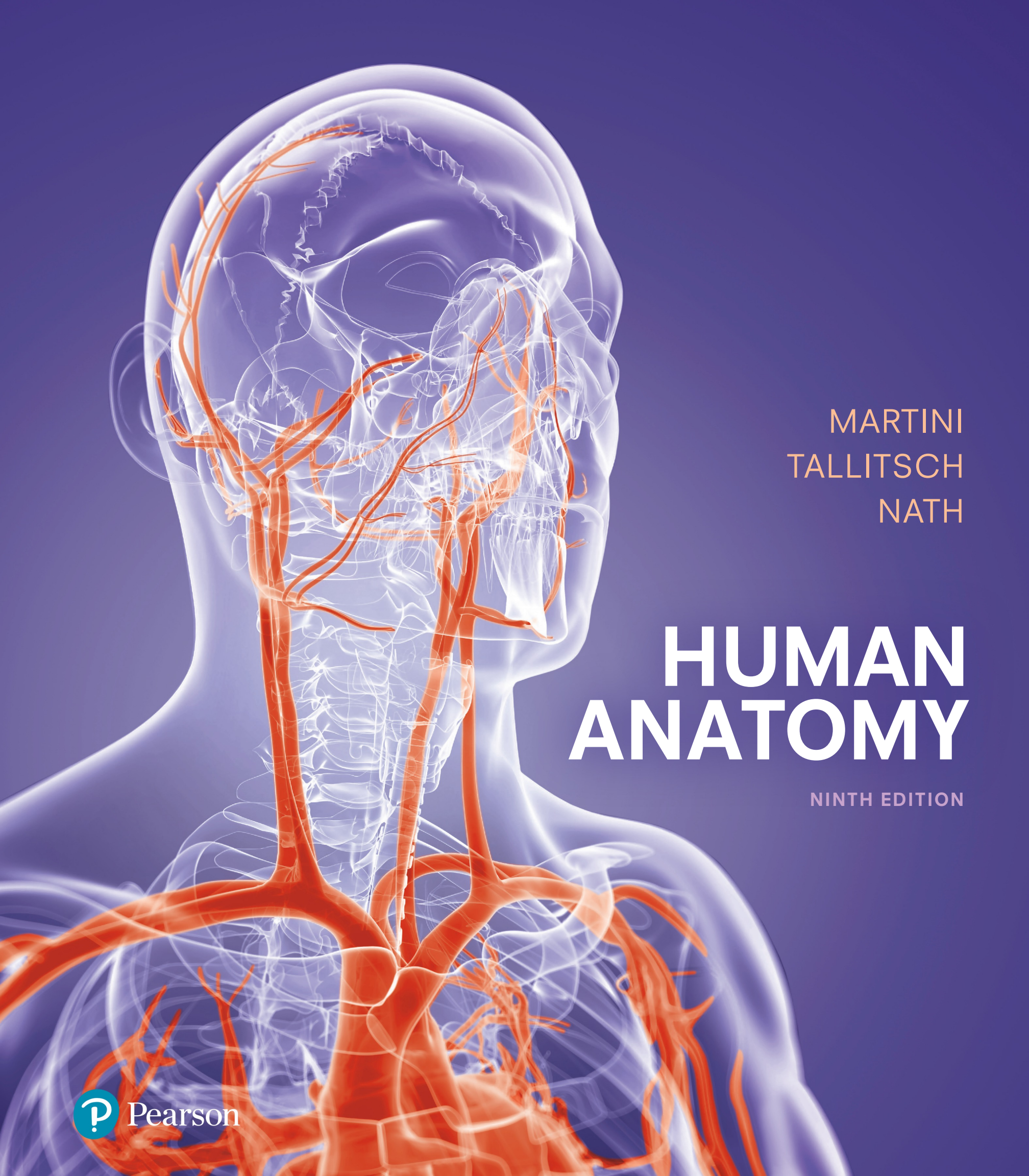

MARTINI
TALLITSCH
NATH

HUMAN ANATOMY

NINTH EDITION

Pearson

Contents in Brief

CLINICAL CASES

SPOTLIGHT FIGURES

HUMAN ANATOMY

NINTH EDITION

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330 Hudson Street, NY NY 10013

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Cover Illustration Credit: Sebastian Kaulitzki/Science Photo Library/Getty

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Library of Congress Cataloging-in-Publication Data
Names: Martini, Frederic, author. | Tallitsch, Robert B., author. | Nath, Judi Lindsley, author.
Title: Human anatomy / Frederic H. Martini, Ph.D., University of Hawaii at Manoa, Robert B. Tallitsch, Ph.D., Augustana College, Rock Island, IL, Judi L. Nath, Ph.D., Lourdes University, Sylvania, OH; with William C. Ober, M.D., art coordinator and illustrator; Claire E. Ober, R.N., illustrator; Kathleen Welch, M.D., clinical consultant: Ruth Anne O'Keefe, clinical consultant; Ralph T. Hutchings, biomedical photographer.
Description: Ninth edition. | Glenview, IL: Pearson [2018]
Identifiers: LCCN 2016033415 | ISBN 9780134320762 (alk. paper)
Subjects: LCSH: Human anatomy. | Human anatomy—Atlases.
Classification: LCC QM23.2 .M356 2018 | DDC 612--dc23 LC record available at https://lccn.loc.gov/2016033415

1 16

Pearson

ISBN 10: 0-13-432076-X; ISBN 13: 978-0-13-432076-2 (Student edition)
ISBN 10: 0-13-429229-4; ISBN 13: 978-0-13-429229-8 (Exam copy)
ISBN 10: 0-13-442494-8; ISBN 13: 978-0-13-4424941 (Books a la Carte edition)

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Frederic (Ric) Martini

Author

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

Robert B. Tallitsch

Author

Dr. Tallitsch received his Ph.D. in physiology with an anatomy minor from the University of Wisconsin–Madison at the ripe old age of 24. Dr. Tallitsch has been on the biology faculty at Augustana College (Illinois) since 1975. His teaching responsibilities include human anatomy, neuroanatomy, histology, and cadaver dissection. He is also a member of the Asian Studies faculty at Augustana College, teaching a course in traditional Chinese medicine. Dr. Tallitsch has been designated as one of the "unofficial teachers of the year" by the graduating seniors at Augustana 19 out of the last 20 years. Dr. Tallitsch is a member of the American Association of Anatomists, where he serves as a Career Development Mentor; the American Association of Clinical Anatomists; and the Human Anatomy and Physiology Society. In addition to his teaching responsibilities, Dr. Tallitsch currently serves as a reviewer for the Problem-Based Learning Clearinghouse and has served as a visiting faculty member at the Beijing University of Chinese Medicine and Pharmacology (Beijing, PRC), the Foreign Languages Faculty at Central China Normal University (Wuhan, PRC), and in the Biology Department at Central China Normal University (Wuhan, PRC).

Judi L. Nath

Author

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

William C. Ober

Art Coordinator and Illustrator

Dr. Ober received his undergraduate degree from Washington and Lee University and his M.D. from the University of Virginia. He also studied in the Department of Art as Applied to Medicine at Johns Hopkins University. After graduation, Dr. Ober completed a residency in Family Practice and later was on the faculty at the University of Virginia in the Department of Family Medicine and in the Department of Sports Medicine. He also served as Chief of Medicine of Martha Jefferson Hospital in Charlottesville, VA. He is currently a Visiting Professor of Biology at Washington and Lee University, where he has taught several courses and led student trips to the Galápagos Islands. He was on the Core Faculty at Shoals Marine Laboratory for 24 years, where he taught Biological Illustration every summer. Dr. Ober has collaborated with Dr. Martini on all of his textbooks in every edition.

Claire E. Ober

Illustrator

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

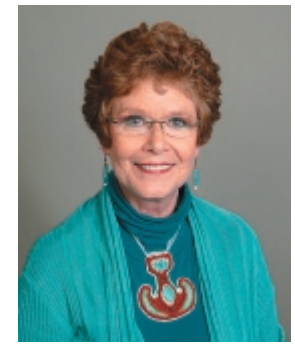
Kathleen Welch

Clinical Consultant

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

Ruth Anne O'Keefe

Clinical Consultant



Dr. O'Keefe did her undergraduate studies at Marquette University, attended graduate school at the University of Wisconsin, and received her M.D. from George Washington University. She was the first woman to study orthopedic surgery at The Ohio State University. She did fellowship training in trauma surgery at Loma Linda University. She has always been passionate about global health and has done orthopedic surgery in high-need areas around the world, taking her own surgical teams to places such as the Dominican Republic, Honduras, Peru, Burkina Faso, and New Zealand. She serves on the board of Global Health Partnerships, a group that partners with a clinic serving 50,000 very poor people in rural Kenya. Dr. O'Keefe has enjoyed teaching at all levels and at all the universities in places where she has lived. She now lives in Albuquerque with her Sweet Ed. She is mother of four, grandmother of thirteen, and foster grandmother to many.

Ralph T. Hutchings

Biomedical Photographer

Mr. Hutchings was associated with The Royal College of Surgeons of England for 20 years. An engineer by training, he has focused for years on photographing the structure of the human body. The result has been a series of color atlases, including the *Color Atlas of Human Anatomy,* the *Color Atlas of Surface Anatomy,* and *The Human Skeleton* (all published by Mosby-Yearbook Publishing). For his anatomical portrayal of the human body, the International Photographers Association chose Mr. Hutchings as the best photographer of humans in the twentieth century. He lives in North London, where he tries to balance the demands of his photographic assignments with his hobbies of early motor cars and airplanes.

Preface

Welcome to the ninth edition of *Human Anatomy*! This edition marks a significant change to the author team with the retirement of Michael Timmons and the addition of a fine colleague and excellent writer, Judi Nath.

We have made significant changes to *every* chapter of the text. As a result, this book—which was already highly visual—is now even more visual and engaging. These changes will enhance students' understanding of the chapters and the intricacies of the human body. Our new and revised visuals will promote student involvement with the figures.

In addition, the author team has revised the chapter narratives to be even more "student friendly" with a lively writing style. We have repositioned figure callouts and tried to place all graphics on the same two-page spread with their anatomical descriptions.

New to the Ninth Edition

Our goal is to build on the strengths of previous editions while meeting the needs of today's students. The author team has paid significant attention to the latest research on the science of teaching and learning. Our reading of this research has informed the revision of both the art program and text narratives in this edition. As a result, we believe this edition will prove even more effective for attracting students' attention, enhancing their understanding, and promoting their retention of anatomical concepts.

- **EVERY ILLUSTRATION** has been revised, either partially or totally.
- **EVERY CHAPTER** has been extensively rewritten to
  - Engage students with an informal, friendly approach
  - Reposition figure callouts for easy reading and understanding
  - Place figures in a logical design that is both attractive and effective
  - Place figures as close to their anatomical descriptions as possible
  - Increase the number of bullet lists and numbered lists to better facilitate student learning
  - Use standardized terminology of the latest editions of *Terminologia Anatomica*, *Terminologia Histologica*, *Terminologia Embryologica*, and *Stedman's Medical Dictionary*

- **NEW Chapter Opener Clinical Cases** have been added to every chapter. These clinical cases increase student interest in the topics and vividly demonstrate the importance of anatomical concepts in the health professions. In addition, all of the existing Clinical Notes features, found within the chapters, have been updated or replaced to reflect current topics and the latest research.
- **NEW Tips & Tools** boxes are concise, catchy memory devices to help students easily remember anatomical facts and concepts.
- **NEW Key Points** boxes give students a quick summary of the material discussed in the upcoming section of the chapter.
- **Improved text-art integration** throughout enhances the readability of figures with the text.
- **NEW MasteringA&P features** include the following:
  - Ready to Go Teaching Modules, created by teachers for teachers, are organized around eight of the toughest topics in human anatomy. They provide suggestions to instructors on which assets in MasteringA&P can best be used before, during, and after class to effectively teach the topic.
  - A Coaching Activity for the new Spotlight Figure in Chapter 17 on the sympathetic nervous system.
  - Revised and updated Dynamic Study Modules.

Chapter-by-Chapter Revisions

In addition to a significant rewriting of every chapter within the text, as outlined above, the following changes have been made in each chapter of the ninth edition of *Human Anatomy*:

1 Foundations: An Introduction to Anatomy

- Nine illustrations either are new or have been significantly revised.
- All Clinical Notes within this chapter have been revised.
- One new Tips & Tools box was added to this chapter.
- The section dealing with sectional anatomy was extensively revised to better facilitate student learning

2 Foundations: The Cell

- Eight illustrations either are new or have been significantly revised.
- The sections dealing with the plasma membrane, cellular cytoskeleton and intercellular attachments were reorganized and revised to better facilitate student learning.

3 Foundations: Tissues and Early Embryology

- Sixteen illustrations either are new or have been significantly revised.
- Four new Tips & Tools boxes were added to this chapter.

4 The Integumentary System

- Nine illustrations either are new or have been significantly revised.
- One new Tips & Tools box was added to this chapter.

5 The Skeletal System: Osseous Tissue and Bone Structure

- Nine illustrations either are new or have been significantly revised.
- The sections dealing with blood and nerve supply to bones and factors regulating growth were reorganized and revised to better facilitate student learning.

6 The Skeletal System: Axial Division

- Twenty-nine illustrations either are new or have been significantly revised.
- Two new Tips & Tools boxes were added to this chapter.

7 The Skeletal System: Appendicular Division

- Twenty-four illustrations either are new or have been significantly revised.
- One new Tips & Tools box was added to this chapter.

8 The Skeletal System: Joints

- The chapter title has been changed from Articulations to Joints.
- Twenty-one illustrations either are new or have been significantly revised.
- The sections dealing with darthroses (freely movable synovial joints) and the elbow and radio-ulnar joints were reorganized and revised.

9 The Muscular System: Skeletal Muscle Tissue and Muscle Organization

- Thirteen illustrations either are new or have been significantly revised.
- All sections dealing with the microanatomy and the physiology of skeletal muscle contraction were extensively revised.
- One new Tips & Tools box was added to this chapter.

10 The Muscular System: Axial Musculature

- Fourteen illustrations either are new or have been significantly revised.
- The organization of the sections dealing with muscles of the vertebral column and muscles of the perineum and the pelvic diaphragm was changed to better facilitate student learning.
- One new Tips & Tools box was added to this chapter.

11 The Muscular System: Appendicular Musculature

- Thirty illustrations either are new or have been significantly revised.
- Five new Tips & Tools boxes were added to this chapter.

12 Surface Anatomy and Cross-Sectional Anatomy

- Eighteen illustrations either are new or have been significantly revised.
- Four Clinical Note illustrations have been added to this chapter.

13 The Nervous System: Nervous Tissue

- The chapter title has been changed from Neural Tissue to Nervous Tissue.
- Sixteen illustrations either are new or have been significantly revised.
- The section dealing with synaptic transmission was reorganized and revised to better facilitate student learning.

14 The Nervous System: The Spinal Cord and Spinal Nerves

- Seventeen illustrations either are new or have been significantly revised.
- The sections dealing with the spinal meninges and the peripheral distribution of spinal nerves were reorganized and revised to better facilitate student learning.

15 The Nervous System: Sensory and Motor Tracts of the Spinal Cord

- Seven illustrations either are new or have been significantly revised.
- The entire chapter was significantly revised to better facilitate student learning.

16 The Nervous System: The Brain and Cranial Nerves

- Thirty-four illustrations either are new or have been significantly revised.
- One new Tips & Tools box was added to this chapter.

17 The Nervous System: Autonomic Nervous System

- Eleven illustrations either are new or have been significantly revised.
- All material describing the anatomy of the sympathetic nervous system was revised to better facilitate student learning
- A new Spotlight Figure on the sympathetic nervous system has been added.
- New material was added to clarify the anatomy of the sympathetic ganglia

18 The Nervous System: General and Special Senses

- Twenty-eight illustrations either are new or have been significantly revised.
- All sections dealing with the physiology of the general and special senses were extensively revised.

19 The Endocrine System

- Eleven illustrations either are new or have been significantly revised.
- All sections dealing with the physiology of the endocrine glands were extensively revised.
- All material describing the anatomy of the pituitary gland was reorganized and revised to better facilitate student learning.

20 The Cardiovascular System: Blood

- Eight illustrations either are new or have been significantly revised.
- One new Tips & Tools box was added to this chapter.

21 The Cardiovascular System: The Heart

- Twelve illustrations either are new or have been significantly revised.
- All material describing the anatomy of the pericardium and the surface anatomy of the heart were revised to better facilitate student learning.

22 The Cardiovascular System: Vessels and Circulation

- Twenty-six illustrations either are new or have been significantly revised.
- One new Tips & Tools box was added to this chapter.

23 The Lymphatic System

- Seventeen illustrations either are new or have been significantly revised.
- All sections dealing with the development and immunological functions of the lymphatic cells, lymphatic vessels, and lymph nodes were extensively revised.

24 The Respiratory System

- Eighteen illustrations either are new or have been significantly revised.
- The organization of several sections was changed to better facilitate student learning.

25 The Digestive System

- Twenty-three illustrations either are new or have been significantly revised.

26 The Urinary System

- Thirteen illustrations either are new or have been significantly revised.
- All sections dealing with the anatomy of the nephron were revised to better facilitate student learning
- All sections dealing with the physiology of the urinary system were extensively revised.

27 The Reproductive System

- Twenty-two illustrations either are new or have been significantly revised.
- All sections dealing with the physiology of the male and female reproductive systems were extensively revised

28 The Reproductive System: Embryology and Human Development

- All of the Embryology Summaries have been revised.

Acknowledgments

Once again, the creative talents and patience brought to this project by our artist team, William Ober, M.D., Claire E. Ober, R.N., and Anita Impagliazzo, M.F.A., are inspiring and valuable beyond expression. Bill, Claire, and Anita worked intimately and tirelessly with us, imparting a unity of vision to the book while making each illustration clear and beautiful. Their superb art program is greatly enhanced by the incomparable bone and cadaver photographs of Ralph T. Hutchings, formerly of The Royal College of Surgeons of England. In addition, Dr. Pietro Motta, Professor of Anatomy, University of Roma, La Sapienza, provided several superb SEM images for use in the text. Thanks also to Dr. Ruth Anne O'Keefe for her excellent work on the clinical material, and to Colonel (ret) Michael Yard of Indiana University – Purdue University Indianapolis, for his additional feedback on clinical cases and notes. We are grateful to Elise Lansdon of Elise Lansdon Design for her excellent work on the design of the ninth edition of *Human Anatomy.*

Special thanks also goes to our new Portfolio Manager, Cheryl Cechvala, who came in the midst of revisions and supported us to the end. Content Producer, Caroline Ayres, guided us through all the stages from development to pages. This text wouldn't be what it is today without their valuable expertise and help.

We would like to acknowledge the many users and reviewers whose advice, comments, and collective wisdom helped shape this text into its final form. Their passion for the subject, their concern for accuracy and method of presentation, and their experience with students of widely varying abilities and backgrounds have made the revision process interesting and educating.

Reviewers

Jeffrey Blodig, *Johnson County Community College*
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Kimberly Ritterhoff, *University of Dayton*
Divya Sharma, *Triton College*
Deborah Shelley, *Fresno City College*
Michael Yard, *Indiana University – Purdue University Indianapolis*

We are also indebted to the Pearson staff, whose efforts were vital to the creation of this edition. A special note of thanks and appreciation goes to the editorial staff at Pearson. Thanks also to Barbara Yien, Courseware Director, Courseware Analysts Alice Fugate and Molly Ward, and Kimberly Twardochleb, Editorial Coordinator. We express thanks to Patrice Fabel and Lauren Chen for their work on the media programs that support *Human Anatomy,* especially MasteringA&P and Practice Anatomy Lab™ (PAL™). Thanks also to Norine Strang for her role in the production of the text.

We are very grateful to Adam Jaworski, Vice President, and Serina Beauparlant, Editor in Chief, for their continued enthusiasm and support of this project. We appreciate the contributions of Derek Perrigo, Senior Anatomy and Physiology Specialist, and Allison Rona, Executive Marketing Manager, who keep their fingers on the pulse of the market and help us meet the needs of our customers. Thanks also to the remarkable and tireless Pearson Science sales reps.

We are also grateful that the contributions of all the aforementioned people have led to this text receiving the following awards: the Association of Medical Illustrators Award, the Text and Academic Authors Award, the New York International Book Fair Award, the 35th Annual Bookbuilders West Award, and the 2010 Text and Academic Authors Association "Texty" Textbook Excellence Award.

Finally, we would like to thank our families for their love, patience, and support during the revision process. We could not have accomplished this without the help of our spouses—Kitty, Mary, and Mike.

In an effort to improve future editions, we ask that readers with pertinent information, suggestions, or comments concerning the organization or content of this textbook send their remarks to Robert Tallitsch directly, by the email address below, or care of Publisher, Applied Sciences, Pearson Benjamin Cummings, 1301 Sansome Street, San Francisco, CA 94111.

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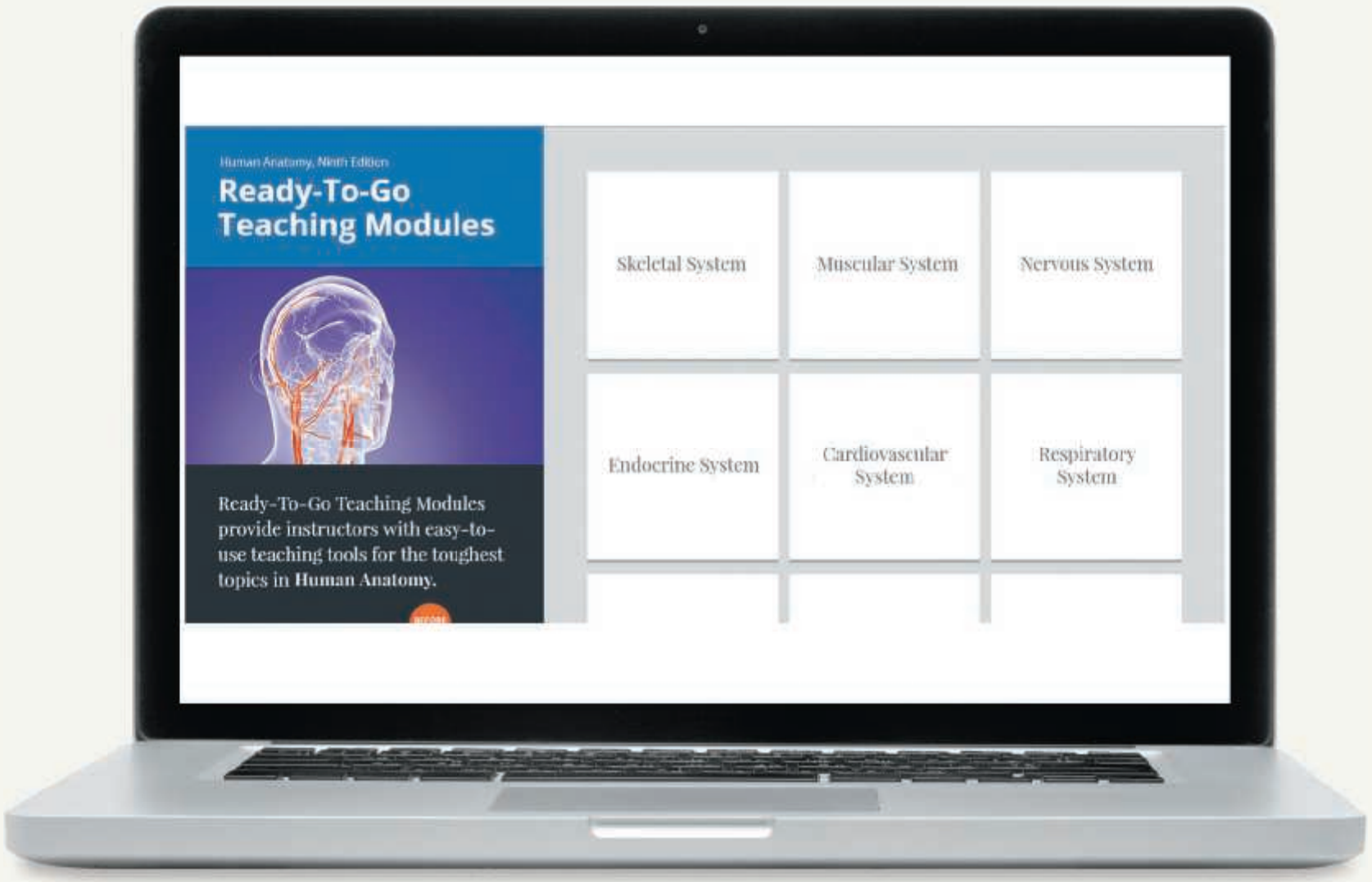
(RobertTallitsch@augustana.edu)
Judi L. Nath

Get Ready for a Whole New Human Anatomy Experience

Celebrated author Judi Nath (*Fundamentals of Anatomy & Physiology* and *Visual Anatomy & Physiology*) brings a fresh voice and a clear, engaging writing style to the **Ninth Edition** of **Human Anatomy**. The Ninth Edition continues the Martini legacy of a visually stunning presentation with exceptionally clear photographs, detailed illustrations, and captivating clinical content.

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



Prepare for the Classroom

New Study Tools

throughout each chapter help students understand and navigate the content.

NEW! Summary Boxes
at the beginning of each section outline the key points from that reading.

▶ **KEY POINT** Dermal ridges form friction ridges, ensuring a secure grip on objects. Dermal ridges also form fingerprints, a unique genetic identifier of an individual.

▶ **KEY POINT** The position of the wrist affects the functioning of the hand. Many muscles of the forearm, therefore, affect the actions of the wrist because (1) all of the muscles that flex or extend the wrist originate on the humerus, radius, and/or ulna and (2) many muscles that flex or extend the fingers originate on the radius and/or ulna.

TIPS & TOOLS

Remembering the names of the epidermal layers of thick skin

A mnemonic to help you remember the names of the epidermal layers of thick skin, from deep to superficial, is "Brent Spiner gained Lieutenant Commander" (basale, spinosum, granulosum, lucidum, corneum).

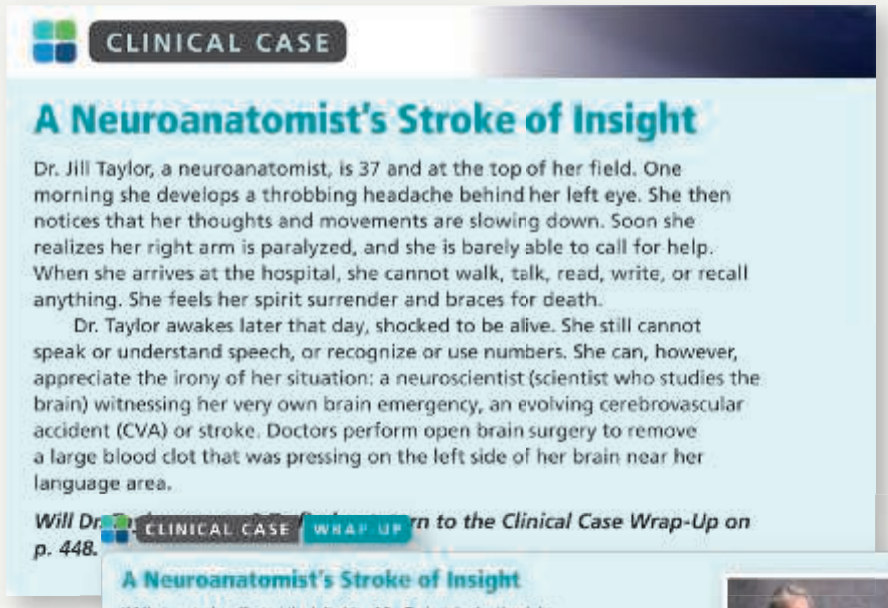
NEW! Tips & Tools
offer advice on how to approach some of the toughest topics.

TIPS & TOOLS

Here is a simple trick to remember the four anterior superficial forearm muscles originating from the medial epicondyle of the humerus. Hold both arms out, palms touching. Then slide your right hand proximally until your palm reaches your elbow with your fingers pointing toward your wrist. With each finger representing one of the four muscles, think PFPF: **P**ronator teres (index finger), **F**lexor carpi radialis (middle finger), **P**almaris longus (ring finger), and **F**lexor carpi ulnaris (little finger).

and Future Careers

NEW! Clinical Cases help motivate students for their future careers. Each chapter opens with a story-based Clinical Case related to the chapter content and ends with a Clinical Case Wrap-Up.



CLINICAL CASE

A Neuroanatomist's Stroke of Insight

Dr. Jill Taylor, a neuroanatomist, is 37 and at the top of her field. One morning she develops a throbbing headache behind her left eye. She then notices that her thoughts and movements are slowing down. Soon she realizes her right arm is paralyzed, and she is barely able to call for help. When she arrives at the hospital, she cannot walk, talk, read, write, or recall anything. She feels her spirit surrender and braces for death.

Dr. Taylor awakes later that day, shocked to be alive. She still cannot speak or understand speech, or recognize or use numbers. She can, however, appreciate the irony of her situation: a neuroscientist (scientist who studies the brain) witnessing her very own brain emergency, an evolving cerebrovascular accident (CVA) or stroke. Doctors perform open brain surgery to remove a large blood clot that was pressing on the left side of her brain near her language area.

Will Dr[illegible]rn to the Clinical Case Wrap-Up on p. 448.

CLINICAL CASE WRAP UP

A Neuroanatomist's Stroke of Insight

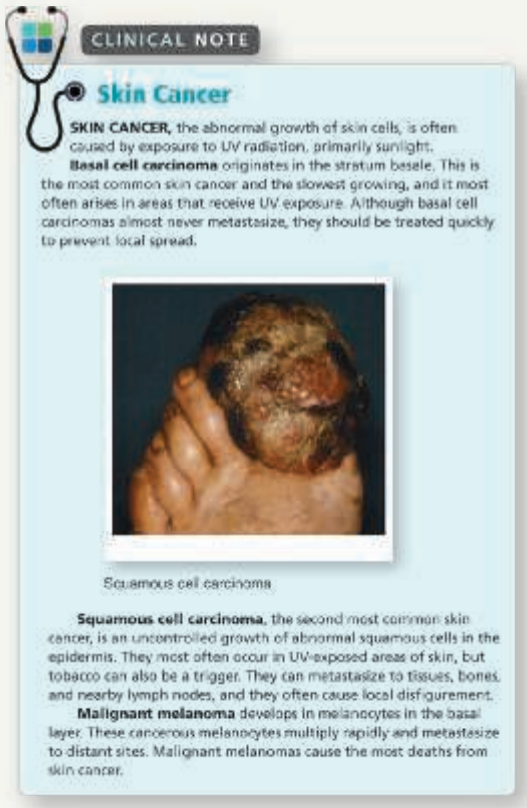
While her stroke affected the left side of Dr. Taylor's brain, the right side continued functioning. Because language and thoughts are typically controlled in the left hemisphere (the dominant hemisphere of a right-handed person), Dr. Taylor "sat in an absolutely silent mind" for the first month. Since the center for mathematical calculation is situated in the left hemisphere, she had to learn to use numbers all over again. And because the primary motor cortex governing the right side of the body resides in the precentral gyrus of the left hemisphere, she had to learn to use her right arm again. Full recovery took 8 years.

The stroke destroyed some brain cells, but others were able to form new neuronal connections. Neuroplasticity, this ability of nerve cells to make new connections, allows the brain to reorganize itself after injury.

Dr. Taylor wants anatomy students to know two things. First, "If you study the brain, you will never be bored." Second, "If you treat stroke patients like they will recover, they are more likely to recover." She has written a best-selling memoir about her experience, *My Stroke of Insight: A Brain Scientist's Personal Journey*.

1. How would you know, based on signs and symptoms, which side of Dr. Taylor's brain was injured by the stroke?
2. What is neuroplasticity, and why was it important in Dr. Taylor's recovery?

See the text Answers on the back of the book.



CLINICAL NOTE

Skin Cancer

SKIN CANCER, the abnormal growth of skin cells, is often caused by exposure to UV radiation, primarily sunlight.

Basal cell carcinoma originates in the stratum basale. This is the most common skin cancer and the slowest growing, and it most often arises in areas that receive UV exposure. Although basal cell carcinomas almost never metastasize, they should be treated quickly to prevent local spread.

Squamous cell carcinoma

Squamous cell carcinoma, the second most common skin cancer, is an uncontrolled growth of abnormal squamous cells in the epidermis. They most often occur in UV-exposed areas of skin, but tobacco can also be a trigger. They can metastasize to tissues, bones, and nearby lymph nodes, and they often cause local disfigurement.

Malignant melanoma develops in melanocytes in the basal layer. These cancerous melanocytes multiply rapidly and metastasize to distant sites. Malignant melanomas cause the most deaths from skin cancer.

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

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

Related Clinical Terms

aphasia: A neurological condition caused by damage to the portions of the brain that are responsible for language.

ataxia: Loss of muscle coordination in the arms or legs due to cerebellar dysfunction.

chronic traumatic encephalopathy (CTE): A traumatic brain injury resulting from repeated sports-related head trauma.

concussion: A mild traumatic brain injury that may be accompanied by a period of unconsciousness.

dementia: A chronic or persistent disorder of the mental processes caused by brain disease or injury and marked by memory disorders, personality changes, and impaired reasoning.

epidural hematoma: The accumulation of blood between the inner table of the skull and the dura mater.

hydrocephalus: A condition marked by an excessive accumulation of cerebrospinal fluid within the brain ventricles.

microcephaly: A birth defect in which the head circumference is much smaller than expected for the age and sex of the child.

Parkinson's disease: A neurological disorder resulting from a degeneration of the dopaminergic neurons in the substantia nigra.

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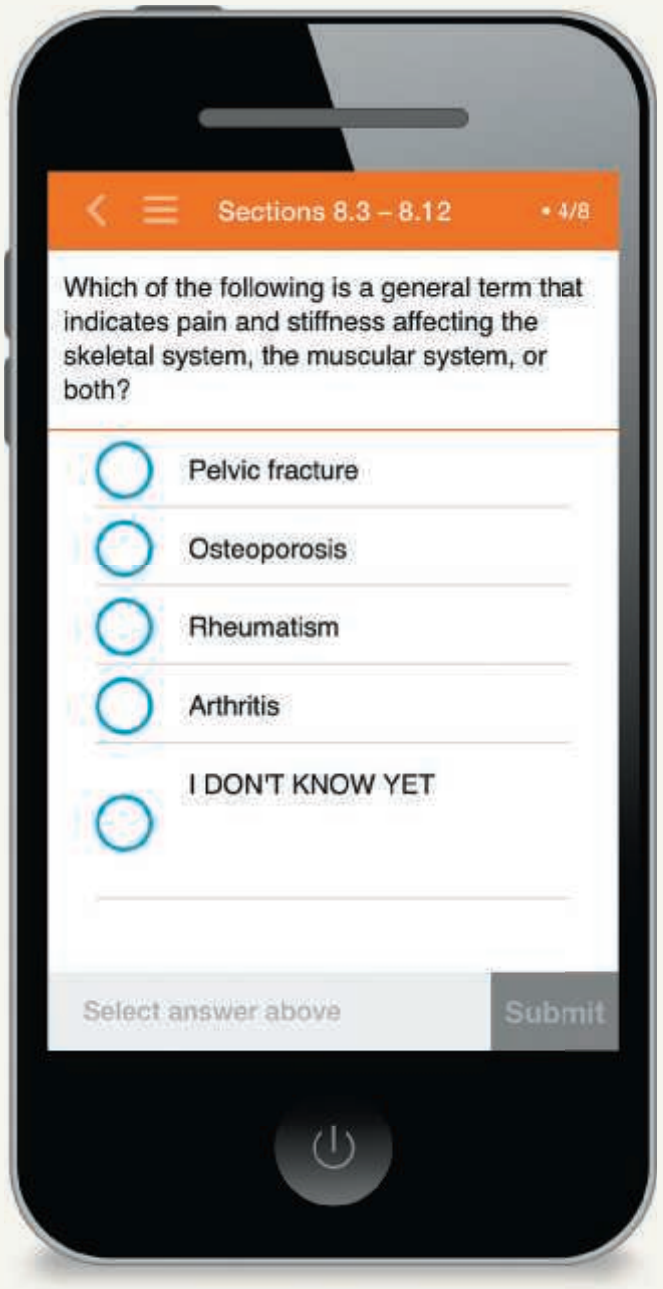

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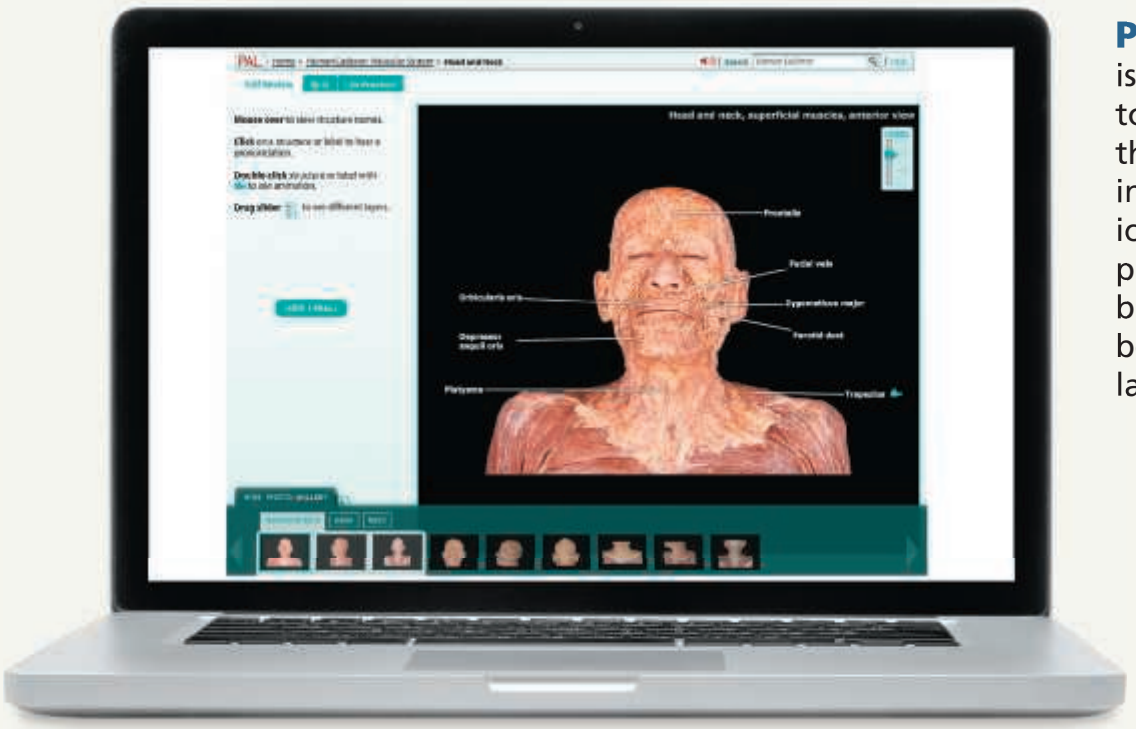

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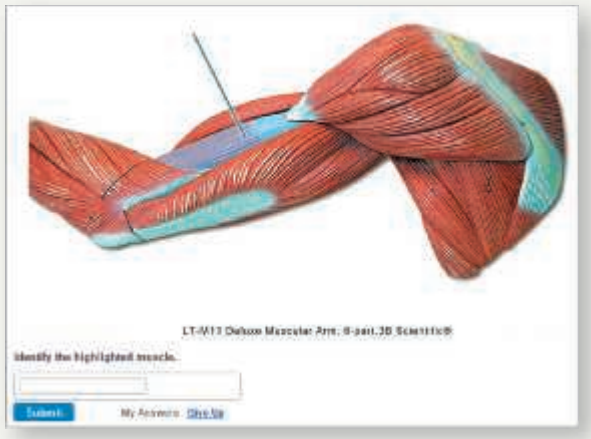

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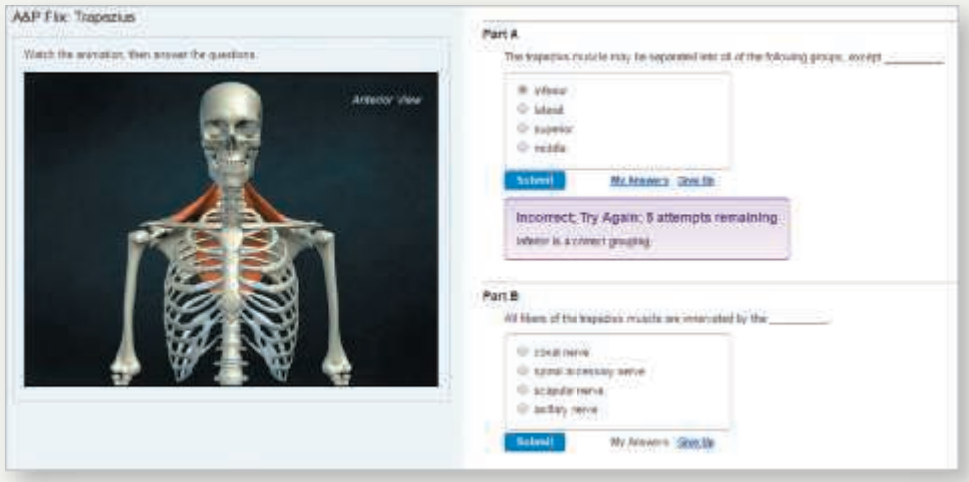

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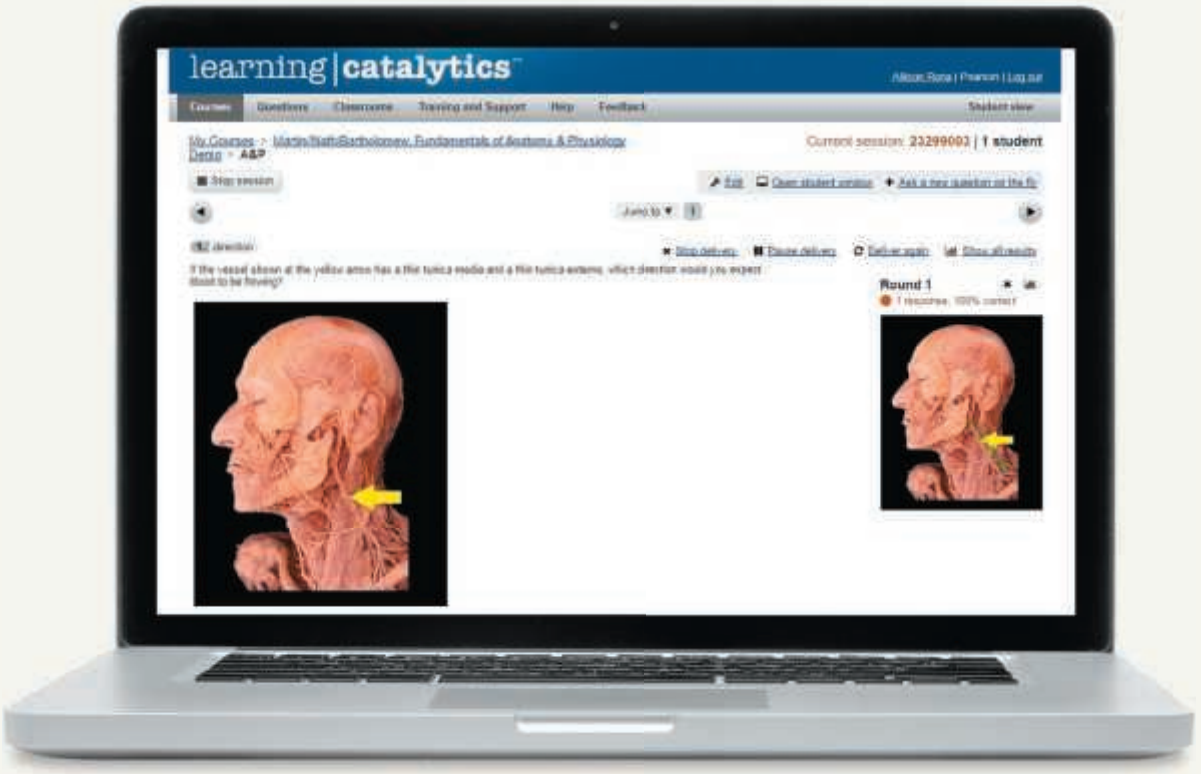

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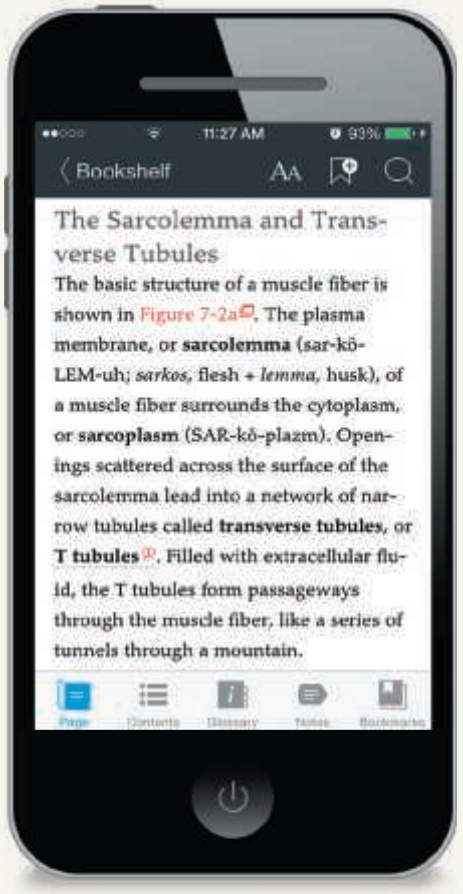

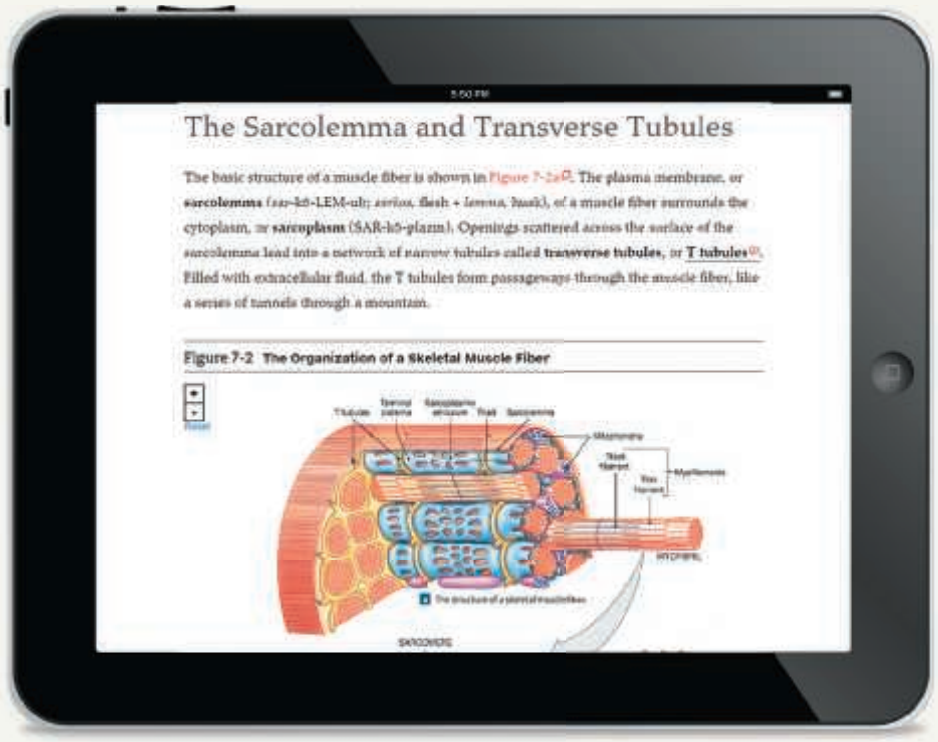

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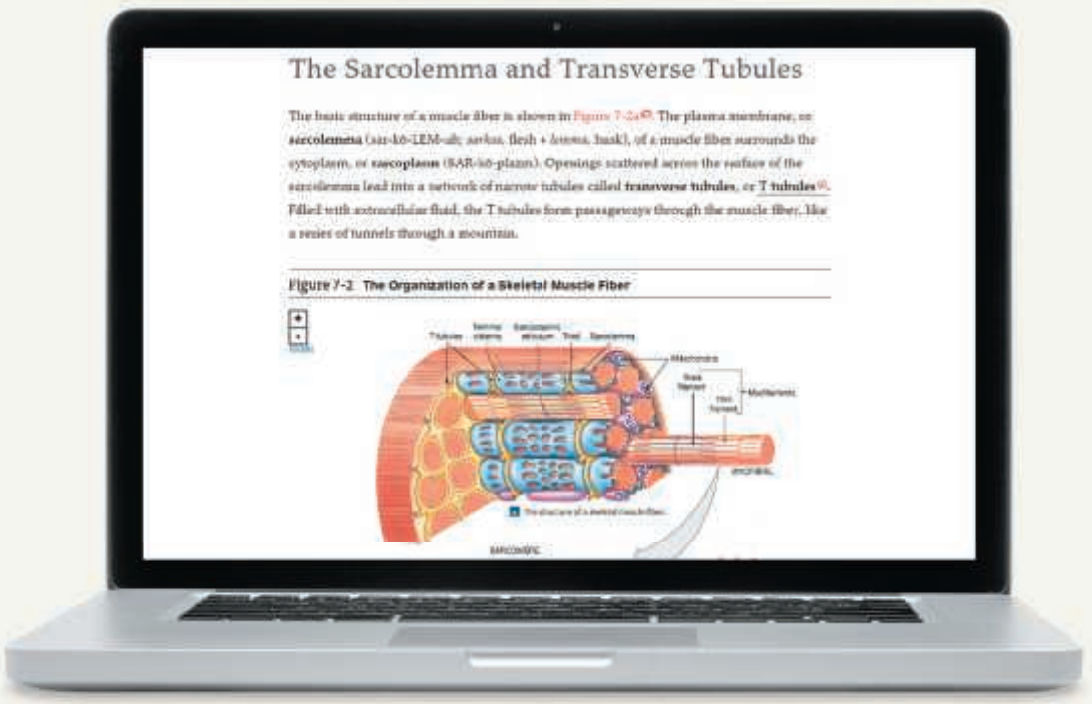

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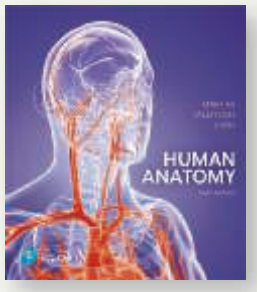

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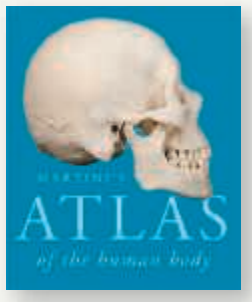

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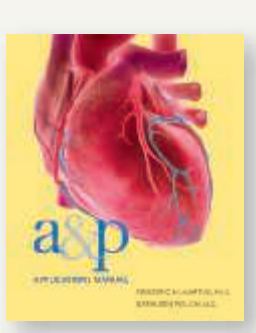

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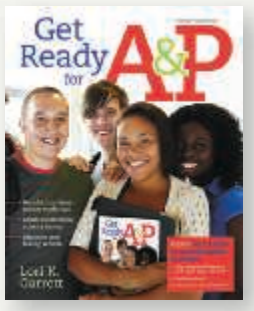

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Contents

1

Foundations

An Introduction to Anatomy

Learning Outcomes

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

1.1 Define the limits of microscopic anatomy and compare and contrast cytology and histology. p. 2

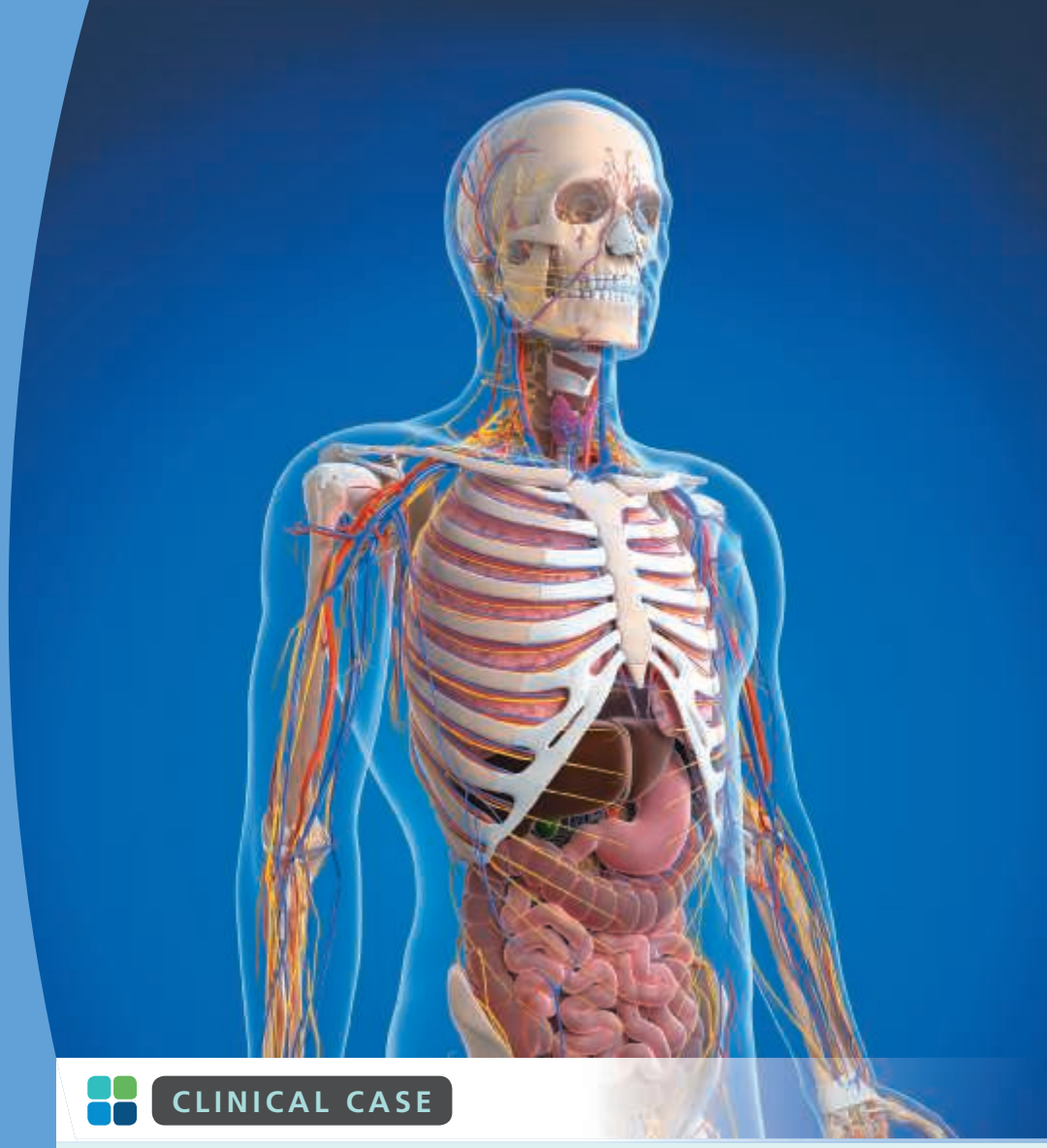
1.2 Compare and contrast the various ways to approach gross anatomy. p. 2

1.3 Define the various subspecialties of anatomy. p. 2

1.4 Explain the major levels of organization in a living organism. p. 5

1.5 Identify the organ systems of the human body and compare and contrast their functions. p. 7

1.6 Understand and correctly apply descriptive anatomical and directional terminology. p. 14



CLINICAL CASE

Using Anatomy to Save a Life

Zach, a 20-year-old college sophomore, is late for his anatomy class, so he decides to ride his bike to class instead of walking. As he enters an intersection, he is struck by a speeding pickup truck. The impact throws him 50 feet, and he lands on his head and left side.

Emergency medical technicians (EMTs) arrive within minutes. They roll the unconscious Zach onto his back for initial assessment. He has an obvious open skull fracture (bone break with pierced skin), open fractures of his left upper and lower extremities, and multiple rib fractures on his left side, and he exhibits rapid, shallow breathing. Assuming he has neck and back injuries, the EMTs splint him carefully for transport to the nearest Level I (highest designation) trauma center.

En route, an EMT calls the triage nurse in the emergency room (who assigns medical priority) and reports that he is arriving with a young male trauma victim with an Injury Severity Score (ISS) of 57. The nurse tells him to immediately report to the trauma room and sounds the alert for the trauma team.

With an ISS of 57, what are Zach's chances of survival? To find out, turn to the Clinical Case Wrap-Up on p. 26.

WE ALL USE our knowledge of human anatomy in our daily lives: We remember specific anatomical features to identify friends and family, and we observe changes in body movements and facial expressions for clues to what others are thinking. **Anatomy** is the study of the external and internal structures of the body and the physical relationships between body parts. In practical terms, anatomy is the careful observation of the human body.

Anatomical information provides clues about probable functions. **Physiology** is the study of the function of bodily structures, and we explain physiological mechanisms in terms of the underlying anatomy. *All specific physiological functions are performed by specific anatomical structures*. For instance, functions of the nasal cavity include filtering, warming, and humidifying inhaled air. The shapes of the bones projecting into the nasal cavity cause turbulence in the inhaled air. As the air swirls, it contacts the moist lining of the nasal cavity, which warms and humidifies the air, and any suspended particles stick to the moist surfaces. In this way, the air is conditioned and filtered before it reaches the lungs.

This text discusses the anatomical structures and functions that make human life possible. Our goals are to help you

1. develop a three-dimensional understanding of anatomical relationships,
2. prepare for more advanced courses in anatomy, physiology, and related subjects, and
3. make informed decisions about your personal health.

1.1 Microscopic Anatomy

▶ **KEY POINT** Microscopic anatomy—the study of structures too small to be seen by the naked eye—includes the specialties of cytology and histology.

Microscopic anatomy is the study of structures that cannot be seen without magnification. The boundaries of microscopic anatomy are established by the limits of the equipment used **(Figure 1.1)**. A simple hand lens shows details that barely escape the naked eye, while an electron microscope shows structural details that are more than a million times smaller. As we proceed through the text, we will consider details at various size levels.

Microscopic anatomy is subdivided into two specialties that consider features within a characteristic range of sizes:

- **Cytology** (sī-TOL-ō-jē) analyzes the internal structure of **cells**, the smallest units of life. Living cells are composed of complex chemicals in various combinations, and our lives depend on the chemical processes occurring in the trillions of cells that form our body.
- **Histology** (his-TOL-ō-jē) takes a broader perspective and examines **tissues**, groups of specialized cells and cell products that work together and perform specific functions. The human body has four basic tissue types: epithelial tissue, connective tissue, muscle tissue, and neural tissue (which will be described in Chapter 3).

Tissues combine to form organs such as the heart, kidney, liver, and brain. An **organ** is an anatomical structure that has multiple functions. Many tissues and most organs are examined easily without a microscope, and at this point we cross the boundary from microscopic anatomy into gross anatomy.

1.1 CONCEPT CHECK

1 Histologists study what structures?
2 Define an organ.

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

1.2 Gross Anatomy

▶ **KEY POINT** We study gross anatomy—the study of structures visible to the naked eye—by examining surface anatomy, regional anatomy, or systemic anatomy.

Gross anatomy (*macroscopic anatomy*) is the study of structures and features that are visible to the unaided (naked) eye**.** There are several ways to approach gross anatomy:

- **Surface anatomy** is the study of general anatomical form, or **morphology**, and how superficial (surface) anatomical markings relate to deeper anatomical structures.
- **Regional anatomy** is the study of the superficial and internal features in a specific area of the body, such as the head, neck, or trunk. Advanced courses in anatomy often stress a regional approach because it emphasizes the relationships among structures.
- **Systemic anatomy** is the study of anatomy based upon the body's organ systems. An **organ system** is a group of organs that function together to produce coordinated effects. For example, the heart, blood, and blood vessels form the cardiovascular system, which distributes oxygen and nutrients throughout the body. There are 11 organ systems in the human body, which we will introduce later in the chapter. Introductory anatomy texts, including this one, usually use a systemic approach to organize information about important structural and functional patterns.

1.2 CONCEPT CHECK

3 How does the work of a gross anatomist differ from that of a histologist?
4 What is an organ system, and how does it apply to systemic anatomy?

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

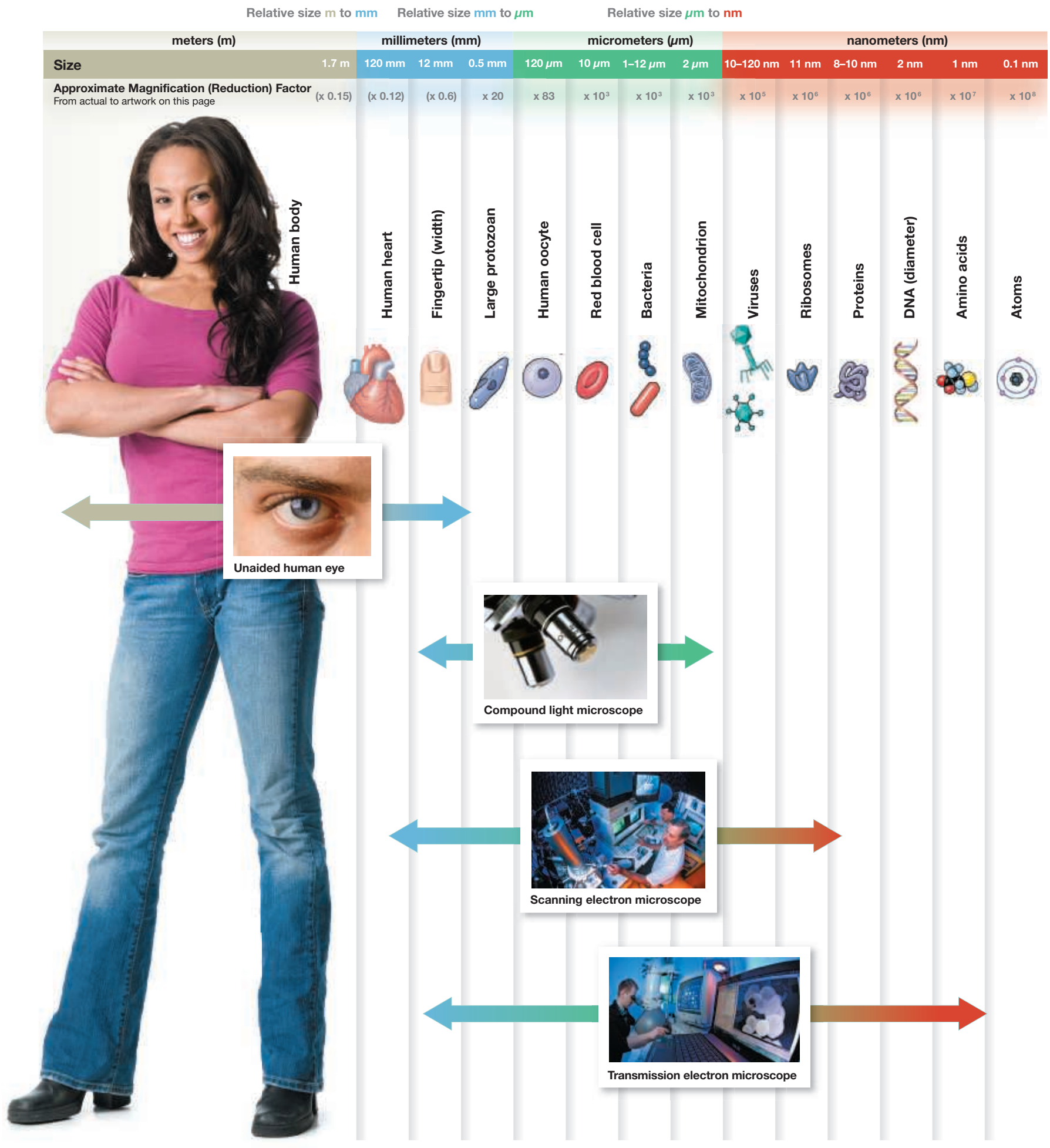
1.3 Other Types of Anatomical Studies

▶ **KEY POINT** Other anatomical specialties that are important in the understanding of the human body are developmental, comparative, clinical, surgical, radiographic, and cross-sectional anatomy.

Other anatomical specialties you will read about in this text include the following:

- **Developmental anatomy** studies the changes in form that take place between conception and physical maturity. Because it considers anatomical structures with a broad range of sizes (from a single cell to an adult human), developmental anatomy involves both microscopic and gross anatomy. Developmental anatomy is important in medicine because many structural abnormalities result from errors that occur during development. The most extensive structural changes occur during the first two months of development; **embryology** (em-brē-OL-ō-jē) is the study of these early developmental processes.
- **Comparative anatomy** studies the anatomical organization of different types of animals. Observed similarities may reflect evolutionary relationships. For example, humans, chickens, and salmon are all called vertebrates because they share a combination of anatomical features not found in any other group of animals, including a spinal column composed of individual structures called vertebrae **(Figure 1.2a)**. Comparative anatomy uses the techniques of gross, microscopic, and developmental anatomy.

Figure 1.1 The Study of Anatomy at Different Scales. The amount of detail recognized depends on the method of study and the degree of magnification.



Research shows that related animals typically go through similar developmental stages **(Figure 1.2b,c)**.

Several other gross anatomical specialties are important in medical diagnosis:

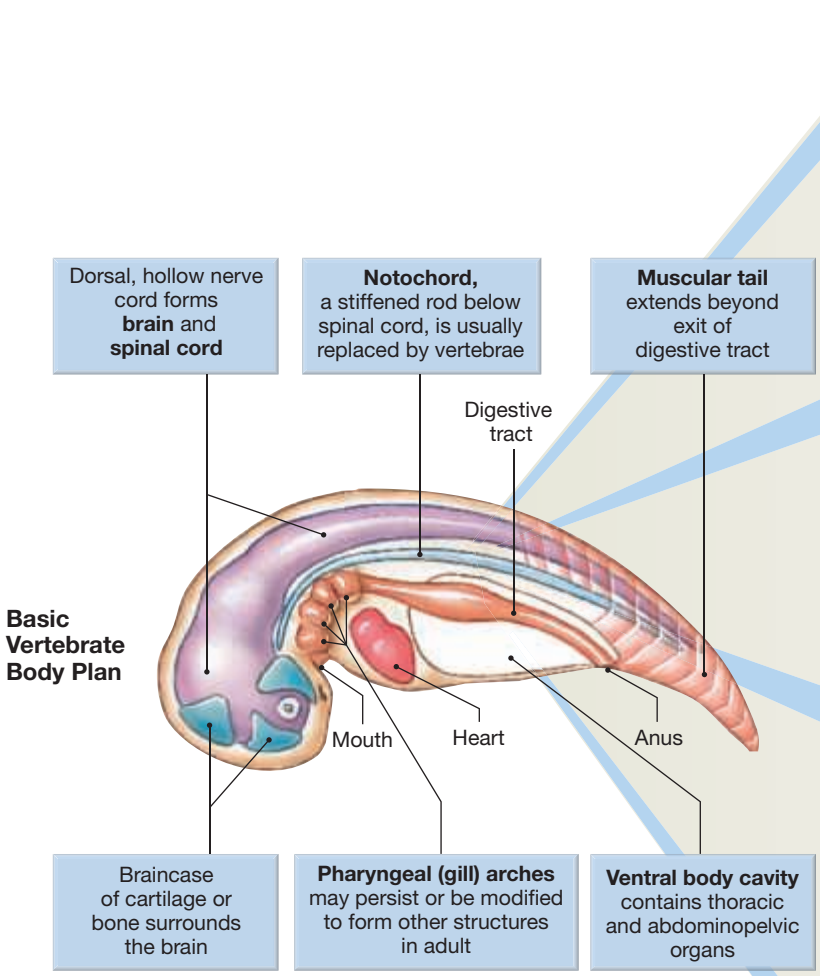
- **Clinical anatomy** focuses on anatomical features that may undergo recognizable pathological changes during illness.
- **Surgical anatomy** studies anatomical landmarks important for surgical procedures.
- **Radiographic anatomy** utilizes x-rays, ultrasound scans, or other specialized procedures performed on an intact body to visualize and study anatomical structures.
- **Cross-sectional anatomy** has emerged due to advances in radiographic anatomy, such as computerized tomography (CT) and spiral CT scans.

CLINICAL NOTE

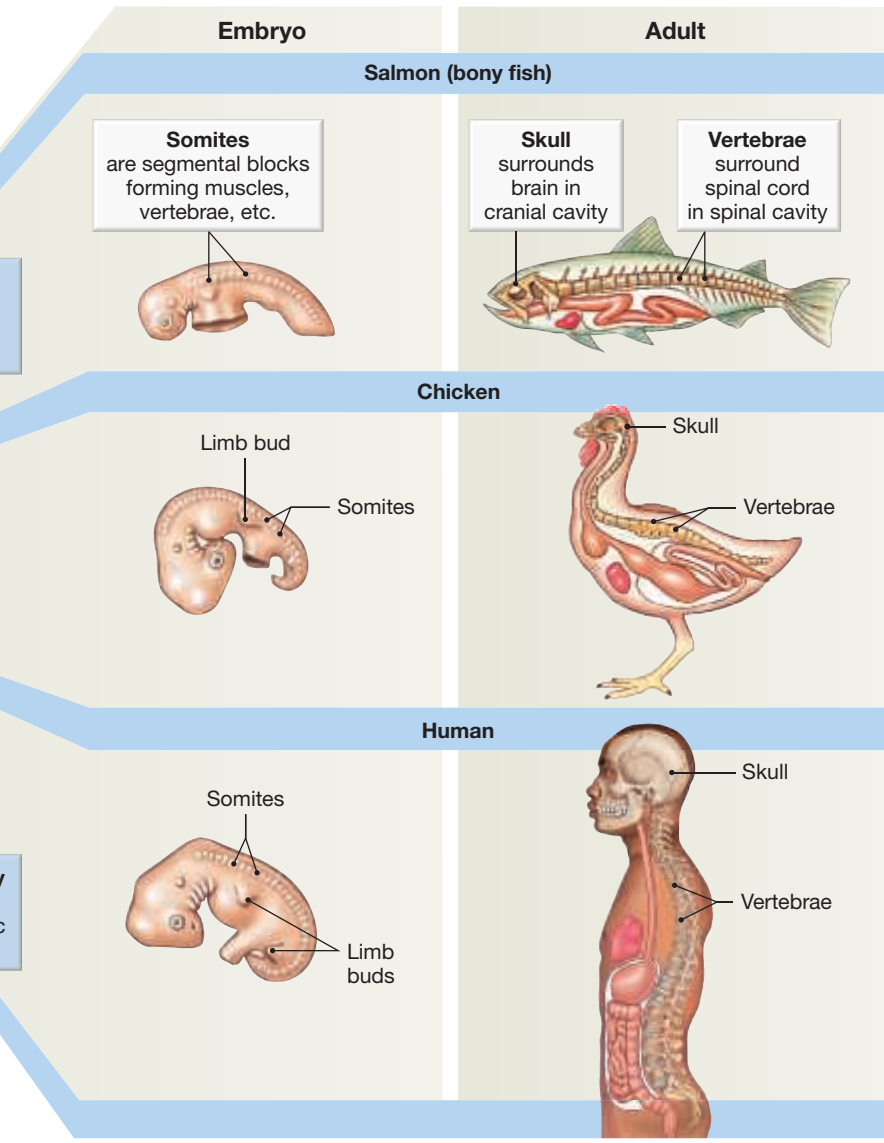
The Diagnosis of Disease

Homeostasis is the maintenance of a relatively constant internal environment suitable for the survival of cells, tissues, and organs. It is achieved by a system of control mechanisms activated by negative feedback. **Disease** is the failure to maintain homeostatic conditions. The disease process may affect any aspect of physiology from the cellular to the organismic level. The body's defenses can overcome some diseases, but others require medical intervention.

Figure 1.2 Comparative Anatomy. Humans are classified as vertebrates, a group that also includes animals as different in appearance as salmon and chickens.



a All vertebrates share a basic pattern of anatomical organization that differs from that of other animals.



b The similarities between vertebrates are most apparent when comparing embryos at comparable stages of development.

c The similarities are less obvious when comparing adult vertebrates.

1.3 CONCEPT CHECK

5 How does surgical anatomy differ from clinical anatomy?

6 Cross-sectional anatomy is a subspecialty of which anatomical specialty?

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

1.4 Levels of Organization

▶ **KEY POINT** The levels of structural organization in the human body range from the chemical/molecular level (the simplest level) to the entire organism (the most complex level).

Our study of the human body begins at the chemical, or molecular, level of organization. The human body consists of more than a dozen different elements, but four of them (hydrogen, oxygen, carbon, and nitrogen) account for more than 99 percent of the total number of atoms **(Figure 1.3a)**. At the chemical level, atoms interact to form three-dimensional molecules with distinctive properties. The major classes of molecules in the human body are indicated in **Figure 1.3b**.

The next level of organization, the cellular level, includes cells, the smallest living units in the body **(Figure 1.4)**. Cells contain internal structures called organelles. Cells and their organelles are made of complex chemicals. (Cell structure and the function of the major organelles found within cells are presented in Chapter 2.) As shown in **Figure 1.4**, chemical interactions produce complex proteins within a muscle cell in the heart. Muscle cells are unusual because they can contract powerfully, shortening along their longitudinal axis.

Heart muscle cells are connected to form a distinctive muscle tissue, an example of the tissue level of organization. Layers of muscle tissue form most of the wall of the heart, a hollow, three-dimensional organ. We are now at the organ level of organization **(Figure 1.4)**.

Normal functioning of the heart depends on interrelated events at the chemical, cellular, tissue, and organ levels of organization. Coordinated contractions in the muscle cells of cardiac muscle tissue produce a heartbeat. When that beat occurs, the internal anatomy of the organ enables it to function as a pump. With each contraction, the heart pushes blood into the vascular system, a network of blood vessels. Together, the heart, blood, and vascular system form an organ system: the cardiovascular system (CVS).

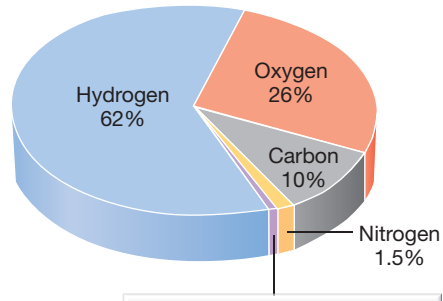
Each level of organization is dependent on the others. Damage at any level may affect the entire system. A chemical change in heart muscle cells may cause abnormal contractions or even stop the heartbeat. Physical damage to muscle tissue, such as a chest wound, can make the heart ineffective even when most of the heart muscle cells are intact. An inherited abnormality in heart structure can make it an ineffective pump even if muscle cells and tissues are normal.

Note that anything affecting a system ultimately affects all the components of that system. For example, damage to a major blood vessel somewhere else in the body can cause the heart to lose the ability to pump blood effectively. If the heart cannot pump and blood cannot flow, oxygen and nutrients cannot be distributed to tissues. In a very short time, the tissue breaks down as heart muscle cells die from oxygen and nutrient starvation.

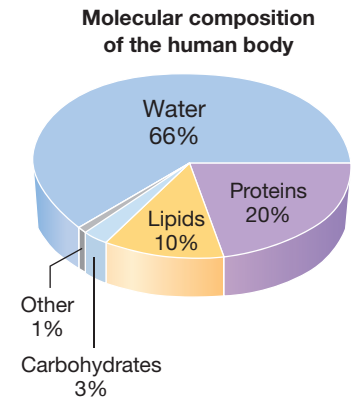
Of course, the changes that occur when the heart is not pumping effectively are not limited to the cardiovascular system; all the cells, tissues, and organs in the body will be damaged. This observation brings us to the highest level of organization, an organism—in this case, a human. The organism level reflects the interactions among organ systems **(Figure 1.4)**. All are vital; every system must be working properly and in harmony with every other system, or survival will be impossible.

When all systems are functioning normally, the characteristics of the internal environment are relatively stable at all levels. This tendency toward stability, called **homeostasis** (hō-mē-ō-STĀ-sis; *homeo*, unchanging, + *stasis*, standing), is maintained by physiological processes.

Figure 1.3 Composition of the Body at the Chemical Level of Organization.



a Elemental composition of the body. Trace elements include silicon, fluorine, copper, manganese, zinc, selenium, cobalt, molybdenum, cadmium, chromium, tin, aluminum, and boron.



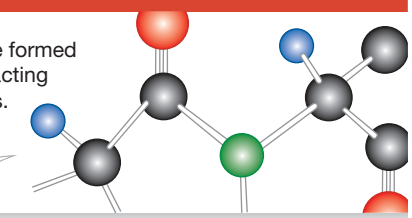
b Molecular composition of the body.

Figure 1.4 Levels of Organization

Size

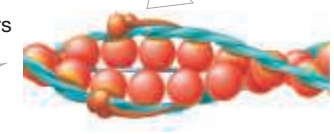
0.1 nm — **Chemical or Molecular Level**

Molecules are formed from interacting atoms.

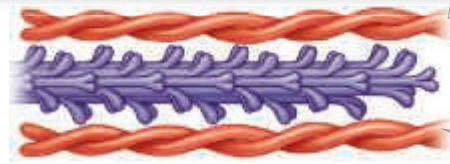


10 nm

Complex contractile protein fibers are organized from molecules.



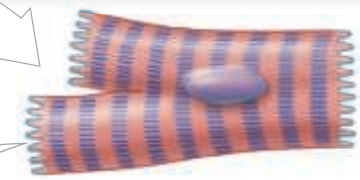
10 μm



Contractile protein fibers are found within heart muscle cells.

1 mm — **Cellular Level**

Interlocking cardiac muscle cells form cardiac muscle tissue.

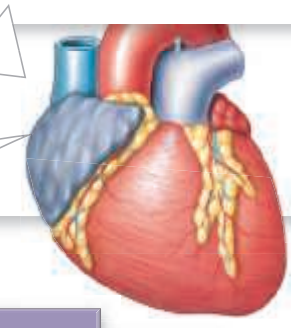


1 mm — **Tissue Level**

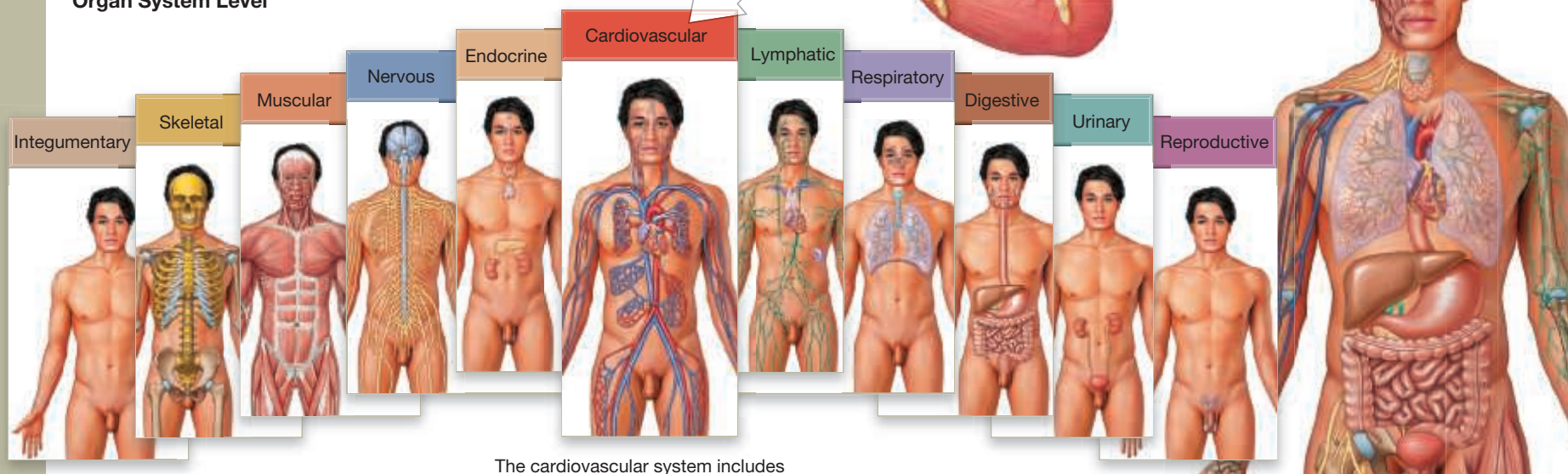
Cardiac muscle tissue makes up most of the heart walls.

120 mm — **Organ Level**

The heart is a complex three-dimensional organ.



Organ System Level



The cardiovascular system includes the heart, blood, and blood vessels.

1.7 m — **Organism Level**

All organ systems work together to keep the body healthy and alive.

1.4 CONCEPT CHECK

7 Cyanosis is a medical condition in which a person's lips and fingertips turn blue due to the inadequate delivery of oxygen to tissues. If a patient is exhibiting cyanosis, why should the patient's heart be examined *in addition to* the patient's lungs?

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

CLINICAL NOTE

Disease, Pathology, and Diagnosis

Pathology is the study of disease. Diseases produce **signs** (objective evidence that the health provider can detect, such as fever or limited motion) and **symptoms** (subjective indications that the patient perceives, such as pain or fatigue). A **diagnosis** is an identification of the nature of an illness based on its signs and symptoms.

The World Health Organization (WHO) developed the International Classification of Diseases (ICD) as an international diagnostic standard. The ICD is important for health management and epidemiology (the study of disease occurrence, distribution, and cause). The current ICD-10 contains 69,823 diseases.

1.5 An Introduction to Organ Systems

▶ **KEY POINT** The 11 organ systems of the human body enable us to carry out vital life functions such as responsiveness, growth and differentiation, reproduction, movement, and metabolism and excretion.

Figure 1.5 summarizes the functions of the 11 organ systems of the human body. **Figure 1.6** details the components and primary functions of each organ system. Like all living organisms, humans share vital characteristics and processes:

- **Responsiveness:** The ability of an organism to respond to changes in its immediate environment is termed **responsiveness**. Examples include you jerking your hand away from a hot stove, your dog barking at approaching strangers, and amoebas gliding toward potential prey. Organisms also make longer-lasting responses as they adjust to their environments. For example, as winter approaches, an animal grows a heavier coat or migrates to a warmer climate. Adaptability is the capacity to make longer-lasting adjustments.
- **Growth and Differentiation:** Over a lifetime, organisms grow larger, increasing in size by increasing the size or number of their cells. In multicellular organisms, the individual cells become specialized to perform particular functions. This specialization is called **differentiation**. Growth and differentiation in cells and organisms produce changes in form and function. For example, the anatomical proportions and physiological capabilities of an adult human are quite different from those of an infant.
- **Reproduction:** Organisms reproduce, creating subsequent generations of their own kind, whether unicellular or multicellular.
- **Movement:** Organisms produce movement, which may be internal (transporting food, blood, or other materials inside the body) or external (moving through the environment).

Figure 1.5 An Introduction to Organ Systems. An overview of the 11 organ systems and their major functions.

ORGAN SYSTEM		MAJOR FUNCTIONS
	**Integumentary**	Protects against environmental hazards; controls temperature
	**Skeletal**	Supports and protects soft tissues; stores minerals; forms blood
	**Muscular**	Provides movement and support; generates heat
	**Nervous**	Directs immediate responses to stimuli, usually by coordinating the activities of other organ systems
	**Endocrine**	Directs long-term changes in the activities of other organ systems
	**Cardiovascular**	Distributes cells and dissolved materials, including nutrients, wastes, and gases
	**Lymphatic**	Defends against infection and disease
	**Respiratory**	Delivers air to sites where gas exchange occurs between the air and circulating blood
	**Digestive**	Processes and digests food; absorbs nutrients; stores energy reserves
	**Urinary**	Eliminates excess water, salts, and wastes; controls pH; regulates blood pressure
	**Reproductive**	Produces sex cells and hormones

- **Metabolism and Excretion:** Organisms rely on chemical reactions to provide energy for responsiveness, growth, reproduction, and movement. They also synthesize complex chemicals, such as proteins. The term **metabolism** refers to *all* the chemical operations under way in the body. Types of metabolic reactions include **catabolism** (the *breakdown* of complex molecules into simple ones) and **anabolism** (the *synthesis* of complex molecules from simple ones). Normal metabolic operations require the **absorption** (*taking in*) of materials from the environment. To generate energy efficiently, cells require various nutrients, as well as oxygen, an atmospheric gas. The term **respiration** refers to cells' absorption, transport, and use of oxygen. Metabolic operations generate potentially harmful wastes that must be removed through the process of **excretion**.

Figure 1.6 The Organ Systems of the Body

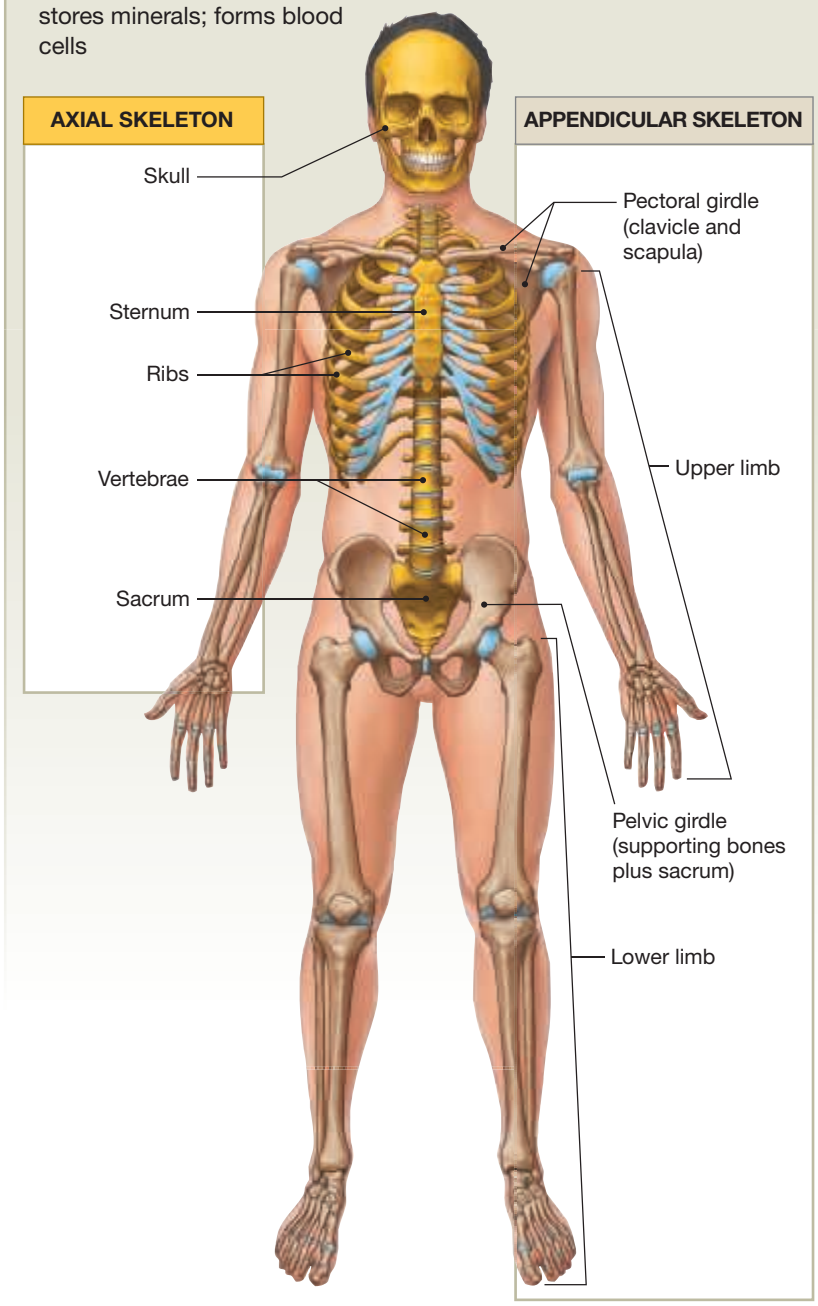
The Integumentary System

Protects against environmental hazards; helps control body temperature

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

The Skeletal System

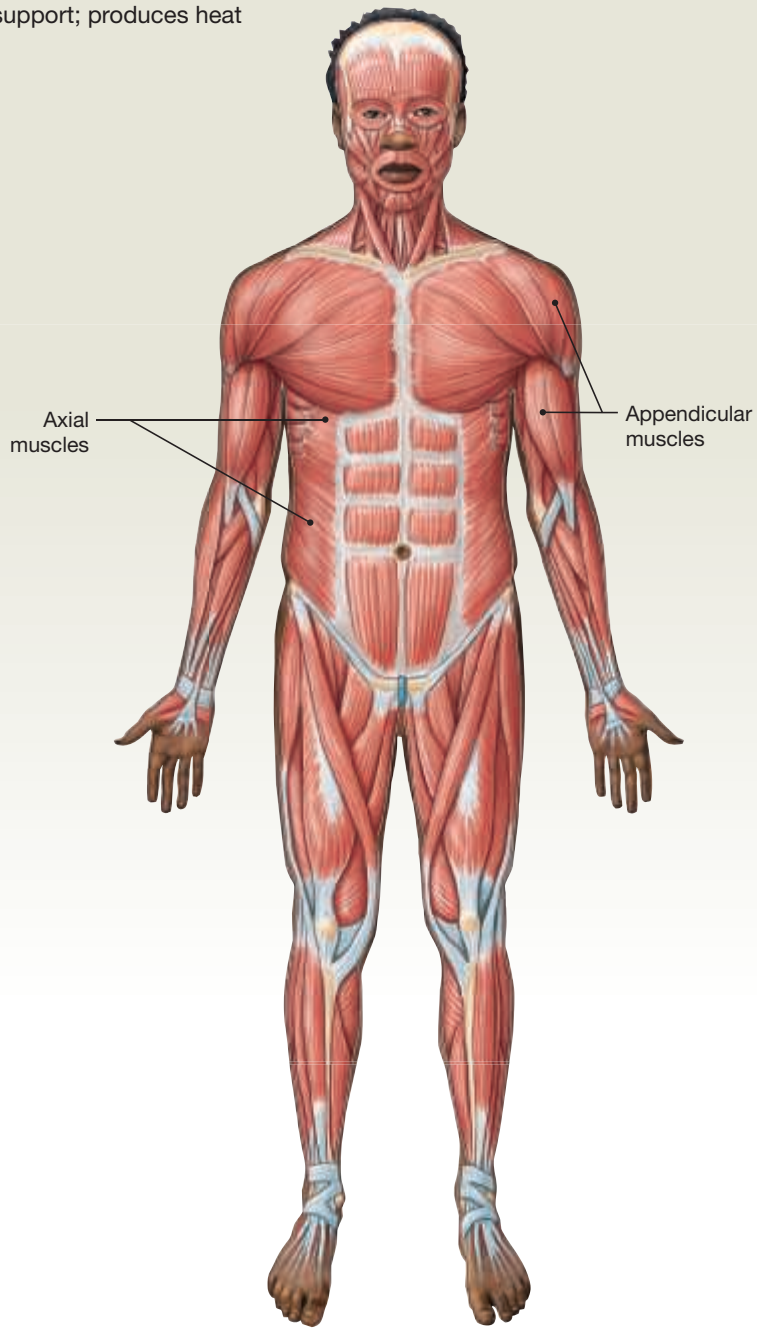
Supports and protects tissues; stores minerals; forms blood cells



Organ/Componenent	Primary Functions
Bones, Cartilages, and Joints	Support and protect soft tissues; bones store minerals
Axial skeleton (skull, vertebrae, sacrum, coccyx, sternum, supporting cartilages and ligaments)	Protects brain, spinal cord, sense organs, and soft tissues of thoracic cavity; supports the body weight over lower limbs
Appendicular skeleton (limbs and supporting bones and ligaments)	Provides internal support and positioning of the limbs; supports and moves axial skeleton
Ligaments	Connect bone to bone, bone to cartilage, or cartilage to cartilage
Bone Marrow	Primary site of blood cell production (red bone marrow); storage of energy reserves in fat cells (yellow bone marrow)

The Muscular System

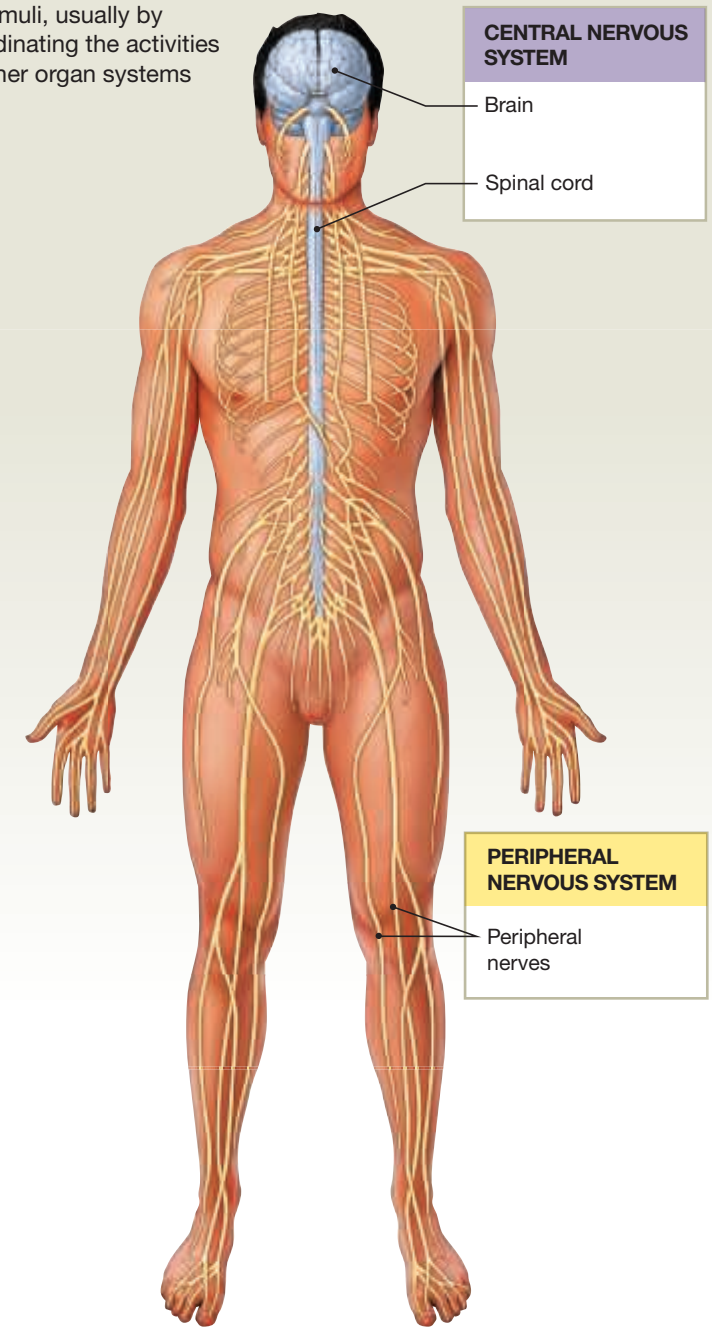
Allows for locomotion; provides support; produces heat



Organ/Component	Primary Functions
Skeletal Muscles	Provide skeletal movement; control entrances to digestive and respiratory tracts and exits to digestive and urinary tracts; produce heat; support skeleton; protect soft tissues
Axial muscles	Support and position axial skeleton
Appendicular muscles	Support, move, and brace limbs
Tendons and Aponeuroses	Transmit the contractile forces of skeletal muscle to bone in order to move

The Nervous System

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



Organ/Component	Primary Functions
Central Nervous System (CNS)	Control center for nervous system; processes information; short-term control over activities of other systems
Brain	Performs complex integrative functions; controls both voluntary and autonomic activities
Spinal cord	Relays information to and from brain; performs less-complex integrative activities
Special senses	Provide sensory input to the brain relating to sight, hearing, smell, taste, and equilibrium
Peripheral Nervous System (PNS)	Links CNS with other systems and with sense organs