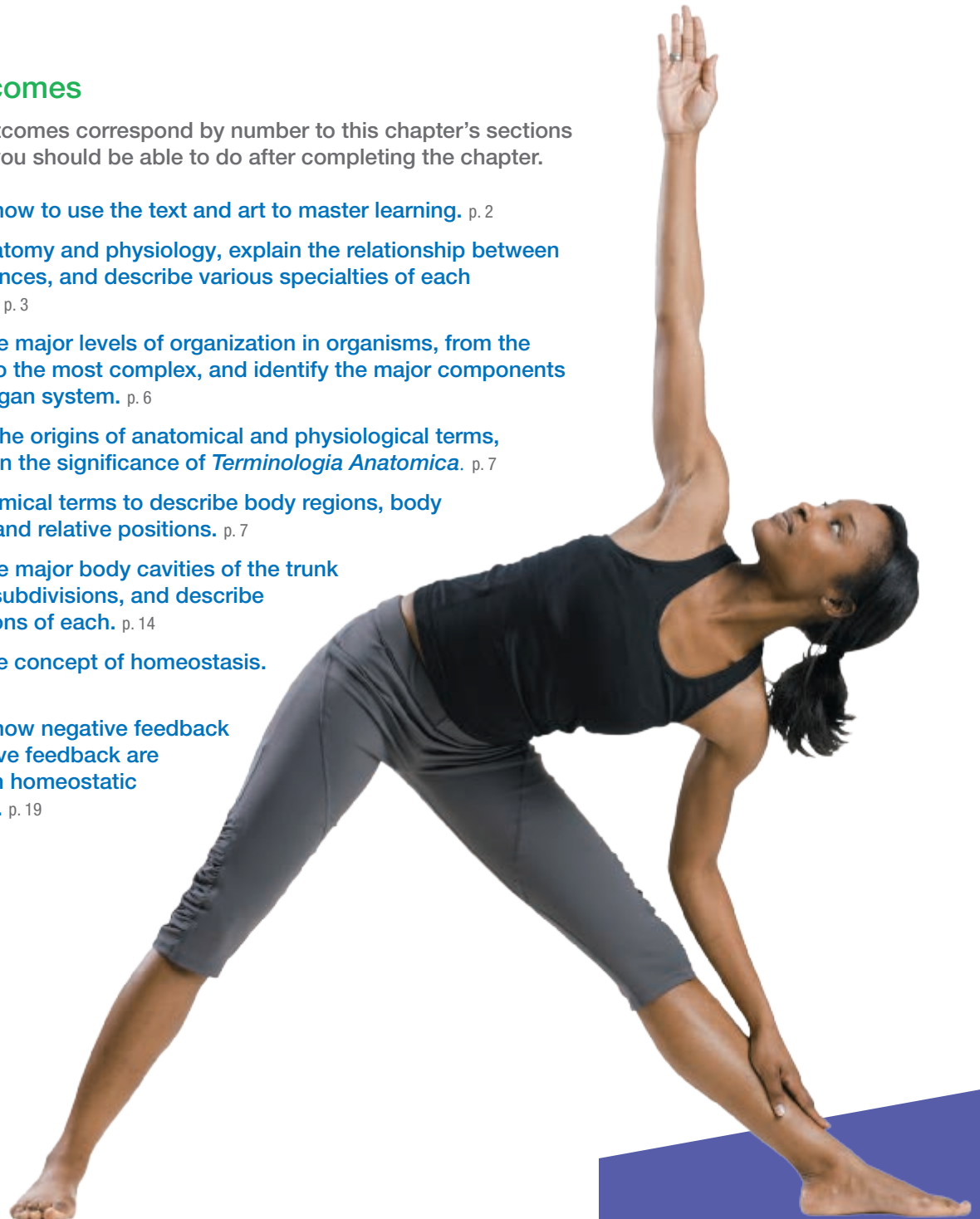
# 1

# 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. 2
- 1-2 ■ Define anatomy and physiology, explain the relationship between these sciences, and describe various specialties of each discipline. p. 3
- 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. 6
- 1-4 ■ Describe the origins of anatomical and physiological terms, and explain the significance of *Terminologia Anatomica*. p. 7
- 1-5 ■ Use anatomical terms to describe body regions, body sections, and relative positions. p. 7
- 1-6 ■ Identify the major body cavities of the trunk and their subdivisions, and describe the functions of each. p. 14
- 1-7 ■ Explain the concept of homeostasis. p. 18
- 1-8 ■ Describe how negative feedback and positive feedback are involved in homeostatic regulation. p. 19







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

1 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. 26.**

## 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



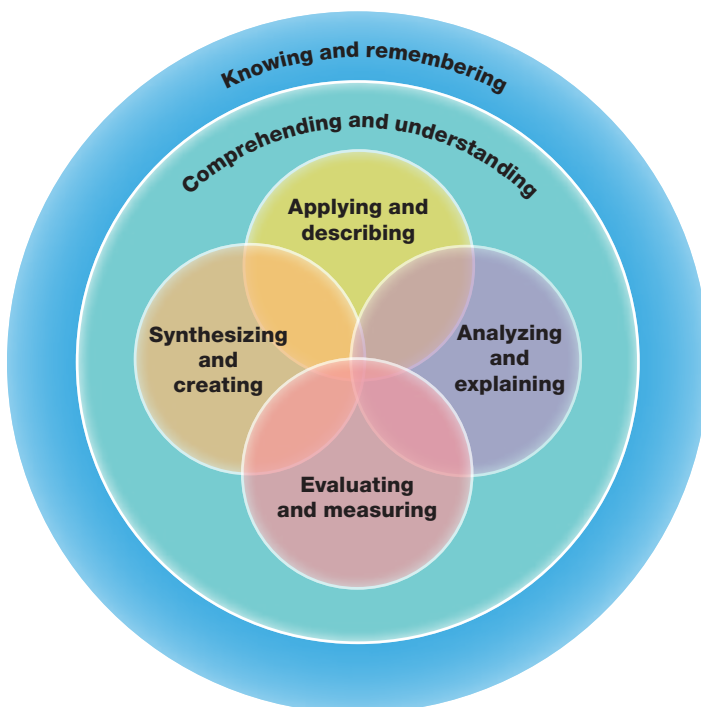
of your college textbooks, but we'll focus on this book, since it was designed for students such as you.

## 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

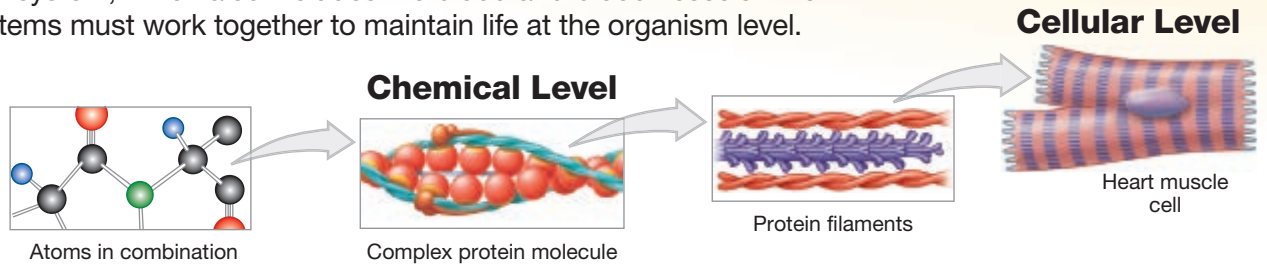
**Surface anatomy** involves locating structures on or near the body surface. A familiarity with anatomical landmarks (structures that can be felt or palpated), anatomical regions (specific areas used for reference purposes), and terms for anatomical directions will make the material in subsequent chapters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





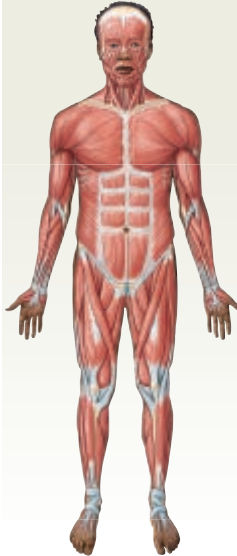



# SPOTLIGHT

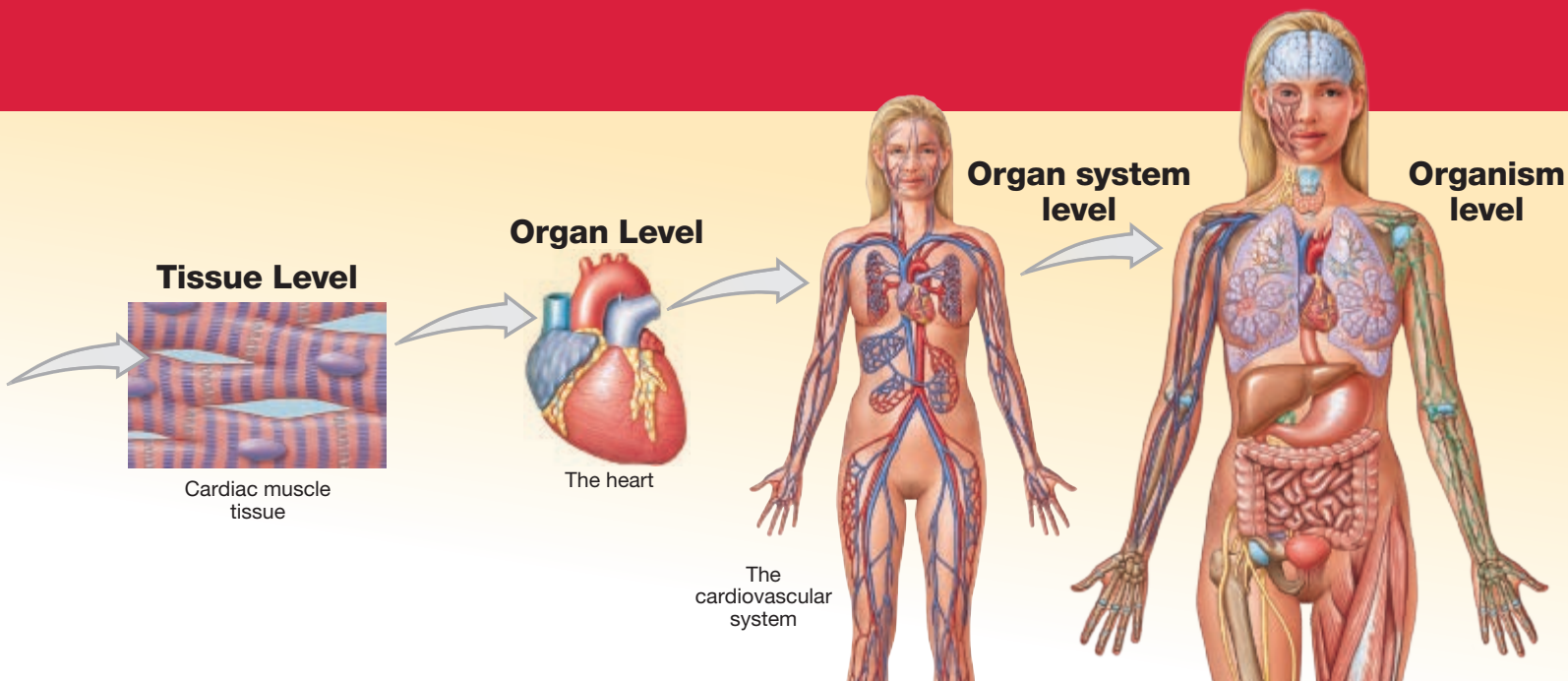
## Figure 1–2 Levels of Organization







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>



Lymphatic	Respiratory	Digestive	Urinary	Male Reproductive	Female Reproductive
 <p><b>Major Organs</b></p> <ul style="list-style-type: none"> <li>• Spleen</li> <li>• Thymus</li> <li>• Lymphatic vessels</li> <li>• Lymph nodes</li> <li>• Tonsils</li> </ul> <p><b>Functions</b></p> <ul style="list-style-type: none"> <li>• Defends against infection and disease</li> <li>• Returns tissue fluids to the bloodstream</li> </ul>	 <p><b>Major Organs</b></p> <ul style="list-style-type: none"> <li>• Nasal cavities</li> <li>• Sinuses</li> <li>• Larynx</li> <li>• Trachea</li> <li>• Bronchi</li> <li>• Lungs</li> <li>• Alveoli</li> </ul> <p><b>Functions</b></p> <ul style="list-style-type: none"> <li>• Delivers air to alveoli (sites in lungs where gas exchange occurs)</li> <li>• Provides oxygen to bloodstream</li> <li>• Removes carbon dioxide from bloodstream</li> <li>• Produces sounds for communication</li> </ul>	 <p><b>Major Organs</b></p> <ul style="list-style-type: none"> <li>• Teeth</li> <li>• Tongue</li> <li>• Pharynx</li> <li>• Esophagus</li> <li>• Stomach</li> <li>• Small intestine</li> <li>• Large intestine</li> <li>• Liver</li> <li>• Gallbladder</li> <li>• Pancreas</li> </ul> <p><b>Functions</b></p> <ul style="list-style-type: none"> <li>• Processes and digests food</li> <li>• Absorbs and conserves water</li> <li>• Absorbs nutrients</li> <li>• Stores energy reserves</li> </ul>	 <p><b>Major Organs</b></p> <ul style="list-style-type: none"> <li>• Kidneys</li> <li>• Ureters</li> <li>• Urinary bladder</li> <li>• Urethra</li> </ul> <p><b>Functions</b></p> <ul style="list-style-type: none"> <li>• Excretes waste products from the blood</li> <li>• Controls water balance by regulating volume of urine produced</li> <li>• Stores urine prior to voluntary elimination</li> <li>• Regulates blood ion concentrations and pH</li> </ul>	 <p><b>Major Organs</b></p> <ul style="list-style-type: none"> <li>• Testes</li> <li>• Epididymides</li> <li>• Ductus deferentia</li> <li>• Seminal vesicles</li> <li>• Prostate gland</li> <li>• Penis</li> <li>• Scrotum</li> </ul> <p><b>Functions</b></p> <ul style="list-style-type: none"> <li>• Produces male sex cells (sperm), seminal fluids, and hormones</li> <li>• Sexual intercourse</li> </ul>	 <p><b>Major Organs</b></p> <ul style="list-style-type: none"> <li>• Ovaries</li> <li>• Uterine tubes</li> <li>• Uterus</li> <li>• Vagina</li> <li>• Labia</li> <li>• Clitoris</li> <li>• Mammary glands</li> </ul> <p><b>Functions</b></p> <ul style="list-style-type: none"> <li>• Produces female sex cells (oocytes) and hormones</li> <li>• Supports developing embryo from conception to delivery</li> <li>• Provides milk to nourish newborn infant</li> <li>• Sexual intercourse</li> </ul>