

MARTINI / BARTHOLOMEW



SIXTH EDITION

ESSENTIALS OF

# Anatomy & Physiology

ESSENTIALS OF

# Anatomy & Physiology

SIXTH EDITION

Frederic H. Martini, Ph.D.  
Edwin F. Bartholomew, M.S.

WITH

William C. Ober, M.D.  
ART COORDINATOR AND ILLUSTRATOR

Claire W. Garrison, R.N.  
ILLUSTRATOR

Kathleen Welch, M.D.  
CLINICAL CONSULTANT

Ralph T. Hutchings  
BIOMEDICAL PHOTOGRAPHER

**PEARSON**

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

Executive Editor: Leslie Berriman  
Associate Editor: Katie Seibel  
Assistant Editor: Nicole McFadden  
Director of Development: Barbara Yien  
Senior Managing Editor: Deborah Cogan  
Production Project Manager: Caroline Ayres  
Copyeditor: Michael Rossa  
Production Management and Composition:  
S4Carlisle Publishing Services  
Director, Media Development: Lauren Fogel

Media Producer: Joseph Mochnick  
Design Managers: Mark Ong and Marilyn Perry  
Interior Designer: Gary Hespeneide  
Cover Designer: Riezebos Holzbaur Design Group  
Senior Photo Editor: Donna Kalal  
Photo Researcher: Caroline Commins  
Senior Manufacturing Buyer: Stacey Weinberger  
Marketing Manager: Derek Perrigo  
Cover Photo Credit: John Howard/Digital Vision/  
Getty Images

**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.

Credits and acknowledgments borrowed from other sources and reproduced, with permission, in this textbook appear on the appropriate page within the text or on p. CR-1.

---

Copyright © 2013, 2010, 2007 by Frederic H. Martini and Edwin F. Bartholomew. Published by Pearson Education, Inc. All rights reserved. Manufactured 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 likewise. To obtain permission(s) to use material from this work, please submit a written request to Pearson Education, Inc., Permissions Department, 1900 E. Lake Ave., Glenview, IL 60025. For information regarding permissions, call (847) 486-2635.

Many of the designations used by manufacturers and sellers to distinguish their products are claimed as trademarks. Where those designations appear in this book, and the publisher was aware of a trademark claim, the designations have been printed in initial caps or all caps.

MasteringA&P®, Practice Anatomy Lab™ (PAL™), and Interactive Physiology® are trademarks, in the U.S. and/or other countries, of Pearson Education, Inc. or its affiliates.

Library of Congress Cataloging-in-Publication data

Martini, Frederic.

Essentials of anatomy & physiology / Frederic H. Martini, Edwin F. Bartholomew ; with William C. Ober . . . [et al.].—6th ed.

p. cm.

Includes index

ISBN-13: 978-0-321-78745-3 (student ed.)

ISBN-10: 0-321-78745-5 (student ed.)

ISBN-13: 978-0-321-80207-1 (instructor's review copy)

ISBN-10: 0-321-80207-1 (instructor's review copy)

1. Human physiology. 2. Human anatomy. I. Bartholomew, Edwin F. II. Ober, William C. III. Title. IV. Title: Essentials of anatomy and physiology.

QP36.M42 2013

612—dc23

2011037955

ISBN 10: 0-321-78745-5 (Student Edition)

ISBN 13: 978-0-321-78745-3 (Student Edition)

ISBN 10: 0-321-80207-1 (Instructor's Review Copy)

ISBN 13: 978-0-321-80207-1 (Instructor's Review Copy)

ISBN 10: 0-321-79222-X (BALC)

ISBN 13: 978-0-321-79222-8 (BALC)

1 2 3 4 5 6 7 8 9 10—DOW—15 14 13 12 11

**PEARSON**

# Text and Illustration Team



**FREDERIC (RIC) MARTINI, PH.D.** (author) received his Ph.D. from Cornell University. In addition to his technical and journal publications, he has been the lead author of nine undergraduate texts on anatomy and physiology or anatomy. 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 20 years and is now a President Emeritus of HAPS. He 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) received his undergraduate degree from Bowling Green State University in Ohio and his M.S. from the University of Hawaii. His interests range widely, from human anatomy and physiology to the marine environment and “backyard” aquaculture. Mr. Bartholomew has taught human anatomy and physiology at both the secondary and undergraduate levels. In addition, he has taught a wide variety of other science courses (from botany to zoology) at Maui Community College. For many years, he taught at historic Lahainaluna High School, the oldest high school west of the Rockies, where he assisted in establishing an LHS Health Occupations Students of America (HOSA) chapter. He has written journal articles, a weekly newspaper column, and many magazine articles. Working with Dr. Martini, he coauthored *Structure & Function of the Human Body* and *The Human Body in Health and Disease* (Pearson). Along with Dr. Martini and Dr. Judi Nath, he coauthored *Fundamentals of Anatomy & Physiology, 9th edition*.



**WILLIAM C. OBER, M.D.** (art coordinator and illustrator) received his undergraduate degree from Washington and Lee University and his M.D. from the University of Virginia. While in medical school, 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. He was Chief of Medicine at Martha Jefferson Hospital and was an Instructor in the Division of Sports Medicine at UVA. He also was part of the Core Faculty at Shoals Marine Laboratory for 22 years, where he taught Biological Illustration every summer. He is currently a visiting professor of Biology at Washington and Lee University. The textbooks illustrated by his company Medical & Scientific Illustration have won numerous design and illustration awards.



**CLAIRE W. GARRISON, R.N.** (illustrator) practiced pediatric and obstetric nursing before turning to medical illustration as a full-time career. She received her degree at Mary Baldwin College with distinction in studio art. Following a five-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.



**KATHLEEN WELCH, M.D.** (clinical consultant) received her M.D. from the University of Washington in Seattle and did her residency at the University of North Carolina in Chapel Hill. For two 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. She has been in private practice since 1987. 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, New Zealand Procure PHO, and the Human Anatomy and Physiology Society.



**RALPH T. HUTCHINGS** (biomedical photographer) 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 chose Mr. Hutchings as the best photographer of humans in the twentieth century. He lives in North London, where he tries to balance the demands of his photographic assignments with his hobbies of early motorcars and airplanes.

## DEDICATION

*To Kitty, P.K., Kathy, Ivy, and Kate:  
We couldn't have done this without you.  
Thank you for your encouragement, patience,  
and understanding.*

---

# Preface

**Welcome to the Sixth Edition of *Essentials of Anatomy & Physiology!*** This textbook introduces the essential concepts needed for an understanding of the human body and helps students place information in a meaningful context, develop their problem-solving skills, and prepare for a career in a medical or allied health field. In this edition, we continue to build on this text's hallmark quality: a clear, effective visual and narrative presentation of anatomy and physiology. During the revision process, the author and illustrator team drew upon their combined content knowledge, research skills, artistic talents, and 50-plus years of classroom experience to make this the best edition yet.

The broad changes to this edition are presented in the **New to the Sixth Edition** section below. Also below are the sections **Terminology Changes in the Sixth Edition**, **Learning Outcomes**, and **Chapter-by-Chapter Changes in the Sixth Edition**. A visual tour of the book follows in the remaining pages of the Preface.

## New to the Sixth Edition

In addition to the technical changes in this edition, such as updated statistics and anatomy and physiology descriptions, we have simplified the presentations to make the narrative easier to read. We have also focused on improving the integration of illustrations with the narrative. These are the key changes in this new edition:

- **Easier narrative** uses simpler, shorter, more active sentences to make reading and studying easier for students.
- **New Spotlight figures** combine text and art to communicate key topics in visually effective single-page or two-page presentations.
- **Improved text-art integration** throughout the illustration program enhances the readability of figures. Part captions are now integrated into the figures so that the relevant text is located immediately next to each part of a figure.
- **More visual Clinical Notes** draw students' attention to clinical information and scenarios they might encounter in their future careers.
- **New Career Paths** provide students with excellent introductions to some of the most popular careers in healthcare. These interview-based vignettes showcase

11 different healthcare practitioners and feature first-hand accounts of the career, clinical images, and key statistics on annual earnings, job outlook, and education and training requirements. The following professions are featured: paramedic/emergency medical technician (EMT), dental hygienist, massage therapist, physician assistant, physical therapist, phlebotomist, pediatric nurse, respiratory therapist, registered dietician, pharmacy technician, and sonographer.

- **New System Integrator figures** for each body system replace the “Systems in Perspective” figures from previous editions. These “build-a-body” figures reinforce the mechanisms of system integration by gradually increasing in complexity as each new system is examined.
- **Easier-to-read tables** have been redesigned and simplified, and references to them within the narrative are now in color to make them easier to find.
- **MasteringA&P®** ([www.masteringaandp.com](http://www.masteringaandp.com)) is an online learning and assessment system designed to help instructors teach more efficiently and proven to help students learn. Instructors can assign homework from proven media programs such as Practice Anatomy Lab™ (PAL™) 3.0 and Essentials of Interactive Physiology®—all organized by chapter—and have assignments automatically graded. There are also abundant items from each chapter's content, including Reading Quizzes and Art-labeling Activities. All items are organized by the chapter Learning Outcomes. In the MasteringA&P® Study Area, students can access a full suite of self-study tools, listed in detail at the end of each textbook chapter.

## Terminology Changes in the Sixth Edition

We have revised terminology in selected cases to match the most common usage in medical specialties. We used *Terminologia Anatomica* and *Terminologia Histologica* as our reference for anatomical and tissue terms. Furthermore, possessive forms of diseases are now used when the proposed alternative has not been widely accepted, e.g., Parkinson disease is now Parkinson's disease. In addition, several terms that were

primary in the Fifth Edition have become secondary terms in the Sixth Edition. The changes, which affect virtually all the chapters in the text, are detailed in the table below.

Primary Terms	
Fifth Edition	Sixth Edition
acrosomal cap	acrosome
anterior pituitary	anterior lobe of the pituitary gland
aqueduct of midbrain	cerebral aqueduct
canal of Schlemm	scleral venous sinus
crista	crista ampullaris
ellipsoidal joint	condylar joint
fibrous cartilage	fibrocartilage
fibrous tunic, vascular tunic, and neural tunic	fibrous layer, vascular layer, and inner layer
induced immunity	artificially induced immunity
inner ear	internal ear
intercellular cement	proteoglycans
lymphoid system	lymphatic system
macula lutea	macula
nonspecific defenses	innate (nonspecific) defenses
occluding junction	tight junction
organ of Corti	spiral organ
plicae circulares	circular folds
posterior pituitary	posterior lobe of the pituitary gland
specific defenses	adaptive (specific) defenses
stratum germinativum	stratum basale
subcutaneous layer	hypodermis
suprarenal	adrenal
tympanic duct	scala tympani
vestibular duct	scala vestibuli

## Learning Outcomes

The chapters of the Sixth Edition are organized around specific Learning Outcomes that indicate what students should be able to do after studying the chapter.

- **Learning Outcomes** are chapter-opening numbered lists that indicate what students should be able to do after completing the chapter.
- **Full-sentence chapter headings** do more than introduce new topics; they state the core fact or concept that will be presented in the section. There is a one-to-one correspondence between the Learning Outcomes and the full-sentence section headings in every chapter.
- **Checkpoints** are located at the close of each section and ask students to pause and check their understanding of facts and concepts. The Checkpoints reinforce the Learning Outcomes presented on the chapter-opening page, resulting in a systematic integration of the Learning

Outcomes over the course of the chapter. Answers are located in the blue Answers tab at the back of the book.

All assessments in MasteringA&P are organized by the Learning Outcomes, making it easy for instructors to organize their courses and demonstrate results against goals for student achievement.

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

This annotated Table of Contents provides select examples of revision highlights in each chapter of the Sixth Edition.

### Chapter 1 An Introduction to Anatomy and Physiology

- Figure 1-1 Levels of Organization revised
- Figure 1-2 Organ Systems of the Human Body revised
- Figure 1-5 Positive Feedback revised
- Figure 1-6 Anatomical Landmarks revised
- Figure 1-8 Directional References revised
- New Spotlight Figure 1-9 Imaging Techniques
- Figure 1-10 Planes of Section revised
- Figure 1-11 The Ventral Body Cavity and Its Subdivisions revised

### Chapter 2 The Chemical Level of Organization

- Figure 2-1 A Diagram of Atomic Structure revised
- Figure 2-3 The Electron Shells of Two Atoms revised
- Figure 2-4 Ionic Bonding revised
- Figure 2-5 Covalent Bonds in Three Common Molecules revised
- Figure 2-6 Hydrogen Bonds between Water Molecules revised
- New Spotlight Figure 2-7 Chemical Notation
- Figure 2-8 The Effect of Enzymes on Activation Energy revised
- Figure 2-9 The Role of Water Molecules in Solutions revised
- Figure 2-11 The Structure, Formation, and Breakdown of Complex Sugars revised
- Figure 2-13 Fatty Acids revised
- Figure 2-15 A Cholesterol Molecule revised
- Figure 2-16 A Phospholipid Molecule revised
- Figure 2-17 Amino Acids and the Formation of Peptide Bonds revised
- Figure 2-19 A Simplified View of Enzyme Structure and Function revised
- Figure 2-20 The Structure of Nucleic Acids revised
- New Clinical Note: Fatty Acids and Health

### Chapter 3 Cell Structure and Function

- New Spotlight Figure 3-1 Anatomy of a Model Cell
- Figure 3-6 Osmosis revised

- Figure 3-7 Effects of Osmosis across Plasma Membranes revised
- Figure 3-10 Receptor-Mediated Endocytosis revised
- Figure 3-11 Phagocytosis revised
- New Spotlight Figure 3-14 Protein Synthesis and Packaging
- Figure 3-18 Transcription revised
- Figure 3-19 Translation revised
- Figure 3-20 Stages of a Cell's Life Cycle revised

#### Chapter 4 The Tissue Level of Organization

- Figure 4-1 An Orientation to the Tissues of the Body revised
- Figure 4-2 Cell Junctions revised
- Figure 4-3 The Surfaces of Epithelial Cells revised
- Figure 4-4 Simple Epithelia revised
- Figure 4-5 Stratified Epithelia revised
- Figure 4-6 Mechanisms of Glandular Secretion revised
- Figure 4-7 Major Types of Connective Tissue revised
- New Figure 4-9 Loose Connective Tissues
- New Figure 4-10 Dense Connective Tissues
- Figure 4-11 Types of Cartilage revised
- Figure 4-12 Bone revised
- Figure 4-13 Tissue Membranes revised
- Figure 4-14 Muscle Tissue revised
- Clinical Note: Marfan Syndrome revised

#### Chapter 5 The Integumentary System

- Figure 5-1 The General Structure of the Integumentary System revised
- Figure 5-2 The Structure of the Epidermis revised
- Figure 5-3 Melanocytes revised
- Figure 5-5 Hair Follicles and Hairs revised
- Figure 5-6 Sebaceous Glands and Their Relationship to Hair Follicles revised
- Figure 5-9 Events in Skin Repair revised
- New Figure 5-10 System Integrator
- Clinical Note: Hair Loss revised
- New Career Paths: EMT/ Paramedic

#### Chapter 6 The Skeletal System

- Figure 6-1 Shapes of Bones revised
- Figure 6-3 The Microscopic Structure of a Typical Bone revised
- Figure 6-5 Endochondral Ossification revised
- Figure 6-7 Steps in the Repair of a Fracture revised
- Figure 6-12 Sectional Anatomy of the Skull revised
- Figure 6-17 Typical Vertebrae of the Cervical, Thoracic, and Lumbar Regions revised
- Figure 6-19 The Sacrum and Coccyx revised
- Figure 6-20 The Thoracic Cage revised
- Figure 6-22 The Scapula revised
- Figure 6-23 The Humerus revised

- Figure 6-24 The Radius and the Ulna revised
- Figure 6-25 Bones of the Wrist and Hand revised
- Figure 6-26 The Pelvis revised
- Figure 6-28 The Femur revised
- Figure 6-29 The Right Tibia and Fibula revised
- Figure 6-30 The Bones of the Ankle and Foot revised
- Figure 6-31 The Structure of Synovial Joints revised
- Figure 6-32 Angular Movements revised
- Figure 6-33 Rotational Movements revised
- New Spotlight Figure 6-35 Synovial Joints
- Figure 6-36 Intervertebral Articulations revised
- Figure 6-40 The Knee Joint revised
- New Figure 6-41 System Integrator
- Clinical Note: Types of Fractures revised
- Clinical Note: Rheumatism and Arthritis revised
- New Career Paths: Dental Hygienist

#### Chapter 7 The Muscular System

- Figure 7-1 The Organization of Skeletal Muscles revised and cross-sectional views of skeletal muscle, muscle fascicle, and muscle fiber added
- Figure 7-3 Changes in the Appearance of a Sarcomere during Contraction of a Skeletal Muscle Fiber revised
- New Spotlight Figure 7-4 Skeletal Muscle Innervation
- New Spotlight Figure 7-5 The Contraction Cycle
- Figure 7-9 Muscle Metabolism revised
- Figure 7-10 Cardiac and Smooth Muscle Tissues revised
- Figure 7-11 An Overview of the Major Skeletal Muscles revised
- Figure 7-12 Muscles of the Head and Neck revised
- Figure 7-15 Oblique and Rectus Muscles and the Diaphragm revised
- Figure 7-16 Muscles of the Pelvic Floor revised
- Figure 7-17 Muscles That Position the Pectoral Girdle revised
- Figure 7-18 Muscles That Move the Arm revised
- Figure 7-19 Muscles That Move the Forearm and Wrist revised
- Figure 7-20 Muscles That Move the Thigh revised
- Figure 7-21 Muscles That Move the Leg revised
- Figure 7-22 Muscles That Move the Foot and Toes revised and deep dissection view added
- New Figure 7-23 System Integrator
- Clinical Note: Tetanus revised
- Clinical Note: Intramuscular Injections revised
- New Career Paths: Massage Therapist

#### Chapter 8 The Nervous System

- Figure 8-2 The Anatomy of a Representative Neuron revised
- Figure 8-4 Neuroglia in the CNS revised
- Figure 8-5 Schwann Cells and Peripheral Axons revised



- Figure 8-6 The Anatomical Organization of the Nervous System revised
- Figure 8-7 The Resting Potential Is the Membrane Potential of an Undisturbed Cell revised
- New Spotlight Figure 8-8 Generation of an Action Potential
- Figure 8-10 The Structure of a Typical Synapse revised
- Figure 8-11 The Events at a Cholinergic Synapse revised
- Figure 8-12 Two Common Types of Neuronal Pools revised
- Figure 8-13 The Meninges revised
- Figure 8-14 Two Common Types of Neuronal Pools revised
- Figure 8-16 The Brain revised
- Figure 8-17 The Ventricles of the Brain revised
- Figure 8-20 Hemispheric Lateralization revised
- Figure 8-21 Brain Waves revised
- Figure 8-24 The Diencephalon and Brain Stem revised
- Figure 8-28 The Components of a Reflex Arc revised
- Figure 8-29 A Stretch Reflex revised
- Figure 8-32 The Corticospinal Pathway revised
- New Figure 8-36 System Integrator
- Clinical Note: Epidural and Subdural Hemorrhages revised
- Clinical Note: Aphasia and Dyslexia revised
- Clinical Note: Alzheimer's Disease revised
- New Career Paths: Physician Assistant

### Chapter 9 The General and Special Senses

- Figure 9-2 Referred Pain revised
- Figure 9-4 Baroreceptors and the Regulation of Autonomic Functions revised
- Figure 9-6 The Olfactory Organs revised
- Figure 9-10 The Sectional Anatomy of the Eye revised
- Figure 9-11 The Pupillary Muscles revised
- Figure 9-14 The Circulation of Aqueous Humor revised
- Figure 9-15 Focal Point, Focal Distance, and Visual Accommodation revised
- New Spotlight Figure 9-17 Accommodation Problems
- Figure 9-19 The Structure of Rods and Cones revised
- Figure 9-21 The Visual Pathways revised
- Figure 9-22 The Anatomy of the Ear revised
- Figure 9-25 The Vestibular Complex revised
- Figure 9-27 Sound and Hearing revised
- New Figure 9-28 Pathways for Auditory Sensations
- Clinical Note: Hearing Deficits revised

### Chapter 10 The Endocrine System

- Figure 10-1 Organs and Tissues of the Endocrine System revised
- Figure 10-3 Mechanisms of Hormone Action revised
- Figure 10-4 Three Mechanisms of Hypothalamic Control over Endocrine Organs revised

- Figure 10-7 Negative Feedback Control of Endocrine Secretion revised
- Figure 10-8 Pituitary Hormones and Their Targets revised
- Figure 10-9 The Thyroid Gland revised
- Figure 10-10 The Homeostatic Regulation of Calcium Ion Concentrations revised
- Figure 10-11 The Parathyroid Glands revised
- Figure 10-13 The Endocrine Pancreas revised
- Figure 10-14 The Regulation of Blood Glucose Concentrations revised
- New Spotlight Figure 10-15 The General Adaptation Syndrome
- New Figure 10-16 System Integrator
- Clinical Note: Endocrine Disorders revised
- Clinical Note: Diabetes Mellitus revised
- Clinical Note: Hormones and Athletic Performance revised
- New Career Paths: Physical Therapist

### Chapter 11 The Cardiovascular System: Blood

- New Spotlight Figure 11-1 The Composition of Whole Blood
- Figure 11-3 Sickling in Red Blood Cells revised
- Figure 11-4 Recycling of Hemoglobin revised
- Figure 11-5 The Origins and Differentiation of RBCs, Platelets, and WBCs revised
- Figure 11-7 Blood Types and Cross-Reactions revised
- New Figure 11-8 Blood Type Testing
- Figure 11-11 Events in the Coagulation Phase of Hemostasis revised
- Clinical Note: Abnormal Hemoglobin revised

### Chapter 12 The Cardiovascular System: The Heart

- Figure 12-2 The Location of the Heart in the Thoracic Cavity revised
- Figure 12-3 The Surface Anatomy of the Heart revised and new part c added
- Figure 12-4 The Heart Wall and Cardiac Muscle Tissue revised
- Figure 12-6 The Valves of the Heart revised
- Figure 12-7 The Coronary Circulation revised
- Figure 12-8 Action Potentials and Muscle Cell Contraction in Skeletal and Cardiac Muscle revised
- Figure 12-9 The Conducting System of the Heart revised
- New Figure 12-10 An Electrocardiogram
- New Figure 12-11 The Cardiac Cycle
- New Figure 12-12 Autonomic Innervation of the Heart

### Chapter 13 The Cardiovascular System: Blood Vessels and Circulation

- Figure 13-2 The Structure of the Various Types of Blood Vessels revised
- Figure 13-3 A Plaque within an Artery revised

- New Figure 13-5 The Function of Valves in the Venous System revised
- Figure 13-6 Pressures within the Systemic Circuit revised
- Figure 13-7 Forces Acting across Capillary Walls revised
- New Figure 13-9 Short-Term and Long-Term Cardiovascular Responses
- New Figure 13-10 The Baroreceptor Reflexes of the Carotid and Aortic Sinuses
- New Figure 13-11 The Chemoreceptor Reflexes
- New Figure 13-12 The Hormonal Regulation of Blood Pressure and Blood Volume
- Figure 13-13 An Overview of the Pattern of Circulation revised
- Figure 13-18 Arteries of the Neck, Head, and Brain revised
- Figure 13-19a Major Arteries of the Trunk revised
- Figure 13-25 Fetal Circulation revised
- New Figure 13-26 System Integrator
- New Career Paths: Phlebotomist

#### Chapter 14 The Lymphatic System and Immunity

- New Figure 14-1 The Components of the Lymphatic System
- Figure 14-4 The Origin and Distribution of Lymphocytes revised
- New Figure 14-5 The Tonsils
- Figure 14-7 The Thymus revised
- Figure 14-8 The Spleen revised
- Figure 14-9 The Body's Innate Defenses revised
- New Figure 14-10 Events in Inflammation
- Figure 14-11 Types of Immunity revised
- New Figure 14-12 An Overview of the Immune Response
- New Figure 14-13 Antigen Recognition by and Activation of Cytotoxic T Cells
- Figure 14-14 The B Cell Response to Antigen Exposure revised
- New Table 14-2 Cells That Participate in Tissue Defenses
- New Figure 14-17 A Summary of the Immune Response and Its Relationship to Innate (Nonspecific) Defenses
- New Figure 14-18 System Integrator
- New Career Paths: Pediatric Nurse

#### Chapter 15 The Respiratory System

- Figure 15-3 The Nose, Nasal Cavity, and Pharynx revised
- Figure 15-4 The Anatomy of the Larynx and Vocal Cords revised
- Figure 15-11 Respiratory Volumes and Capacities revised
- Figure 15-13 Carbon Dioxide Transport in Blood revised
- Figure 15-14 A Summary of Gas Transport and Exchange revised
- Figure 15-15 Basic Regulatory Patterns of Respiration revised

- Figure 15-16 The Control of Respiration revised
- New Figure 15-17 System Integrator
- Clinical Note: Decompression Sickness revised
- New Clinical Note: Emphysema and Lung Cancer
- New Career Paths: Respiratory Therapist

#### Chapter 16 The Digestive System

- New Figure 16-1 The Components of the Digestive System
- Figure 16-3 Peristalsis revised
- Figure 16-7 The Swallowing Process revised
- Figure 16-9 The Phases of Gastric Secretion revised
- Figure 16-10 The Segments of the Small Intestine revised and added new part b
- Figure 16-11 The Intestinal Wall revised and added new part d
- Figure 16-12 The Activities of Major Digestive Tract Hormones revised
- Figure 16-15 Liver Histology revised
- New Spotlight Figure 16-18 Chemical Events in Digestion
- New Figure 16-19 System Integrator
- New Career Paths: Registered Dietitian

#### Chapter 17 Metabolism and Energetics

- Figure 17-3 Glycolysis revised
- Figure 17-5 The Electron Transport System and ATP Formation revised
- New Figure 17-6 A Summary of the Energy Yield of Aerobic Metabolism
- Figure 17-7 Carbohydrate Metabolism revised
- Figure 17-8 Alternate Catabolic Pathways revised
- New Figure 17-9 Lipoproteins and Lipid Transport
- New Figure 17-11 The MyPlate Food Guide
- New Figure 17-12 Mechanisms of Heat Transfer
- Clinical Note: Dietary Fats and Cholesterol revised

#### Chapter 18 The Urinary System

- Figure 18-2 The Position of the Kidneys revised
- Figure 18-3 The Structure of the Kidney revised
- Figure 18-5 A Representative Nephron and the Collecting System revised
- Figure 18-6 The Renal Corpuscle revised
- New Figure 18-7 Physiological Processes of the Nephron
- Figure 18-8 The Effects of ADH on the DCT and Collecting Duct revised
- New Spotlight Figure 18-9 A Summary of Kidney Function
- Figure 18-10 The Renin-Angiotensin System and Regulation of GFR revised
- Figure 18-11 Organs for the Conduction and Storage of Urine revised
- Figure 18-12 The Micturition Reflex revised
- New Figure 18-13 The Composition of the Human Body

- Figure 18-14 Ions in Body Fluids revised
- New Figure 18-15 The Basic Relationship between Carbon Dioxide and Plasma pH
- New Figure 18-16 System Integrator
- Clinical Note: The Treatment of Kidney Failure revised
- New Career Paths: Pharmacy Technician

### Chapter 19 The Reproductive System

- Figure 19-2 The Scrotum, Testes, and Seminiferous Tubules revised
- Figure 19-3 Spermatogenesis revised
- Figure 19-4 Spermatozoon Structure revised
- Figure 19-6 The Penis revised
- New Spotlight Figure 19-7 Regulation of Male Reproduction
- Figure 19-9 Oogenesis revised
- Figure 19-10 Follicle Development and the Ovarian Cycle revised
- Figure 19-12 The Female External Genitalia revised to include vestibular bulb and vestibular gland
- New Spotlight Figure 19-14 Regulation of Female Reproduction
- New Figure 19-16 System Integrator
- Clinical Note: Birth Control Strategies revised
- New Career Paths: Diagnostic Medical Sonographer

### Chapter 20 Development and Inheritance

- Figure 20-1 Fertilization revised
- New Figure 20-4 The Inner Cell Mass and Gastrulation
- Figure 20-5 Extraembryonic Membranes and Placenta Formation revised
- New Figure 20-9 Changes in Body Form and Proportion during Development revised
- New Figure 20-10 Factors Involved in the Initiation of Labor and Delivery
- Figure 20-12 The Milk Let-Down Reflex revised
- New Figure 20-14 Predicting Genotypes and Phenotypes with Punnett Squares
- New Figure 20-15 Inheritance of an X-Linked Trait
- Figure 20-16 A Map of Human Chromosomes revised

## Acknowledgments

Every textbook represents a group effort. Foremost on the list are the faculty and reviewers whose advice, comments, and collective wisdom helped shape this edition. Their interest in the subject, their concern for the accuracy and method of presentation, and their experience with students of widely varying abilities and backgrounds made the review process an

educational experience. To these individuals, who carefully recorded their comments, opinions, and sources, we express our sincere thanks and best wishes.

We would also like to thank the many users, survey respondents, and focus group members whose advice, comments, and collective wisdom helped shape this text into its final form. Their passion for the subject, their concern for accuracy and method of presentation, and their experience with students of widely varying abilities and backgrounds have made the review process much more fruitful. We thank them for their participation and list their names and affiliations below.

## Reviewers for the Sixth Edition

**Michelle A. Baragona**, *Northeast Mississippi Community College*

**Sheri L. Boyce**, *Messiah College*

**Darrell Davies**, *Kalamazoo Valley Community College*

**Robert S. Dill**, *Bergen Community College*

**Margaret T. Flemming**, *Austin Community College*

**Anne Geller**, *San Diego Mesa College*

**Donna Hazelwood**, *Dakota State University*

**Julie A. Huggins**, *Arkansas State University*

**Gary W. Hunt**, *Tulsa Community College*

**Melissa A. Meador**, *Arkansas State University—Beebe*

**Susan Caley Opsal**, *Illinois Valley Community College*

**Jeanine L. Page**, *Lock Haven University*

**Christine Parker**, *Finger Lakes Community College*

**Diane B. Pelletier**, *Green River Community College*

**David M. Pounds**, *University of North Carolina School of the Arts*

**Natalia Schmidt**, *Leeward Community College University of Hawaii*

## Reviewers for the Fifth Edition

**Diane Berger**, *Kankakee Community College*

**Margaret T. Flemming**, *Austin Community College*

**Anne Geller**, *San Diego Mesa College*

**Michael Guthrie**, *City College of San Francisco*

**Georgia Householder**, *Southwest Virginia Community College*

**Susan Caley Opsal**, *Illinois Valley Community College*

**Diane B. Pelletier**, *Green River Community College*

**Penny Revelle**, *City College Baltimore County—Essex*

**Deborah Temperly**, *Delta College*

**Larry Walker**, *Trident Tech College*

**Bert Wartski**, *Duke University*

**Thomas White**, *State University College at Buffalo*

Our gratitude is also extended to the many faculty and students at campuses across the United States (and out of the country) who made suggestions and comments that helped us improve this edition of *Essentials of Anatomy & Physiology*.

A textbook has two components: narrative and visual. In preparing the narrative, we were ably assisted yet again by our keen-eyed copyeditor Michael Rossa, who played a vital role in shaping this text by helping us keep the text organization, general tone, and level of presentation consistent throughout.

Virtually without exception, reviewers stressed the importance of accurate, integrated, and visually attractive illustrations in helping students understand essential material. The creative talents brought to this project by our artist team, William Ober, M.D., and Claire Garrison, R.N., are inspiring and very much appreciated. Bill and Claire worked intimately and tirelessly with us, imparting a unity of vision to the book as a whole while making it both clear and beautiful. The superb art program is also greatly enhanced by the incomparable bone and cadaver photographs of Ralph T. Hutchings, formerly of The College of Surgeons in England.

We are deeply indebted to the Pearson production staff and S4Carlisle, whose efforts were so vital to the creation of this edition. Special thanks are due to Caroline Ayres and Norine Strang for their skillful management of the project through the entire production process. We appreciate the excellent design contributions of Mark Ong and Marilyn

Perry, Design Managers; Gary Hespenheide, interior text designer; and Yvo Riezebos, cover designer.

We must also express our appreciation to Nicole McFadden, Assistant Editor, for her work on the numerous print and media supplements, and to Joseph Mochnick for his work on the media supplements that accompany this title.

Thanks also to Derek Perrigo, Marketing Manager, and the entire Pearson Science sales team for keeping their fingers on the pulse of the market and helping us meet the needs of our users.

Above all, thanks to our editor, Katie Seibel, for her patience in nurturing this project and her efforts to coordinate the various components of the package, and to Leslie Berriman, Executive Editor, for her dedication to the success of this book.

Finally, we would like to thank our families for their love and support during the revision process.

No two people could expect to produce a flawless textbook of this scope and complexity. Any errors or oversights are strictly our own rather than those of the reviewers, artists, or editors. In an effort to improve future editions, we ask that readers with pertinent information, suggestions, or comments concerning the organization or content of this textbook email us directly at the email address below. Any and all comments and suggestions will be deeply appreciated and carefully considered in the preparation of the next edition.

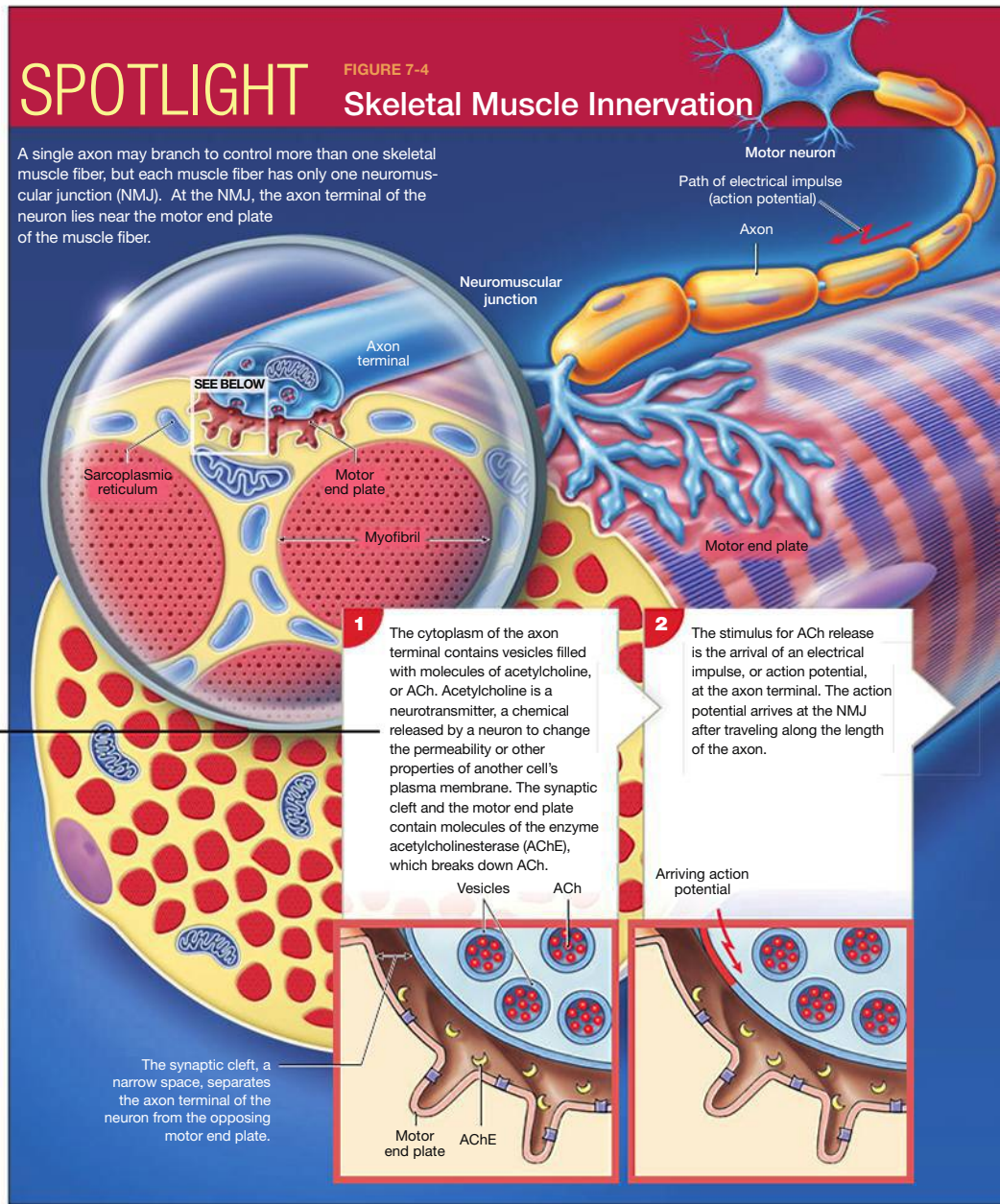
[martini@pearson.com](mailto:martini@pearson.com)

# Text-Art Integration

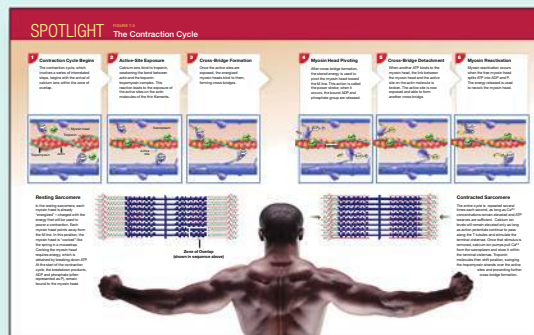
## NEW! SPOTLIGHT FIGURES

are one- or two-page presentations that combine text and art to communicate anatomical, physiological, or clinical information in a visually effective format.

**Clear steps—**  
**combining text**  
**and art—** guide  
students through complex  
processes.



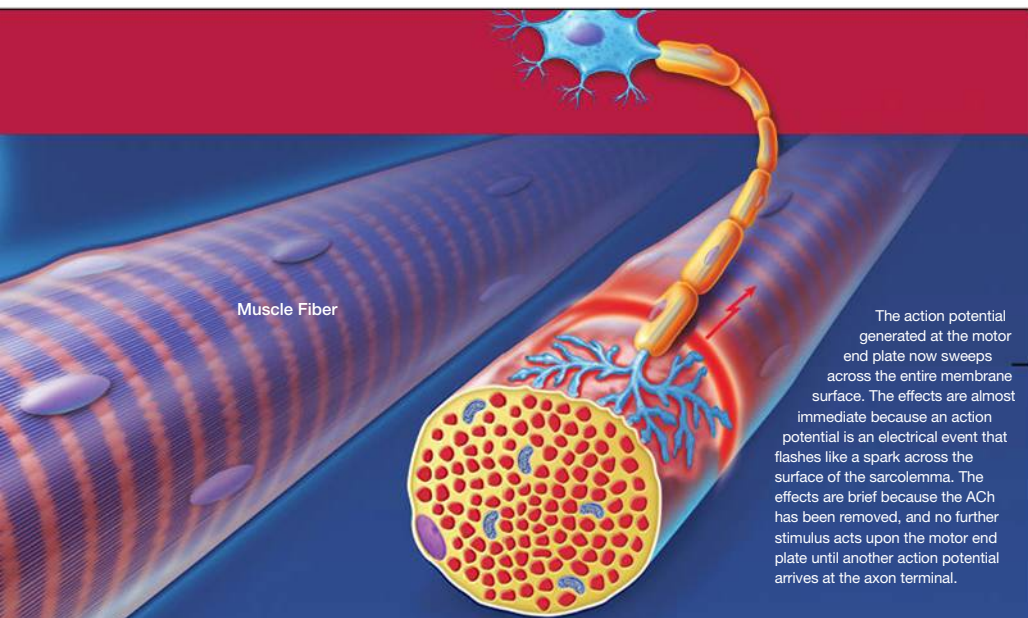
## MORE EXAMPLES OF TEXT-ART INTEGRATION



**The Contraction Cycle**  
Chapter 7, pages 200–201



**Synovial Joints**  
Chapter 6, page 178



Muscle Fiber

The action potential generated at the motor end plate now sweeps across the entire membrane surface. The effects are almost immediate because an action potential is an electrical event that flashes like a spark across the surface of the sarcolemma. The effects are brief because the ACh has been removed, and no further stimulus acts upon the motor end plate until another action potential arrives at the axon terminal.

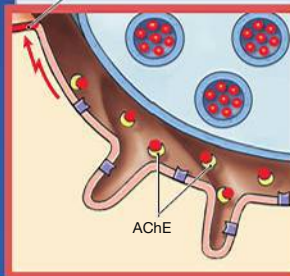
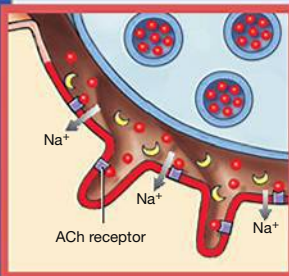
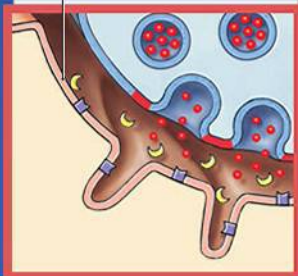
**3** When the action potential reaches the neuron's axon terminal, permeability changes in the membrane trigger the exocytosis of ACh into the synaptic cleft. Exocytosis occurs as vesicles fuse with the neuron's plasma membrane.

**4** ACh molecules diffuse across the synaptic cleft and bind to ACh receptors on the surface of the motor end plate. ACh binding alters the membrane's permeability to sodium ions. Because the extracellular fluid contains a high concentration of sodium ions, and sodium ion concentration inside the cell is very low, sodium ions rush into the sarcoplasm.

**5** The sudden inrush of sodium ions results in the generation of an action potential in the sarcolemma. AChE quickly breaks down the ACh on the motor end plate and in the synaptic cleft, thus inactivating the ACh receptors.

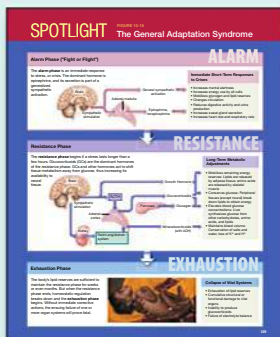
Motor end plate

Action potential

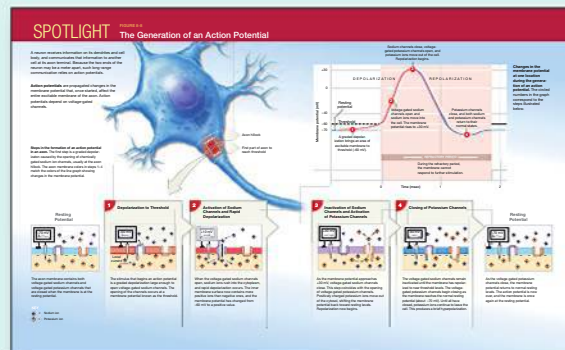


The explanation is built directly into the illustration for efficient and effective learning.

The all-in-one-place presentation means no flipping back and forth between narrative and illustration to get the full story.



The General Adaptation Syndrome  
Chapter 10, page 369



The Generation of an Action Potential  
Chapter 8, pages 254–255

# Preparing Students for Careers in Healthcare

**NEW! CAREER PATHS** introduce students to some of the most popular careers in healthcare using first-hand accounts, clinical images, and key statistics that will help students zero in on their dream career and motivate them in their studies.

## Career Paths DENTAL HYGIENIST

"The mouth is kind of a window to your entire body," says dental hygienist Mary Cattadoris. "I can look at people's teeth and I can tell if they clench or grind from stress." She once had a nurse whose mouth looked abnormal. Cattadoris recommended the nurse see a doctor—it turned out she had leukemia.

**"The mouth is kind of a window to your entire body"**

Cattadoris works in private practice in Scarborough, Maine, which is one of two states (Colorado is the other one) where dental hygienists can practice without the direct supervision of a dentist, once they have completed additional testing and years of practice. As a result, Cattadoris works with a dentist, not for one. Of the patients she sees each day, most of her work is preventive: scaling for tartar, cleanings, fluoride treatments, sealants, x-rays, whitening, and more recently, laser periodontal therapy, which is a specialty in which she had to become certified. She does an oral health assessment and cancer screening of each new patient, then works out a treatment plan. If the patient requires more than just regular cleanings, she refers him or her to the dentist in the practice, or sometimes directly to an orthodontist. Though she has more autonomy, her day-to-day responsibilities are similar to those of a dental hygienist working under a dentist's supervision.

A particular passion of hers within the job is education: teaching her patients that good oral health involves more than just brushing your teeth twice a day. "It always shocks me to recognize how little people know when it comes to disease prevention and diet," she says. "There are areas in the world that have never seen a dentist, and yet the people are cavity-free because they don't have processed sugar. Some very smart people don't have a good dental IQ, and it's exciting to change their thought process."

Cattadoris says that interpersonal skills and communication are an important part of being a dental hygienist. The amount of work hygienists need to do with their hands also requires good dexterity, as well as attention to detail. "Knowledge of anatomy and physiology is vital," Cattadoris says, noting that her education included an entire semester of head and neck anatomy. "You need to know what normal looks like,"

she says. "You can recognize when things are not healthy, and you can compliment them on what they're doing well."

In addition to working with or for dentists in private practice, dental hygienists can also work in schools, public health clinics, correctional institutions, and nursing homes. Some go into research or teaching. They are usually able to work a nine-to-five, Monday through Friday schedule, though many private practices are open on some nights or weekends for the convenience of their patients. Occasionally, they will have to respond to an emergency call.



**Think this is the CAREER for you?**

**KEY STATS**

- ◆ **Education and Training.** A degree from an accredited dental hygiene school is required. Most programs offer an associate's degree, although some offer a certificate, a bachelor's degree, or a master's degree.
- ◆ **Licensure.** All states require dental hygienists to be licensed, and nearly all states require candidates to pass a written and clinical examination.
- ◆ **Earnings.** Earnings vary but the median annual wage is \$68,250.
- ◆ **Job Outlook.** Employment is expected to grow faster than the national average—by 36 percent through 2018.
- ◆ **Additional Information.** Visit the Website of the American Dental Hygienists Association at <http://www.adha.org>.

Bureau of Labor Statistics, U.S. Department of Labor, Occupational Outlook Handbook, 2010-11 Edition, Dental Hygienists on the Internet at <http://www.bls.gov/ocd/occs097.htm> (visited September 14, 2011).

**Interview-based vignettes** relate the highlights and challenges of each career from the perspective of a working practitioner.

**A series of clinical images** further illuminate each career.

**Key Stats** provide students with insight into average annual earnings, job outlook, and education and training requirements for each career.

## MORE EXAMPLES OF CAREER PATHS



**EMT/Paramedic**  
Chapter 5, page 139



**Massage Therapist**  
Chapter 7, page 242



**Physician Assistant**  
Chapter 8, page 303



**Physical Therapist**  
Chapter 10, page 377



**Phlebotomist**  
Chapter 13, page 468

## MORE VISUAL! CLINICAL NOTES

draw students' attention to the diseases and disorders they will encounter in future workplace situations.



### Clinical Note

#### Rheumatism and Arthritis

**Rheumatism** (ROO-muh-tiz-um) is a general term describing pain and stiffness arising in the skeletal or muscular systems, or both. There are several major forms of rheumatism. **Arthritis** (ar-THRI-tis) includes all the rheumatic diseases that affect synovial joints. Arthritis always involves damage to the articular cartilages, but the specific cause can vary. Arthritis can result from bacterial or viral infection, injury to the joint, metabolic problems, or severe physical stresses.

**Osteoarthritis** (os-té-ó-ar-THRI-tis), also known as *degenerative arthritis*, or *degenerative joint disease (DJD)*, usually affects individuals age 60 or older. This disease can result from cumulative wear and tear at the joint surfaces or from genetic factors affecting collagen formation. In the U.S. population, 25 percent of women and 15 percent of men over age 60 show signs of this disease. **Rheumatoid arthritis** is an inflammatory condition that affects about 0.5–1 percent of the adult population. At least some cases result when the immune response mistakenly attacks the joint tissues. Allergies, bacteria, viruses, and genetic factors have all been proposed as contributing to or triggering the destructive inflammation.

Regular exercise, physical therapy, and drugs that reduce inflammation (such as aspirin) can slow the progress of osteoarthritis. Surgical procedures can realign or redesign the affected joint. In extreme cases involving the hip, knee, elbow, or shoulder, the defective joint can be replaced by an artificial one.



**THE BIG PICTURE** boxes provide students with the key concepts they should remember five years after their anatomy & physiology course, regardless of the specific career path they pursue in the future.

### The BIG PICTURE

A joint cannot be both highly mobile and very strong. The greater the mobility, the weaker the joint, because mobile joints rely on support from muscles and ligaments rather than solid bone-to-bone connections.



**Pediatric Nurse**  
Chapter 14, page 501



**Respiratory Therapist**  
Chapter 15, page 533



**Registered Dietitian**  
Chapter 16, page 573



**Pharmacy Technician**  
Chapter 18, page 638



**Sonographer**  
Chapter 19, page 672

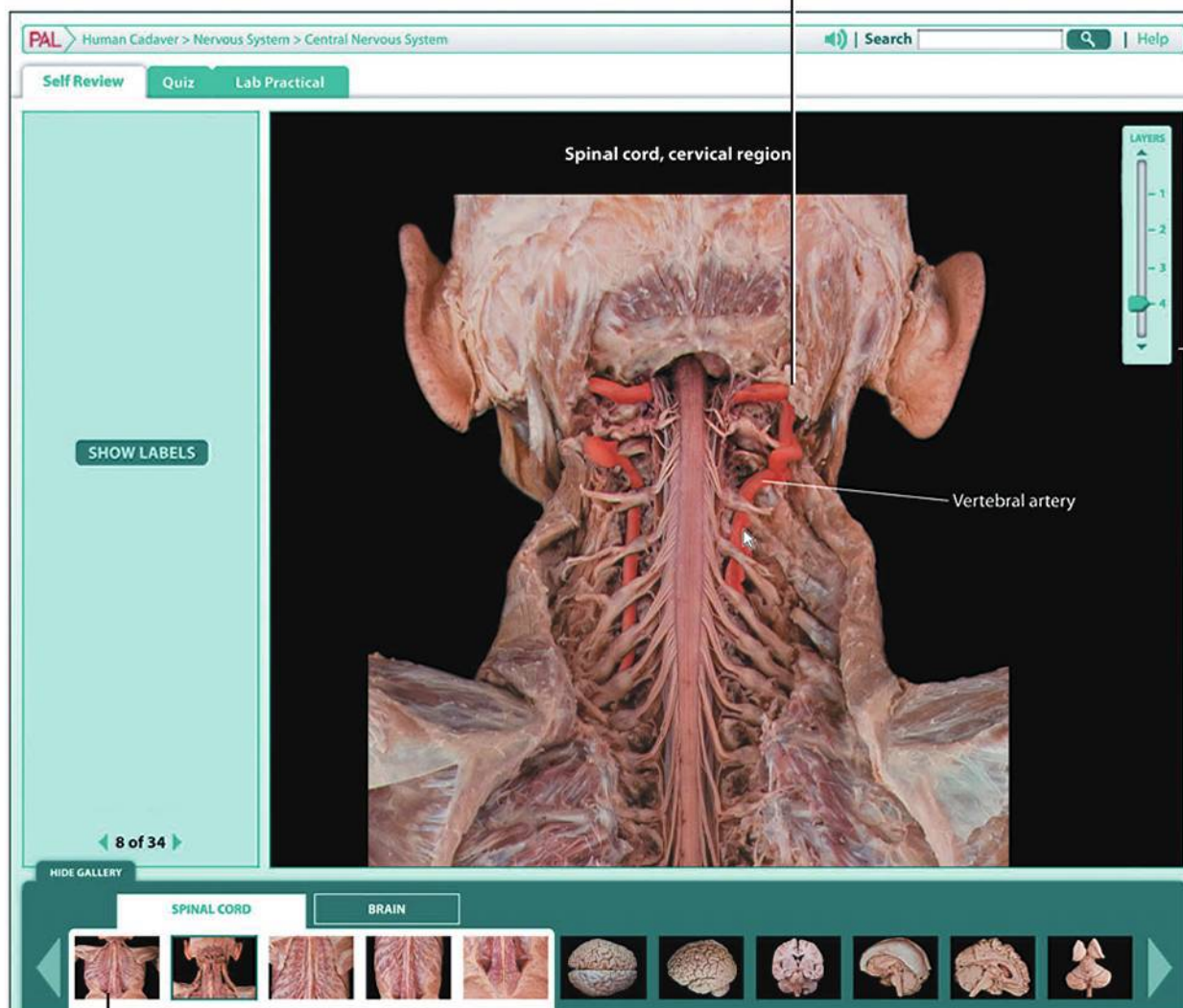


# Practice Anatomy Lab™ (PAL™) 3.0

**PAL 3.0** is a virtual anatomy study and practice tool that gives students 24/7 access to the most widely used lab specimens, including the human cadaver, anatomical models, histology, cat, and fetal pig.

## NEW! INTERACTIVE CADAVER MODULE

**Carefully prepared dissections** show nerves, veins, and arteries across body systems.

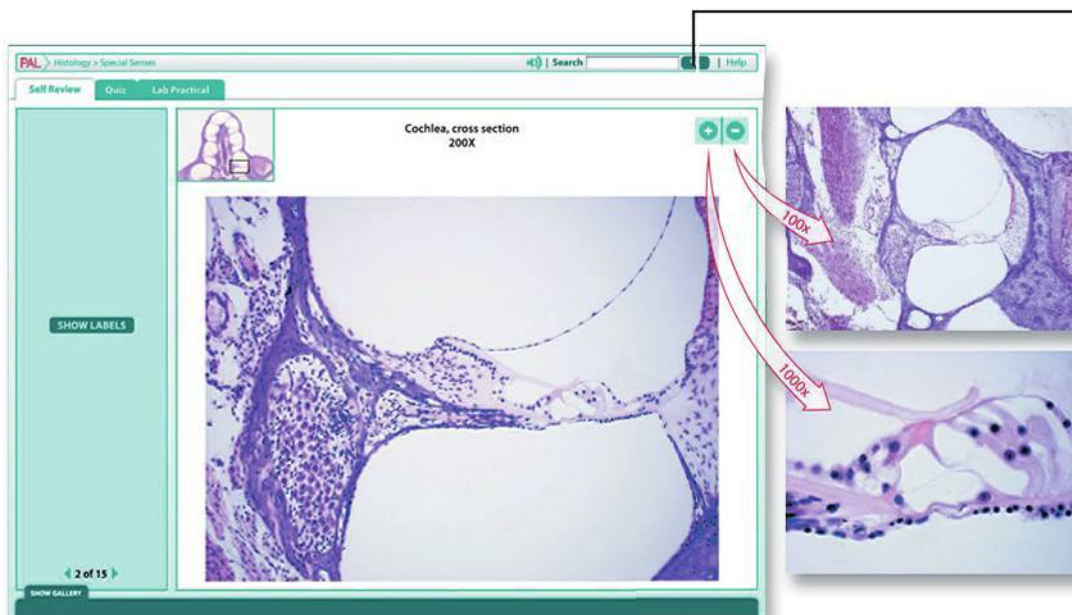


**Photo gallery** allows students to quickly see thumbnails of images for a particular region or sub-region.

**Layering slider** allows students to peel back layers of the human cadaver and explore hundreds of brand-new dissections specially commissioned for version 3.0.

**PAL 3.0** is available in the Study Area of MasteringA&P® ([www.masteringaandp.com](http://www.masteringaandp.com)). The **PAL 3.0 DVD** is also available for purchase.

## NEW! INTERACTIVE HISTOLOGY MODULE



**Magnification buttons** allow students to view the same tissue slide at varying magnifications, thereby helping them identify structures and their characteristics.

## 3-D ANATOMY ANIMATIONS

**Anatomy Animations** of origins, insertions, actions, and innervations of over 60 muscles are now viewable in two modules: Human Cadaver and Anatomical Models. Under the Animations tab, over 50 anatomy animations of group muscle actions and joints are also viewable. A new closed-captioning option provides textual presentation of narration to help students retain information and supports ADA compliance.



### PAL 3.0 ALSO INCLUDES:

- **NEW!** Question randomization feature
- **NEW!** Hundreds of new images and views
- **NEW!** Turn-off highlighting feature
- **NEW!** IR DVD with Test Bank for PAL 3.0
- Built-in audio pronunciations
- Rotatable bones
- Simulated fill-in-the-blank lab practical exams

**SEE FOR YOURSELF!** Check out the new PAL 3.0 at [www.masteringaandp.com](http://www.masteringaandp.com).

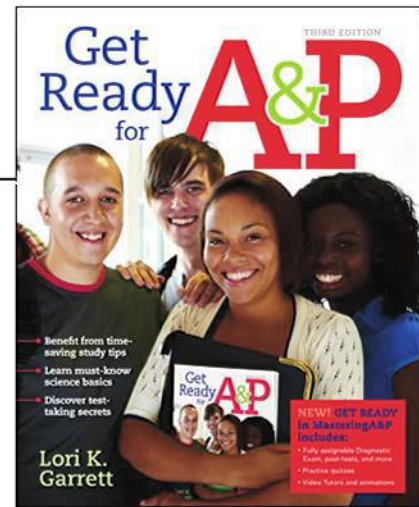
# An Online Learning and Assessment System



## Get your students ready for the A&P course.

*Get Ready for A&P* allows you to assign tutorials and assessments on topics students should have learned prior to the A&P course.

- Study Skills
- Basic Math Review
- Terminology
- Body Basics
- Chemistry
- Cell Biology



## Motivate your students to come to class prepared.

Assignable Reading Quizzes motivate your students to read the textbook before coming to class.

MasteringA&P | Logged in as Jennifer Smith, Student | Help | Log Out

**Reading Quiz Question 8.1**  
Part A - Reading Quiz Question 8.1

Which neuroglia are the most abundant and versatile of the glial cells?

oligodendrocytes  
 Schwann cells  
 ependymal cells  
 astrocytes

submit | my answers | show answer | review part

**Feedback** | Close

Astrocytes are the most abundant and versatile glial cells. They anchor neurons to capillaries, aid in the exchange between neurons and blood, guide the migration of young neurons, and help control the chemical environment around neurons. Schwann cells form the myelin sheath in peripheral nerves. Ependymal cells form the blood-brain barrier in the CNS. Oligodendrocytes form the myelin sheath in the CNS.

submit item

## Assign art from the textbook.

Assign and assess Art-labeling Activities based on figures from the textbook.

**Part A**

Label the regional structures of the nephron.  
Drag the labels onto the diagram to identify the regional structures of the nephron.

Try Again, 3 attempts remaining

submit | my answers | show answer | review part

**Feedback** | Close


You labeled 2 of 5 targets incorrectly. Review the structure in which the filtrate of urine is formed.

**IP: Gas Exchange**

Click on the link or the image below to explore Gas Exchange in Interactive Physiology (IP), then answer the questions to the right.

IP: Gas Exchange

EXTERNAL RESPIRATION: LOADING O<sub>2</sub>



**Part A**

\_\_\_\_\_ has a greater partial pressure in the pulmonary capillaries than in the alveoli, so it diffuses into the \_\_\_\_\_.

CO<sub>2</sub>, pulmonary capillaries  
 O<sub>2</sub>, pulmonary cavities  
 O<sub>2</sub>, alveoli  
 CO<sub>2</sub>, alveoli

Try Again

submit | hints | my answers | show answer | review part

**Feedback**

No, O<sub>2</sub> has a greater partial pressure in the alveoli than in the pulmonary capillaries.

**Part B**

Which gas law explains why there is as much CO<sub>2</sub> exchanged between the alveoli and blood as there is O<sub>2</sub> exchanged, despite the fact that the partial pressure difference is so much smaller for CO<sub>2</sub>?

Boyle's law  
 Henry's law  
 Dalton's law

submit | hints | my answers | show answer | review part

**Part C**

How would the partial pressures of O<sub>2</sub> and CO<sub>2</sub> change in an exercising muscle?


The partial pressure of O<sub>2</sub> would increase, and the partial pressure of CO<sub>2</sub> would decrease.  
 The partial pressure of O<sub>2</sub> would decrease, and the partial pressure of CO<sub>2</sub> would increase.

submit | hints | my answers | show answer | review part

**Give your students extra coaching.** Assign tutorials from your favorite media—such as Essentials of Interactive Physiology® (IP)—to help students understand and visualize tough topics. MasteringA&P provides coaching through helpful wrong-answer feedback and hints.

**Give students 24/7 lab practice.** Practice Anatomy Lab™ (PAL™) 3.0 is a tool that helps students study for their lab practicals outside of the lab. To learn more about PAL 3.0, see pages xvi–xvii.

**Part B - Question 2**



13-583: Life Size Muscle Icons, 27 part, 28 Scientific

**Identify the highlighted muscle.**

submit | my answers | show answer | review part

MasteringA&P

Logged in as Josh McDaniels, Instructor | Help | Log Out

**Anatomy & Physiology 101** (MHA/YU7072)

My Courses - | Course Settings | View as Student

Course Home | Assignments | Roster | Gradebook | Item Library

Instructor Resources | eText | Study Area

Filter: Showing score in All Categories for All Students

Score | Time | Difficulty | Students Per Page: 25

Name	Ch. 1	Ch. 2	Ch. 3	Ch. 4	Ch. 5	Ch. 6	Ch. 7	Ch. 8	Ch. 9	Ch. 10	Ch. 11	Total			
Class Average	91.5	97.3	95.5	63.6	89.5	90.3	87.1	91.8	83.3	86.2	89.4	77.5	72.3	78.8	81.3
Mitchell, Doug	88.0	69.0	98.0	61.0	100	100	91.0	85.0	100	95.0	99.0	64.0	0.0	100	73.3
Larsen, Melina	100	100	96.0	83.0	100	99.0	0.0	95.0	100	100	0.0	87.0	0.0	100	82.1
Thomas, Dylan	98.0	100	96.0	64.0	100	0.0	88.0	100	75.0	100	86.0	77.0	100	100	71.1
Faulson, Madison	59.0	65.0	87.0	0.0	100	97.0	83.0	95.0	88.0	95.0	93.0	65.0	94.0	52.0	72.2
Chavez, Matthew	84.0	97.0	93.0	92.0	98.0	49.0	72.0	72.0	47.0	80.0	86.0	36.0	100	39.0	78.1
Pakel, Indira	100	100	98.0	68.0	97.0	100	96.0	100	99.0	100	89.0	75.0	77.0	88.0	90.3
McAister, Rachel	87.0	80.0	93.0	0.0	100	86.0	75.0	80.0	83.0	90.0	99.0	67.0	100	100	64.8
Lee, Erika	77.0	58.0	51.0	54.0	65.0	50.0	85.0	94.0	74.0	90.0	64.0	88.0	90.0	90.0	77.7

**Identify struggling students before it's too late.**

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

# Tools to Make the Grade

## MasteringA&P<sup>®</sup> STUDY AREA

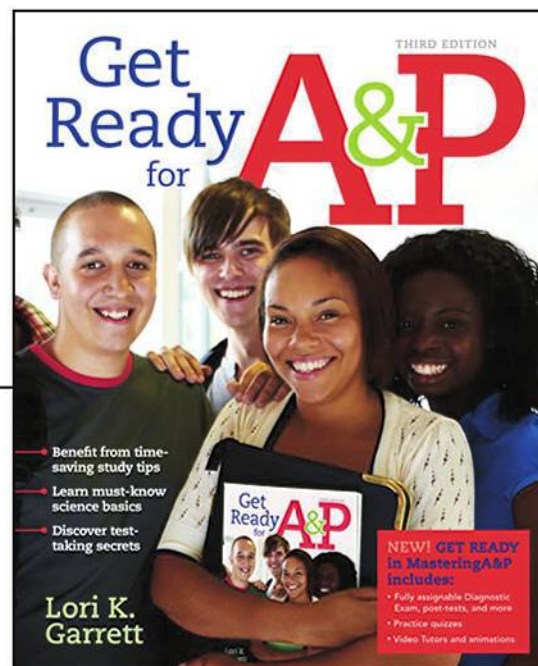
**MasteringA&P** ([www.masteringaandp.com](http://www.masteringaandp.com)) includes a Study Area that will help students get ready for tests with its simple three-step approach. Students can:

1. **Take a pre-test** and obtain a personalized study plan.
2. **Learn and practice** with animations, labeling activities, and interactive tutorials.
3. **Self-test** with quizzes and a chapter post-test.

### Get Ready for A&P

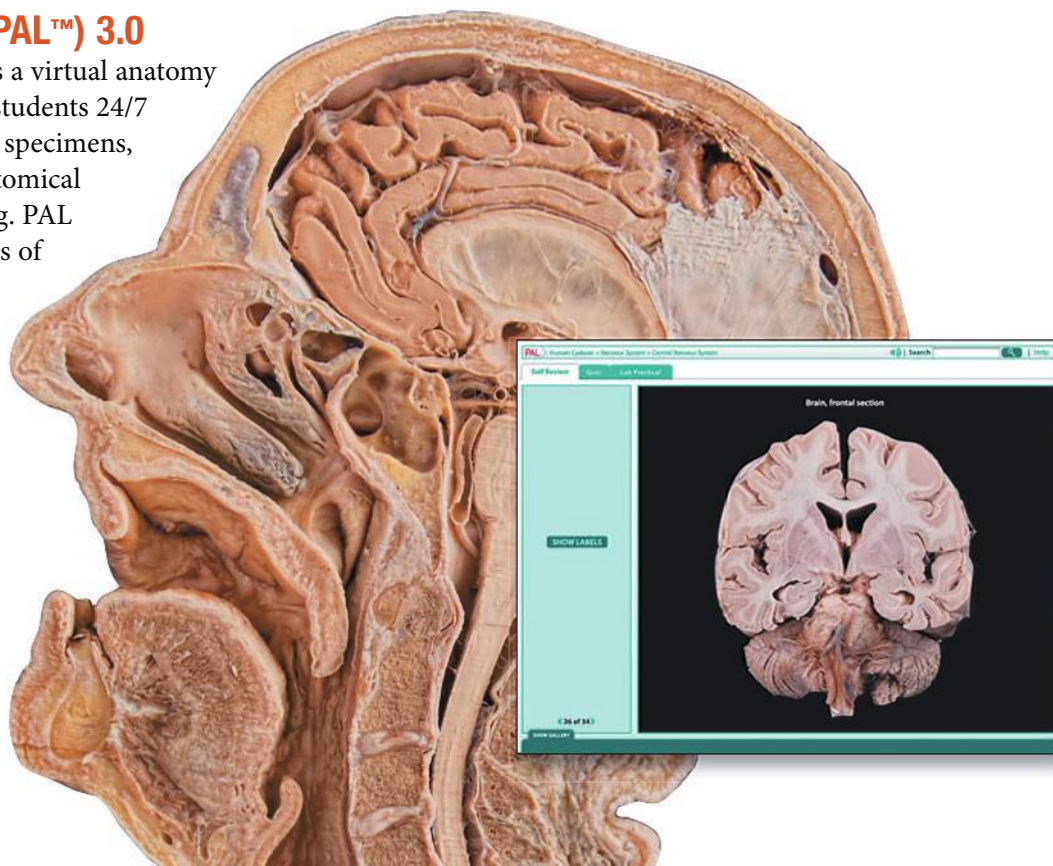
Students can access the *Get Ready for A&P* eText, activities, and diagnostic tests for these important topics:

- Study Skills
- Body Basics
- Basic Math Review
- Chemistry
- Terminology
- Cell Biology



### Practice Anatomy Lab<sup>™</sup> (PAL<sup>™</sup>) 3.0

Practice Anatomy Lab (PAL) 3.0 is a virtual anatomy study and practice tool that gives students 24/7 access to the most widely used lab specimens, including the human cadaver, anatomical models, histology, cat, and fetal pig. PAL 3.0 retains all of the key advantages of version 2.0, including ease-of-use, built-in audio pronunciations, rotatable bones, and simulated fill-in-the-blank lab practical exams. See pages xvi–xvii.



## MP3 Tutor Sessions



Students can download the MP3 Tutor Sessions for specific chapters of the textbook and study wherever, whenever. They can listen to mini-lectures about the toughest topics and take audio quizzes to check their understanding.



### Topics:

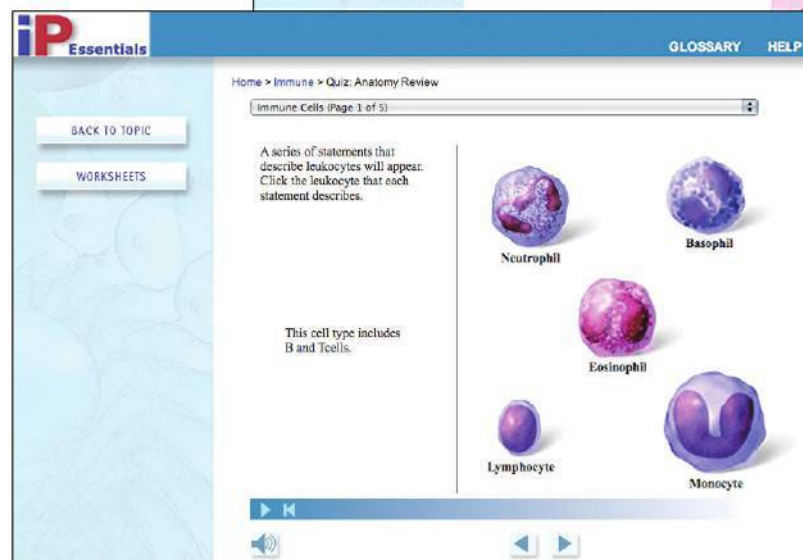
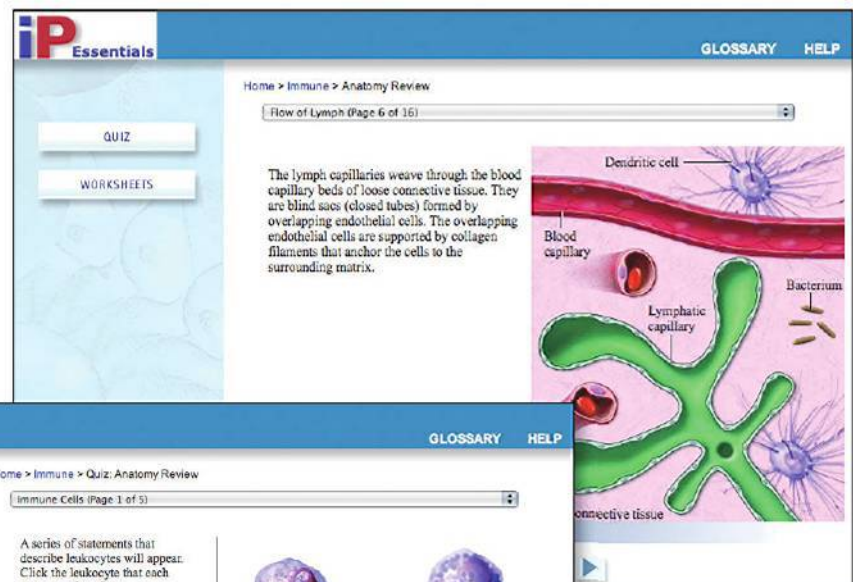
- Homeostasis
- Inorganic Compounds
- Membrane Transport
- Epithelial Tissue
- Layers and Associated Structures of the Integument
- How Bones React to Stress
- Types of Joints and their Movements
- Sliding Filament Theory of Contraction
- Events at the Neuromuscular Junction
- Generation of an Action Potential
- Differences between the Sympathetic and Parasympathetic Divisions
- The Visual Pathway
- Hypothalamic Regulation
- Hemoglobin: Function and Impact
- Cardiovascular Pressure
- Differences between Innate and Adaptive Immunity
- Digestion and Absorption
- Urine Production
- Hormonal Control of the Menstrual Cycle
- Egg Implantation

## Essentials of Interactive Physiology® (IP)

IP helps students understand the hardest part of A&P: physiology. Fun, interactive tutorials, games, and quizzes give students additional explanations to help them grasp difficult concepts.

### Modules:

- Muscular System
- Nervous System
- Cardiovascular System
- Respiratory System
- Urinary System
- Fluids & Electrolytes
- Endocrine System
- Digestive System
- Immune System



# Support for Students

## eText

MasteringA&P ([www.masteringaandp.com](http://www.masteringaandp.com)) includes an eText. Students can access their textbook wherever and whenever they are online. eText pages look exactly like the printed text yet offer additional functionality. Students can do the following:

- Create notes.
- Highlight text in different colors.
- Create bookmarks.
- Zoom in and out.
- View in single-page or two-page view.
- Click hyperlinked words and phrases to view definitions.
- Search quickly and easily for specific content.

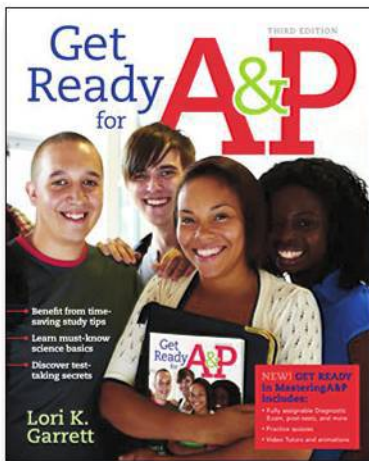
**Search quickly and easily** for specific content.

The screenshot displays the Pearson MasteringA&P eText interface. The page title is "SPOTLIGHT FIGURE 11-1 The Composition of Whole Blood". The main content area is titled "A Fluid Connective Tissue" and discusses the composition of blood, including plasma and formed elements. A diagram shows the composition of plasma: 92% Water, 7% Plasma Proteins, and 1% Other Solutes. A table below the diagram lists the components: Plasma (55%, Range: 46-63%), Plasma Proteins (7%), Other Solutes (1%), Water (92%), Formed Elements, and Platelets (1%).

Copyright © 2009 Pearson Education, Inc. All rights reserved. Legal Notice Privacy Policy Permissions Feedback

**Easily access definitions** of key words.

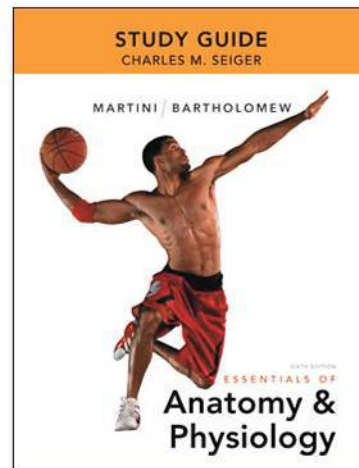
**Highlight text** and make notes.



## Get Ready for A&P

by Lori K. Garrett

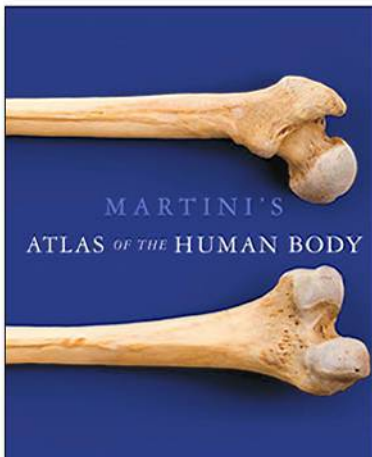
This book and online component were created to help students be better prepared for their A&P course. Features include pre-tests, guided explanations followed by interactive quizzes and exercises, and end-of-chapter cumulative tests. Also available in the Study Area of [www.masteringaandp.com](http://www.masteringaandp.com).



## Study Guide

by Charles M. Seiger

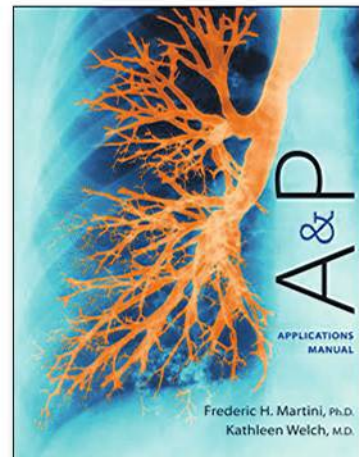
The Study Guide includes a variety of review activities, including multiple choice questions, labeling exercises, and concept maps—all organized by the Learning Outcomes from the book.



## Martini's Atlas of the Human Body

by Frederic H. Martini

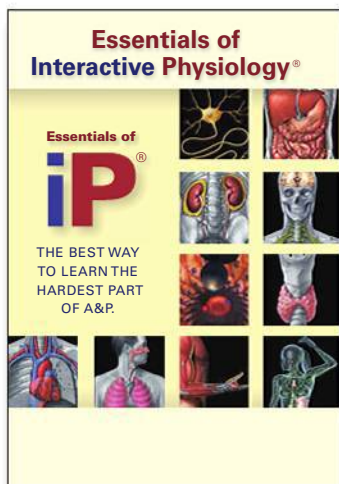
The Atlas offers an abundant collection of anatomy photographs, radiology scans, and embryology summaries, helping students visualize structures and become familiar with the types of images seen in a clinical setting.



## A&P Applications Manual

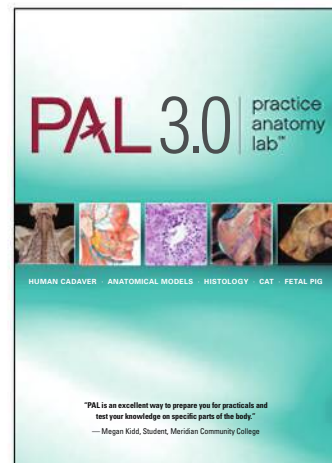
by Frederic H. Martini and Kathleen Welch

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 careers.



## Essentials of Interactive Physiology® (IP) CD-ROM

IP helps students understand the hardest part of A&P: physiology. Fun, interactive tutorials, games, and quizzes give students additional explanations to help them grasp difficult physiological concepts.



## Practice Anatomy Lab™ (PAL™) 3.0 DVD

PAL 3.0 is an indispensable virtual anatomy study and practice tool that gives students 24/7 access to the most widely used lab specimens, including the human cadaver, anatomical models, histology, cat, and fetal pig.

See **pages xx-xxi** for the MasteringA&P Study Area.



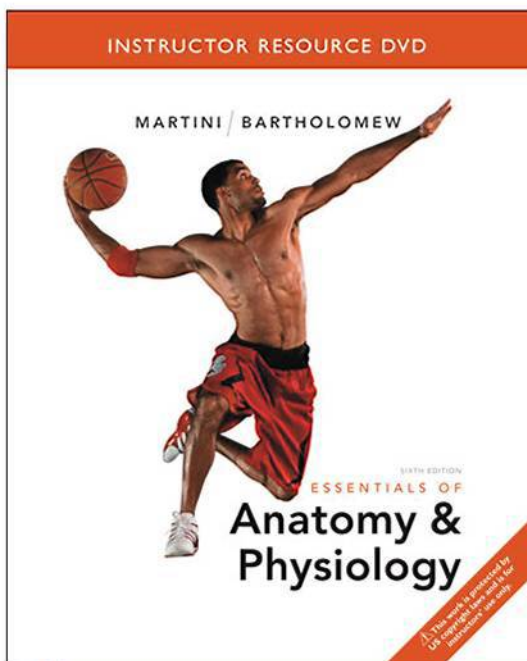
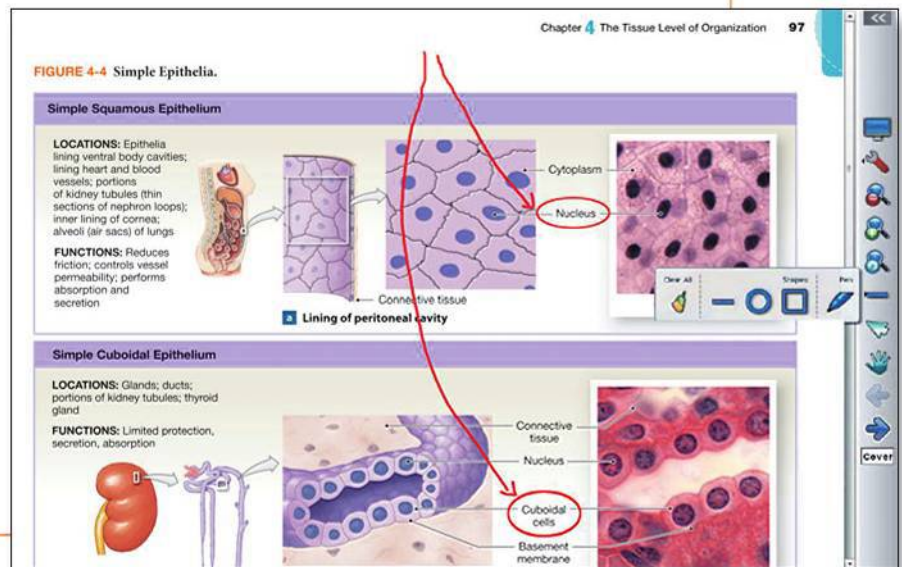
# Support for Instructors

## eText with Whiteboard Mode

The *Essentials of Anatomy & Physiology* eText comes with Whiteboard Mode, allowing instructors to use the eText for dynamic classroom presentations. Instructors can show one-page or two-page views from the book, zoom in or out to focus on select topics, and use the Whiteboard Mode to point to structures, circle parts of a process, trace pathways, and customize their presentations.

Instructors can also add notes to guide students, upload documents, and share their custom-enhanced eText with the whole class.

Instructors can find the eText with Whiteboard Mode on MasteringA&P®.

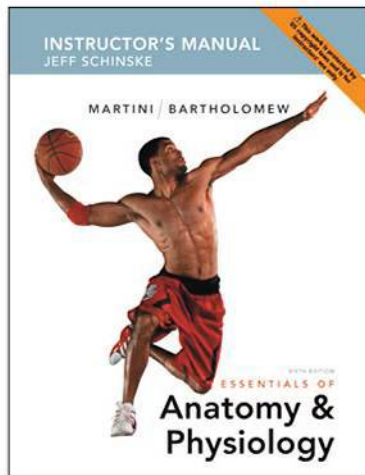


## Instructor Resource DVD (IRDVD)

978-0-321-79218-1 / 0-321-79218-1

The IRDVD offers a wealth of instructor media resources, including presentation art, lecture outlines, test items, and answer keys—all in one convenient location. The IRDVD includes:

- Textbook images in JPEG format (in two versions—one with labels and one without)
- Customizable textbook images embedded in PowerPoint® slides (in three versions—one with editable labels, one without labels, and one as step-edit art)
- Customizable PowerPoint lecture slides, combining lecture notes, images and tables, and animations
- Clicker Questions
- Quiz Show Clicker Questions
- *Martini's Atlas of the Human Body* images in JPEG format
- *Martini's A&P Applications Manual* images in JPEG format
- *Essentials of Interactive Physiology*® (IP) Exercise Sheets and Answer Key
- Test Bank in TestGen® and Microsoft® Word formats
- Instructor's Manual in Microsoft Word and PDF formats
- Lecture Outlines in Microsoft Word format
- Transparency Acetate masters for all figures and tables
- Separate DVD for PAL™ 3.0 Instructor Presentation Images and Test Bank



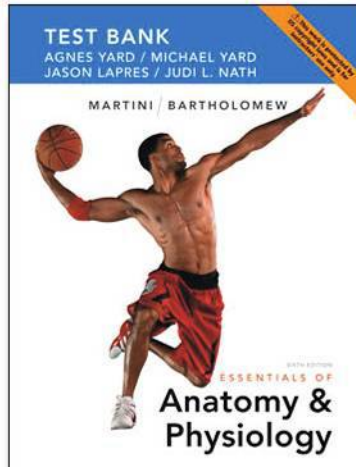
## Instructor's Manual

by Jeff Schinske

978-0-321-79219-8 / 0-321-79219-X

This useful resource includes a wealth of materials to help instructors organize their lectures, such as lecture ideas, analogies, suggested classroom demonstrations, applications, common student misconceptions/problems, and terminology aids. It also includes

sections on encouraging student talk, making learning active, and incorporating diversity and the human side of A&P.

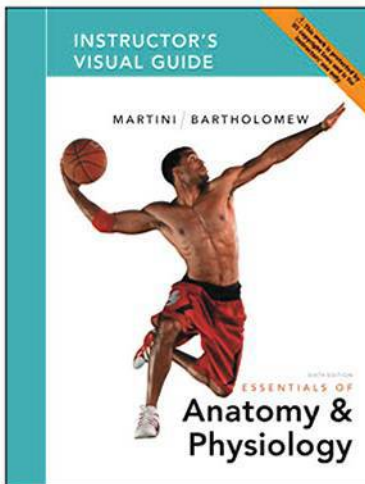


## Printed Test Bank

by Agnes Yard, Michael Yard, Jason LaPres, and Judi L. Nath

978-0-321-79227-3 / 0-321-79227-0

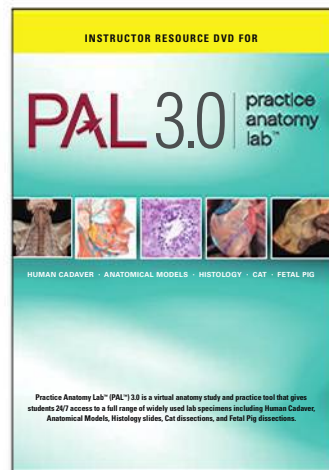
The test bank of more than 2,000 questions tied to the Learning Outcomes in each chapter helps instructors design a variety of tests and quizzes. The test bank includes multiple choice, matching, art labeling, and essay questions. This supplement is the print version of TestGen that is in the IRDVD package.



## Instructor's Visual Guide

978-0-321-79225-9 / 0-321-79225-4

This guide is a printed and bound collection of thumbnails of the images and media on the IRDVD. With this take-anywhere supplement, instructors can plan lectures when away from their computers.



## Instructor Resource DVD for Practice Anatomy Lab™ (PAL™) 3.0

978-0-321-74963-5 / 0-321-74963-4

This DVD includes everything instructors need to present PAL 3.0 in lecture and lab. It includes all of the images in PowerPoint® and JPEG formats, links to animations, and access to a test bank in MasteringA&P with more than 4,000 lab practical questions.

## Transparency Acetates

978-0-321-79220-4 / 0-321-79220-3

All figures and tables from the text are included in the printed Transparency Acetates. Complex figures are broken out for readable projected display. A full set of Transparency Acetate masters of all figures and tables is also available on the IRDVD.

## Blackboard

Pre-loaded book-specific content and test item files accompanying the text are available in Blackboard.

See **pages xviii–xix** for MasteringA&P.

# Contents



## 1 An Introduction to Anatomy and Physiology 1

- 1-1** The common functions of all living things include responsiveness, growth, reproduction, movement, and metabolism 2
- 1-2** Anatomy is structure, and physiology is function 3  
Anatomy • Physiology
- 1-3** Levels of organization progress from atoms and molecules to a complete organism 4
- 1-4** The human body consists of 11 organ systems 6
- 1-5** Homeostasis is the tendency toward internal balance 6
- 1-6** Negative feedback opposes variations from normal, whereas positive feedback exaggerates them 10  
Negative Feedback • Positive Feedback
- 1-7** Anatomical terms describe body regions, anatomical positions and directions, and body sections 12  
Surface Anatomy • Sectional Anatomy
- 1-8** Body cavities protect internal organs and allow them to change shape 19  
The Thoracic Cavity • The Abdominopelvic Cavity
- Spotlight**  
Imaging Techniques 16
- Clinical Note**  
Homeostasis and Disease 6
- Chapter Review** 21



## 2 The Chemical Level of Organization 25

- 2-1** Atoms are the basic particles of matter 26  
Atomic Structure • Isotopes • Atomic Weight • Electron Shells
- 2-2** Chemical bonds are forces formed by atom interactions 28  
Ionic Bonds • Covalent Bonds • Hydrogen Bonds
- 2-3** Decomposition, synthesis, and exchange reactions are important chemical reactions in physiology 31  
Basic Energy Concepts • Types of Reactions • Reversible Reactions
- 2-4** Enzymes catalyze specific biochemical reactions by lowering a reaction's activation energy 34

- 2-5** Inorganic compounds usually lack carbon, and organic compounds always contain carbon 34
- 2-6** Physiological systems depend on water 35
- 2-7** Body fluid pH is vital for homeostasis 36
- 2-8** Acids, bases, and salts are inorganic compounds with important physiological roles 37  
Salts • Buffers and pH
- 2-9** Carbohydrates contain carbon, hydrogen, and oxygen in a 1:2:1 ratio 38  
Monosaccharides • Disaccharides and Polysaccharides
- 2-10** Lipids contain a carbon-to-hydrogen ratio of 1:2 40  
Fatty Acids • Fats • Steroids • Phospholipids
- 2-11** Proteins are formed from amino acids and contain carbon, hydrogen, oxygen, and nitrogen 43  
Protein Function • Protein Structure • Enzyme Function
- 2-12** DNA and RNA are nucleic acids 46  
Structure of Nucleic Acids
- 2-13** ATP is a high-energy compound used by cells 48
- 2-14** Chemicals form functional units called cells 49
- Spotlight**  
Chemical Notation 32
- Clinical Note**  
Fatty Acids and Health 41
- Chapter Review** 51



## 3 Cell Structure and Function 55

- 3-1** The study of cells provides the foundation for understanding human physiology 56  
The Study of Cells • An Overview of Cell Anatomy
- 3-2** The plasma membrane separates the cell from its surrounding environment and performs various functions 57  
Membrane Lipids • Membrane Proteins • Membrane Carbohydrates
- 3-3** Diffusion and filtration are passive transport mechanisms that assist membrane passage 61  
Diffusion • Filtration
- 3-4** Carrier-mediated and vesicular transport mechanisms assist membrane passage 65  
Carrier-Mediated Transport • Vesicular Transport

- 3-5 Organelles within the cytoplasm perform specific functions 69**  
The Cytosol • The Organelles
- 3-6 The nucleus contains DNA and enzymes essential for controlling cellular activities 76**  
Nuclear Structure and Contents • Information Storage in the Nucleus
- 3-7 DNA controls protein synthesis, cell structure, and cell function 78**  
Transcription • Translation
- 3-8 Stages of a cell's life cycle include interphase, mitosis, and cytokinesis 81**  
Interphase • Mitosis • Cytokinesis
- 3-9 Tumors and cancers are characterized by abnormal cell growth and division 84**
- 3-10 Differentiation is cellular specialization as a result of gene activation or repression 85**

**Spotlights**

- Anatomy of a Model Cell 58
- Protein Synthesis and Packaging 74

**Clinical Notes**

- DNA Fingerprinting 78
- Mutations 82

Chapter Review 86



## 4 The Tissue Level of Organization 90

- 4-1 The four tissue types are epithelial, connective, muscle, and neural 91**
- 4-2 Epithelial tissue covers body surfaces, lines cavities and tubular structures, and serves essential functions 92**  
Functions of Epithelia • Intercellular Connections • The Epithelial Surface • The Basement Membrane • Epithelial Renewal and Repair
- 4-3 Cell shape and number of layers determine the classification of epithelia 95**  
Cell Layers • Cell Shapes • Classification of Epithelia • Glandular Epithelia
- 4-4 Connective tissue provides a protective structural framework for other tissue types 101**  
Connective Tissue Proper • Types of Connective Tissue Proper • Fluid Connective Tissues • Supporting Connective Tissues
- 4-5 Tissue membranes are physical barriers of four types: mucous, serous, cutaneous, and synovial 109**  
Mucous Membranes • Serous Membranes • The Cutaneous Membrane • Synovial Membranes

- 4-6 The three types of muscle tissue are skeletal, cardiac, and smooth 111**  
Skeletal Muscle Tissue • Cardiac Muscle Tissue • Smooth Muscle Tissue
- 4-7 Neural tissue responds to stimuli and conducts electrical impulses throughout the body 113**
- 4-8 The response to tissue injury involves inflammation and regeneration 114**
- 4-9 With advancing age, tissue repair declines and cancer rates increase 114**  
Aging and Tissue Structure • Aging and Cancer Incidence

**Clinical Notes**

- Exfoliative Cytology 99
- Marfan Syndrome 103
- Adipose Tissue and Weight Control 104
- Cartilages and Joint Injuries 108

Chapter Review 115



## 5 The Integumentary System 120

- 5-1 The epidermis is composed of strata (layers) with various functions 122**  
Stratum Basale • Intermediate Strata • Stratum Corneum
- 5-2 Factors influencing skin color are epidermal pigmentation and dermal circulation 124**  
The Role of Pigmentation • The Role of Dermal Circulation
- 5-3 Sunlight has detrimental and beneficial effects on the skin 125**  
The Epidermis and Vitamin D<sub>3</sub> • Skin Cancers
- 5-4 The dermis is the tissue layer that supports the epidermis 126**
- 5-5 The hypodermis connects the dermis to underlying tissues 126**
- 5-6 Hair is composed of dead, keratinized cells that have been pushed to the skin surface 127**  
The Structure of Hair and Hair Follicles • Functions of Hair • Hair Color
- 5-7 Sebaceous glands and sweat glands are exocrine glands found in the skin 129**  
Sebaceous (Oil) Glands • Sweat Glands
- 5-8 Nails are keratinized epidermal cells that protect the tips of fingers and toes 130**
- 5-9 Several steps are involved in repairing the integument following an injury 131**  
Repair of Skin Injuries • Effects of Burns
- 5-10 Effects of aging include dermal thinning, wrinkling, and reduced melanocyte activity 133**

**Clinical Notes**

Drug Administration through the Skin 123

Hair Loss 128

**Career Paths**

EMT/Paramedic 139

Chapter Review 135



## 6 The Skeletal System 140

- 6-1** The skeletal system has five primary functions 141
- 6-2** Bones are classified according to shape and structure 141
  - Macroscopic Features of Bone • Microscopic Features of Bone
- 6-3** Ossification and appositional growth are mechanisms of bone formation and enlargement 145
  - Intramembranous Ossification • Endochondral Ossification • Bone Growth and Body Proportions • Requirements for Normal Bone Growth
- 6-4** Bone growth and development depend on a balance between bone formation and resorption, and on calcium availability 147
  - The Role of Remodeling in Support • The Skeleton as a Calcium Reserve • Repair of Fractures
- 6-5** Osteopenia has a widespread effect on aging skeletal tissue 150
- 6-6** The bones of the skeleton are distinguished by surface markings and grouped into two skeletal divisions 150
  - Bone Markings (Surface Features) • Skeletal Divisions
- 6-7** The bones of the skull, vertebral column, and thoracic cage make up the axial skeleton 153
  - The Skull • The Vertebral Column and Thoracic Cage
- 6-8** The pectoral girdle and upper limb bones, and the pelvic girdle and lower limb bones, make up the appendicular skeleton 163
  - The Pectoral Girdle • The Upper Limb • The Pelvic Girdle • The Lower Limb
- 6-9** Joints are categorized according to their range of motion or anatomical organization 171
  - Immovable Joints (Synarthroses) • Slightly Movable Joints (Amphiarthroses) • Freely Movable Joints (Diarthroses)
- 6-10** Anatomical and functional properties of synovial joints enable various skeletal movements 174
  - Types of Movement • Types of Synovial Joints
- 6-11** Intervertebral articulations and appendicular articulations demonstrate functional differences in support and mobility 177
  - Intervertebral Articulations • Articulations of the Upper Limb • Articulations of the Lower Limb

- 6-12** The skeletal system supports and stores energy and minerals for other body systems 182

**Spotlight**

Synovial Joints 178

**Clinical Notes**

Types of Fractures 148

Osteoporosis 150

Rheumatism and Arthritis 173

Hip Fractures 180

**Career Paths**

Dental Hygienist 189

Chapter Review 183



## 7 The Muscular System 190

- 7-1** Skeletal muscle performs five primary functions 191
- 7-2** A skeletal muscle contains muscle tissue, connective tissues, blood vessels, and nerves 191
  - Connective Tissue Organization • Blood Vessels and Nerves
- 7-3** Skeletal muscle fibers have distinctive features 193
  - The Sarcolemma and Transverse Tubules • Myofibrils • The Sarcoplasmic Reticulum • Sarcomeres
- 7-4** Communication between the nervous system and skeletal muscles occurs at neuromuscular junctions 196
  - The Neuromuscular Junction • The Contraction Cycle
- 7-5** Sarcomere shortening and muscle fiber stimulation produce tension 197
  - Frequency of Muscle Fiber Stimulation • Number of Muscle Fibers Activated • Isotonic and Isometric Contractions • Muscle Elongation Following Contraction
- 7-6** ATP is the energy source for muscle contraction 206
  - ATP and CP Reserves • ATP Generation • Energy Use and the Level of Muscle Activity • Muscle Fatigue • The Recovery Period
- 7-7** Muscle performance depends on muscle fiber type and physical conditioning 209
  - Types of Skeletal Muscle Fibers • Physical Conditioning
- 7-8** Cardiac and smooth muscle tissues differ structurally and functionally from skeletal muscle tissue 210
  - Cardiac Muscle Tissue • Smooth Muscle Tissue
- 7-9** Descriptive terms are used to name skeletal muscles 212
  - Origins, Insertions, and Actions • Names of Skeletal Muscles
- 7-10** Axial muscles are muscles of the head and neck, vertebral column, trunk, and pelvic floor 216
  - Muscles of the Head and Neck • Muscles of the Spine • The Axial Muscles of the Trunk • Muscles of the Pelvic Floor

**7-11** Appendicular muscles are muscles of the shoulders, upper limbs, pelvic girdle, and lower limbs 224  
Muscles of the Shoulders and Upper Limbs • Muscles of the Pelvis and Lower Limbs

**7-12** With advancing age, the size and power of muscle tissue decrease 232

**7-13** Exercise produces responses in multiple body systems 235

#### Spotlights

Skeletal Muscle Innervation 198

The Contraction Cycle 200

#### Clinical Notes

Interference with Neural Control Mechanisms 196

Rigor Mortis 197

Tetanus 204

Hernias 219

Intramuscular Injections 223

#### Career Paths

Massage Therapist 242

Chapter Review 236



## 8 The Nervous System 243

**8-1** The nervous system has anatomical and functional divisions 244

**8-2** Neurons are specialized for intercellular communication and are supported by cells called neuroglia 245

Neurons • Neuroglia • Organization of Neurons in the Nervous System

**8-3** In neurons, a change in the plasma membrane's electrical potential may result in an action potential (nerve impulse) 251

The Membrane Potential • Propagation of an Action Potential

**8-4** At synapses, communication occurs among neurons or between neurons and other cells 257

Structure of a Synapse • Synaptic Function and Neurotransmitters • Neuronal Pools

**8-5** The brain and spinal cord are surrounded by three layers of membranes called the meninges 260

The Dura Mater • The Arachnoid • The Pia Mater

**8-6** The spinal cord contains gray matter surrounded by white matter and connects to 31 pairs of spinal nerves 261

Gross Anatomy • Sectional Anatomy

**8-7** The brain has several principal structures, each with specific functions 264

The Major Regions of the Brain • The Ventricles of the Brain • The Cerebrum • The Diencephalon • The Midbrain • The Pons • The Cerebellum • The Medulla Oblongata

**8-8** The PNS connects the CNS with the body's external and internal environments 277

The Cranial Nerves • The Spinal Nerves • Nerve Plexuses

**8-9** Reflexes are rapid, automatic responses to stimuli 281

Simple Reflexes • Complex Reflexes • Integration and Control of Spinal Reflexes

**8-10** Separate pathways carry sensory information and motor commands 285

Sensory Pathways • Motor Pathways

**8-11** The autonomic nervous system, composed of the sympathetic and parasympathetic divisions, is involved in the unconscious regulation of body functions 287

The Sympathetic Division • The Parasympathetic Division • Relationships Between the Sympathetic and Parasympathetic Divisions

**8-12** Aging produces various structural and functional changes in the nervous system 291

**8-13** The nervous system is closely integrated with other body systems 294

#### Spotlight

The Generation of an Action Potential 254

#### Clinical Notes

Demyelination Disorders 250

Epidural and Subdural Hemorrhages 261

Spinal Cord Injuries 264

Aphasia and Dyslexia 271

Seizures 273

Cerebral Palsy 287

Alzheimer's Disease 294

#### Career Paths

Physician Assistant 303

Chapter Review 295



## 9 The General and Special Senses 304

**9-1** Sensory receptors connect our internal and external environments with the nervous system 305

**9-2** General sensory receptors are classified by the type of stimulus that excites them 306

Pain • Temperature • Touch, Pressure, and Position • Chemical Detection

**9-3** Olfaction, the sense of smell, involves olfactory receptors responding to chemical stimuli 310

The Olfactory Pathways

**9-4** Gustation, the sense of taste, involves taste receptors responding to chemical stimuli 312

The Taste Pathways