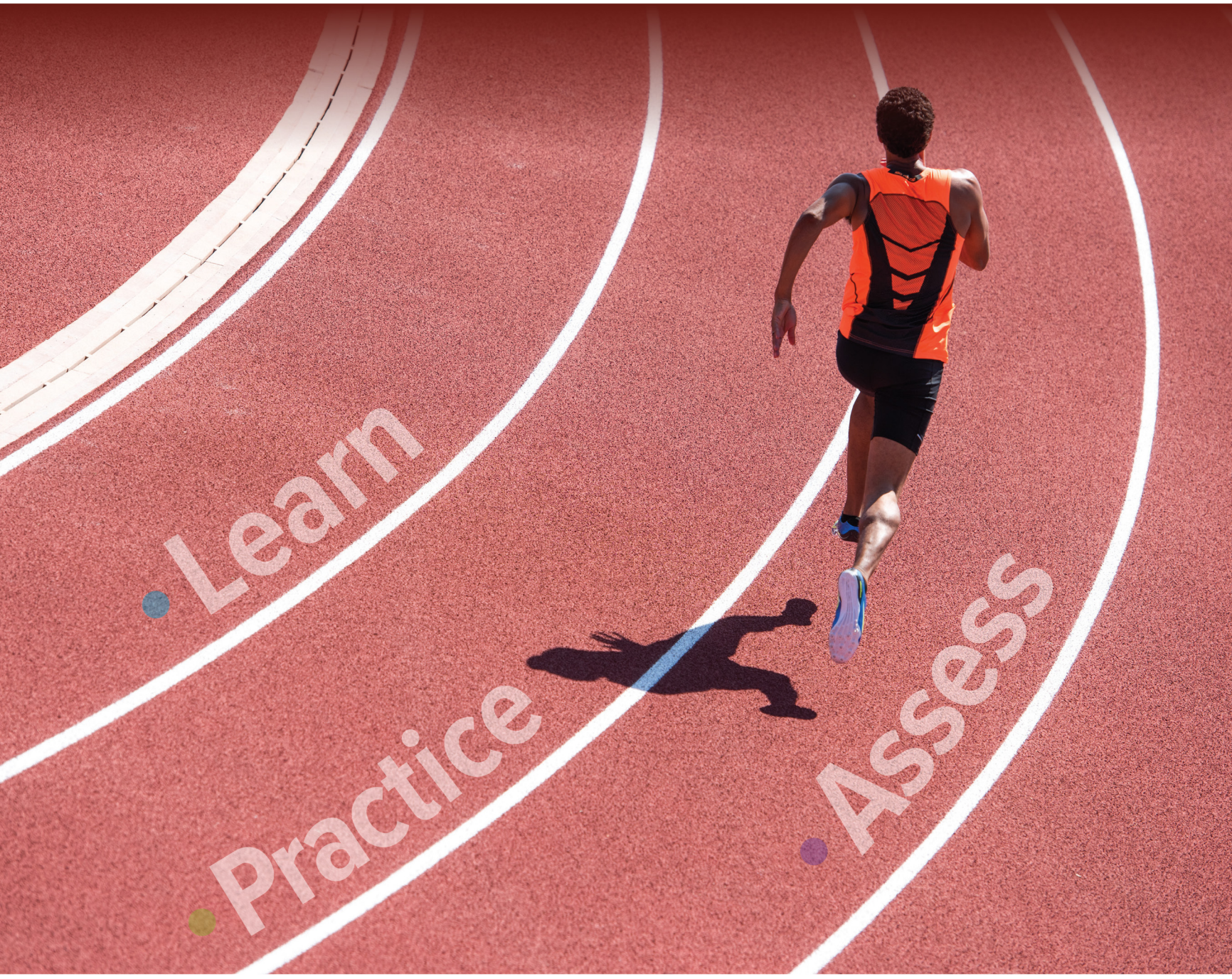
HOLE'S Human Anatomy & Physiology

Fifteenth Edition



David Shier • Jackie Butler • Ricki Lewis

Mc Graw Hill Education

HOLE'S HUMAN ANATOMY & PHYSIOLOGY

FIFTEENTH EDITION

HOLE'S HUMAN ANATOMY & PHYSIOLOGY

FIFTEENTH EDITION

DAVID SHIER

EMERITUS FACULTY,
WASHTENAW COMMUNITY COLLEGE

JACKIE BUTLER

GRAYSON COLLEGE

RICKI LEWIS

ALDEN MARCH BIOETHICS INSTITUTE

DIGITAL AUTHORS

LESLIE DAY

NORTHEASTERN UNIVERSITY

JULIE PILCHER

UNIVERSITY OF SOUTHERN INDIANA

Mc Graw Hill Education

HOLE'S HUMAN ANATOMY & PHYSIOLOGY, FIFTEENTH EDITION

This book is printed on acid-free paper.

1 2 3 4 5 6 7 8 9 LWI 21 20 19 18

ISBN 978-1-259-86456-8
MHID 1-259-86456-1

Executive Brand Manager: *Amy Reed*
Product Developer: *Michelle Gaseor*
Marketing Manager: *James Connely*
Content Project Managers: *Jane Mohr, Christina Nelson, and Sandra Schnee*
Buyer: *Sandy Ludovissy*
Design: *Tara McDermott*
Content Licensing Specialist: *Lori Hancock*
Cover Image: ©*Tim Tadder/Getty Images*
Compositor: *SPi Global*

Library of Congress Cataloging-in-Publication Data

Names: Shier, David, author. | Butler, Jackie, author. | Lewis, Ricki, author.
Title: Hole's human anatomy & physiology / DAVID SHIER, Emeritus Faculty, Washtenaw Community College, Jackie Butler, Grayson College, Ricki Lewis, Alden March Bioethics Institute ; digital authors Leslie Day, Northeastern University, Julie Pilcher, University of Southern Indiana.
Other titles: Hole's human anatomy and physiology | Human anatomy & physiology
Description: Fifteenth edition. | New York, NY : McGraw-Hill Education, [2019] | Includes index.
Identifiers: LCCN 2017025439 | ISBN 9781259864568 (alk. paper)
Subjects: LCSH: Human physiology. | Human anatomy.
Classification: LCC QP34.5 .S49 2019 | DDC 612--dc23 LC record available at https://lccn.loc.gov/2017025439

mheducation.com/highered

BRIEF CONTENTS

About the Authors vi | Acknowledgments viii | Updates and Additions ix | Dynamic Art Program xvi | Learn, Practice, Assess xviii | McGraw-Hill Connect xx | LearnSmart Prep xxii | Contents xxiii | Connections xxviii

PREVIEW

Foundations for Success 1

UNIT 1
LEVELS OF ORGANIZATION 9

1 Introduction to Human Anatomy and Physiology 9
2 Chemical Basis of Life 59
3 Cells 84
4 Cellular Metabolism 122
5 Tissues 149

UNIT 2
SUPPORT AND MOVEMENT 178

6 Integumentary System 178
7 Skeletal System 200
8 Joints of the Skeletal System 268
9 Muscular System 292

UNIT 3
INTEGRATION AND COORDINATION 359

10 Nervous System I: Basic Structure and Function 359
11 Nervous System II: Divisions of the Nervous System 389
12 Nervous System III: Senses 444
13 Endocrine System 489

UNIT 4
TRANSPORT 529

14 Blood 529
15 Cardiovascular System 558
16 Lymphatic System and Immunity 618

UNIT 5
ABSORPTION AND EXCRETION 651

17 Digestive System 651
18 Nutrition and Metabolism 696
19 Respiratory System 731
20 Urinary System 769
21 Water, Electrolyte, and Acid-Base Balance 804

UNIT 6
THE HUMAN LIFE CYCLE 824

22 Reproductive Systems 824
23 Pregnancy, Growth, and Development 868
24 Genetics and Genomics 907

Appendices 927
Glossary 940
Index 963

Mc Graw Hill Education
5011333

ABOUT THE AUTHORS

Courtesy of Fran Simon

DAVID SHIER

Emeritus Faculty
Washtenaw Community College

David Shier has more than thirty years of experience teaching anatomy and physiology, primarily to premedical, nursing, dental, and allied health students. He has effectively incorporated his extensive teaching experience into another student-friendly revision of *Hole's Essentials of Human Anatomy and Physiology* and *Hole's Human Anatomy and Physiology.* His interest in physiology and teaching began with a job as a research assistant at Harvard Medical School from 1976–1979. He completed his Ph.D. at the University of Michigan in 1984, and served on the faculty of the Medical College of Ohio from 1985–1989. He began teaching at Washtenaw Community College in 1990. David has experience in online course delivery, including recording lectures for so-called "flipped" classrooms. He has also been interested in the relationship between pedagogy and assessment, and the use of tools traditionally associated with assessment (e.g., lab quizzes) as pedagogical tools, often associated with group activities.

Courtesy of Michael's Photography

JACKIE BUTLER

Grayson College

Jackie Butler's professional background includes work at the University of Texas Health Science Center conducting research about the genetics of bilateral retinoblastoma. She later worked at MD Anderson Hospital investigating remission in leukemia patients. A popular educator for more than thirty years at Grayson College, Jackie has taught microbiology and human anatomy and physiology for health science majors. Her experience and work with students of various educational backgrounds have contributed significantly to another revision of *Hole's Essentials of Human Anatomy and Physiology* and *Hole's Human Anatomy and Physiology.* Jackie Butler received her B.S. and M.S. degrees from Texas A&M University, focusing on microbiology, including courses in immunology and epidemiology.

Courtesy of Dr. Wendy Josephs

RICKI LEWIS

Alden March Bioethics Institute

Ricki Lewis's career communicating science began with earning a Ph.D. in Genetics from Indiana University in 1980. It quickly blossomed into writing for newspapers and magazines, and writing the introductory textbook *Life.* Since then she has taught a variety of life science courses and has authored the textbook *Human Genetics: Concepts and Applications* and books about gene therapy, stem cells, and scientific discovery. She is a genetic counselor for a large medical practice, teaches a graduate online course in "Genethics" at Albany Medical College, and writes for Medscape Medical News, Genetic Literacy Project, Rare Disease Report, and medical journals. Ricki also writes the popular DNA Science blog at Public Library of Science and is a frequent public speaker.

DIGITAL AUTHORS

Courtesy of Leslie Day

Courtesy of Gary Pilcher

LESLIE DAY

Northeastern University

Leslie Day earned her B.S. in Exercise Physiology from UMass Lowell, a M.S. in Applied Anatomy & Physiology from Boston University, and a Ph.D. in Biology from Northeastern University with her research on the kinematics of locomotion. She currently works as an Associate Clinical Professor in the Department of Physical Therapy, Movement and Rehabilitation Sciences at Northeastern University. Her main teaching role is in Gross Anatomy and Neuroanatomy courses. Students enjoy her clinical teaching style, use of technology, and innovative teaching methods. She has received the University Teaching with Technology award three times and in 2009 was awarded the Excellence in Teaching award. In 2017 she received national recognition for her teaching by being the recipient of the ADInstruments Sam Drogo Technology in the Classroom award from the Human Anatomy & Physiology Society (HAPS). Her current research focuses on the effectiveness of different teaching pedagogies on students' motivation and learning, including the flipped-classroom and various technologies.

JULIE C. PILCHER

University of Southern Indiana

Julie Pilcher began teaching during her graduate training in Biomedical Sciences at Wright State University, Dayton, Ohio, while working on her doctorate in cardiovascular physiology. She found that working as a teaching assistant held her interest more than her research. Upon completion of her Ph.D. in 1986, she embarked on her teaching career, working for many years as an adjunct in a variety of schools in St. Louis and Detroit. The courses she taught included Microbiology, General Biology, and Anatomy and Physiology. In 1998 she began teaching Anatomy and Physiology full-time at the University of Southern Indiana, Evansville, eventually serving as coordinator for the course. Her work with McGraw-Hill began with doing reviews of textbook chapters and lab manuals. Later she was involved in writing content during the early stages of LearnSmart development for several anatomy and physiology texts. Her pedagogical interests include use of online assessment materials and development of a flipped classroom.

ACKNOWLEDGMENTS

Any textbook is the result of hard work by a large team. Although we directed the revision, many "behind-the scenes" people at McGraw-Hill were indispensable to the project. We would like to thank Thomas Timp, Amy Reed, Fran Simon, Michelle Gaseor, Joan Weber, Katie Ward, Michael Koot, Tammy Ben, Jim Connely, Kristine Rellihan, Angie Fitzpatrick, Jayne Klein, Christina Nelson, Sandy Ludovissy, Tara McDermott, Sandy Schnee, and Lori Hancock: and most of all, John Hole, for giving us the opportunity and freedom to continue his classic work. We especially thank our wonderfully patient families for their support.

David Shier, Jackie Butler, Ricki Lewis

REVIEWERS

We would like to acknowledge the valuable contributions of all professors and their students who have provided detailed recommendations for improving chapter content and illustrations throughout the revision process for each edition. They have played a vital role in building a solid foundation for *Hole's Human Anatomy & Physiology.*

Jaysen C. Arno, *Pitt Community College*
Sharon R. Barnewall, *Columbus State Community College*
Cathy Bill, MS, DVM, *Columbus State Community College*
Jennifer M. Boalick, *Guilford Technical Community College*
Janet Brodsky, *Ivy Tech Community College, Lafayette*
Dr. Jack Brown, EdD, *Paris Junior College*
James Cain, *Aurora University*
Susan Caley Opsal, *Illinois Valley Community College*
Natalia V. Chugunov, MD, *Ivy Tech Community College, South Bend*
Paula Edgar, *John Wood Community College*
Georgia Everett, *Ivy Tech Community College, Kokomo*
Sharon Feaster, *Hinds Community College*
Dr. Alana Gabler, *Southwest Mississippi Community College*
Emily K. Getty, M.Sci.Ed, *Ivy Tech Community College*
Andrew Goliszek, Ph.D., *North Carolina A&T State University*
Janelle Green, *KCTCS Hazard Community and Technical College*
Ray Hawkins, *ASU Mid-South Community College*
Jennifer Holloway, *Faulkner State Community College*
Carol Johnson, *Lone Star College North Harris*
Mary Kananen, *Penn State University Altoona*
Dr. Craig Lafferty, *Arkansas State University Mid-South*
Rosario Murdie, *Ivy Tech Community College*
Ivan Paul, *John Wood Community College*
Mary Leigh Poole, *Holmes Community College Goodman*
Letha Richards, *Coahoma Community College*
Michelle Scanavino, *Moberly Area Community College*
Marilyn Shopper, *Johnson County Community College*
Dr. Melanie Shorter Cooper, *Fayetteville State University*
Ester Siegfried, *Penn State University Altoona*
Sanjay Tiwary, *Hinds Community College Jackson*
Dr. Nancy Tress, *University of Pittsburgh at Titusville*
Janice Webster, *Ivy Tech Community College*
Scott Rahschulte, *Ivy Tech Community College*
Koushik Roy, *Southwest TN Community College*
Albert Urazaev, *Ivy Tech Community College*

DEDICATION

This book is dedicated with much affection and appreciation to our families, our students, and in particular to Fran Simon and Jayne Klein, whose leadership and support continue to bring out the best from the authors with whom they work.

UPDATES AND ADDITIONS

Global Changes

- LEARN, PRACTICE, and ASSESS components have been clearly identified throughout the text.
- Small boxes have been integrated into the text flow or into big boxes (*Clinical Application, From Science to Technology*).
- *Learning Outcomes* have been moved to their respective sections throughout each chapter.
- Existing *Reconnect* and *A Glimpse Ahead* features now relate back to a new section, Core Themes in Anatomy and Physiology, in chapter 1. A short paragraph highlights the connection to *Key Concepts* (The Cell, Internal Environment, Homeostasis Interdependency of Cells, Structure and Function) and *Underlying Mechanisms and Processes* (Gradients and Permeability, Cellular Differentiation, Cell Membrane Mechanisms, Cell-to-Cell Communication, Feedback Loops, Balance, Energy Processes).
- *Reconnect* and *A Glimpse Ahead* refer to specific subsections rather than to pages, providing a broader context for students.
- Longer paragraphs have been broken up to better suit today's learner.

SELECTED SPECIFIC CHANGES AT-A-GLANCE

Chapter	Topic	Change	Rationale
1	Common themes in anatomy and physiology	New section 1.4	Clarity, reinforcement of basic principles
1	Life and the maintenance of life	Old sections 1.4 and 1.5 combined as 1.5	Minimize change in chapter flow with addition of section 1.4
1	Homeostasis	Rewritten section on control mechanisms and feedback loops	Clarity, detail
1	Homeostasis	Rewritten discussion of positive feedback. New fig. 1.8*a* and *b* on positive feedback (previous 1.8 combined with 1.7 as 1.7*b*)	Clarity, detail, visual support
1	Organization of the human body	Rewritten description of the mediastinum	Clarity, accuracy
1	Organ systems	Introduction of the term *innervated* early on	Clarity
1	Relative position	Introduction of combined terms, such as *anterolateral*	Clarity, detail
2	Atoms and elements	Text rewritten and an explanation of criteria for natural occurring elements added to Appendix D	Clarity, accuracy
2	Ionic bonds	Text rewritten	Accuracy
2	Acidosis and alkalosis	Rewritten description of examples	Clarity
2	Water	Discussion of solvent, solute, and solution added	Clarity
2	Lipids	The term *triglycerides* used preferentially to *fats*	Clarity, accuracy
2	Protein structure	Amino acid sequence defined in context	Clarity
2	Protein Structure	Fig. 2.19, placement of enlargement arrow changed	Clarity
3	Microscopy	Comparison of LM, TEM, SEM moved from small box to fig. 3.4 legend	Style change
3	Microscopy	Fig. 3.3 (white man in white coat at TEM) dropped	Delete stereotype
3	Other cellular structures	Reordered text and figures so that components (microtubules, microfilaments, intermediate filaments) precede structures (centrosomes, cilia, flagella)	Logic, clarity
3	Movements into and out of cell	First paragraph distinguishes mechanisms by energy use or not rather than physical or physiological	Clarity

—Continued

UPDATES AND ADDITIONS

SELECTED SPECIFIC CHANGES AT-A-GLANCE —*Continued*

Chapter	Topic	Change	Rationale
3	Fig. 3.24b	Replaced shrunken RBC	Detail
3	Mitosis	New *Glimpse Ahead* and text stress 23 chromosome pairs adding up to 46 and replicated vs. unreplicated chromosomes	Clarity
4	Intro	New first two sentences place anabolism and catabolism into context	Clarity
4	Triglyceride/fat terminology	Triglyceride primary term	Accuracy
4	Protein synthesis	Series of figures redone	Clarity
4	Cofactors + coenzymes	Added coverage of coenzyme Q10	Familiarity
4	Cellular respiration	Theoretical maximum ATP = 30–32	Accuracy
4	Mutations	Fewer disease examples to better focus concepts	Clarity
5	Connective Tissue	Added new line art, micrograph, and locator icon for dense irregular connective tissue	Clarity
5	Connective tissue	Revised discussion of bone tissue	Clarity
6	Clinical Application, Tanning and Skin Cancer	Changed the “e” in the ABCDE rule to evolution (change)	Accuracy
6	Skin color	Added the terms eumelanin and pheomelanin to the discussion	Clarity, detail
6	Fig. 6.12 Body temperature regulation	Changed muscle activity generates heat to skeletal muscle activity generates heat	Clarity
7	Bone Growth and Development	Put the definition of ossification in the first paragraph of the section	Clarity
7	Radiograph of epiphyseal plates	Moved to the first mention of epiphyseal plates	Clarity
7	Clinical Application, Preventing Fragility Fractures	Revised	Update
8	Joint movements	Added photos demonstrating extension/flexion of the shoulder and extension/flexion of the hip	Clarity
8	Figure 8.14 Shoulder joint	Redrawn	Accuracy
8	Clinical Application, Joint Disorders	Revised	Update
9	Thick and thin muscle filaments	Fig. 9.6 revised to more accurately show orientation of thin filaments	Accuracy, clarity
9	Stimulus for contraction	Revised to more clearly describe relative roles of sodium and potassium ions	Clarity, accuracy
9	Muscle relaxation	Revised to clarify the role of the synaptic cleft	Clarity, accuracy
9	Creatine phosphate	Fig. 9.11 redrawn	Accuracy, clarity
9	Cellular respiration	Fig. 9.12 modified to reflect current estimates of ATP yield	Update, accuracy
9	Interaction of skeletal muscles	Rewritten section on agonist, antagonist, prime mover, and synergist	Clarity, clinical relevance

SELECTED SPECIFIC CHANGES AT-A-GLANCE —*Continued*

Chapter	Topic	Change	Rationale
9	Recording of a muscle contraction	Optimal length defined in context	Clarity
9	Origin and insertion	Rewritten to include alternate terminology—proximal attachment and distal attachment	Clarity, update
9	Major skeletal muscles	Fig. 9.25 redrawn to depict more accurate location and relative size of muscles	Clarity, accuracy
9	Muscle actions	Revised actions for neck muscles in table 9.6	Accuracy, clarity
9	Muscles that move the head and vertebral column	Fig. 9.26 revised	Accuracy, clarity
9	Movements at shoulder	Fig. 9.27 revised	Accuracy, clarity
9	Muscles of the arm and forearm	Supinator added to fig. 9.32	Clarity
9	Muscles of the arm and forearm	Figure 9.33 revised	Accuracy, clarity
9	Pelvic floor	Table 9.12 reorganized for clarity: External anal sphincter added	Clarity. accuracy
9	Muscles that move the leg	Text revised to include components of quadriceps femoris group	Detail, clarity
10	General characteristics of the nervous system	Revised discussion of CNS, PNS, and synapses	Clarity, accuracy
10	Clinical Application 10.1, Migraine	Partly rewritten	Update
10	Neuroglia	Added functions for Schwann cells and satellite cells	Update
10	Axonal regeneration	Fig. 10.10 revised	Accuracy, clarity
10	The synapse	Fig. 10.11 revised	Clarity
10	Resting potential	Section revised	Accuracy, clarity
10	Cell membrane potential	*Action potential* used in preference to *impulse*	Clarity, consistency
10	Ion movements during action potentials	Fig. 10.6 revised with units added to graphs	Clarity
10	Ion movements during action potentials	Section revised	Detail, Clarity
10	Neurotransmitters	Action linked to the type of receptor present	Clarity, Detail
10	Facilitation	Mechanism revised	Update
10	Sections on convergence and divergence	Revised	Clarity

—Continued

UPDATES AND ADDITIONS

SELECTED SPECIFIC CHANGES AT-A-GLANCE —*Continued*

Chapter	Topic	Change	Rationale
11	CSF	Fig. 11.4 revised	Clarity
11	Brain	Fig. 11.6 revised	Clarity
11	Brain	Fig. 11.7 revised	Clarity
11	Brain	Fig. 11.8 revised	Accuracy, clarity
11	Brain	Names of specific areas of cortex (e.g., somatosensory cortex) added to discussion	Clarity
11	Memory	Added discussion of working memory	Update
11	Basal nuclei	Fig. 11.10 revised	Clarity, accuracy
11.	Brainstem	Several text revisions	Clarity
11	Sleep	Added definition of sleep to text discussion	Clarity
11	Cerebellar peduncles	Fig. 11.13 redrawn	Clarity
11	Spinal cord	Explanations of numbering of spinal nerves moved to this section and revised	Clarity
11	Spinal cord	Distinction between posterior and anterior roots revised	Clarity
11	Spinal cord	Terms *posterior root* and *anterior root* used preferentially to *dorsal root* and *ventral root*	Update
11	Segmental innervation	Revised figs 11.18 and 11.19 to label spinal segments	Clarity
11	Tracts	Figs 11.21 and 11.22 revised	Clarity, accuracy
11	Peripheral nervous system	Expanded subdivisions of the nervous system in table 11.8.	Clarity, accuracy
11	Cranial nerves	Fig. 11.25 revised to better show left and right cerebral hemispheres	Accuracy
11	Autonomic nervous system	Revised introduction and general organization	Clarity
12	Sensation and Perception	Revised text	Clarity, accuracy
12	Touch and pressure senses	Revised text	Clarity
12	Cannabinoids	Section rewritten	Update
12	Taste	Section reorganized and revised	Clarity, accuarcy
12	Cochlear duct	Fig. 12.12 revised	Clarity
12	Cochlea, spiral organ	Fig. 12.13 revised	Clarity, accuracy
12	Motion sickness	Section revised	Clarity
12	Iris	Section revised	Clarity, accuracy
12	Disorders of the eye	New table 12.8	Clinical relevance
13	Prolactin secretion	Description of control revised	Update
13	Actions of oxytocin	Text discussion expanded	Update
13	Thyroid hormone disorders	New text discussion	Clinical relevance

SELECTED SPECIFIC CHANGES AT-A-GLANCE —*Continued*

Chapter	Topic	Change	Rationale
13	Catecholamine synthesis	New fig. 13.31	Clarity, detail
13	Hormones of the adrenal cortex	Revised table 13.11	Clarity
13	Clincal Application 13.1, Diabetes mellitus	Revised	Clarity, update
13	Stress response	Section partially rewritten to add exhaustion phase	Clarity, detail
14	Clinical Application, Universal Precautions	Revised	Update
14	Plasma proteins	Revised the albumin discussion	Clarity
15	Heart	Revised the discussion of the regulation of the cardiac cycle	Clarity
15	Fig 15.22b Autonomic impulses alter the activities of the SA and AV nodes	Nervous structures recolored	Consistency of color with chapter 11
15	Fig 15.49 Major branches of the external iliac artery	Moved leader for femoral artery on posterior view	Accuracy
16	Body Defenses Against Infection (Immunity)	Immunity definition moved to the beginning of the section because both innate defenses and adaptive defenses provide immunity	Accuracy, clarity
16	Clinical Application, Immunity Breakdown: HIV/AIDS	In table 16A on how AIDS is not transmitted, changed donating blood to receiving donated blood	Accuracy, clarity
17	Structure of the wall of the alimentary canal	Expanded serosa discussion to differentiate between the serosa of digestive organs within the abdominal cavity and the serosa of digestive organs not contained within the abdominal cavity	Accuracy
17	Fig 17.4b Segmentation mixes the contents of the small intestine	Added leaders and labels for alternating rings of contraction and the mixing that occurs as a result	Clarity
17	Clinical Application, Disorders of the Large Intestine	Revised to distinguish between inflammatory bowel disease and irritable bowel disease	Clarity
18	Protein sources	Revised the discussion of complete proteins and incomplete proteins	Accuracy
18	Clinical Application, Dietary Supplements	New photo	Update
19	Upper respiratory tract	Larynx included in upper respiratory tract	Clinical relevance
19	Larynx	Reworded description of location relative to the laryngopharynx	Clarity, accuracy
19	Clinical Application 19.1, The Effects of Cigarette Smoking on the Respiratory System	Added new section on electronic cigarettes	Clinical relevance, update
19	Glottis	Fig. 19.7 revised	Detail, accuracy
19	Structure of respiratory tubes	Added paragraph on bronchodilation and bronchoconstriction	Clarity
19	Breathing mechanism	Wording added describing movement of gas down a pressure gradient	Clarity

—Continued

UPDATES AND ADDITIONS

SELECTED SPECIFIC CHANGES AT-A-GLANCE —*Continued*

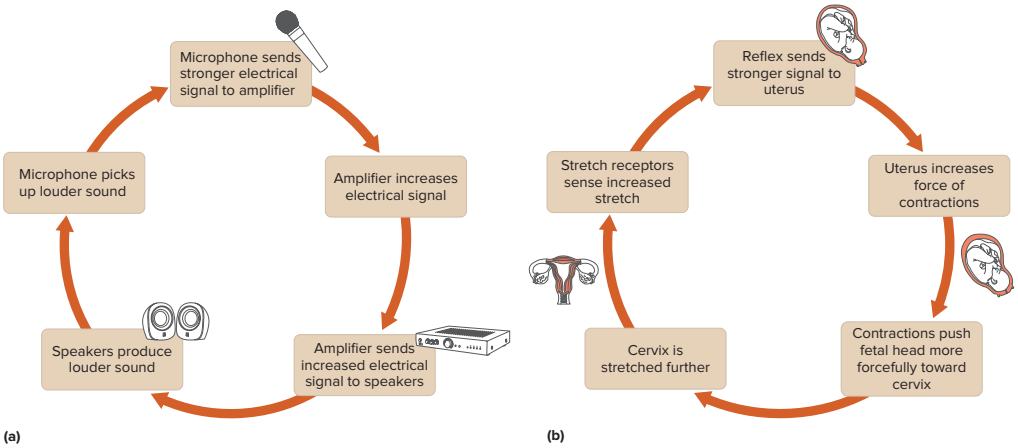
Chapter	Topic	Change	Rationale
19	Inspiration and expiration	Sections revised	Clarity
19	Clinical Application 19.2, Lung Irritants	New photo depicts air pollution in Beijing	Update
19	Respiratory volumes and capacities	Added text on tidal volume	Clarity
19	Respiratory volumes and capacities	Fig. 19.27 revised	Clarity
19	Nonrespiratory air movements	*Speaking* added to section	Detail
19	Factors affecting breathing	Section revised	Clarity, update
19	Factors affecting breathing	Fig. 19.28 revised	Clarity, accuracy
19	Respiratory membrane	Revised discussion, revised fig. 19.33	Accuracy
19	Diffusion through the respiratory membrane	Revised discussion	Accuracy, clarity
19	Gas transport	Additions to text on oxygen transport, including conditions of low oxygen	Clarity, clinical relevance
19	Gas transport	Additions to text on carbon dioxide transport	Clarity
20	Cortical versus juxtamedullary nephrons	Introduced earlier in text and in further revised fig. 20.6	Clarity, accuracy
20	Renal blood vessels	Portal system reinforced in text	Clarity
20	Nephrons	Added discussion of nephron subdivisions. Figures and text revised accordingly	Clarity, update
20	Basic renal processes	Revised introduction to urine formation. Fig. 20.15 revised for a more schematic presentation.	Clarity
20	Glomerular filtration	Section reorganized	Clarity
20	Control of glomerular filtration	New fig. 20.18, revised text	Clarity
20	Tubular reabsorption	Some text moved to earlier, under basic renal processes	Clarity
20	Sodium and water reabsorption	Section rewritten, fig. 20.21 (formerly 20.20) revised	Clarity, update
20	Tubular secretion	Fig. 20.22 (formerly 20.21) revised	Clarity
20	Urine concentration	Text and fig. 20.23 (formerly 20.22), and table 20.3 revised	Clarity
20	Urinary bladder and relationship to sphincters	Redrawn figure 20.31 (formerly 20.30)	Accuracy, clarity
20	Micturition	Text rewritten	Accuracy, clarity,
21	Aldosterone and antidiuretic hormone	Clarification of sites of action	Clarity
21	Regulation of electrolyte output	Calcitonin included	Clarity
21	Absorption of anions	Mechanism rewritten	Accuracy
21	Chemical buffer systems	Table 21.3 revised	Clarity

SELECTED SPECIFIC CHANGES AT-A-GLANCE —*Continued*

Chapter	Topic	Change	Rationale
21	Acid-base imbalances	Acidemia, alkalemia distinguished from acidosis, alkalosis	Accuracy
21	Alkalosis	Text reorganized into numbered list to parallel presentation of acidosis	Clarity
22	Career Corner, Midwife	Job description and certification rewritten	Accuracy, clarity
22	Prostate gland	Revised secretion description	Accuracy
22	Clinical Application, Prostate Cancer	Revised	Update
22	Terminology—oocyte, ovum (egg), zygote	Terms were changed as per correct usage: oocyte = cell that can and does undergo meiosis I; ovum (egg) = cell that results when the fertilized oocyte completes meiosis II; zygote = cell that results when the nuclei of the sperm and ovum join	Accuracy, clarity
22	Menstrual cycle This will affect other chapters.	Changed from using reproductive cycle to menstrual cycle	Accuracy
22	Birth control	Deleted diaphragm and cervical cap	Update
22	Clinical Application, Breast Cancer	Revised	Update
22	Table 22.6 Diseases Associated with Sexually Transmitted Infections	Changed the numbers of infected cases and added *Trichomonas vaginalis*	Update
23	From Science to Technology, Assisted Reproductive Technologies	Revised	Update
23	Fig. 23.9 Primary germ layers	Redrawn	Accuracy, clarity
23	Clinical Application, Some Causes of Birth Defects	Revised and added Zika virus	Update
23	Fetal blood and oxygen transport	Rewritten	Clarity
23	Clinical Application, Human Milk	Revised	Accuracy
23	Table 23.11 Ten leading causes of death	Reordered and percentages changed as necessary	Accuracy
24	Sister chromatids	Insert added to fig. 24.1	Clarity
24	Meiosis	Reconnect explanation reinforces role of meiosis in inheritance	Detail, clarity
24	Career Corner, Genetic Counselor	Counseling other than face-to-face	Update
24	Eye color inheritance	New *Reconnect* to iris	Clarity
24	Fig. 24.13	Re-ordered so sequence is as in pregnancy: fetal DNA, CVS, amniocentesis	Clarity, update, familiarity
24	Section 24.7, Genomics and Health Care	Complete rewrite, covers genetic testing and treatments	Update

DYNAMIC ART PROGRAM

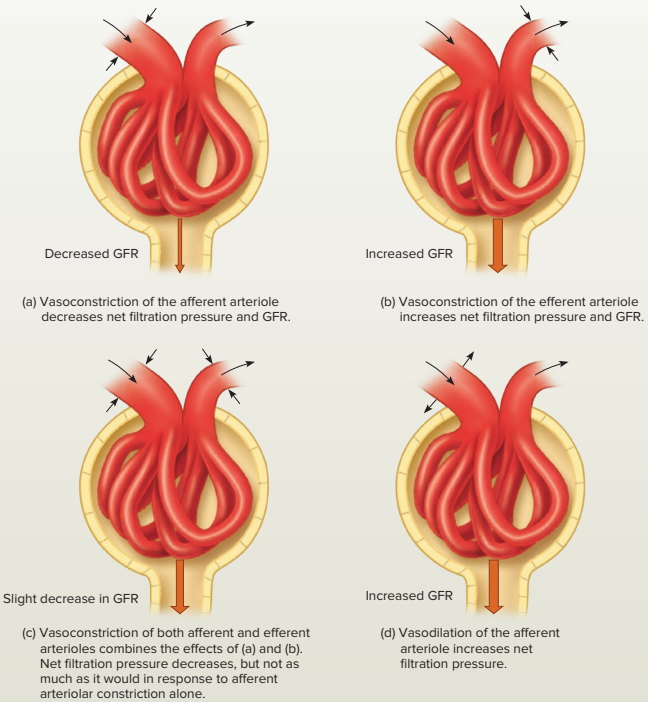
The authors have examined every figure to ensure it is engaging and accurate. The fifteenth edition's art program will help students understand the key concepts of anatomy and physiology.

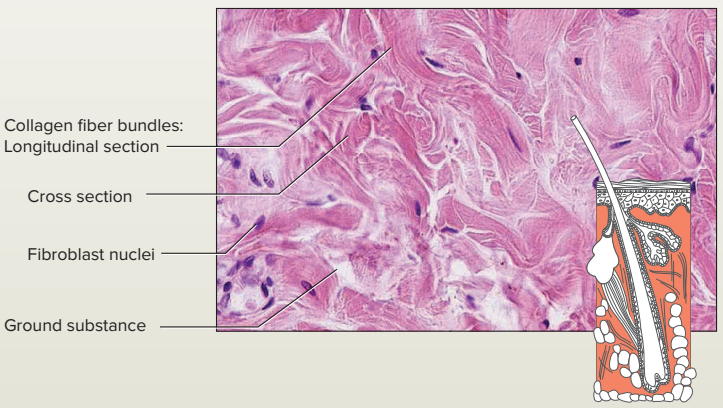


New Art – in some cases line art has been added to help clarify key principles. In other cases micrographs have been replaced for clarity and visual impact.

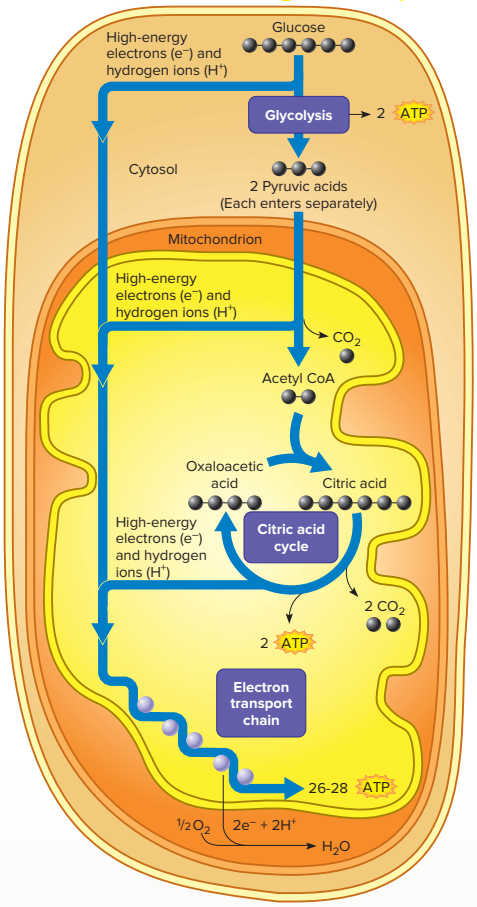
New figure illustrating familiar and physiological examples of positive feedback.

New figure illustrating vascular effects on glomerular filtration rate (GFR)





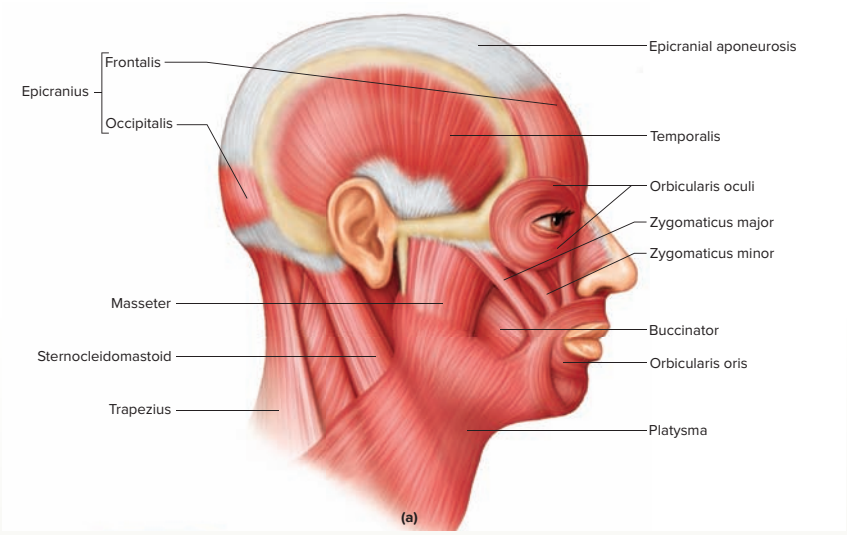
New micrograph showing the structure of dense, irregular connective tissue.



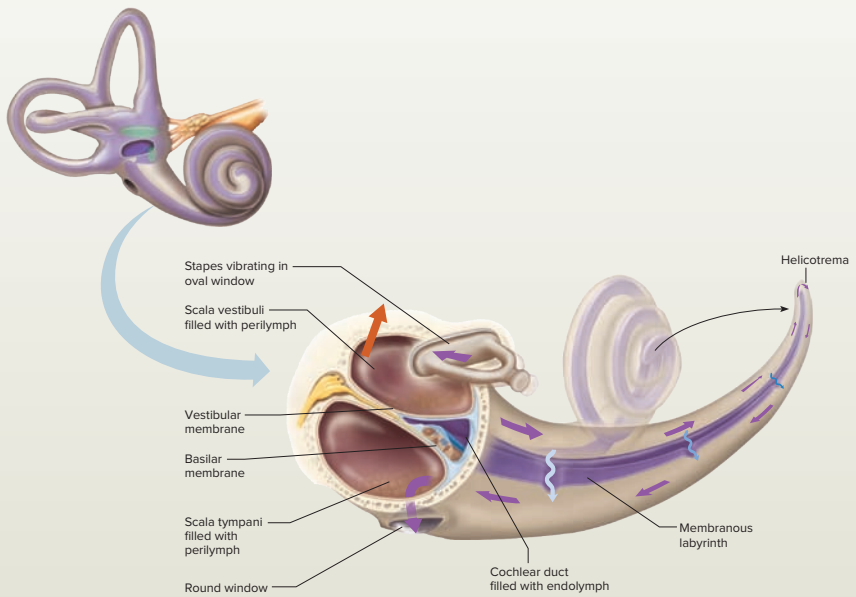
Revised art – Many existing art pieces have been impoved for clarity or updated for accuracy.

Aerobic respiration updated to reflect accepted yields of ATP

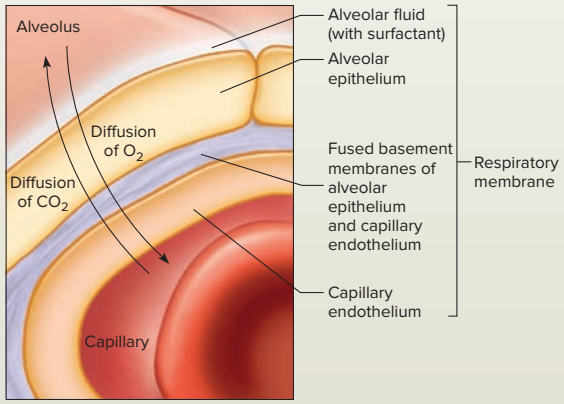
Muscle figures redrawn for accuracy



Sound transduction in the inner ear redrawn for clarity



Respiratory membrane redrawn for accuracy



LEARN, PRACTICE, ASSESS

Learn

Learning tools to help the student succeed. . .

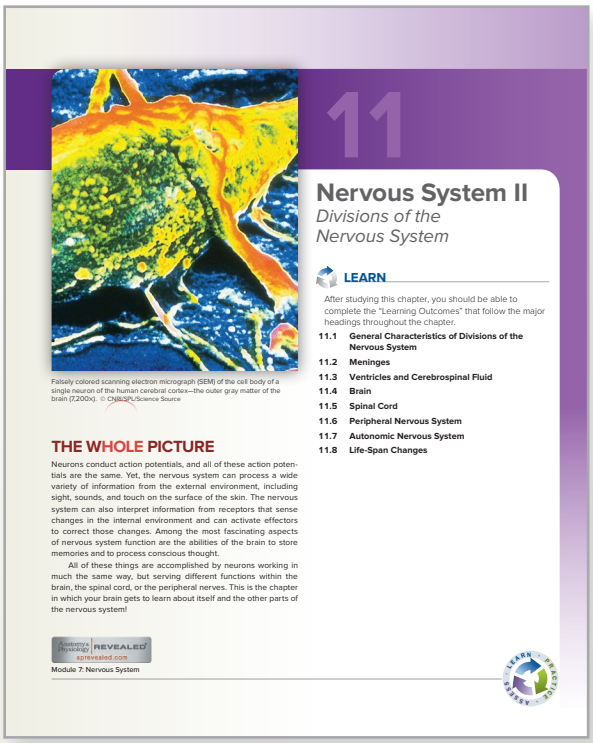
Check out the *Preview, Foundations for Success*, on page 1. The Chapter Preview was specifically designed to help the student **LEARN** how to study. It provides helpful study tips.

LEARN

After studying this chapter, you should be able to complete the "Learning Outcomes" that follow the major headings throughout the chapter.

11.1 General Characteristics of Divisions of the Nervous System

Learning Outcomes have been moved! They now follow the appropriate heading within the chapter. They continue to be closely linked to Chapter Assessments and Integrative Assessments/Critical Thinking questions found at the end of the chapter. Learning Outcomes are also tied to Connect content.


11

Nervous System II

Divisions of the Nervous System

LEARN

After studying this chapter, you should be able to complete the "Learning Outcomes" that follow the major headings throughout the chapter.

11.1 General Characteristics of Divisions of the Nervous System
11.2 Meninges
11.3 Ventricles and Cerebrospinal Fluid
11.4 Brain
11.5 Spinal Cord
11.6 Peripheral Nervous System
11.7 Autonomic Nervous System
11.8 Life-Span Changes

Falsely colored scanning electron micrograph (SEM) of the cell body of a single neuron of the human cerebral cortex—the outer gray matter of the brain (7,200x). © CNRI/Science Source

THE WHOLE PICTURE

Neurons conduct action potentials, and all of these action potentials are the same. Yet, the nervous system can process a wide variety of information from the external environment, including sight, sounds, and touch on the surface of the skin. The nervous system can also interpret information from receptors that sense changes in the internal environment and can activate effectors to correct those changes. Among the most fascinating aspects of nervous system function are the abilities of the brain to store memories and to process conscious thought.

All of these things are accomplished by neurons working in much the same way, but serving different functions within the brain, the spinal cord, or the peripheral nerves. This is the chapter in which your brain gets to learn about itself and the other parts of the nervous system!

Anatomy & Physiology REVEALED 2 aprevealed.com

Module 7: Nervous System

The WHOLE Picture answers the question: "What is the big picture of how this chapter relates to Human Anatomy and Physiology"?

Anatomy and Physiology Revealed (APR) icon at the beginning of each chapter tells which system in APR applies to this chapter.

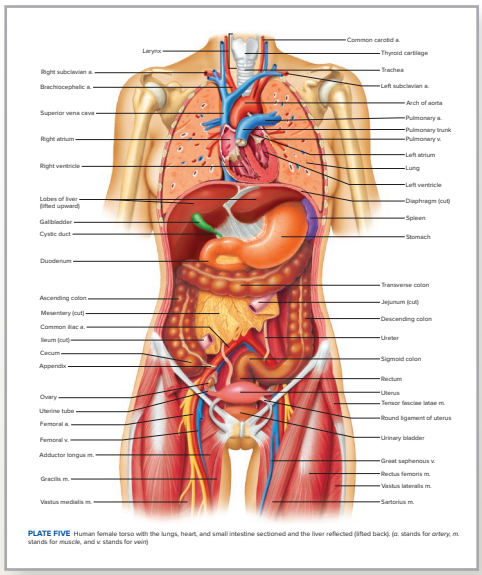


PLATE FIVE Human female torso with the lungs, heart, and small intestine sectioned and the liver reflected (lifted back). (*a.* stands for *artery*, *m.* stands for *muscle*, and *v.* stands for *vein*)

Reference Plates offer detail of body structures.

Practice

Practice questions after major sections test understanding of the material.

PRACTICE

13. What is hemisphere dominance?
14. What are the functions of the nondominant hemisphere?
15. Distinguish between short-term and long-term memory.
16. What is the function of the basal nuclei?

Figure Questions, part of key figures in each chapter, provide an additional assessment.

FIGURE 11.15 APR Spinal cord. (*a*) A cross section of the spinal cord. (*b*) A micrograph of the spinal cord (10×). (b) © Carolina Biological Company/Medical Images

PRACTICE

Where would you expect to find the cell bodies of neurons in the above figure?

Answer can be found in Appendix G.

Understanding Words helps the student remember scientific word meanings. Examine root words, stems, prefixes, suffices, pronunciations, and build a solid anatomy and physiology vocabulary.

UNDERSTANDING WORDS

cephal-, head: enc*epha*litis—inflammation of the brain.
chiasm-, cross: optic *chiasma*—X-shaped structure produced by the crossing over of optic nerve fibers.
flacc-, flabby: *flacc*id paralysis—loss of tone in muscles innervated by damaged axons.
funi-, small cord or fiber: *funi*culus—major nerve tract or bundle of myelinated axons within the spinal cord.
gangli-, swelling: *gangli*on—mass of neuron cell bodies.
mening-, membrane: *mening*es—membranous coverings of the brain and spinal cord.
plex-, interweaving: choroid *plex*us—mass of specialized capillaries associated with spaces in the brain.

Career Corners introduce interesting career opportunities.

CAREER CORNER
Occupational Therapist

The man with amyotrophic lateral sclerosis (ALS, or Lou Gehrig's disease) had been growing frustrated with his increasing inability to carry out the activities of daily living. He couldn't use his hands, and his wrists were growing weaker. A visit from an occupational therapist greatly improved both his independence and his spirit.

The occupational therapist showed the man how to continue to use a bathroom sink by supporting his weight on

Clinical Applications present disorders, physiological responses to environmental factors, and other topics of general interest.

From Science to Technology boxes relate the evolution of modern medical tools, such as tissue engineering and immunotherapy, from the discoveries of basic science.

11.1 CLINICAL APPLICATION
Traumatic Brain Injury

A traumatic brain injury (TBI) results from mechanical force such as from a fall, accident, attack, or sports-related injury. According to the Brain Trauma Foundation, TBI in the United States is the leading cause of death and disability from ages one to forty-four years, and is responsible for 52,000 deaths per year. More than 5 million people have such injuries, which are classified as mild, mild repetitive, or severe.

Mild TBI, also known as a concussion, produces loss of consciousness or altered mental status. Its effects are more psychological than neurological, and it does not appear to cause lasting damage. Symptoms include disturbed sleep, ringing in the ears, memory lapse, balance problems, irritability, and sensitivity to light and sound. These physical symptoms are heightened if the person also suffers from depression or post-traumatic stress disorder (PTSD). Mild TBI may cause PTSD if, as the brain hits the skull, the injury generates a shearing force that impairs the prefrontal cortex's control of a region called the amygdala so that it becomes overactive. As a result, the person cannot let go of psychological trauma, which is the definition of PTSD.

5.2 FROM SCIENCE TO TECHNOLOGY
Tissue Engineering: Building a Replacement Bladder

If an appliance part is damaged or fails, replacing it is simple. Not so for the human body. Donor organs and tissues for transplant are in short supply, so in the future spare parts may come from tissue engineering. In this technology, a patient's cells, extracellular matrix, and other biochemicals are grown with a synthetic scaffold to form an implant. The cells come from the patient, so the immune system does not reject them. Tissue engineering has provided skin, cartilage, bone, and blood vessels. Combining engineered tissues into structures that can replace organs is where the creativity comes in. Consider the replacement bladder.

Each year in the United States, about 10,000 people need their urinary bladders repaired or replaced. Typically a urologic surgeon replaces part of the bladder with part of the large intestine. However, the function of the intestine is to absorb, and the function of the bladder is to hold waste. Tissue engineering is providing a better replacement bladder. The natural organ is balloonlike, with layers of smooth muscle, connective tissue, and a lining of urothelium.

Researchers pioneered replacement bladders in children who have birth defects in which the malfunctioning bladder can harm the kidneys. Each patient donated a postage-stamp-size sample of bladder tissue that consisted of about a million cells, from which the researchers separated two types of progenitor cells—for smooth muscle and urothelium—and let them divide in culture in a specific mixture of growth factors. Within seven weeks the million cells had divided to yield 1.5 billion cells, which were seeded onto domes made of a synthetic material. The confluent layers of cells that formed were attached to the lower portions of the patients' bladders, after removing the upper portions. The scaffolds degenerated over time, leaving new bladders built from the patients' own cells. Today tissue-engineered bladders are also used in adults whose bladders have been removed to treat cancer.

Assess

Tools to help make the connection and master anatomy & physiology!

Chapter Assessments check understanding of the chapter's learning outcomes.

Integrative Assessments/Critical Thinking questions connect and apply information from previous chapters as well as information within the current chapter.

Chapter Summary Outlines help review the chapter's main ideas.

ASSESS
CHAPTER ASSESSMENTS

11.1 General Characteristics of Divisions of the Nervous System
1. Explain the general functions of the brain and spinal cord, and their interrelationship.

11.2 Meninges
2. Name the layers of the meninges, and explain their functions.

11.3 Ventricles and Cerebrospinal Fluid
3. Describe the relationship among the cerebrospinal fluid, the ventricles, the choroid plexuses, and arachnoid granulations.
4. List the functions of cerebrospinal fluid.

18. Name the functions of the midbrain, pons, and medulla oblongata.
19. Describe the location and function of the reticular formation.
20. Distinguish between normal and paradoxical sleep.
21. The cerebellum _____.
    a. communicates with the rest of the CNS
    b. creates awareness of the body's location in space
    c. coordinates skeletal muscle activity
    d. all of the above

11.5 Spinal Cord
22. Describe the structure of the spinal cord.
23. List the two main functions of the spinal cord.

ASSESS
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING

Outcomes 4.4, 11.4
1. In planning treatment for a patient who has had a cerebrovascular accident (CVA), why would it be important to know whether the CVA was caused by a ruptured or obstructed blood vessel?

Outcomes 7.6, 7.7, 11.2, 11.3
2. If a physician plans to obtain a sample of spinal fluid from a patient, what anatomical site can be safely used, and how should the patient be positioned to facilitate this procedure?

4. Brown-Seguard syndrome is due to an injury on one side of the spinal cord. It is characterized by paralysis below the injury and on the same side as the injury, and by loss of sensations of temperature and pain on the opposite side. How would you explain these symptoms?

Outcomes 11.5, 11.6
5. The biceps-jerk reflex employs motor neurons that exit from the spinal cord primarily in the fifth spinal nerve (C5), that is, fifth from the top of the cord. The triceps-jerk reflex involves motor neurons primarily in the seventh spinal nerve (C7). How might these reflexes be used to help locate the site of damage

Chapter Summary

11.1 General Characteristics of Divisions of the Nervous System

The central nervous system (CNS) consists of the brain and spinal cord.

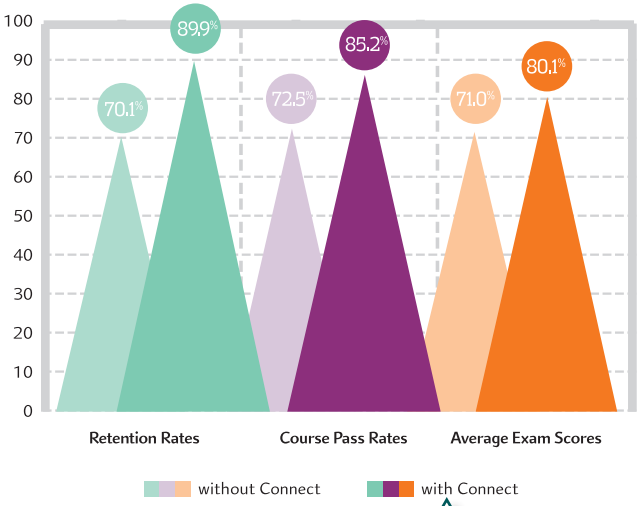
1. The brain oversees sensation and perception, movement, and thinking.
2. The brainstem connects the brain and spinal cord, allowing communication between the two.
3. The spinal cord provides communication between the CNS and the PNS.

McGraw-Hill Connect® is a highly reliable, easy-to-use homework and learning management solution that utilizes learning science and award-winning adaptive tools to improve student results.

Homework and Adaptive Learning

- Connect's assignments help students contextualize what they've learned through application, so they can better understand the material and think critically.
- Connect will create a personalized study path customized to individual student needs through SmartBook®.
- SmartBook helps students study more efficiently by delivering an interactive reading experience through adaptive highlighting and review.

Connect's Impact on Retention Rates, Pass Rates, and Average Exam Scores



Using **Connect** improves retention rates by **19.8%**, passing rates by **12.7%, and** exam scores by **9.1%.**

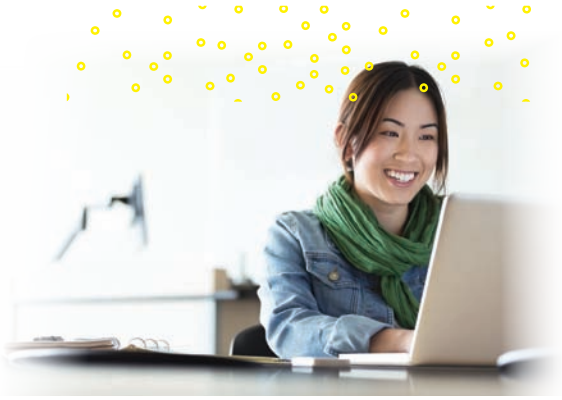
Over **7 billion questions** have been answered, making McGraw-Hill Education products more intelligent, reliable, and precise.

Quality Content and Learning Resources

- Connect content is authored by the world's best subject matter experts, and is available to your class through a simple and intuitive interface.
- The Connect eBook makes it easy for students to access their reading material on smartphones and tablets. They can study on the go and don't need internet access to use the eBook as a reference, with full functionality.
- Multimedia content such as videos, simulations, and games drive student engagement and critical thinking skills.

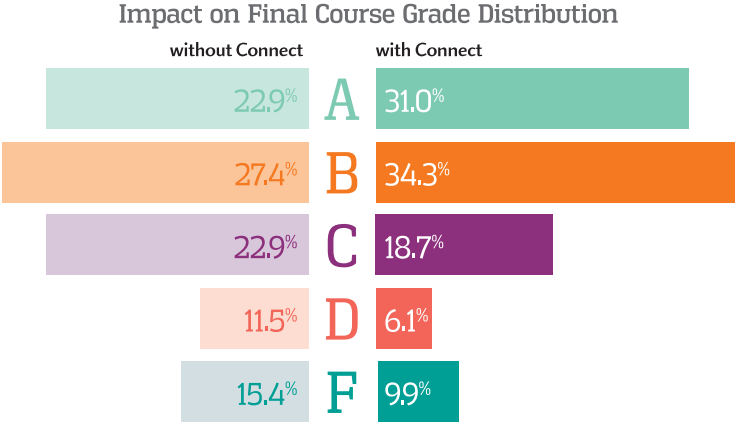
73% of instructors who use **Connect** require it; instructor satisfaction **increases** by 28% when **Connect** is required.

Robust Analytics and Reporting



©Hero Images/Getty Images

- Connect Insight® generates easy-to-read reports on individual students, the class as a whole, and on specific assignments.
- The Connect Insight dashboard delivers data on performance, study behavior, and effort. Instructors can quickly identify students who struggle and focus on material that the class has yet to master.
- Connect automatically grades assignments and quizzes, providing easy-to-read reports on individual and class performance.



More students earn **As** and **Bs** when they use **Connect**.

Trusted Service and Support

- Connect integrates with your LMS to provide single sign-on and automatic syncing of grades. Integration with Blackboard®, D2L®, and Canvas also provides automatic syncing of the course calendar and assignment-level linking.
- Connect offers comprehensive service, support, and training throughout every phase of your implementation.
- If you're looking for some guidance on how to use Connect, or want to learn tips and tricks from super users, you can find tutorials as you work. Our Digital Faculty Consultants and Student Ambassadors offer insight into how to achieve the results you want with Connect.

50% of the country's students are not ready for A&P

LearnSmart® Prep can help!

Improve preparation for the course and increase student success with the only adaptive Prep tool available for students today. Areas of individual weaknesses are identified in order to help students improve their understanding of core course areas needed to succeed.

LEARNSMART®

Prep for A&P

Students seek lab time that fits their busy schedules. Anatomy & Physiology REVEALED 3.2, our Virtual Dissection tool, allows students to practice anytime, anywhere, and now features enhanced physiology interactives with clinical and 3D animations.

Anatomy & Physiology | REVEALED® 3.2

Virtual dissection

Bringing to life complex processes is a challenge. Ph.I.L.S. 4.0 is the perfect way to reinforce key physiology concepts with powerful lab experiments. Tools like physiology interactives, Ph.I.L.S., and world-class animations make it easier than ever.

Ph.I.L.S.

Physiology supplements

The Practice Atlas for Anatomy & Physiology is a new interactive tool that pairs images of common anatomical models with stunning cadaver photography. This atlas allows students to practice naming structures on both models and human bodies, anytime and anywhere.

Practice Atlas for Anatomy & Physiology

Since 2009, our adaptive programs in A&P have hosted 1 million unique users who have answered more than 1 billion questions/probes, providing the only data-driven solutions to help students get from their first college-level course to program readiness.

CONTENTS

About the Authors vi | Acknowledgments viii | Updates and Additions ix | Dynamic Art Program xvi | Learn, Practice, Assess xviii | McGraw-Hill Connect xx | LearnSmart Prep xxii | Contents xxii | Clinical Applications xxviii

PREVIEW

Foundations for Success 1
P.1 Approaches to Learning 2
P.2 Strategies for Success 2
CHAPTER ASSESSMENTS 7
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 8
CHAPTER SUMMARY 8

© Comstock Images/Jupiterimages RF

UNIT 1
LEVELS OF ORGANIZATION 9

CHAPTER **1**
Introduction to Human Anatomy and Physiology 9

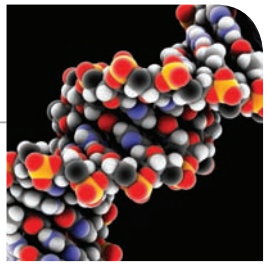
1.1 Origins of Medical Science 10
1.2 Anatomy and Physiology 11
1.3 Levels of Organization 12
1.4 Core Themes in Anatomy and Physiology 14
1.5 Life and the Maintenance of Life 15
1.6 Organization of the Human Body 20
1.7 Life-Span Changes 29
1.8 Anatomical Terminology 29
Some Medical and Applied Sciences 33
CHAPTER ASSESSMENTS 35
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 36
CHAPTER SUMMARY 36

© Brand X Pictures/PunchStock RF

REFERENCE PLATES 1–25
The Human Organism 39

CHAPTER **2**
Chemical Basis of Life 59

2.1 The Importance of Chemistry in Anatomy and Physiology 60
2.2 Structure of Matter 60

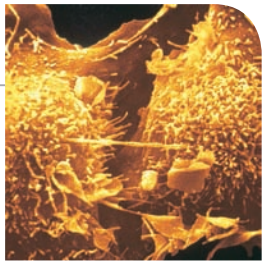


© Science Photo Library/Alamy RF

2.3 Chemical Constituents of Cells 70
CHAPTER ASSESSMENTS 81
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 81
CHAPTER SUMMARY 82

CHAPTER **3**
Cells 84

3.1 Cells Are the Basic Units of the Body 85
3.2 A Composite Cell 85
3.3 Movements Into and Out of the Cell 100
3.4 The Cell Cycle 108
3.5 Control of Cell Division 112
3.6 Stem and Progenitor Cells 114
3.7 Cell Death 115
CHAPTER ASSESSMENTS 118
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 119
CHAPTER SUMMARY 119



© Keith R. Porter/Science Source

CHAPTER **4**
Cellular Metabolism 122

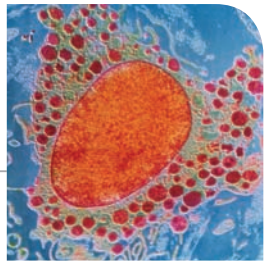
4.1 Metabolic Processes 123
4.2 Control of Metabolic Reactions 125

© Biophoto Associates/ Science Source

4.3 Energy for Metabolic Reactions 127
4.4 Cellular Respiration 129
4.5 Nucleic Acids and Protein Synthesis 134
4.6 Changes in Genetic Information 144
CHAPTER ASSESSMENTS 145
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 146
CHAPTER SUMMARY 147

CHAPTER **5**
Tissues 149

5.1 Cells Are Organized Into Tissues 150
5.2 Epithelial Tissues 151
5.3 Connective Tissues 160
5.4 Types of Membranes 171
5.5 Muscle Tissues 171
5.6 Nervous Tissues 171
CHAPTER ASSESSMENTS 174
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 175
CHAPTER SUMMARY 175

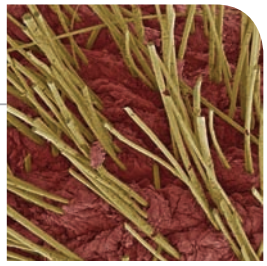


© Science Photo Library/ Getty Images RF

UNIT 2
SUPPORT AND MOVEMENT 178

CHAPTER **6**
Integumentary System 178

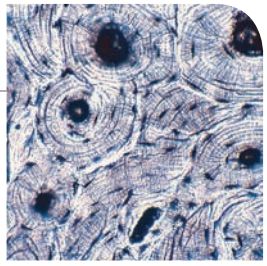
6.1 Skin and Its Tissues 179
6.2 Accessory Structures of the Skin 185
6.3 Skin Functions 190
6.4 Healing of Wounds and Burns 191
6.5 Life-Span Changes 194
INNERCONNECTIONS: INTEGUMENTARY SYSTEM 195
CHAPTER ASSESSMENTS 196
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 197
CHAPTER SUMMARY 197



© Steve Gschmeissner/ Science Source RF

CHAPTER **7**
Skeletal System 200

7.1 Bone Shape and Structure 201
7.2 Bone Development and Growth 203
7.3 Bone Function 210
7.4 Skeletal Organization 213
7.5 Skull 216
7.6 Vertebral Column 227
7.7 Thoracic Cage 232
7.8 Pectoral Girdle 232
7.9 Upper Limb 234
7.10 Pelvic Girdle 239
7.11 Lower Limb 242
7.12 Life-Span Changes 246
CHAPTER ASSESSMENTS 247
INNERCONNECTIONS: SKELETAL SYSTEM 248
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 249
CHAPTER SUMMARY 249



© McGraw-Hill Education/Dennis Strete

REFERENCE PLATES 26–54
Human Skull 253

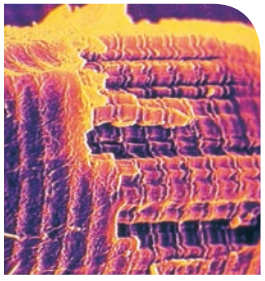
CHAPTER **8**
Joints of the Skeletal System 268

8.1 Types of Joints 269
8.2 Types of Joint Movements 275
8.3 Examples of Synovial Joints 277
8.4 Life-Span Changes 285
CHAPTER ASSESSMENTS 289
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 289
CHAPTER SUMMARY 290

© Keith Brofsky/Getty Images RF

CHAPTER **9**
Muscular System 292

9.1 Structure of a Skeletal Muscle 293
9.2 Skeletal Muscle Contraction 297
9.3 Muscular Responses 304
9.4 Smooth Muscle 308
9.5 Cardiac Muscle 309
9.6 Skeletal Muscle Actions 310
9.7 Major Skeletal Muscles 313
9.8 Life-Span Changes 341
CHAPTER ASSESSMENTS 341
INNERCONNECTIONS:: MUSCULAR SYSTEM 342
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 343
CHAPTER SUMMARY 344



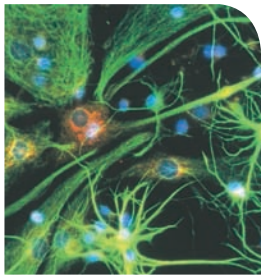
© CNRI/Science Source

REFERENCE PLATES 55–75 347
Surface Anatomy and Cadaver Dissection 347

UNIT 3
INTEGRATION AND COORDINATION 359

CHAPTER **10**

Nervous System I: Basic Structure and Function 359



© N. Kedersha/Science Source

10.1 General Characteristics of the Nervous System 360
10.2 General Functions of the Nervous System 361
10.3 Description of Cells of the Nervous System 363
10.4 Classification of Cells of the Nervous System 363
10.5 The Synapse 370
10.6 Cell Membrane Potential 372
10.7 Synaptic Transmission 378
10.8 Impulse Processing 382

CHAPTER ASSESSMENTS 383
INNERCONNECTIONS: NERVOUS SYSTEM 385
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 386
CHAPTER SUMMARY 386

CHAPTER **11**

Nervous System II: Divisions of the Nervous System 389

© CNRI/SPL/Science Source

11.1 General Characteristics of the Divisions of the Nervous System 390
11.2 Meninges 391
11.3 Ventricles and Cerebrospinal Fluid 392
11.4 Brain 395
11.5 Spinal Cord 409
11.6 Peripheral Nervous System 417
11.7 Autonomic Nervous System 428
11.8 Life-Span Changes 438

CHAPTER ASSESSMENTS 439
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 440
CHAPTER SUMMARY 440

CHAPTER **12**

Nervous System III: Senses 444

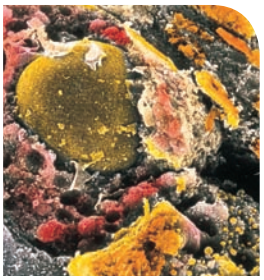
© SPL/Science Source

12.1 General Characteristics of Sensory Function 445
12.2 Receptors, Sensation, and Perception 446
12.3 General Senses 447
12.4 Special Senses 453
12.5 Life-Span Changes 483

CHAPTER ASSESSMENTS 484
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 485
CHAPTER SUMMARY 486

CHAPTER **13**

Endocrine System 489



© Prof. P. Motta/Univ. "La Sapienza", Rome/SPL/Science Source

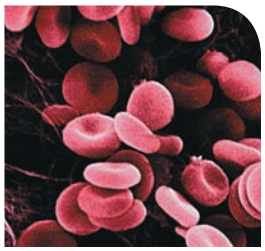
13.1 General Characteristics of the Endocrine System 490
13.2 Hormone Action 491
13.3 Control of Hormonal Secretions 498
13.4 Pituitary Gland 499
13.5 Thyroid Gland 506
13.6 Parathyroid Glands 509
13.7 Adrenal Glands 511
13.8 Pancreas 516
13.9 Other Endocrine Glands 518
13.10 Stress and Its Effects 521
13.11 Life-Span Changes 523

INNERCONNECTIONS: ENDOCRINE SYSTEM 524
CHAPTER ASSESSMENTS 525
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 526
CHAPTER SUMMARY 526

UNIT 4
TRANSPORT 529

CHAPTER **14**

Blood 529



© Image Source/Getty Images RF

14.1 Characteristics of Blood 530
14.2 Blood Cells 531
14.3 Plasma 543
14.4 Hemostasis 545
14.5 Blood Groups and Transfusions 550

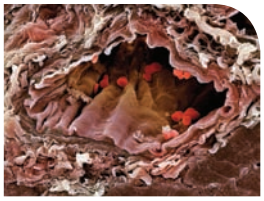
CHAPTER ASSESSMENTS 554
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 555
CHAPTER SUMMARY 555

CHAPTER **15**

Cardiovascular System 558

15.1 General Characteristics of the Cardiovascular System 559
15.2 The Heart 559
15.3 Blood Vessels 576
15.4 Blood Pressure 584
15.5 Paths of Circulation 592
15.6 Arterial System 593
15.7 Venous System 604
15.8 Life-Span Changes 610

CHAPTER ASSESSMENTS 612
INNERCONNECTIONS: CARDIOVASCULAR SYSTEM 613
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 614
CHAPTER SUMMARY 615



© Steve Gschmeissner/ Science Source RF

CHAPTER **16**

Lymphatic System and Immunity 618

16.1 Lymphatic Pathways 619
16.2 Tissue Fluid and Lymph 622
16.3 Lymphatic Tissues and Lymphatic Organs 623
16.4 Body Defenses Against Infection (Immunity) 628
16.5 Life-Span Changes 644

INNERCONNECTIONS: LYMPHATIC SYSTEM 645
CHAPTER ASSESSMENTS 646
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 647
CHAPTER SUMMARY 647

© Dr. Kari Lounatmaa/Science Source

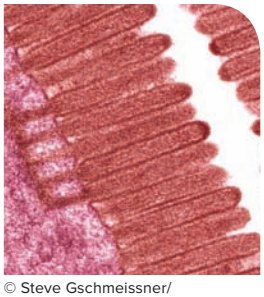
UNIT 5
ABSORPTION AND EXCRETION 651

CHAPTER **17**

Digestive System 651

17.1 General Characteristics of the Digestive System 652
17.2 Mouth 655
17.3 Salivary Glands 660
17.4 Pharynx and Esophagus 662
17.5 Stomach 665
17.6 Pancreas 670
17.7 Liver and Gallbladder 671
17.8 Small Intestine 678
17.9 Large Intestine 685
17.10 Life-Span Changes 690

INNERCONNECTIONS: DIGESTIVE SYSTEM 691
CHAPTER ASSESSMENTS 692
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 693
CHAPTER SUMMARY 693



© Steve Gschmeissner/ Science Source RF

CHAPTER **18**

Nutrition and Metabolism 696

18.1 Carbohydrates 697
18.2 Lipids 698
18.3 Proteins 700
18.4 Energy Expenditures 702
18.5 Appetite Control 706
18.6 Vitamins 706
18.7 Minerals 713
18.8 Healthy Eating 718
18.9 Life-Span Changes 725

CHAPTER ASSESSMENTS 725
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 727
CHAPTER SUMMARY 727

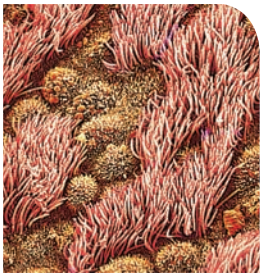
© Digital Vision/Getty Images RF

CHAPTER **19**

Respiratory System 731

19.1 General Characteristics of thex Respiratory System 732
19.2 Organs of the Respiratory System 732
19.3 Breathing Mechanism 742
19.4 Control of Breathing 751
19.5 Alveolar Gas Exchanges 755
19.6 Gas Transport 759
19.7 Life-Span Changes 763

INNERCONNECTIONS: RESPIRATORY SYSTEM 764
CHAPTER ASSESSMENTS 765
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 766
CHAPTER SUMMARY 766

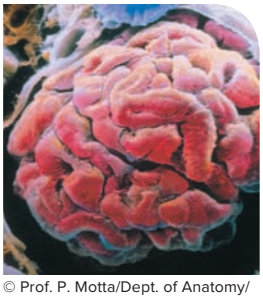


© Susumu Nishinaga/SPL/ Science Source

CHAPTER **20**

Urinary System 769

20.1 General Characteristics of the Urinary System 770
20.2 Kidneys 770
20.3 Urine Formation 778



© Prof. P. Motta/Dept. of Anatomy/ University "La Sapienza" Rome/ SPL/Science Source

20.4 Storage and Elimination of Urine 793
20.5 Life-Span Changes 799
CHAPTER ASSESSMENTS 799
INNERCONNECTIONS: URINARY SYSTEM 800
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 801
CHAPTER SUMMARY 801

CHAPTER **21**
Water, Electrolyte, and Acid-Base Balance 804

21.1 The Balance Concept 805
21.2 Distribution of Body Fluids 805

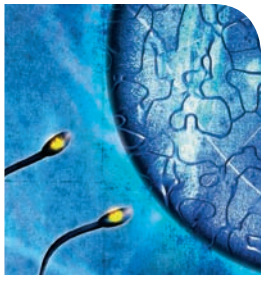
© Prof. P.M. Motta & M. Castellucci/SPL/Science Source

21.3 Water Balance 807
21.4 Electrolyte Balance 811
21.5 Acid-Base Balance 813
21.6 Acid-Base Imbalances 818
21.7 Compensation 820
CHAPTER ASSESSMENTS 821
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 821
CHAPTER SUMMARY 822

UNIT 6
THE HUMAN LIFE CYCLE 824

CHAPTER **22**
Reproductive Systems 824

22.1 Meiosis and Sex Cell Production 825
22.2 Organs of the Male Reproductive System 827
22.3 Hormonal Control of Male Reproductive Functions 839



© Brand X Pictures RF

22.4 Organs of the Female Reproductive System 840
22.5 Hormonal Control of Female Reproductive Functions 849
22.6 Mammary Glands 853
22.7 Birth Control 854
22.8 Sexually Transmitted Infections 858
CHAPTER ASSESSMENTS 861
INNERCONNECTIONS: REPRODUCTIVE SYSTEMS 862
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 863
CHAPTER SUMMARY 863

CHAPTER **23**
Pregnancy, Growth, and Development 868

23.1 Fertilization 869
23.2 Pregnancy and the Prenatal Period 871
23.3 Postnatal Period 895
23.4 Aging 900
CHAPTER ASSESSMENTS 902
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 903
CHAPTER SUMMARY 903

© Big Cheese Photo/Jupiterimages RF

CHAPTER **24**
Genetics and Genomics 907

24.1 Genes and Genomes 908
24.2 Modes of Inheritance 909
24.3 Factors That Affect Expression of Single Genes 913
24.4 Multifactorial Traits 914
24.5 Matters of Sex 916
24.6 Chromosome Disorders 917
24.7 Genomics and Healthcare 922
CHAPTER ASSESSMENTS 923
INTEGRATIVE ASSESSMENTS/CRITICAL THINKING 924
CHAPTER SUMMARY 925

© Barros & Barros/Getty Images

APPENDIX **A** Scientific Method 927
APPENDIX **B** Metric Measurement System and Conversions 928
APPENDIX **C** Laboratory Tests of Clinical Importance 929
APPENDIX **D** Periodic Table of the Elements 932
APPENDIX **E** Cellular Respiration 933
APPENDIX **F** A Closer Look at DNA and RNA Structures 937
APPENDIX **G** Figure Question Answers 939

Glossary 940
Index 963

CLINICAL CONNECTIONS

Clinical Applications

CHAPTER 1
1.1: Ultrasonography and Magnetic Resonance Imaging: A Tale of Two Patients 13

CHAPTER 3
3.1: Faulty Ion Channels Cause Disease 91
3.2: Disease at the Organelle Level 96

CHAPTER 4
4.1: Inborn Errors of Metabolism 128

CHAPTER 5
5.1: The Body's Glue: The Extracellular Matrix 162
5.2: Abnormalities of Collagen 164

CHAPTER 6
6.1: Indoor Tanning and Skin Cancer 183
6.2: Hair Loss 187
6.3: Acne 189
6.4: Elevated Body Temperature 192

CHAPTER 7
7.1: Fractures 210
7.2: Preventing Fragility Fractures 213
7.3: Disorders of the Vertebral Column 231

CHAPTER 8
8.1: Joint Disorders 286
8.2: Replacing Joints 288

CHAPTER 9
9.1: Some Muscular System Disorders 299
9.2: Use and Disuse of Skeletal Muscles 308
9.3: TMJ Syndrome 316

CHAPTER 10
10.1: Migraine 362
10.2: Multiple Sclerosis 367
10.3: Factors Affecting Impulse Conduction 379
10.4: Opiates in the Human Body 382
10.5: Drug Addiction 384

CHAPTER 11
111: Traumatic Brain Injury 392
11.2: Cerebrospinal Fluid Pressure 396
11.3: Parkinson Disease 404
11.4: Brain Waves 410
11.5: Uses of Reflexes 414
11.6: Amyotrophic Lateral Sclerosis 419
11.7: Spinal Cord Injuries 420
11.8: Spinal Nerve Injuries 431

CHAPTER 12
12.1: Treating Pain 451
12.2: Mixed-Up Senses—Synesthesia 454
12.3: Smell and Taste Disorders 457
12.4: Middle Ear Infection 460
12.5: Getting a Cochlear Implant 463
12.6: Hearing Loss 467
12.7: Refraction Disorders 479

CHAPTER 13
13.1: Abusing Hormones to Improve Athletic Performance 496
13.2: Growth Hormone Ups and Downs 503
13.3: Disorders of the Adrenal Cortex 516
13.4: Diabetes Mellitus 519

CHAPTER 14
14.1: Universal Precautions 532
14.2: Leukemia 542
14.3: Deep Vein Thrombosis 549

CHAPTER 15
15.1: Arrhythmias 578
15.2: Blood Vessel Disorders 586
15.3: Hypertension 591
15.4: Exercise and the Cardiovascular System 593
15.5: Molecular Causes of Cardiovascular Disease 611
15.6: Coronary Artery Disease 612

CHAPTER 16
16.1: Immunity Breakdown: HIV/AIDS 643

CHAPTER 17
17.1: Dental Caries 660
17.2: A Common Problem: Heartburn 669
17.3: Hepatitis 676
17.4: Gallbladder Disease 677
17.5: Disorders of the Large Intestine 689

CHAPTER 18
18.1: Obesity 705
18.2: Dietary Supplements—Proceed with Caution 720
18.3: Nutrition and the Athlete 723

CHAPTER 19
19.1: The Effects of Cigarette Smoking on the Respiratory System 735
19.2: Lung Irritants 744
19.3: Respiratory Disorders That Decrease Ventilation: Bronchial Asthma and Emphysema 751
19.4: Exercise and Breathing 755
19.5: Effects of High Altitude 757
19.6: Disorders That Impair Gas Exchange 758

CHAPTER 20
20.1: Glomerulonephritis 778
20.2: The Nephrotic Syndrome 787
20.3: Chronic Kidney Disease 794
20.4: Kidney Stones 795
20.5: Urinalysis: Clues to Health 798

CHAPTER 21
21.1: Water Balance Disorders 810
21.2: Sodium and Potassium Imbalances 814

CHAPTER 22
22.1: Prostate Cancer 835
22.2: Male Infertility 836
22.3: Female Infertility 854
22.4: Treating Breast Cancer 856

CHAPTER 23
23.1: Some Causes of Birth Defects 882
23.2: Human Milk—The Perfect Food for Human Babies 896
23.3: Living to 100—And Beyond 901

CHAPTER 24
24.1: Down Syndrome 919

From Science to Technology

CHAPTER 2
2.1: Radioactive Isotopes Reveal Physiology 63
2.2: Ionizing Radiation: From the Cold War to Yucca Mountain 64
2.3: CT Scanning and PET Imaging 80

CHAPTER 3
3.1: Stem Cells to Study and Treat Disease 116

CHAPTER 4
4.1: The Human Metabolome 126
4.2: DNA Profiling Frees a Prisoner 138

CHAPTER 5
5.1: Nanotechnology Meets the Blood-Brain Barrier 151
5.2: Tissue Engineering: Building a Replacement Bladder 173

CHAPTER 13
13.1: Treating Diabetes 520

CHAPTER 14
14.1: Treating Sickle Cell Disease 535

CHAPTER 15
15.1: Replacing the Heart—From Transplants to Stem Cell Implants 569
15.2: Altering Angiogenesis 580

CHAPTER 16
16.1: Immunotherapy 635

CHAPTER 17
17.1: Replacing the Liver 673

CHAPTER 23
23.1: Assisted Reproductive Technologies 872
23.2: Preimplantation Genetic Diagnosis 875

A photo on the opening page for each chapter generates interest.
© Comstock Images/Jupiterimages RF

PREVIEW

Foundations for Success

The Preview Chapter not only provides great study tips to offer a foundation for success, but it also offers tips on how to utilize this particular text. Those tips are found in boxes just like this.

Each chapter opens with a learning outline that introduces topics to be discussed in the chapter.

The Whole Picture presents a snapshot of the chapter content and explains how it relates to new knowledge you will be adding to your knowledge base.

THE WHOLE PICTURE

Students often wonder why they are required to take anatomy and physiology in preparation for a career as a healthcare professional. An understanding of homeostasis and normal anatomy and physiology helps the healthcare professional recognize disease as it occurs in their patients.

Students should remember that among the reasons they are taking this course is to build a solid foundation for caring for their future patients.

This digital tool, as indicated below and with the APR icons within the chapters, allows you to explore the human body in depth through simulated dissection of cadavers and histology preparations. It also offers animations on chapter concepts.

Anatomy & Physiology REVEALED
aprevealed.com

LEARN

After studying this chapter, you should be able to complete the "Learning Outcomes" that follow the major headings throughout the chapter.

P.1 Approaches to Learning
P.2 Strategies for Success

Each activity geared to your success—LEARN, PRACTICE, ASSESS—is associated with a colored arrow. The particular arrow is highlighted when an activity is introduced. Note the blue arrow representing LEARN at the beginning of the learning outline at the top of the right-hand column on this page.

UNDERSTANDING WORDS

ana-, up: *ana*tomy—the study of breaking up the body into its parts.
multi-, many: *multi*tasking—performing several tasks simultaneously.
physio-, relationship to nature: *physio*logy—the study of how body parts function.

This section introduces building blocks of words that your instructor may assign. Learning them is a good investment of your time, because they can be used over and over and apply to many of the terms you will use in your career. Inside the back cover and on the facing page is a comprehensive list of these prefixes, suffixes, and root words.

Major divisions within a chapter are called "A-heads." They are numbered sequentially and set in a large colored font. A-heads designate major content areas.

P.1 | Approaches to Learning

After each A-head is a list of Learning Outcomes indicating knowledge you should gain as you work through the section. These outcomes are intended to help you master the similar outcomes set by your instructor. The outcomes are tied directly to assessments of knowledge gained.

LEARN

1. Explain the importance of an individualized approach to learning.

Studying the human body can be overwhelming at times. The new terminology, used to describe body parts and how they work, can make it seem as if you are studying a foreign language. Learning all the parts of the body, along with the composition of each part, and how each part fits with the other parts to make the whole requires memorization. Understanding the way each body part works individually, as well as body parts working together, requires a higher level of knowledge, comprehension, and application. Identifying underlying structural similarities, from the macroscopic to the microscopic levels of body organization, taps more subtle critical thinking skills. This chapter will catalyze success in this active process of learning. (Remember that while the skills and tips discussed in this chapter relate to learning anatomy and physiology, they can be applied to other subjects.)

Learning occurs in different ways or modes. Most students use several modes (multimodal), but are more comfortable and use more effectively one or two, often referred to as learning styles. Some students prefer to read the written word to remember it and the concept it describes or to actually write the words; others learn best by looking at visual representations, such as photographs and drawings. Still others learn most effectively by hearing the information or explaining it to someone else. For some learners, true understanding remains elusive until a principle is revealed in a laboratory or clinical setting that provides a memorable context and engages all of the senses. This text accommodates the range of learning styles. Read-write learners will appreciate the lists, definitions (**glossary**), and tables. Visual learners will discover many diagrams, flow charts, and figures, all with consistent and purposeful use of color. For example, a particular bone is always the same color in figures where bones are color coded. Auditory learners will find pronunciations for new scientific terms to help sound them out, and kinesthetic learners can relate real-life examples and applications to their own acitvities.

After each major section, a question or series of questions or an activity tests your understanding of the material and enables you to practice using the new information. If you cannot answer the question(s) or complete the activity you should reread that section, being on the lookout for the answer(s).

PRACTICE

1. List some difficulties a student may experience when studying the human body.
2. Describe the ways that people learn.

P.2 | Strategies for Success

LEARN

2. Summarize what you should do before attending class.
3. Identify student activities that enhance the classroom experience.
4. List and describe several study techniques that facilitate learning new material.

Many of the strategies for academic success are common sense, but it might help to review them. You may encounter new and helpful methods of learning.

The major divisions are subdivided into "B-heads," which are presented in a large reddish-orange font. These will help you organize the concepts upon which the major divisions are built.

Before Class

Before attending class, prepare by reading and outlining or taking notes on the assigned pages of the text. If outlining, leave adequate space between entries to allow room for note-taking during lectures. Or, fold each page of notes taken before class in half so that class notes can be written on the blank side of the paper across from the reading notes on the same topic. This strategy introduces the topics of the next class discussion, as well as new terms. Some students team a vocabulary list with each chapter's notes. Take the notes from the reading to class and expand them. At a minimum, the student should at least skim through the text, reading A-heads, B-heads, and the chapter summary to become acquainted with the topics and vocabulary before class.

Sometimes in your reading you will be directed back ("Reconnect") to a related concept, discussed in an earlier chapter, to help you better understand the new concept that is being explained. The opposite of looking back and reconnecting is looking ahead. "A Glimpse Ahead" applies concepts being discussed in the particular section of the text to future learning. Chapter 1 (section 1.4, Common Themes in Anatomy and Physiology) introduces core concepts. The Reconnect and A Glimpse Ahead features indicate the applicable common theme and tell how the information is incorporated into understanding the functioning of other body systems.

LEARN

RECONNECT: HOMEOSTASIS | **To Section 1.5,** Life and the Maintenance of Life, Homeostasis

A rate-limiting enzyme acts like a thermostat, maintaining the level of the product of a metabolic pathway.

LEARN

A GLIMPSE AHEAD: GRADIENTS AND PERMEABILITY | **To Section 10.6,** Cell Membrane Potential, Distribution of Ions

The energy we must expend just to stay alive is called the basal metabolic energy. The body uses close to 40% of the basal metabolic energy to actively transport sodium and potassium ions across cell membranes. Imagine learning that 40% of your household budget went for one item—it had better be important! In this case it is. The concentration gradients for sodium and potassium ions that the sodium/potassium pumps establish throughout the body are essential for muscle and nerve cells to function. Chapters 9 and 10 further discuss the functioning of these important cell types.

Students using this book and taking various courses are often preparing for careers in health care. Some students may be undecided as to a specific area or specialty. The Career Corner presents a description of a particular career choice with each chapter.

As you read, you may feel the need for a "study break" or to "chill out." Other times, you may just need to shift gears. Try the following: Look for Clinical Application boxes and From Science to Technology boxes that present sidelights to the main focus of the text. Some of these may cover topics that your instructor chooses to highlight. Read them! They are interesting, informative, and a change of pace.

CAREER CORNER

Radiologic Technologist

At age fifty-two the woman is younger than most of the others having their bone mineral density measured. She had been advised by her gynecologist to have a baseline test to assess the health of her skeleton because her parents had osteoporosis.

A radiologic technologist conducts the test. She explains the procedure to the patient, then positions her on her back on a padded table, fully clothed. The scanner passes painlessly over the patient's hip and lower spine, emitting low-dose X rays that form images of the bones. Spaces on the scan indicate osteopenia, the low bone mineral density that may be a prelude to osteoporosis.

Radiologic technologists administer medical imaging tests, such as ultrasound and magnetic resonance imaging (MRI), as well as mammography and the X-ray cross sections of computerized tomography (CT). They protect patients from radiation with drapes. By positioning the patients and operating scanning devices, they produce images from which a radiologist can diagnose an illness or injury.

A registered radiologic technologist completes two years of training at a hospital or a two- or four-year program at a college or university, and must pass a national certification exam.

9.3 CLINICAL APPLICATION

TMJ Syndrome

Temporomandibular joint (TMJ) syndrome causes facial pain, headache, ringing in the ears, a clicking jaw, insomnia, teeth sensitive to heat or cold, backache, dizziness, and pain in front of the ears. A misaligned jaw or grinding or clenching the teeth can cause TMJ by stressing the temporomandibular joint, which is the articulation between the mandibular condyle of the mandible and the mandibular fossa of the temporal bone. Loss of coordination of these structures affects the nerves that pass through the neck and jaw region, causing the symptoms.

Getting enough sleep and drinking enough water can help prevent symptoms of TMJ, and eating soft foods, applying ice packs, using relaxation techniques, and massaging affected muscles can alleviate symptoms. A physical therapist can recommend exercises that stretch and relax the jaw, which may help some people. Sitting for long hours in one position can cause or worsen TMJ.

Doctors diagnose TMJ syndrome using an electromyograph, in which electrodes record muscle activity in four pairs of head and neck muscle groups. Several treatments are available. The National Institute of Dental and Craniofacial Research recommends that treatments not permanently alter the teeth or jaw. Low doses of certain antidepressants, or injections of botulinum toxin or corticosteroids, may help. Using a procedure called arthrocentesis, a physician might remove fluid accumulating in the affected joint. Another treatment is an oral appliance fitted by a dentist that fine-tunes the action of jaw muscles to form a more comfortable bite. An oral appliance, also known as a bite guard or stabilization splint, is a piece of plastic that fits over the top or bottom teeth. Very rarely, surgery may be required to repair or replace a joint.

4.1 FROM SCIENCE TO TECHNOLOGY

The Human Metabolome

A generation ago, prehealth profession students had to memorize a complex chart of biochemical pathways that represent all of the energy reactions in a cell. The cellular respiration pathways ran down the center, with branches radiating outward and in some places interconnecting into a giant web. Today, several technologies as well as the ability to store massive amounts of data have made possible the Human Metabolome Database.

"Metabolome" refers to all of the small molecules that are part of metabolism in a cell, tissue, organ, or an entire organism. The database is a vast, annotated catalog of those molecules, "metabolites." The government of Canada is supporting the effort to search all published papers and books that describe metabolites and link that information with experimental data. The techniques of electrophoresis and chromatography are used to separate metabolites, and mass spectrometry (MS) and nuclear magnetic resonance (NMR) spectroscopy describe the chemical characteristics of metabolites.

Biochemists estimate that human cells have at least 2,500 different metabolites, but fewer than half have been identified. Far fewer have been analyzed for their concentrations in different cell types under different conditions. In the Human Metabolome Database, each entry has an electronic "MetaboCard" that includes 90 data fields, half with clinical data (such as associated diseases and drug interactions) and half with biochemical data (such as pathways and enzymes that interact with the metabolite). Each entry is also hyperlinked to other databases, interfacing with 1,500 drugs and 3,600 foods and food additives. The information in the Human Metabolome Database is being used in drug discovery, toxicology, transplant monitoring, clinical chemistry, disease diagnosis, and screening of newborns for metabolic diseases.

Anatomy and physiology are visual, connected sciences that operate on several levels, from molecules of a muscle through the whole-body effort of movement. The many vivid photographs, illustrations, diagrams, and tables in this book help you master the material and are excellent review tools.

Photographs and Line Art

Sometimes subdivisions have so many parts that the book goes to a third level, the "C-head." This division is identified in a slightly smaller, black font.

Photographs provide a realistic view of anatomy.

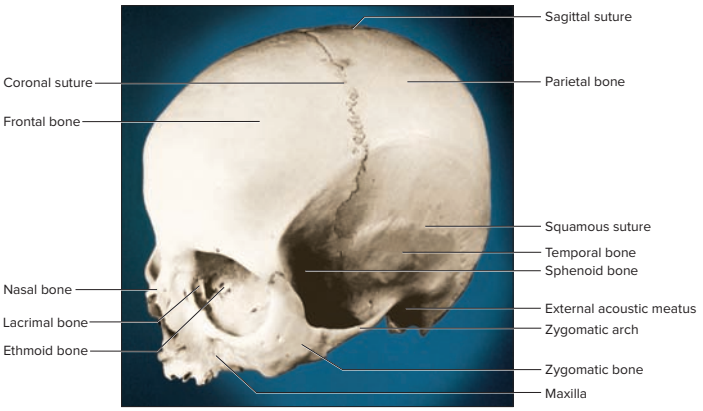


PLATE TWENTY-SEVEN The skull, left anterolateral view.

Line art can present different positions, layers, or perspectives.

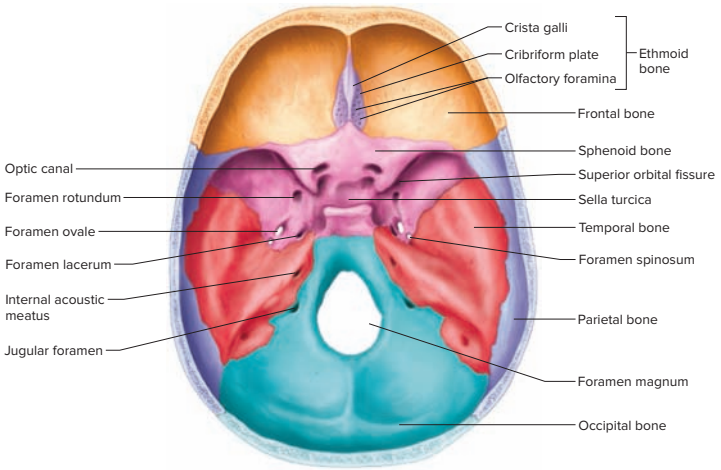


FIGURE 7.26 Floor of the cranial cavity, viewed from above.

Macroscopic to Microscopic

Many figures show anatomical structures in a manner that is macroscopic to microscopic (or vice versa).

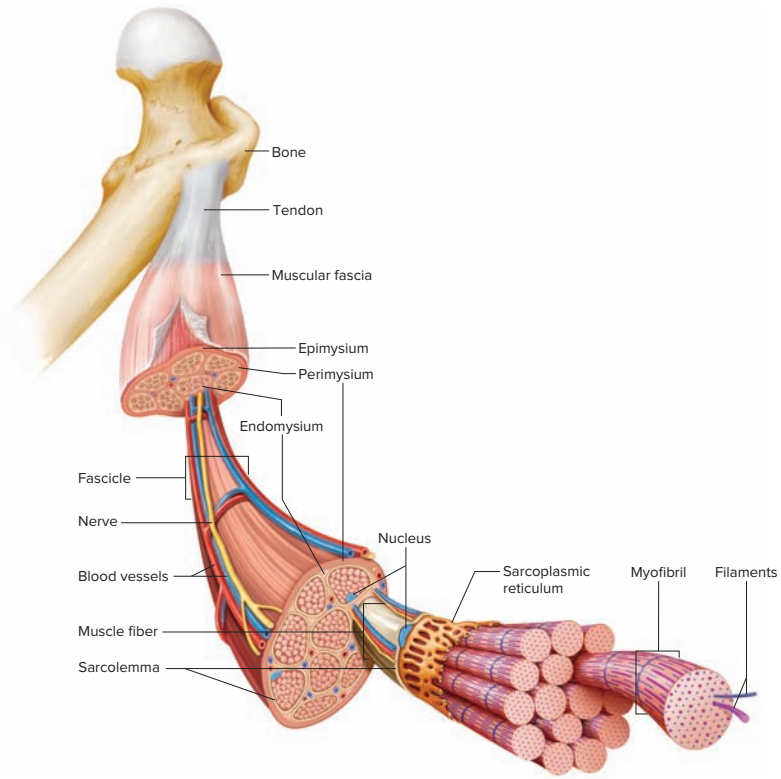


FIGURE 9.2 AP|R A skeletal muscle is composed of a variety of tissues, including layers of connective tissue. Fascia covers the surface of the muscle, epimysium lies beneath the fascia, and perimysium extends into the structure of the muscle where it separates fascicles. Endomysium separates individual muscle fibers.

Figure questions encourage you to think about what you are seeing and "PRACTICE" making connections between the visual representation and the words in the text.

Flow Charts

Flow charts depict sequences of related events, steps of pathways, and complex concepts, easing comprehension. Other figures may show physiological processes.

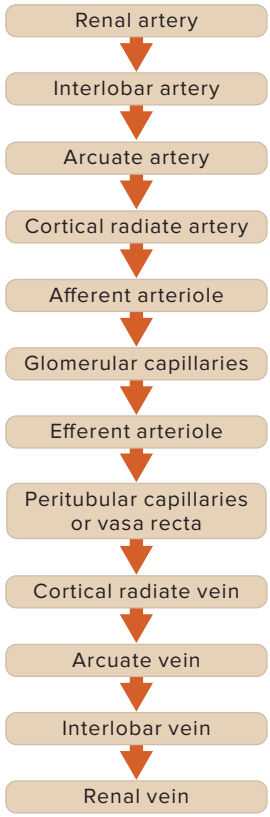


FIGURE 20.8 Pathway of blood through the blood vessels of the kidney and nephron.

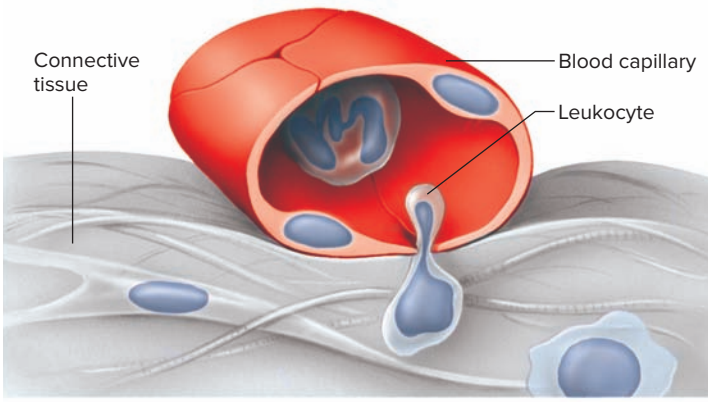


FIGURE 14.15 In a type of movement called diapedesis, leukocytes squeeze between the endothelial cells of a capillary wall and enter the tissue space outside the blood vessel.

PRACTICE

What is a monocyte called once it has left the bloodstream and entered the tissues?

Answer can be found in Appendix G.

Anatomical Structures

Some figures illustrate the locations of anatomical structures.

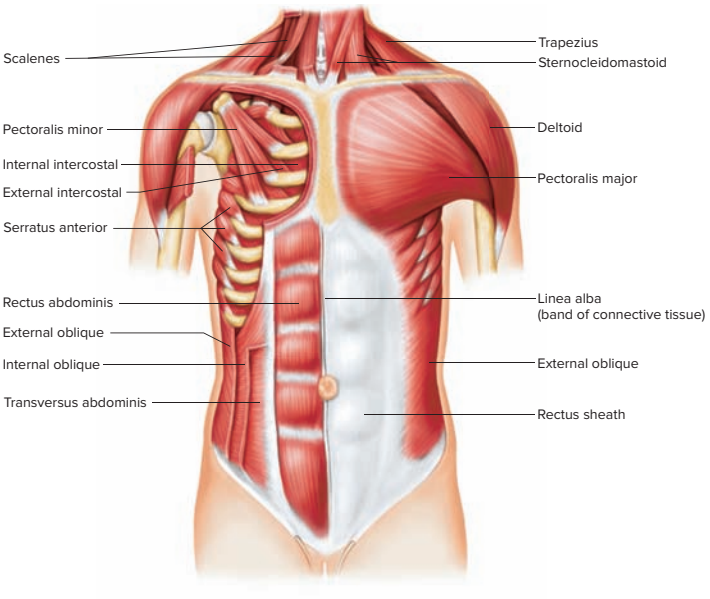


FIGURE 9.28 AP|R Muscles of the anterior chest and abdominal wall. The right pectoralis major and external oblique are removed to show underlying muscles.

Other figures illustrate the functional relationships of anatomical structures.

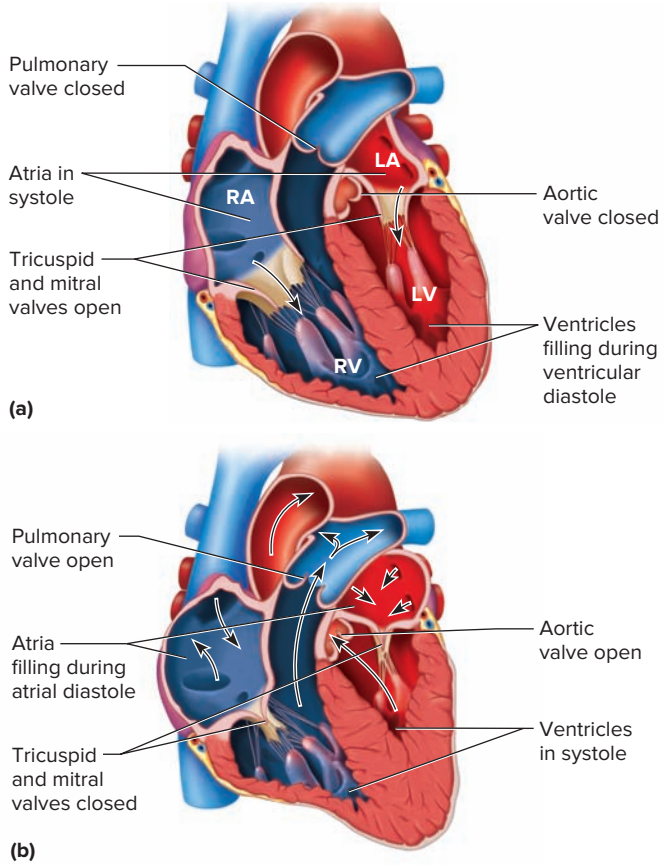


FIGURE 15.14 AP|R A cardiac cycle. The atria (*a*) empty during atrial systole and (*b*) fill with blood during atrial diastole.

Organizational Tables

Organizational tables can help "put it all together," but they are not a substitute for reading the text or having good notes.

TABLE 5.4 Exocrine Glandular Secretions

Type	Description of Secretion	Example
Merocrine glands	A fluid product released through the cell membrane by exocytosis	Salivary glands, pancreatic glands, sweat glands of the skin
Apocrine glands	Cellular product and portions of the free ends of glandular cells pinch off during secretion	Mammary glands, ceruminous glands lining the external acoustic meatus
Holocrine glands	Disintegrated entire cells filled with secretory products	Sebaceous glands of the skin

During Class

It is critical that you attend class regularly, and be on time—even if the instructor's notes are posted online, and the information is in the textbook. For many learners, hearing and writing new information is a better way to retain facts than just scanning notes on a computer screen. Attending lectures and discussion sections also provides more detailed and applied analysis of the subject matter, as well as a chance to ask questions.

Be alert and attentive in class. Take notes by adding either to the outline or notes taken while reading. Auditory learners benefit from recording the lectures and listening to them while doing chores. This is called **multitasking**—doing more than one activity at a time.

Participate in class discussions, asking questions of the instructor and answering questions he or she poses. All of the students are in the class to learn, and many will be glad someone asked a question others would not be comfortable asking. Such student response can alert the instructor to topics that are misunderstood or not understood at all. However, respect class policy. Due to time constraints and class size, asking questions may be more appropriate after a large lecture class or during tutorial (small group) sessions.

After Class

In learning complex material, expediency is critical. Organize, edit, and review notes as soon after class as possible, fleshing out sections where the lecturer got ahead of the listener. Highlighting or underlining (in color, for visual learners) the key terms, lists, important points and major topics make them stand out, which eases both daily reviews and studying for exams.

Lists

Organizing information into lists or categories can minimize information overload, breaking it into manageable chunks. For example, when studying the muscles of the thigh it is easier to learn the insertion, origin, action, and nerve supply of the four muscles making up the *quadriceps femoris* as a group, because they all have the same insertion, action at the knee, and nerve supply—they differ only in their origins.

Mnemonic Devices

Another method for remembering information is the **mnemonic device.** One type of mnemonic device is a list of words, forming

a phrase, in which the first letter of each word corresponds to the first letter of each word that must be remembered. For example, ***F*requent *p*arade *o*ften *t*ests *s*oldiers' *e*ndurance** stands for the skull bones *f*rontal, *p*arietal, *o*ccipital, *t*emporal, *s*phenoid, and *e*thmoid. Another type of mnemonic device is a word formed by the first letters of the items to be remembered. For example, ***ipmat*** represents the stages in the cell cycle: ***i***nterphase, ***p***rophase, ***m***etaphase, ***a***naphase, and ***t***elophase.

Study Groups

Forming small study groups helps some students. Together the students review course material and compare notes. Working as a team and alternating leaders allows students to verbalize the information. Individual students can study and master one part of the assigned material, and then explain it to the others in the group, which incorporates the information into the memory of the speaker. Hearing the material spoken aloud also helps the auditory learner. Be sure to use anatomical and physiological terms, in explanations and everyday conversation, until they become part of your working vocabulary, rather than intimidating jargon. Most important of all—the group must stay on task, and not become a vehicle for social interaction. Your instructor may have suggestions or guidelines for setting up study groups.

Flash Cards

Flash cards may seem archaic in this computer age, but they are still a great way to organize and master complex and abundant information. The act of writing or drawing on a note card helps the tactile learner. Master a few new cards each day, and review cards from previous days, and use them all again at the end of the semester to prepare for the comprehensive final exam. They may even come in handy later, such as in studying for exams for admission to medical school or graduate school. Divide your deck in half and flip half of the cards so that the answer rather than the question is showing. Mix them together and shuffle them. Get used to identifying a structure or process from a description as well as giving a description when provided with a process or structure. This is more like what will be expected of you in the real world of the health-care professional.

Manage Your Time

For each hour in the classroom, most students will spend at least three hours outside of class studying. Many of you have important obligations outside of class, such as jobs and family responsibilities. As important as these are, you still need to master this material on your path to becoming a healthcare professional. Good time management skills are therefore essential in your study of human anatomy and physiology. In addition to class, lab, and study time, spend time waiting for a ride or waiting in a doctor's office, reviewing notes or reading the text.

Daily repetition is helpful, so scheduling several short study periods each day can replace a last-minute crunch to cram for an exam. This does not take the place of time to prepare for the next class. Thinking about these suggestions for learning now can maximize study time throughout the semester, and, hopefully, lead to academic success. A working knowledge of the structure and function of the human body provides the foundation for all careers in the health sciences.

PRACTICE

3. Why is it important to prepare before attending class?
4. Name two ways to participate in class discussions.
5. List several aids for remembering information.

ASSESS

Chapter assessments that are tied directly to the learning outcomes allow you to self-assess your mastery of the material.

CHAPTER ASSESSMENTS

P.1 Approaches to Learning

1. Explain how students learn in different ways.

P.2 Strategies for Success

2. Methods to prepare for class include _____.
   a. reading the chapter
   b. outlining the chapter
   c. taking notes on the assigned reading
   d. making a vocabulary list
   e. all of the above
3. Describe how you can participate in class discussions.
4. Forming the phrase "*I passed my anatomy test.*" To remember the cell cycle (interphase, prophase, metaphase, anaphase, telophase) is an example of a _____.
5. Name a benefit and a drawback of small study groups.
6. Explain the value of repetition in learning and preparation for exams.

A textbook is inherently linear. This text begins with chapter 1 and continues through chapter 24. Understanding physiology and the significance of anatomy, however, requires you to be able to recall previous concepts. Critical thinking is all about linking previous concepts with current concepts under novel circumstances, in new ways. Toward this end, we have included in the Integrative Assessment/Critical Thinking section references to sections from earlier chapters. Making connections is what it is all about!

ASSESS

INTEGRATIVE ASSESSMENTS/CRITICAL THINKING

Outcomes P.1, P.2

1. Which study methods are most successful for you?

Outcome P.2

2. Design a personalized study schedule.

Chapter Summary

A summary of the chapter provides an outline to review major ideas and is a tool for organizing thoughts.

P.1 Approaches to Learning

Try a variety of methods to study the human body.

P.2 Strategies for Success

While strategies for academic success seem to be common sense, you might benefit from reminders of study methods.

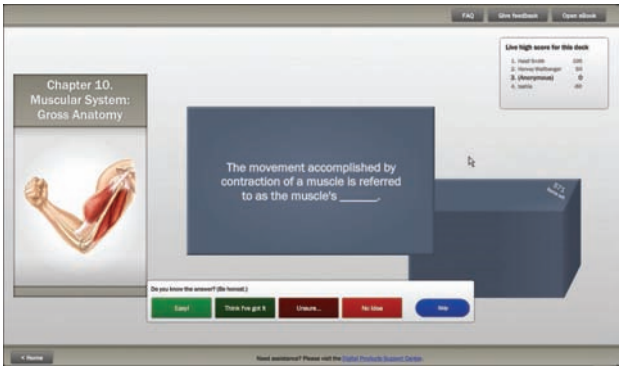
1. Before class
   Read the assigned text material prior to the corresponding class meeting.
   a. Reconnects refer back to helpful, previously discussed concepts.
   b. A Glimpse Ahead applies current learning to future topics.
   c. Clinical Application and From Science to Technology boxes present sidelights to the main focus of the text.
   d. Photographs, line art, flow charts, and organizational tables help in mastery of the materials.
2. During class
   Take notes and participate in class discussions.
3. After class
   a. Organize, edit, and review class notes.
   b. Mnemonic devices aid learning.
      (1) The first letters of the words to remember begin words of an easily recalled phrase.
      (2) The first letters of the items to be remembered form a word.
   c. Small study groups reviewing and vocalizing material can divide and conquer the learning task.
   d. Flash cards help the tactile learner.
   e. Time management skills encourage scheduled studying, including daily repetition instead of cramming for exams.

Check out McGraw-Hill online resources that can help you practice and assess your learning.

McGraw-Hill Connect® Interactive Questions Reinforce your knowledge using assigned interactive questions.

Connect Integrated Activity Practice your understanding.

McGraw-Hill LearnSmart® Discover which concepts you have mastered and which require more attention with this personalized, adaptive learning tool.



McGraw-Hill Anatomy & Physiology | REVEALED®
Go more in depth using virtual dissection of a cadaver.

Your brain enables you to learn, to practice, and to assess your understanding—whether of a textbook, or how to handle a medical emergency. © Brand X Pictures/PunchStock RF

1

Introduction to Human Anatomy and Physiology

LEARN

After studying this chapter, you should be able to complete the "Learning Outcomes" that follow the major headings throughout the chapter.

1.1 Origins of Medical Science
1.2 Anatomy and Physiology
1.3 Levels of Organization
1.4 Core Themes in Anatomy and Physiology
1.5 Life and the Maintenance of Life
1.6 Organization of the Human Body
1.7 Life-Span Changes
1.8 Anatomical Terminology

THE WHOLE PICTURE

Human anatomy and physiology are the studies of the human body and how it works. Our bodies are communities of cells, which are the microscopic units of living organisms. Cells are specialized to take on specific and necessary responsibilities, and together they maintain an environment within the body in which they can all live.

Learning anatomy and physiology requires familiarity with the language used to describe structures and functions. Cells aggregate and interact to form tissues, which in turn layer and fold and intertwine to form organs, which in turn connect into organ systems.

Mastering the principles of anatomy and physiology not only will give you a new appreciation for your day-to-day activities, talents, strengths, and health, but will provide a foundation for you to help your future patients, for those of you going into health care.

Anatomy & Physiology REVEALED
aprevealed.com

Module 1: Body Orientation