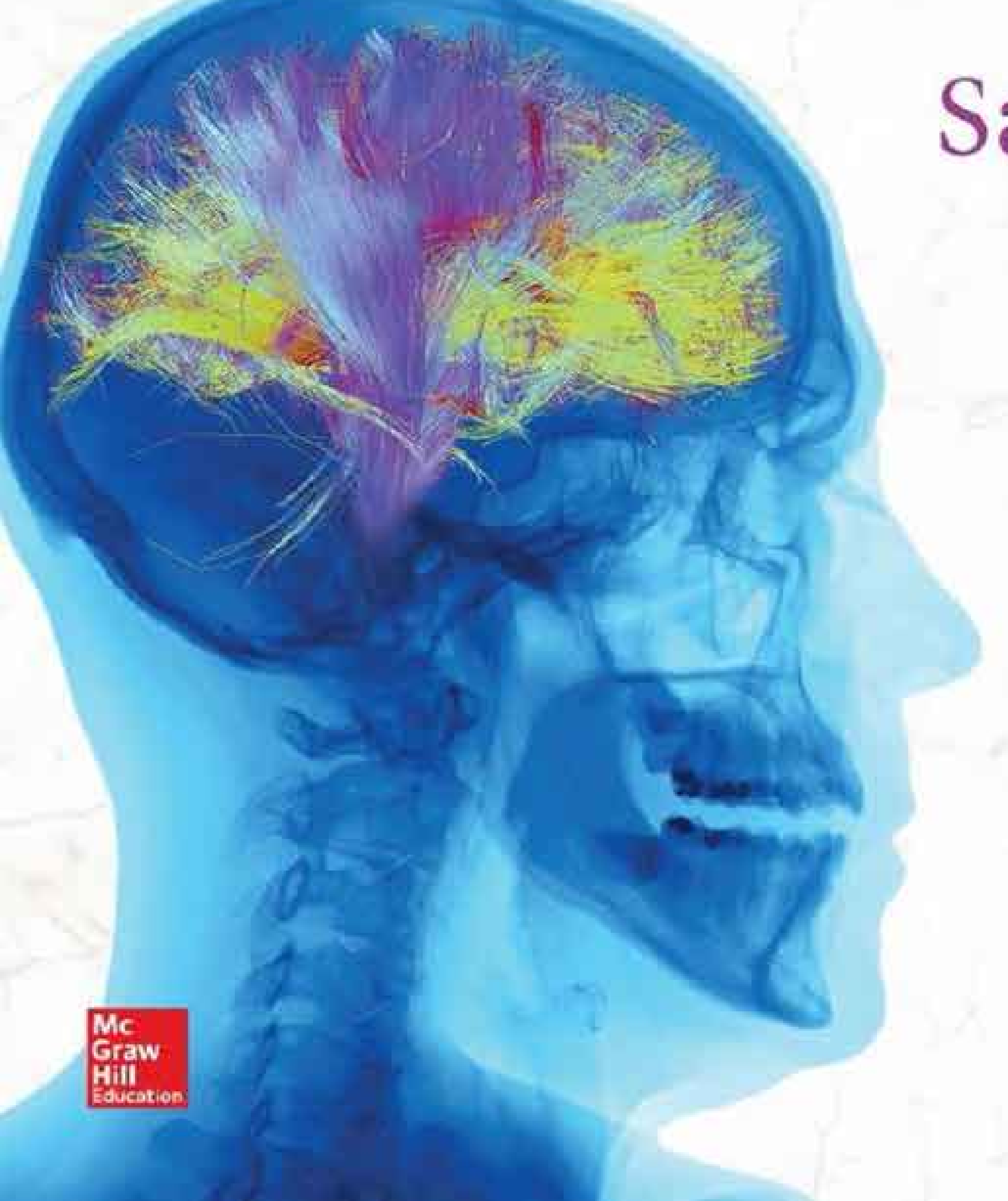
Human Anatomy

FIFTH EDITION

Saladin



Mc Graw Hill Education

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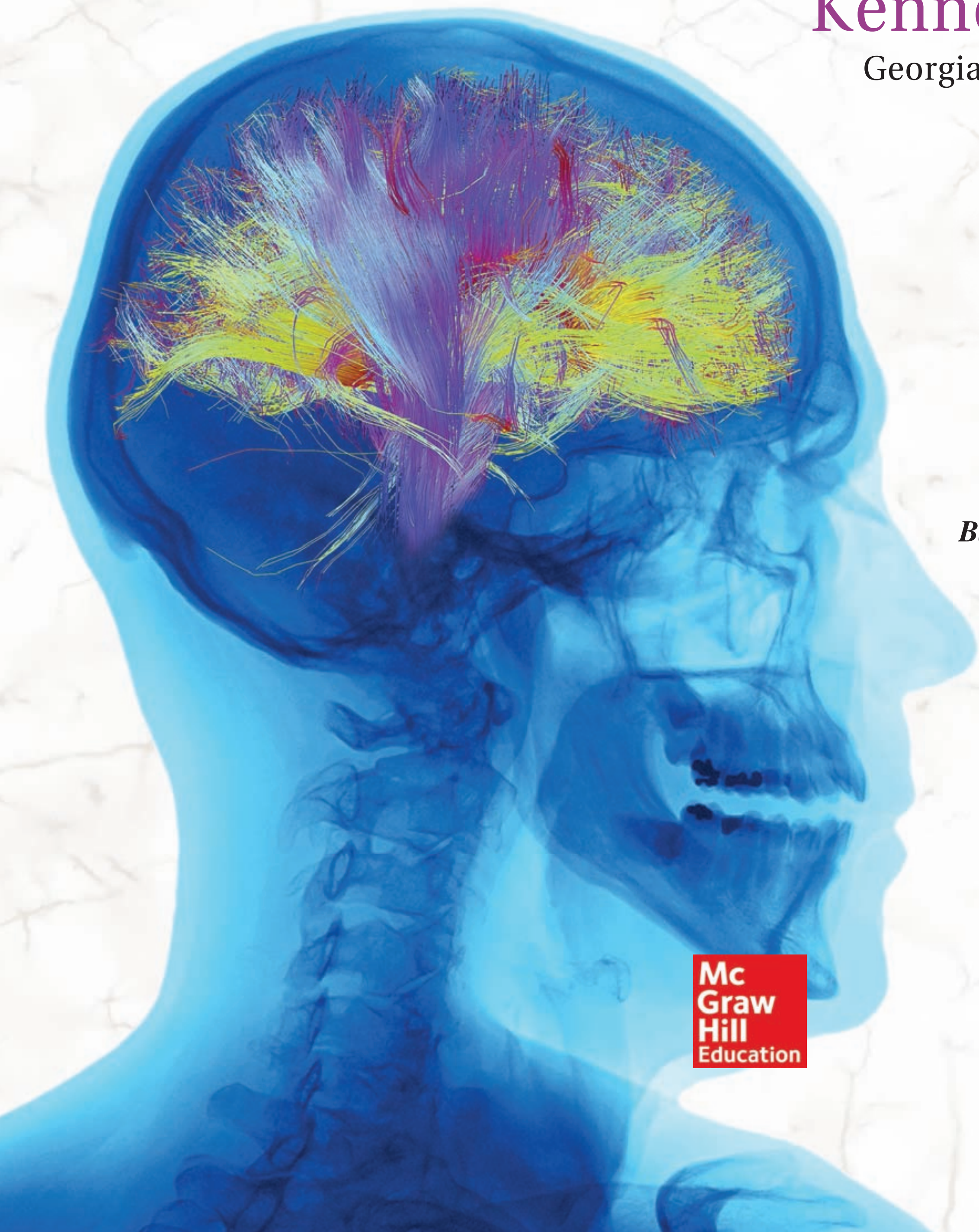
Kenneth S. Saladin
Georgia College & State University



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HUMAN ANATOMY, FIFTH EDITION

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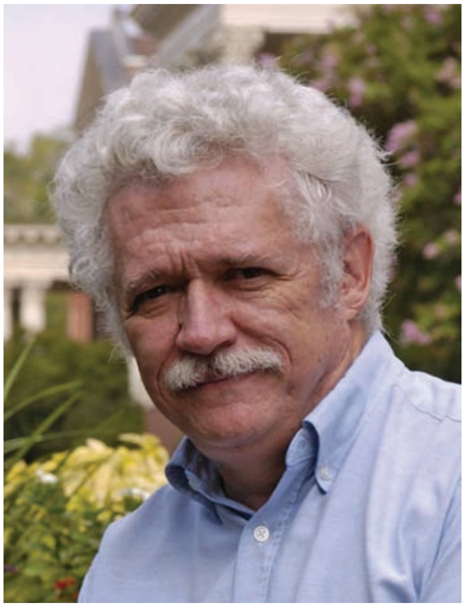
ABOUT THE AUTHORS



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KENNETH SALADIN is Distinguished Professor of Biology at Georgia College & State University, where he has taught since 1977. He received his B.S. in zoology at Michigan State University and his Ph.D. in parasitology at Florida State University. Ken teaches human anatomy and physiology, introduction to medical physiology, histology, premedical seminar, and animal behavior, among other courses. He is a member of the Human Anatomy and Physiology Society, American Association of Anatomists, American Physiological Society, Society for Integrative and Comparative Biology, and American Association for the Advancement of Science. He is the author of the best-selling textbook *Anatomy & Physiology: The Unity of Form and Function* and coauthor, with Robin McFarland, of *Essentials of Anatomy & Physiology.* Ken has used the earnings from his textbooks to fund ecosystem conservation and restoration in the Galápagos Islands, to support the Charles Darwin Research Station in the Galápagos, to remodel and equip a Georgia College anatomy laboratory, and to establish multiple student scholarships and an endowed chair in biomedical science and premedical mentoring. Ken and his wife Diane live in Milledgeville, Georgia, and have two adult children in North Carolina.

Courtesy of Tabitha Dell'Angelo

STEPHEN J. SULLIVAN, digital author for the Connect question bank, has been teaching anatomy and physiology at Bucks County Community College in Pennsylvania since 2002. Steve started consulting with McGraw-Hill on the development of digital tools in 2009. His goal for Connect is to create digital assessments that directly reflect the content and style of Ken Saladin's text, provide student access, and foster student success. Steve is a member of the Human Anatomy and Physiology Society and the American Association of Anatomists, and is a 2013 recipient of the Lindback Award for Distinguished Teaching.

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CHRISTINA A. GAN, digital author for the Connect testbank, has been teaching anatomy and physiology, microbiology, and general biology at Highline College in Des Moines, Washington, since 2004. Before that she taught at Rogue Community College in Medford, Oregon, for six years. Christina earned her M.A. in biology from Humboldt State University, researching the genetic variation of mitochondrial DNA in various salmonid species, and is a member of the Human Anatomy and Physiology Society. When she is not in the classroom or developing digital media, she is climbing, mountaineering, skiing, kayaking, sailing, cycling, and mountain biking throughout the Pacific Northwest.

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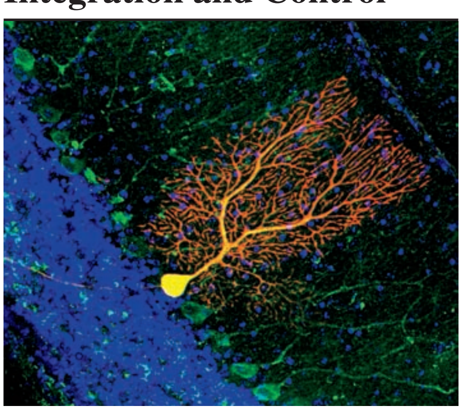
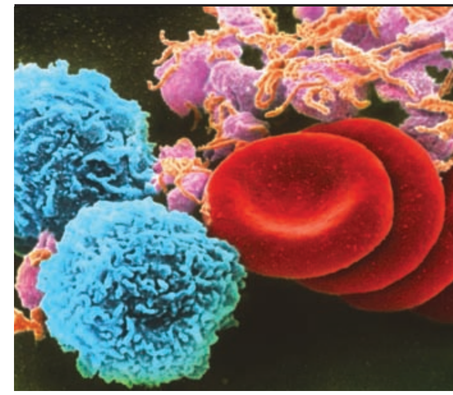
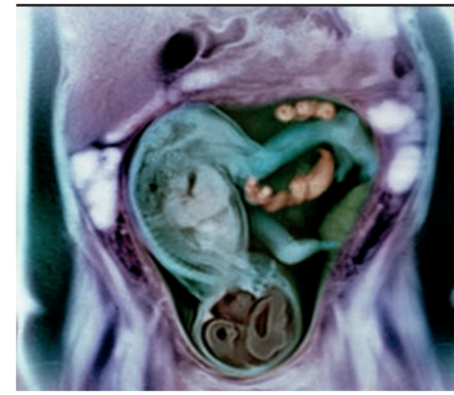


PART FOUR

Maintenance





PREFACE

Saladin's *Human Anatomy* goes beyond descriptions of body structure to read as a story that weaves together basic science, clinical applications, the history of medicine, and the evolutionary basis of human structure. Saladin combines this humanistic perspective with vibrant photos and art to convey the beauty and excitement of the subject to beginning students.

New to the Fifth Edition

New Scientific Information

This fifth edition features new and updated scientific content on the limitations and applications of MRI and PET scans (chapter 1); pseudopods and ciliopathies (chapter 2); the pathogenesis of pressure sores (chapter 3); causes of spontaneous abortion (chapter 4); skin grafting with atomized spray-on stem cells (chapter 5); the reemergence of polio due to anti-vaccination politics (chapter 14); and the newly recognized pancreatic hormone amylin (chapter 18).

This edition also offers new functional perspectives on biomechanics of the fingernails (chapter 5) and patella (chapter 8); myoglobin (chapter 10); serratus posterior muscles (chapter 11); linguistic functions of the right cerebral hemisphere (chapter 15); lamellar corpuscles (chapter 17); the trabeculae carneae and papillary muscles of the heart (chapter 20); the spleen (chapter 22); the shape and interfaces between pulmonary alveoli (chapter 23); and oogenesis and folliculogenesis (chapter 26). Chapter 21 offers new Deeper Insight essays on air embolism and central venous catheters.

New Perspectives

This edition follows *Gray's Anatomy* and other leading authorities in dispensing with *origin* and *insertion* terminology for muscle attachments (for reasons explained on page 241). The muscle tables in chapters 11 and 12 now list muscle attachments without calling them by these increasingly obsolete terms. Muscle innervations are also simplified in these tables by citing the major cranial and spinal nerves rather than their finer branches.

This edition updates many other anatomical terms and deletes most eponyms in keeping with the *Terminologia Anatomica.* It deletes or de-emphasizes other commonly held but erroneous beliefs such as lactic acid as a cause of muscle fatigue (chapter 10), discredited stories such as Phineas Gage's brain trauma effects (chapter 15), the long-believed absence of lymphatic vessels from the CNS (chapter 22), and obsolete practices such as gallstone lithotripsy (chapter 24).

New Art and Photography

This edition has more than 90 changes in the art program ranging from fine adjustments in art and labeling to entirely new figures of pseudopods (fig. 2.14), structure of the nucleus (fig. 2.18), and proteasomes (fig. 2.19c). Improvements have been made in depictions of the optic radiation of the brain (fig. 17.30) and intercalated discs of cardiac muscle (fig. 20.14). Color keys to the bones have been added to all of the skull art in chapter 7.

New and better photography will be found in these pages for the cerebral angiogram (fig. 1.3b); fluorescent-stained cytoskeleton (fig. 2.16b); the 20-week fetus in utero (fig. 4.11f); basal cell carcinoma (fig. 5.13a); persons exhibiting spinal osteoporosis (fig. 6.16c), peripheral edema (fig. 22.2); the developmental effect of thalidomide (fig. 4.15); X-ray anatomy of the hand (fig. 8.5c); dissection of the ankle (fig. 9.26b); vascular casts of skeletal muscle and the thyroid gland (figs. 10.13 and 21.2); histology of lymphatic nodules (fig. 22.8); the lung (fig. 23.10); the pituitary and adrenal glands (figs. 18.3 and 18.8); and new electron micrographs of erythrocytes in a capillary (fig. 19.3c), an eosinophil (fig. 19.7), macrophage action (fig. 22.7), gastric pits (fig. 24.12), the renal glomerulus (fig. 25.9), and seminiferous tubules (fig. 26.4).

What Else Is New?

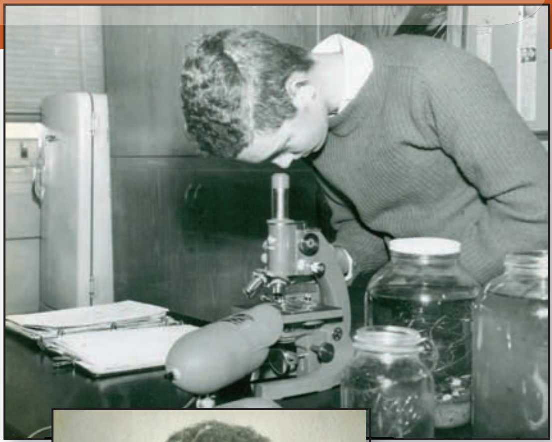
Saladin has added two full-page illustrated summaries of the levels of skeletal muscle structure (table 10.1) and cranial nerve pathways (fig. 15.24), enabling students to step back from the details and see the big picture. Expected Learning Outcomes for each chapter section are now listed by letter (in place of bullet points) for easier reference or assignment by instructors, and are reinforced with Assess Your Learning Outcomes in the Study Guide at the end of each chapter. Feedback from students in his own classroom and e-mails from students worldwide have led Ken to rewrite several passages for economy of words and greater conceptual clarity.

A Storytelling Writing Style

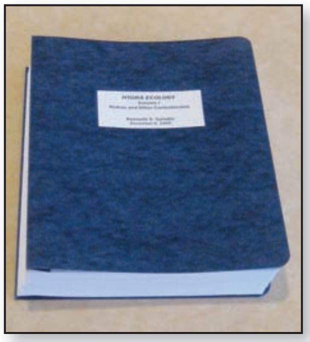
Students and instructors alike cite Saladin's prose style as the number one attraction of this book. Students doing blind comparisons of Ken Saladin's chapters and those of other anatomy books routinely find Saladin clearly written, easy to understand, and a stimulating, interesting read. Saladin's analogy-rich writing enables students to easily visualize abstract concepts in terms of everyday experience.

Such dimensions are more impressive when we scale them up to the size of familiar objects. If the soma of a spinal motor neuron was the size of a tennis ball, its dendrites would form a huge bushy mass that could fill a 30-seat classroom from floor to ceiling. Its axon would be up to a mile long but a little narrower than a garden hose. This is quite a point to ponder. The neuron must assemble molecules and organelles in its "tennis ball" soma and deliver them through its "mile-long garden hose" to the end of the axon.

EVOLUTION OF A STORYTELLER

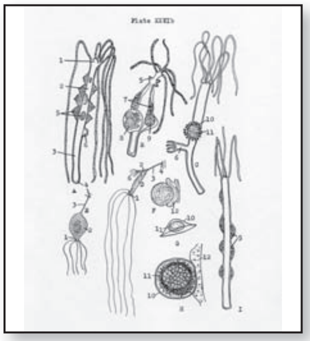


Ken Saladin's penchant for writing began early. For his 10th-grade biology class, he wrote a 318-page monograph on hydras with 53 original India ink drawings and 10 original photomicrographs. We at McGraw-Hill think of this as Ken's "first book." At a young age, Ken already was developing his technical writing style, research habits, and illustration skills.



Courtesy of Ken Saladin

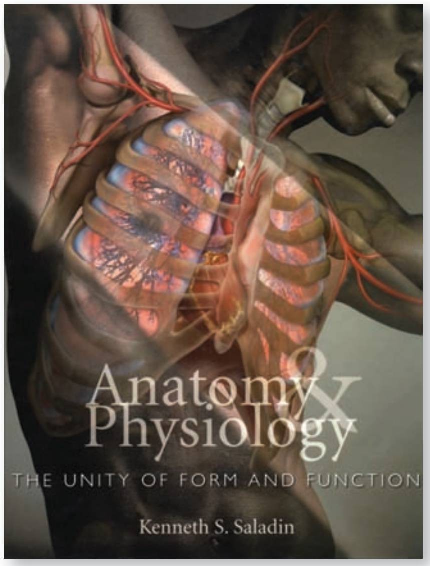
Ken Saladin's "first book," *Hydra Ecology* (1965)



Courtesy of Ken Saladin

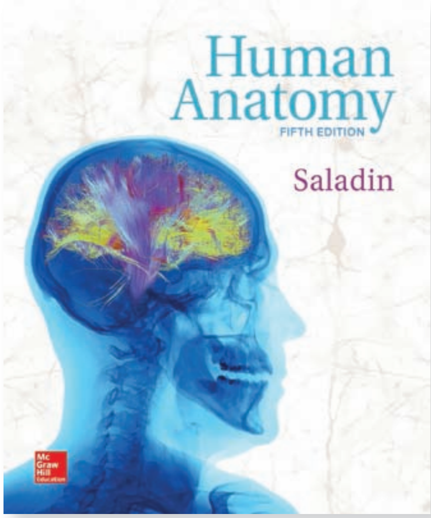
Some of Ken's first pen-and-ink artwork (1965)

Ken in 1964

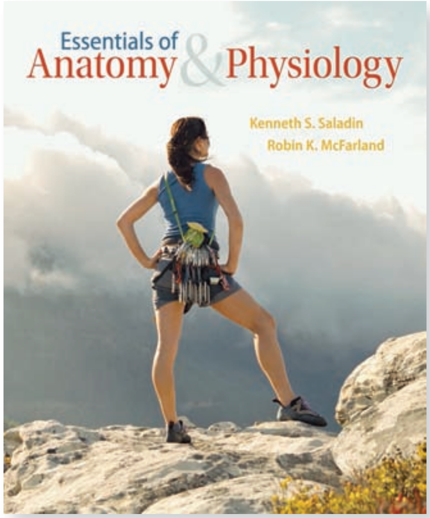


Ken's first textbook published in 1997

Ken served as an A&P textbook reviewer and testbank writer for several years and then embarked on his first book for McGraw-Hill in 1993. He published the first edition of *Anatomy & Physiology: The Unity of Form and Function* in 1997 and his first edition of *Human Anatomy* in 2004. The story continues with *Human Anatomy,* fifth edition.



The story continues in 2016



Essentials book published in 2013

Instructive Artwork for Visual Learners

Saladin's stunning illustrations and photos entice students who regard themselves as "visual learners."

Vivid Illustrations with rich textures and shading and bold, bright colors bring anatomy to life.

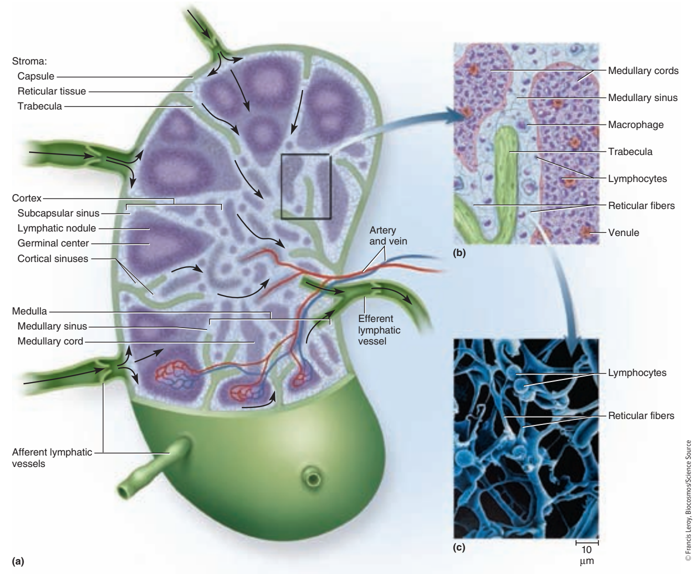


Figure 22.11 Anatomy of a Lymph Node. (a) Partially bisected lymph node showing pathway of lymph flow. (b) Detail of the boxed region in part (a). (c) Reticular fiber stroma and immune cells in a medullary sinus (SEM). APR

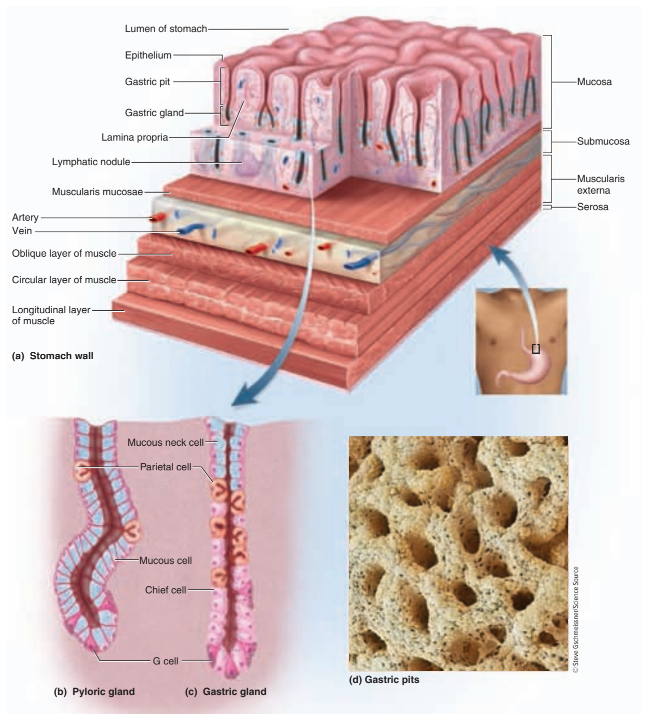


Figure 24.12 Microscopic Anatomy of the Stomach Wall. (a) A block of tissue showing all layers from the mucosa (top) to the serosa (bottom). (b) A pyloric gland from the inferior end of the stomach. Note the absence of chief cells and relatively few parietal cells. (c) A gastric gland, the most widespread type in the stomach. (d) The opening of several gastric pits into the stomach, surrounded by the rounded apical surfaces of the columnar epithelial cells of the mucosa (SEM). APR

Process Figures relate numbered steps in the art with corresponding numbered text descriptions.

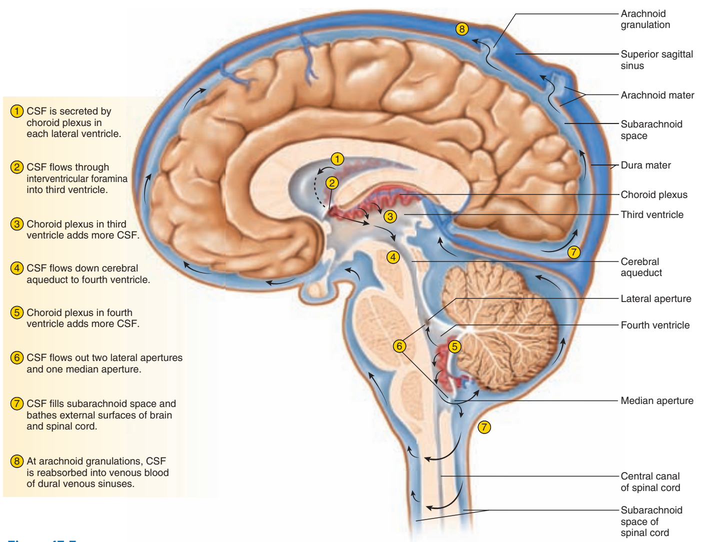


Figure 15.5 The Flow of Cerebrospinal Fluid.

Orientation Tools, like dissection planes and a compass on the anatomical art, clarify the perspective from which a structure is viewed.

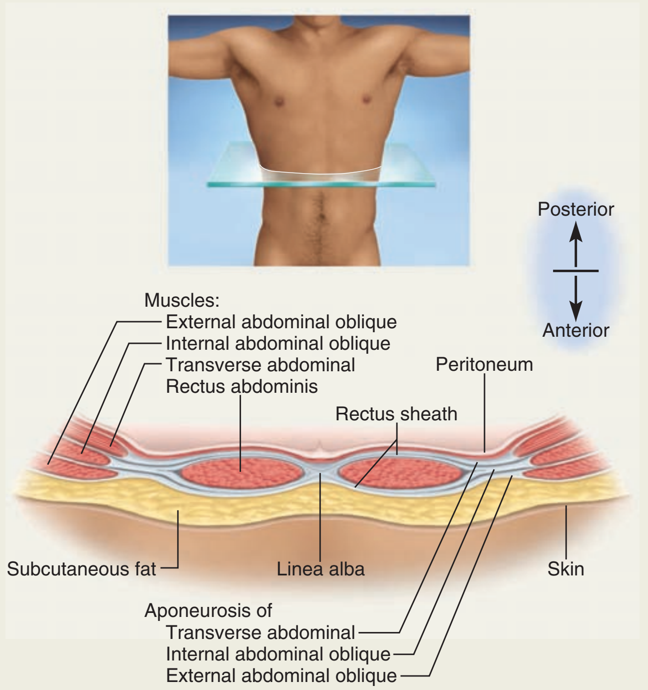


Figure 11.10 Cross Section of the Anterior Abdominal Wall.

The Psychology of Learning

Having taught human anatomy for 38 years, Saladin knows what works in the classroom and incorporates those approaches into the pedagogy of *Human Anatomy*.

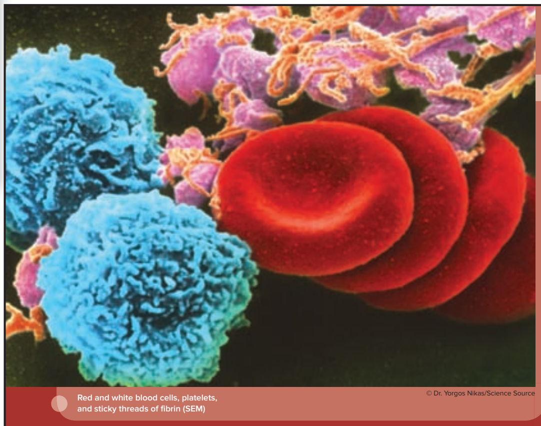
Chapters Organized for Preview and Review

Chapter Outline provides a content preview and facilitates review and study.

Deeper Insights pique the interest of health-science students by showing the clinical relevance of the core science.

Brushing Up reminds students of the relevance of earlier chapters to the one on which they are currently embarking.

Anatomy & Physiology REVEALED® icons indicate which area of this interactive cadaver dissection program corresponds to the chapter topic.



PART FOUR

Red and white blood cells, platelets, and sticky threads of fibrin (SEM)

© Dr. Yorgos Nikas/Science Source

CHAPTER 19

THE CIRCULATORY SYSTEM I

BLOOD

CHAPTER OUTLINE

DEEPER INSIGHTS

BRUSHING UP

To understand this chapter, you may find it helpful to review the following concepts:
- Osmosis (p. 34)
- Red bone marrow (p. 138)
- Erythropoietin (p. 510)

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Module 9: Cardiovascular System

7.1 Overview of the Skeleton

Expected Learning Outcomes

When you have completed this section, you should be able to

a. define the two subdivisions of the skeleton;
b. state the approximate number of bones in the adult body;
c. explain why this number varies with age and from one person to another; and
d. define several terms that denote surface features of bones.

Before You Go On

Answer the following questions to test your understanding of the preceding section:

1. Name the major components of the axial skeleton. Name those of the appendicular skeleton.
2. Explain why an adult does not have as many bones as a child does. Explain why one adult may have more bones than another adult of the same age.
3. Briefly describe each of the following bone features: condyle, epicondyle, process, tubercle, fossa, sulcus, and foramen.

Reinforced Learning

Each section is a conceptually unified topic, framed between a pair of learning "bookends"—a set of learning objectives at the beginning and a set of review and self-testing questions at the end. Each section is numbered for easy reference in lecture, assignments, and ancillary materials.

Expected Learning Outcomes give the student a preview of key points to be learned within the next few pages.

Before You Go On prompts the student to pause and spot-check his or her mastery of the previous few pages before progressing to new material.

Vocabulary Building

Several features help build a student's level of comfort with medical vocabulary.

Pronunciation Guides Knowing proper pronunciation is key to remembering and spelling terms. Saladin gives simple, intuitive "pro-NUN-see-AY-shun" guides to help students over this hurdle and widen the student's comfort zone for medical vocabulary.

Word Origins Accurate spelling and insight into medical terms are greatly enhanced by a familiarity with commonly used word roots, prefixes, and suffixes.

Footnotes throughout the chapters help build the student's working lexicon of word elements. An end-of-book Glossary provides clear definitions of the most important or frequently used terms.

Building Your Medical Vocabulary An exercise at the end of each chapter helps students creatively use their knowledge of new medical word elements.

Types of Neuroglia

There are six major categories of neuroglia, each with a unique function (table 13.1). Four types occur only in the central nervous system (fig. 13.6):

1. **Oligodendrocytes**[15] (OL-ih-go-DEN-dro-sites) somewhat resemble an octopus; they have a bulbous body with as many as 15 armlike processes. Each process reaches out to a nerve fiber and spirals around it like electrical tape wrapped repeatedly around a wire. This wrapping, called the *myelin sheath,* insulates the nerve fiber from the extracellular fluid and speeds up signal conduction in the nerve fiber.

[15]*oligo* = few; *dendro* = branches; *cyte* = cell

Building Your Medical Vocabulary

State a medical meaning of each of the following word elements, and give a term in which it is used.

1. -ic
2. somato-
3. neuro-
4. lipo-
5. dendro-
6. -ite
7. pseudo-
8. oligo-
9. fer-
10. sclero-

Answers in appendix A

Self-Assessment Tools

Saladin provides students with abundant opportunities to evaluate their comprehension of concepts. A wide variety of questions from simple recall to analytical evaluation cover all six cognitive levels of Bloom's Taxonomy of Educational Objectives.

Before You Go On questions test simple recall and lower-level interpretation of information read in the previous few pages.

Apply What You Know tests a student's ability to think of the deeper implications or clinical applications of a point he or she just read.

Figure Legend Questions posed in many of the figure legends prompt the student to interpret the art and apply it to the reading.

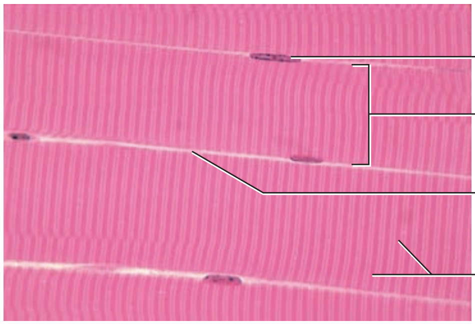

Figure 10.1 **Skeletal Muscle Fibers.**
• *What tissue characteristics evident in this photo distinguish this from cardiac and smooth muscle?* AP|R

- **The placenta.** This organ performs many functions in pregnancy, including fetal nutrition and waste removal. But it also secretes estrogen, progesterone, and other hormones that regulate pregnancy and stimulate development of the fetus and the mother's mammary glands.

Apply What You Know

Often, two hormones have opposite *(antagonistic)* effects on the same target organs. For example, oxytocin stimulates labor contractions, and progesterone inhibits premature labor. Name some other examples of antagonistic effects among the hormones in this chapter.

You can see that the endocrine system is extensive. It includes numerous discrete glands as well as individual cells in the tissues of other organs. The endocrine organs and tissues other than the hypothalamus and pituitary are reviewed in table 18.3.

Before You Go On

Answer the following questions to test your understanding of the preceding section:

9. Name two endocrine glands that are larger in children than in adults. What are their functions?
10. What hormone increases the body's heat production in cold weather? What other functions does this hormone have?
11. Name the main hormone secreted by each layer of the adrenal cortex and one secreted by the adrenal medulla, and state the function of each.
12. What is the difference between a gonadal hormone and a gonadotropin?
13. What hormones are most important in regulating blood glucose concentration? What cells produce them? Where are these cells found?
14. Name one hormone produced by each of the following organs—the heart, liver, and placenta—and state the function of each hormone.

Testing Your Recall sections at the end of each chapter offer 20 simple recall questions to test retention of terminology and basic ideas.

True or False statements require students not merely to evaluate their truth, but also to concisely explain why the false statements are untrue, or rephrase them in a way that makes them true.

Testing Your Comprehension questions are clinical application and other interpretive essay questions that require the student to apply the chapter's basic science to clinical or other scenarios.

Testing Your Recall

1. The hip bone is attached to the axial skeleton through its
   a. auricular surface.
   b. articular cartilage.
   c. pubic symphysis.
   d. conoid tubercle.
   e. coronoid process.
2. Which of these bones supports the most body weight?
   a. ilium
   b. pubis
   c. femur
   d. tibia
   e. talus
3. Which of these structures can be most easily palpated on a living person?
   a. the deltoid tuberosity
   b. the greater sciatic notch
   c. the medial malleolus
   d. the coracoid process of the scapula
   e. the glenoid cavity
4. Compared to the male pelvis, the pelvis of a female
   a. has a less movable coccyx.
   b. has a rounder pelvic inlet.
   c. is narrower between the iliac crests.
   d. has a narrower pubic arch.
   e. has a narrower sacrum.
5. The lateral and medial malleoli are most similar to
   a. the radial and ulnar styloid processes.
   b. the humeral capitulum and trochlea.
   c. the acromion and coracoid process.
   d. the base and head of a metacarpal bone.
   e. the anterior and posterior superior iliac spines.
6. When you rest your hands on your hips, you are resting them on
   a. the pelvic inlet.
   b. the pelvic outlet.
   c. the pelvic brim.
   d. the iliac crests.
   e. the auricular surfaces.
7. The disc-shaped head of the radius articulates with the _____ of the humerus.
   a. radial tuberosity
   b. trochlea
   c. capitulum
   d. olecranon process
   e. glenoid cavity
8. All of the following are carpal bones *except* the _____, which is a tarsal bone.
   a. trapezium
   b. cuboid
   c. trapezoid
   d. triquetrum
   e. pisiform
9. The bone that supports your body weight when you are sitting down is
   a. the acetabulum.
   b. the pubis.
   c. the ilium.
   d. the coccyx.
   e. the ischium.
10. Which of these is the bone of the heel?
    a. cuboid
    b. calcaneus
    c. navicular
    d. trochlear
    e. talus

True or False

Determine which five of the following statements are false, and briefly explain why.

1. There are more carpal bones than tarsal bones.
2. The hands have more phalanges than the feet.
3. The upper limb is attached to the axial skeleton at only one point, the acromioclavicular joint.
4. On a living person, it would be possible to palpate the muscles in the infraspinous fossa but not those of the subscapular fossa.
5. In strict anatomical terminology, the words *arm* and *leg* both refer to regions with only one bone.
6. If you rest your chin on your hands with your elbows on a table, the olecranon of the ulna rests on the table.
7. The most frequently broken bone in humans is the humerus.
8. The proximal end of the radius articulates with both the humerus and ulna.
9. The pisiform bone and patella are both sesamoid bones.
10. The pelvic outlet is the opening in the floor of the greater pelvis leading into the lesser pelvis.

Answers in appendix A

Testing Your Comprehension

1. In adolescents, trauma sometimes separates the head of the femur from the neck. Why do you think this is more common in adolescents than in adults?
2. By palpating the hind leg of a cat or dog or examining a laboratory skeleton, you can see that cats and dogs stand on the heads of their metatarsal bones; the calcaneus does not touch the ground. How is this similar to the stance of a woman wearing high-heeled shoes? How is it different?
3. A deer hunter discovers a human skeleton in the woods and notifies authorities. A news report on the finding describes it as the body of an unidentified male between 17 and 20 years of age. What skeletal features would have been most useful for determining the sex and approximate age of the individual?
4. A surgeon has removed 8 cm of Joan's radius because of osteosarcoma, a bone cancer, and replaced it with a graft taken from one of the bones of Joan's lower limb. What bone do you think would most likely be used as the source of the graft? Explain your answer.
5. Andy, a 55-year-old, 75 kg (165-pound) roofer, is shingling the steeply pitched roof of a new house when he loses his footing and slides down the roof and over the edge, feet first. He braces himself for the fall, and when he hits the ground, he cries out and doubles up in excruciating pain. Emergency medical technicians called to the scene tell him he has broken his hips. Describe, more specifically, where his fractures most likely occurred. On the way to the hospital, Andy says, "You know it's funny, when I was a kid, I used to jump off roofs that high, and I never got hurt." Why do you think Andy was more at risk of a fracture as an adult than he was as a boy?

DEEPER INSIGHT 7.3

Abnormal Spinal Curvatures

Abnormal spinal curvatures (fig. 7.21) can result from abdominal weight gain in obesity or pregnancy; poor posture; weakness or paralysis of the trunk muscles; some diseases; or congenital defects in vertebral anatomy. The most common deformity is an abnormal lateral curvature called *scoliosis*. It occurs most often in the thoracic region, particularly among adolescent girls. It sometimes results from a developmental abnormality in which the body and arch of a vertebra fail to develop on one side. If the person's skeletal growth is not yet complete, scoliosis can be corrected with a back brace.

An exaggerated thoracic curvature is called *kyphosis* (hunchback, in lay language). It is usually a result of osteoporosis, but it also occurs in people with osteomalacia or spinal tuberculosis and in adolescents who engage heavily in such sports as wrestling and weight lifting. An exaggerated lumbar curvature is called *lordosis* (swayback). It can have the same causes as kyphosis, or it can result from added abdominal weight in pregnancy or obesity.

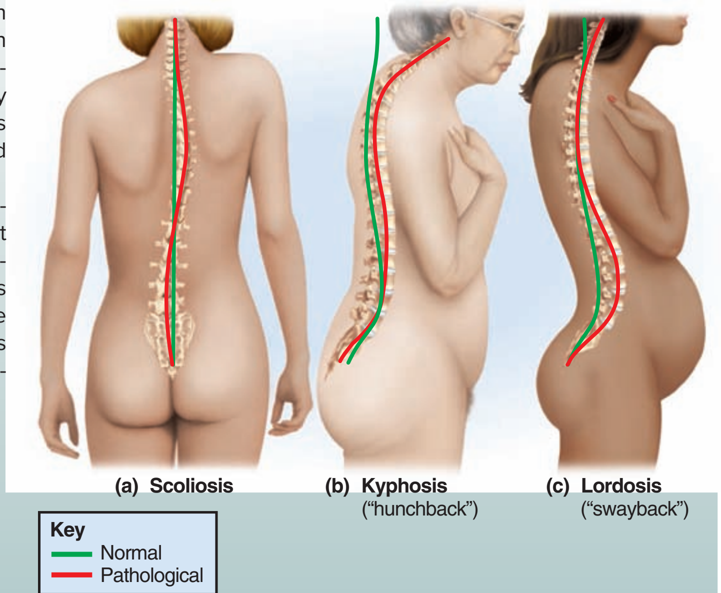

Figure 7.21 Abnormal Spinal Curvatures. (a) Scoliosis, an abnormal lateral deviation. (b) Kyphosis, an exaggerated thoracic curvature common in old age. (c) Lordosis, an exaggerated lumbar curvature common in pregnancy and obesity.

Making it Relevant

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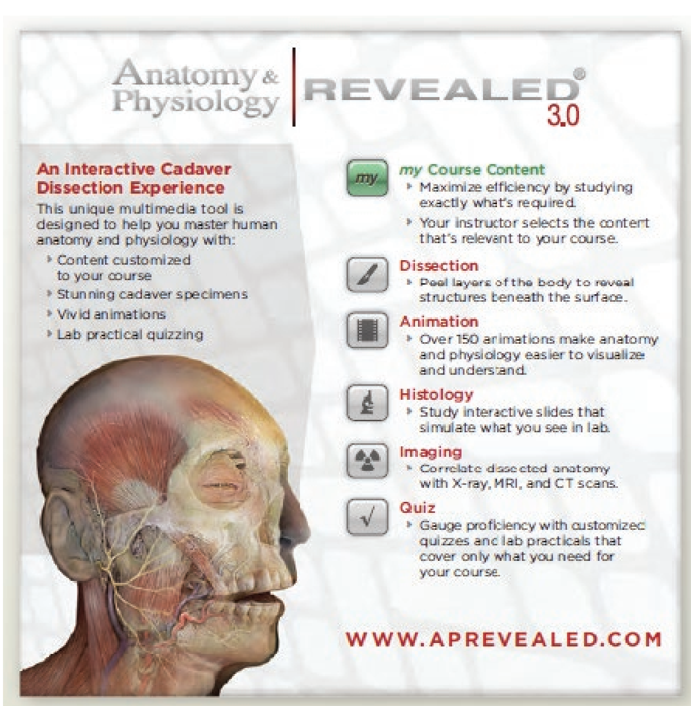

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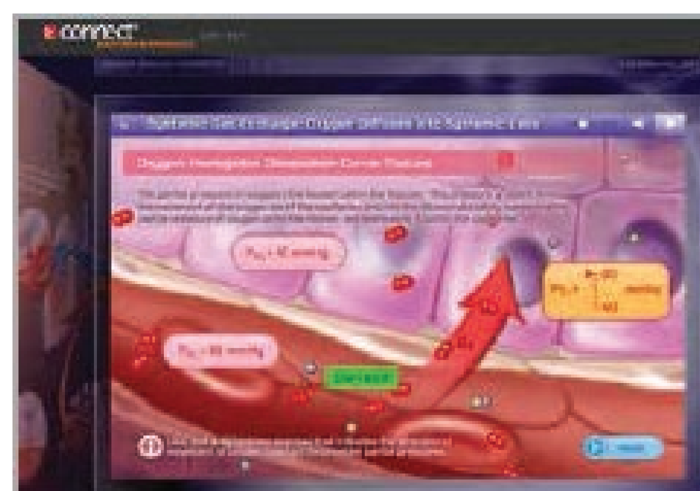

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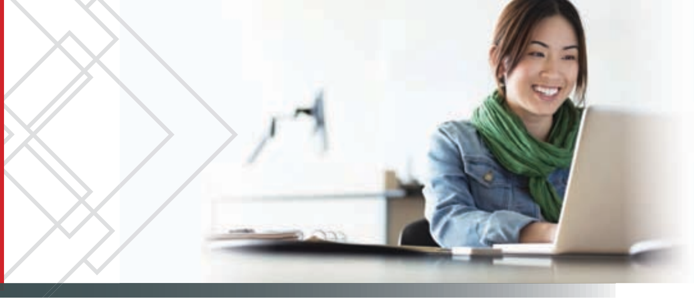

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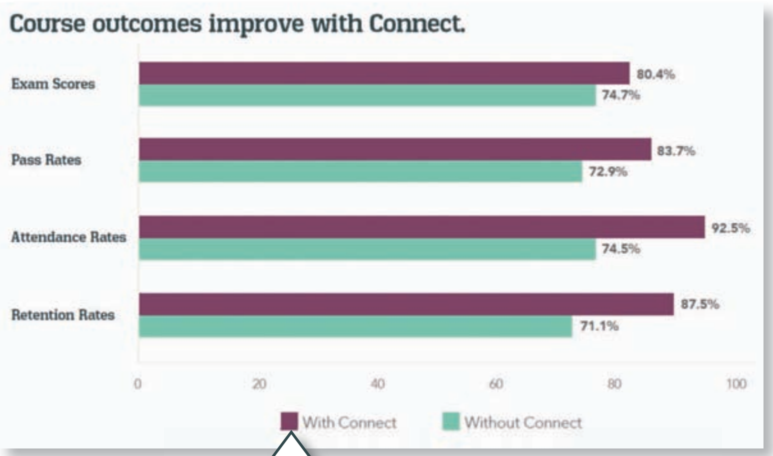

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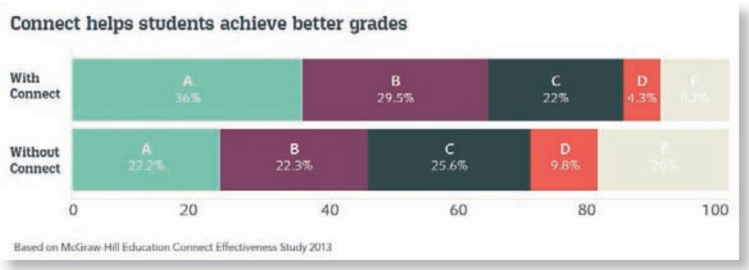

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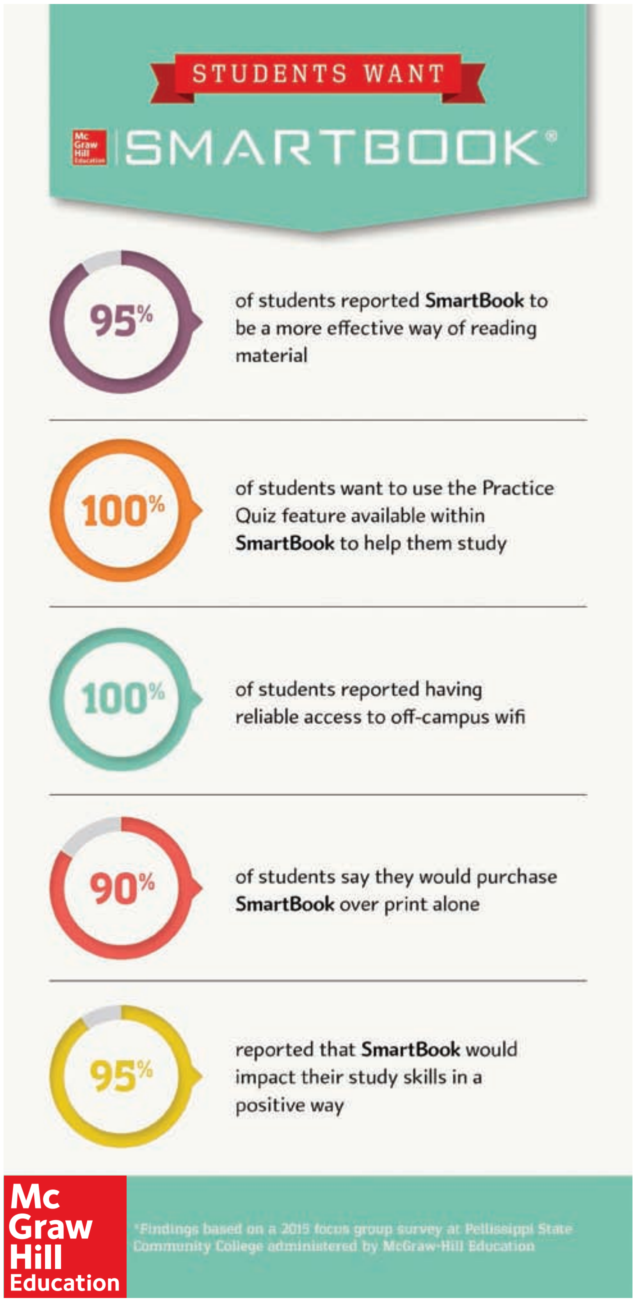

ACKNOWLEDGMENTS

I wish to thank the hundreds of colleagues who have reviewed my writing over the years and tremendously contributed to the factual accuracy, scientific currency, and presentation style of the book before you. Much of this has come about through revising my flagship book, *Anatomy & Physiology: The Unity of Form and Function,* through seven editions. *Human Anatomy* and my book coauthored with Robin McFarland, *Essentials of Anatomy & Physiology,* have derived their own content improvements as they follow in the wake of the heavily reviewed two-semester textbook.

In addition to commissioned reviews of my chapters, spontaneous feedback from other instructors and from students all over the world has been enormously stimulating and helpful in the incessant effort to approach that elusive asymptote called textbook perfection. I'm deeply appreciative of all the encouragement, information, corrections, and suggestions these readers have sent, and I look forward to many more years of such productive correspondence.

My digital team—Steve Sullivan and Chris Gan—have greatly increased the educational value of these books through their work to create self-assessment tools and align McGraw-Hill's Connect resources with the textbook. This has contributed greatly to student and instructor satisfaction with our overall package of learning media, and to the students' success as they master A&P en route to their career aspirations. I am delighted to have them on my team—all for one, and one for all! Thank you so much for what you do to adapt my product to the needs of our students.

I would also like to extend appreciation to members of the Life Sciences Book Team at McGraw-Hill Education who have worked with me on this project, including Amy Reed, Senior Brand Manager; Chloe Bouxsein, Brand Manager; Donna Nemmers, Senior Product Developer; Vicki Krug, Senior Content Project Manager; Lori Hancock, Senior Content Licensing Specialist; Brent dela Cruz, Senior Content Project Manager; David Hash, Senior Designer Jeanne Patterson, freelance Copyeditor; and Julie De Adder, Photo Researcher. Their efforts have yielded another great edition of the text and its companion media suite of Connect products.

Ken Saladin

Georgia College & State University

LETTER TO STUDENTS

Dear Students,

When I was a young boy, I became interested in what I then called “nature study” for two reasons. One was the sheer beauty of nature. I reveled in children’s books with abundant, colorful drawings and photographs of animals, plants, minerals, and gems. It was this esthetic appreciation of nature that made me want to learn more about it and made me happily surprised to discover I could make a career of it. At a slightly later age, another thing that drew me still deeper into biology was to discover writers who had a way with words—who could captivate my imagination and curiosity with their elegant prose. Once I was old enough to hold part-time jobs, I began buying zoology and anatomy books that mesmerized me with their gracefulness of writing and fascinating art and photography. I wanted to write and draw like that myself, and I began learning from “the masters.” I spent many late nights in my room peering into my microscope and jars of pond water, typing page after page of manuscript, and trying pen and India ink as an art medium. My “first book” was a 318-page paper on some little pond animals called hydras, with 53 illustrations, that I wrote for my tenth-grade biology class when I was 16 (see p. ix).

Fast forward about 30 years to when I became a textbook writer, and I found myself bringing that same enjoyment of writing and illustrating to my own anatomy and physiology textbooks. Why? Not only for its intrinsic creative satisfaction, but because I’m guessing that you’re like I was—you can appreciate a book that does more than simply give you the information you need. You appreciate, I trust, a writer who makes it *enjoyable* for you through scientific, storytelling prose and a conceptualized way of illustrating things to spark interest and facilitate understanding. Some of you probably think of yourselves as “visual learners” and others as “verbal learners.” Either way, I hope this book will serve your learning style.

I know from my own students, however, that you need more than captivating illustrations and enjoyable reading. Let’s face it—A&P is a complex subject and it may seem a formidable task to acquire even a basic knowledge of the human body. It was difficult even for me to learn (and the learning never ends). So in addition to simply writing this book, I’ve given a lot of thought to what we call pedagogy—the art of teaching. I’ve designed my chapters to make them easier for you to study and to give you abundant opportunity to check whether you’ve understood what you read—to test yourself (as I advise my own students) before the instructor tests you. In later editions, we brought on a team of digital authors to produce online learning aids that students have commended as extremely helpful to them in learning human anatomy.

Each chapter is broken down into short, digestible bits with a set of learning goals (Expected Learning Outcomes) at the beginning of each section, and self-testing questions (Before You Go On) just a few pages later. Even if you have just 30 minutes to read during a lunch break or a bus ride, you can easily read or review one of these brief sections. There are also numerous self-testing questions at the end of each chapter, in some of the figure legends, and the occasional Apply What You Know questions dispersed through each chapter. The questions cover a broad range of cognitive skills, from simple recall of a term to your ability to evaluate, analyze, and apply what you’ve learned to new clinical situations or other problems.

The Guided Tour on page xii takes you through the learning aids we’ve created for you within the book itself and additional study aids available within Connect. I hope you will take a little time to look at the Guided Tour to see what we have to offer you. The Preface on page x goes a little deeper into my thinking behind the book’s design and content and will also help you get more out of your experience.

I hope you enjoy your study of this book, but I know there are always ways to make it even better. Indeed, what quality you may find in this edition owes a great deal to feedback I’ve received from students all over the world. If you find any typos or other errors, if you have any suggestions for improvement, if I can clarify a concept for you, or even if you just want to comment on something you really like about the book, I hope you’ll feel free to write to me. I correspond quite often with students and would enjoy hearing from you.

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DEDICATION

This book is dedicated to my son Emory.

PART ONE

A new life begins—a human embryo on the point of a pin (scanning electron micrograph)

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CHAPTER 1

THE STUDY OF HUMAN ANATOMY

CHAPTER OUTLINE

DEEPER INSIGHTS

Anatomy & Physiology REVEALED aprevealed.com

Module 1: Body Orientation

This book is an introduction to the structure of the human body. It is meant primarily to provide a foundation for advanced study in fields related to health and fitness. Beyond that purpose, however, the study of anatomy can also provide a satisfying sense of self-understanding. Even as children, we are curious about what's inside the body. Dried skeletons, museum exhibits, and beautifully illustrated atlases of the body have long elicited widespread public fascination.

This chapter lays a foundation for our study of anatomy by considering some broad themes. We will consider what this science encompasses and what methods are used for the study of anatomy. We will lay out a general "road map" of the human body to provide a context for the chapters that follow. We will also get some insights into how a beginning anatomy student can become comfortable with medical terminology.

1.1 The Scope of Human Anatomy

Expected Learning Outcomes

When you have completed this section, you should be able to

a. define *anatomy* and some of its subdisciplines;
b. name and describe some approaches to studying anatomy;
c. describe some methods of medical imaging; and
d. discuss the variability of human anatomy.

Human anatomy is the study of the structural basis of body function. It provides an essential foundation for understanding **physiology,** the study of the functional relevance of that structure; anatomy and physiology together are the bedrock of the health sciences. You can study human anatomy from an atlas; yet as beautiful, fascinating, and valuable as atlases are, they teach almost nothing but the locations, shapes, and names of things. This book is different; it deals with what biologists call **functional morphology**[1]—not just the structure of organs, but the functional reasons behind it.

Anatomy and physiology complement each other; each makes sense of the other, and each molds the other in the course of human development and evolution. We cannot delve into the details of physiology in this book, but enough will be said of function to help you make sense of human structure and to more deeply appreciate the beauty of human form.

The Anatomical Sciences

Anatomy is an ancient human interest, undoubtedly older than any written language we know. We can only guess when people began deliberately cutting into human bodies out of curiosity, simply to know what was inside. Some of the earliest and most influential books of anatomy were written by the Greek philosopher Aristotle (384–322 BCE), the Greek physician Galen (129–c. 199 CE), and the Persian physician Avicenna (Ibn Sina, 980–1037 CE). For nearly 1,500 years, medical professors in Europe idolized these "ancient masters" and considered their works above reproach. Modern human anatomy, however, dates to the sixteenth century, when Flemish physician and professor Andreas Vesalius (1514–64) questioned the accuracy of the earlier authorities and commissioned the first accurate anatomical illustrations for his book, *De Humani Corporis Fabrica* (*On the Structure of the Human Body,* 1543) (fig. 1.1). The tradition begun by Vesalius has been handed down to us through such famous contemporary works as *Gray's Anatomy,* Frank Netter's *Atlas of Human Anatomy,* and many others, to the richly illustrated textbooks used by college students today.

For all its attention to the deceased body, or **cadaver,**[2] human anatomy is hardly a "dead science." New techniques of study continually produce exciting new insights into human structure and its functional relevance; anatomists have discovered far more about the human body in the last century than in the 2,500 years before. Anatomy now embraces several subdisciplines that study human structure from different perspectives. **Gross anatomy** is the study of structure visible to the naked eye, using methods such as surface observation, dissection, X-rays, and MRI scans. **Surface anatomy** is the external structure of the body, and is especially important in conducting a physical examination of a patient. **Radiologic anatomy** is the study of internal structure, using X-rays and other medical imaging techniques described in the next section.

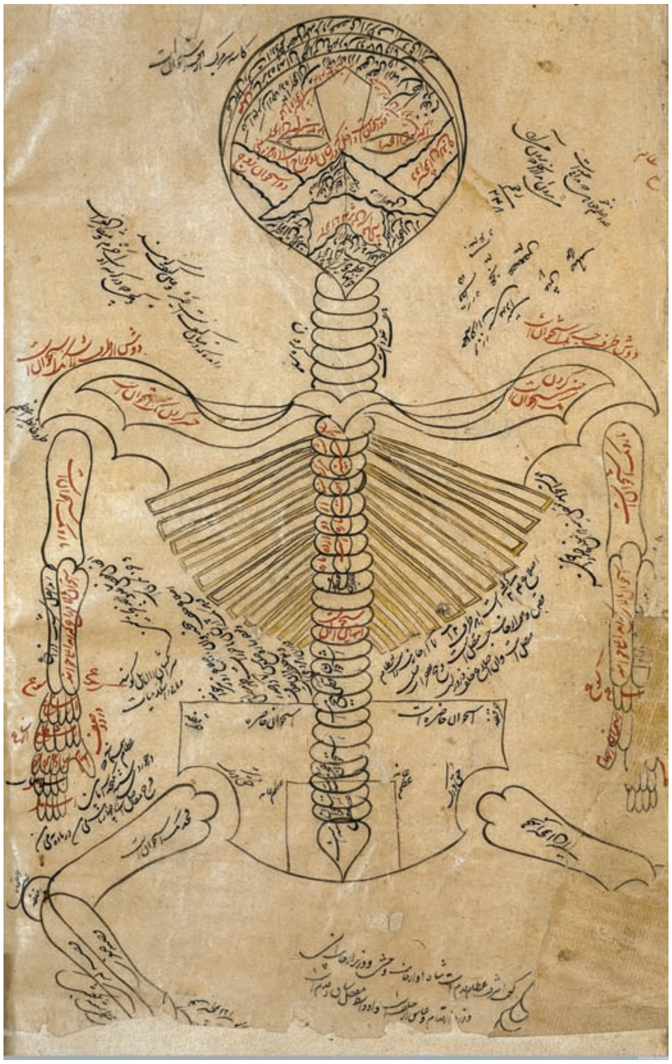
Systemic anatomy is the study of one organ system at a time and is the approach taken by most introductory textbooks such as this one. **Regional anatomy** is the study of multiple organ systems at once in a given region of the body, such as the head or chest. (See the Atlas of Regional and Surface Anatomy on p. 329.) Medical schools and anatomy atlases typically teach anatomy from a regional perspective, because it is more practical to dissect all structures of the head and neck, the chest, or a limb, than it would be to try to dissect the entire digestive system, then the cardiovascular system, and so forth. Dissecting one system almost invariably destroys organs of other systems that stand in the way. Furthermore, as surgeons operate on a particular area of the body, they must think from a regional perspective and attend to the interrelationships of all structures in that area.

Ultimately, the structure and function of the body result from its individual cells. To see those, we usually take tissue specimens, thinly slice and stain them, and observe them under the microscope. This approach is called **histology (microscopic anatomy). Histopathology**[3] is the microscopic examination of tissues for signs of disease. **Cytology**[4] is the study of the structure and function of individual cells.

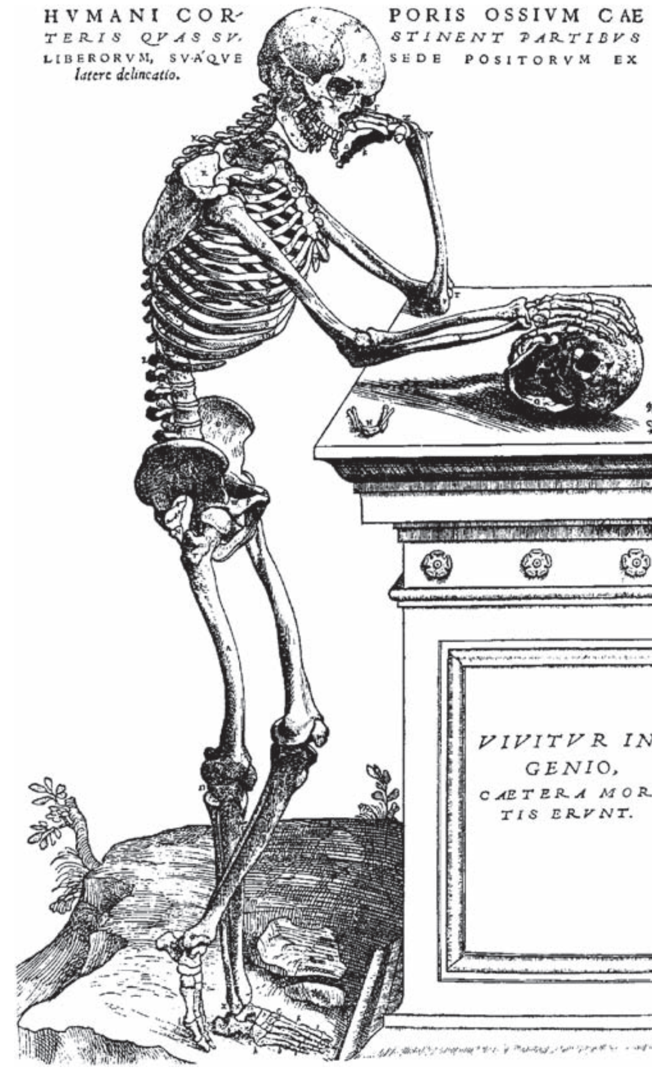
Anatomy, of course, is not limited to the study of humans, but extends to all living organisms. Even students of human structure

[1]*morpho* = form, structure; *logy* = study of

[2]from *cadere* = to fall down or die
[3]*histo* = *tissue*; *patho* = disease; *logy* = study of
[4]*cyto* = cell; *logy* = study of



(a)



(b)

Figure 1.1 **Evolution of Medical Art.** Two illustrations of the skeletal system made about 500 years apart. (a) From an eleventh-century work attributed to Persian physician Avicenna. (b) From *De Humani Corporis Fabrica* (1543) by Andreas Vesalius.

benefit from **comparative anatomy**—the study of more than one species in order to examine structural similarities and differences and analyze evolutionary trends. Anatomy students often begin by dissecting other animals with which we share a common ancestry and many structural similarities. Indeed, many of the reasons for human structure become apparent only when we look at the structure of other animals. In chapter 25, for example, you will see that physiologists had little idea of the purpose of certain tubular loops in the kidney *(nephron loops)* until they compared human kidneys with those of desert and aquatic animals, which have greater and lesser needs to conserve water. The greater an animal's need to conserve water (the drier its habitat), the longer these loops are. Thus, comparative anatomy hinted at the function of the nephron loop, which could then be confirmed through experimental physiology. Such are the insights that can be gained by comparing different species with each other.

Methods of Study

There are several ways to examine the structure of the human body. The simplest is **inspection**—simply looking at the body's appearance in careful detail, as in performing a physical examination or making a clinical diagnosis from surface appearance. Observations of the skin and nails, for example, can provide clues to such underlying problems as vitamin deficiencies, anemia, heart disease, and liver disease. Physical examinations involve not only looking at the body for signs of normalcy or disease, but also touching and listening to it. **Palpation**[5] means feeling a structure with the hands, such as palpating a swollen lymph node or taking a pulse. **Auscultation**[6] (AWS-cul-TAY-shun) is listening to the natural sounds made by the

---

[5]*palp* = touch, feel; *ation* = process
[6]*auscult* = listen; *ation* = process

Figure 1.2 Early Medical Students in the Gross Anatomy Laboratory with Three Cadavers.

body, such as heart and lung sounds. In **percussion,** the examiner taps on the body, feels for abnormal resistance, and listens to the emitted sound for signs of abnormalities such as pockets of fluid, air, or scar tissue.

A deeper understanding of the body depends on **dissection** (dis-SEC-shun)—the careful cutting and separation of tissues to reveal their relationships. The very words *anatomy*[7] and *dissection*[8] both mean "cutting apart"; until the nineteenth century, dissection was called "anatomizing." In many schools of health science, cadaver dissection is one of the first steps in the training of students (fig. 1.2).

Dissection, of course, is not the method of choice when studying a living person! Not long ago, it was common to diagnose disorders through **exploratory surgery**—opening the body and taking a look inside to see what was wrong and what could be done about it. Any breach of the body cavities is risky, however, and most exploratory surgery has now been replaced by **medical imaging** techniques—methods of viewing the inside of the body without surgery (fig. 1.3). The branch of medicine concerned with imaging is called **radiology.** Anatomy learned in this way is called **radiologic anatomy,** and those who use radiologic methods for clinical purposes include **radiologists** and **radiologic technicians.**

Some radiologic methods involve high-energy **ionizing radiation** such as X-rays or particles called positrons. These penetrate the tissues and can be used to produce images on X-ray film or through electronic detectors. The benefits of ionizing radiation must always be weighed against its risks. It is called *ionizing* because it ejects electrons from the atoms and molecules it strikes. This effect can cause mutation and trigger cancer. Thus, ionizing radiation cannot be used indiscriminately. Used judiciously, however, the benefits of a mammogram or dental X-ray substantially outweigh the small risk.

[7]*ana* = apart; *tom* = cut
[8]*dis* = apart; *sect* = cut

Some of the imaging methods to follow are considered *noninvasive* because they do not involve any penetration of the skin or body orifices. *Invasive* imaging techniques may entail inserting ultrasound probes into the esophagus, vagina, or rectum to get closer to the organ to be imaged, or injecting substances into the bloodstream or body passages to enhance image formation.

Any anatomy student today must be acquainted with the basic techniques of radiology and their respective advantages and limitations. Many of the images printed in this book have been produced by the following techniques.

Radiography

Radiography, first performed in 1895, is the process of photographing internal structures with X-rays. Until the 1960s, this was the only widely available imaging method; even today, it accounts for more than 50% of all clinical imaging. X-rays pass through the soft tissues of the body to a photographic film or detector on the other side, where they produce relatively dark images. They are absorbed, however, by dense tissues such as bones, teeth, tumors, and tuberculosis nodules, which leave the image lighter in these areas (fig. 1.3a). The term *X-ray* also applies to a photograph *(radiograph)* made by this method. Radiography is commonly used in dentistry, mammography, diagnosis of fractures, and examination of the chest. Hollow organs can be visualized by filling them with a *radiopaque* substance that absorbs X-rays. Barium sulfate, for example, is given orally for examination of the esophagus, stomach, and small intestine, or by enema for examination of the large intestine. Other substances are given by injection for *angiography,* the examination of blood vessels (fig. 1.3b). Some disadvantages of radiography are that images of overlapping organs can be confusing and slight differences in tissue density are not easily detected. In addition, X-rays present the aforementioned risks of ionizing radiation.

Computed Tomography

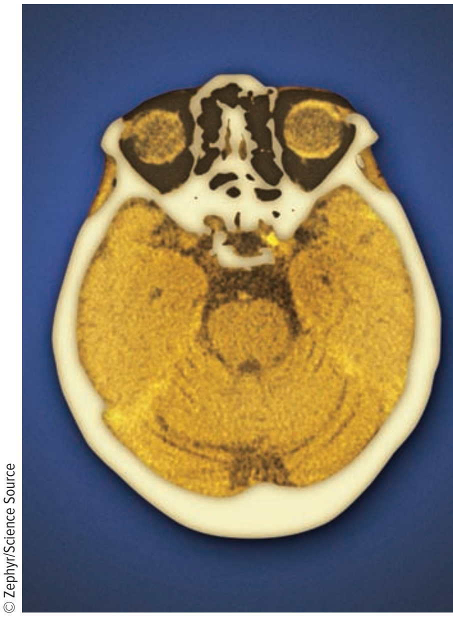
Computed tomography (a **CT scan**) is a more sophisticated application of X-rays. The patient is moved through a ring-shaped machine that emits low-intensity X-rays on one side and receives them with a detector on the opposite side. A computer analyzes signals from the detector and produces an image of a "slice" of the body about as thin as a coin (fig. 1.3c). The computer can "stack" a series of these images to construct a three-dimensional image of the body. CT scanning has the advantage of imaging thin sections of the body, so there is little organ overlap and the image is much sharper than a conventional X-ray. It requires extensive knowledge of cross-sectional anatomy to interpret the images. CT scanning is useful for identifying tumors, aneurysms, cerebral hemorrhages, kidney stones, and other abnormalities.

Magnetic Resonance Imaging

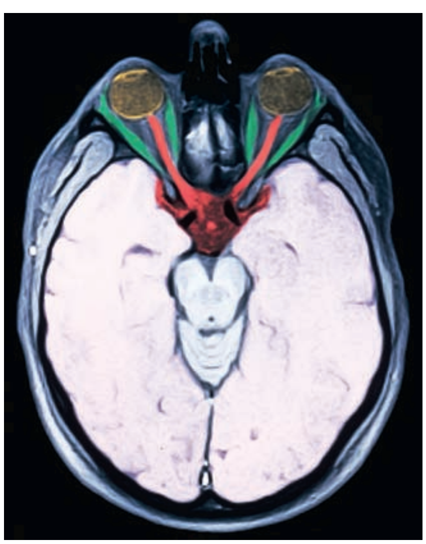
Magnetic resonance imaging (MRI) was conceived as a technique superior to CT for visualizing soft tissues (fig. 1.3d). The patient lies in a chamber surrounded by a large electromagnet that creates a very strong magnetic field. Hydrogen atoms in the tissues align themselves with the field. The technologist then activates a

(a) X-ray (radiograph)

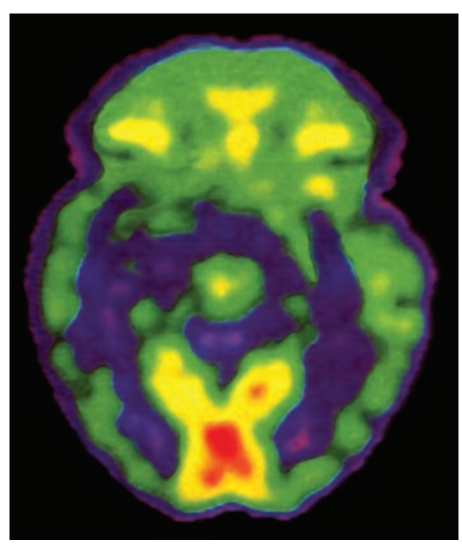
(b) Cerebral angiogram



(c) Computed tomographic (CT) scan



(d) Magnetic resonance image (MRI)



(e) Positron emission tomographic (PET) scan

Figure 1.3 **Radiologic Images of the Head.** (a) X-ray (radiograph) showing the bones and teeth. (b) An angiogram of the cerebral blood vessels. (c) A CT scan at the level of the eyes. (d) An MRI scan at the level of the eyes. The optic nerves appear in red and the muscles that move the eyes appear in green. (e) A PET scan of the brain of an unmedicated schizophrenic patient. Red areas indicate regions of high metabolic rate. In this patient, the visual center of the brain at the rear of the head (bottom of photo) was especially active during the scan.

• *What structures are seen better by MRI than by X-ray? What structures are seen better by X-ray than by PET?*

radio wave emitter, causing the hydrogen atoms to absorb additional energy and align in a different direction. When the radio waves are turned off, the hydrogen atoms abruptly realign to the magnetic field, giving off their excess energy at rates that depend on the type of tissue. A computer analyzes the emitted energy to produce an image of the body. MRI can "see" clearly through the skull and vertebral column to produce images of the nervous tissue. Moreover, it is better than CT for distinguishing between soft tissues such as the white and gray matter of the brain. It also avoids the harmful effects of X-rays. A disadvantage of MRI is that the patient must lie completely still in the enclosed space for about 45 minutes to scan one region of the body, and a complete procedure may entail 90 minutes to scan multiple regions such as the abdominal and pelvic cavities. Some patients find they cannot do this. MRI is also not very suitable for gastrointestinal imaging because it requires long exposures and the stomach and intestines move too much to create a sharp image. *Functional MRI (fMRI)* is a form of MRI that visualizes moment-to-moment changes in tissue function; fMRI scans of the brain, for example, show shifting patterns of activity as the brain applies itself to a specific sensory, mental, or motor task.

Apply What You Know

The concept of MRI was conceived in 1948 but could not be put into clinical practice until the 1970s. Speculate on a possible reason for this delay.

Positron Emission Tomography

Positron emission tomography (the **PET scan**) is used to assess the metabolic state of a tissue and to distinguish which tissues are most active at a given moment (fig. 1.3e). The procedure begins with an injection of radioactively labeled glucose, which emits positrons (electron-like particles with a positive charge). When a positron and electron meet, they annihilate each other and give off gamma rays that can be detected by sensors and processed by computer. The result is a color image that shows which tissues were using the most glucose. In cardiology, PET scans can show the extent of tissue death from a heart attack. Since damaged tissue consumes little or no glucose, it appears dark. In neuroscience, PET scans can similarly reveal the extent of brain damage from stroke or trauma. PET scans are also widely used to diagnose cancer and evaluate tumor status. The PET scan is an example of **nuclear medicine**—the use of radioisotopes to treat disease or to form diagnostic images of the body.

Sonography

Sonography[9] is the second oldest and second most widely used method of imaging. A handheld device pressed against the skin emits high-frequency ultrasound waves and receives the signals reflected back from internal organs. Sonography avoids the harmful effects of X-rays, and the equipment is relatively inexpensive and portable. Its primary disadvantage is that it does not produce a very sharp image. Although sonography was first used medically in the 1950s, images of significant clinical value had to wait until computer technology had developed enough to analyze differences in the way tissues reflect ultrasound. Sonography is not very useful for examining bones or lungs, but it is the method of choice in obstetrics, where the image *(sonogram)* can be used to locate the placenta and evaluate fetal age, position, and development (fig. 1.4). Sonography can also be used to view tissues in motion, such as fetal movements, a beating heart, and blood ejection from the heart. Sonographic imaging of the beating heart is called *echocardiography.*

Figure 1.4 Fetal Sonography. This three-dimensional fetal image was made at 32 weeks of gestation.
• *Why is sonography safer for the fetus than radiography or computed tomography?*

Variation in Human Structure

A quick look around any classroom is enough to show that no two humans look exactly alike; on close inspection, even identical twins exhibit differences. Anatomy atlases and textbooks can easily give you the impression that everyone's internal anatomy is the same, but this simply is not true. Books such as this one can teach you only the most common structure—the anatomy seen in approximately 70% or more of people. Someone who thinks that all human bodies are the same internally would make a very confused medical student or an incompetent surgeon.

Some people completely lack certain organs. For example, most of us have a *palmaris longus* muscle in the forearm and a *plantaris* muscle in the leg, but not everyone. Most of us have five lumbar vertebrae (bones of the lower spine), but some have four and some have six. Most of us have one spleen, but some people have two. Most have two kidneys, but some have only one. Most kidneys are supplied by a single *renal artery* and drained by one *ureter,* but in some people, a single kidney has two renal arteries or ureters. Figure 1.5 shows some common variations in human anatomy, and Deeper Insight 1.1 describes a particularly dramatic variation.

DEEPER INSIGHT 1.1

Situs Inversus and Other Unusual Anatomy

In most people, the heart tilts toward the left, the spleen and sigmoid colon are on the left, the liver and gallbladder lie mainly on the right, the appendix is on the right, and so forth. This normal arrangement of the viscera is called *situs* (SITE-us) *solitus*. About 1 in 8,000 people is born, however, with a striking developmental abnormality called *situs inversus*—the organs of the thoracic and abdominal cavities are reversed between right and left. A selective left–right reversal of the heart is called *dextrocardia*. In *situs perversus*, a single organ occupies an atypical position, not necessarily a left–right reversal—for example, a kidney located low in the pelvic cavity instead of high in the abdominal cavity.

Some conditions, such as dextrocardia in the absence of complete situs inversus, can cause serious medical problems. Complete situs inversus, however, usually causes no functional problems because all of the viscera, though reversed, maintain their normal relationships to each other. Situs inversus is often diagnosed prenatally by sonography, but many people remain unaware of their condition for several decades until it is discovered by medical imaging, on physical examination, or in surgery. However, you can easily imagine the importance of such conditions in diagnosing appendicitis, performing gallbladder surgery, interpreting an X-ray, auscultating the heart valves, or recording an electrocardiogram.

[9] *sono* = sound; *graphy* = recording process

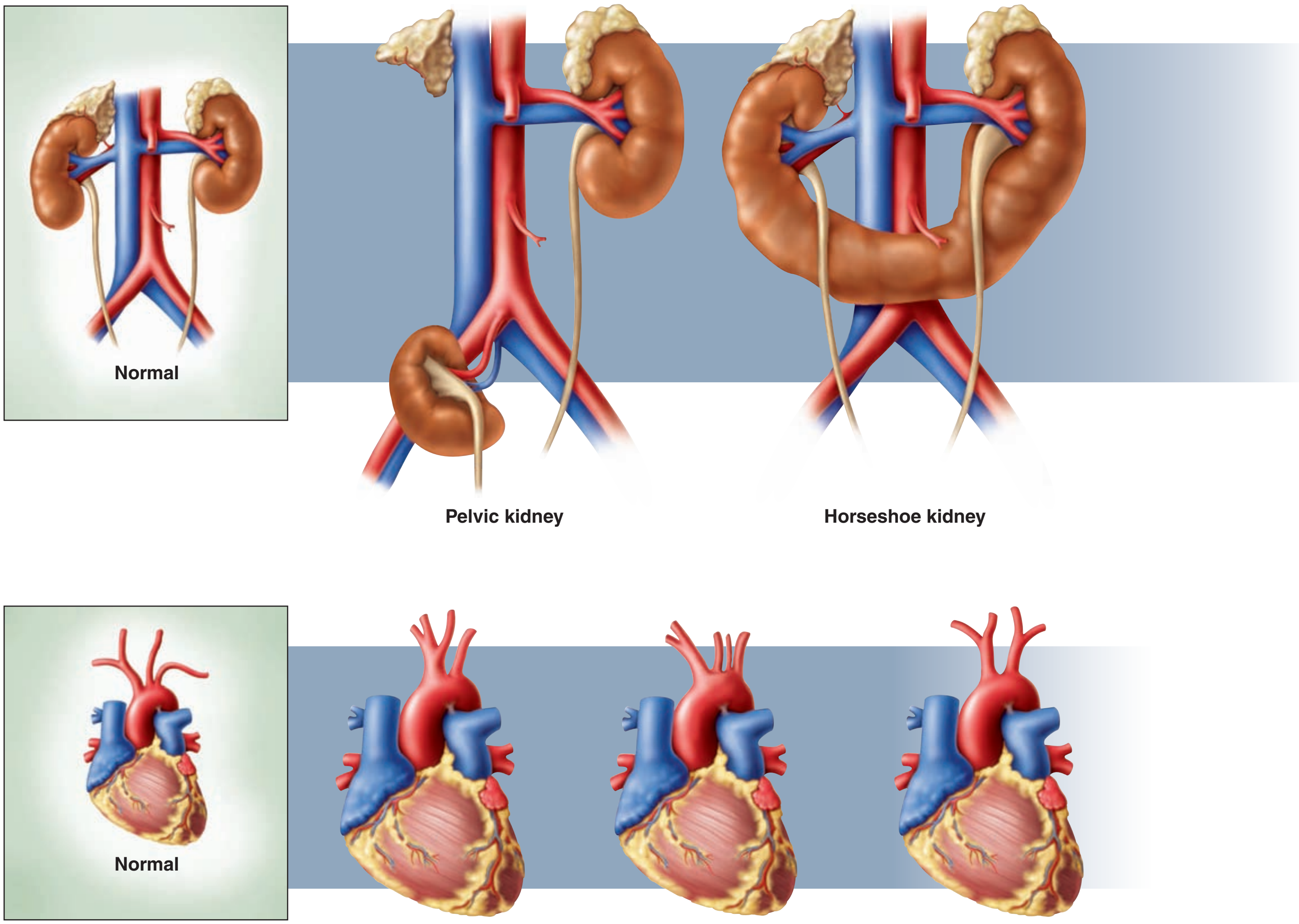


Figure 1.5 Variations in Anatomy of the Kidneys and Major Arteries near the Heart.

Apply What You Know

People who are allergic to penicillin or aspirin often wear Medic Alert bracelets or necklaces that note this fact in case they need emergency medical treatment and are unable to communicate. Why would it be important for a person with situs inversus to have this noted on a Medic Alert bracelet?

Before You Go On

Answer the following questions to test your understanding of the preceding section:

1. How does functional morphology differ from the sort of anatomy taught by a photographic atlas of the body?
2. Why would regional anatomy be a better learning approach than systemic anatomy for a cadaver dissection course?
3. What is the difference between radiology and radiography?
4. What are some reasons that sonography would be unsuitable for examining the size and location of a brain tumor?

1.2 The Human Body Plan

Expected Learning Outcomes

When you have completed this section, you should be able to

a. list in proper order the levels of structural complexity of the body, from organism to atoms;
b. name the human organ systems and state the basic functions and components of each;
c. describe anatomical position and explain why it is important in medical language;
d. identify the three fundamental anatomical planes of the body;
e. define several terms that describe the locations of structures relative to each other;
f. identify the major body regions and their subdivisions;
g. name and describe the body cavities and the membranes that line them; and
h. explain what a potential space is, and give some examples.

The chapters that follow assume a certain core, common language of human structure. You will need to know what we mean by the names for the major body cavities and regions, know the difference between a tissue and an organ, and know where to look if you read that structure X is distal or medial to structure Y, for example. This section introduces this core terminology.

Levels of Human Structure

Although this book is concerned mainly with gross anatomy, the study of human structure spans all levels from the whole organism down to the atomic level. Consider for a moment an analogy to human structure: The English language, like the human body, is very complex, yet an endless array of ideas can be conveyed with a limited number of words. All words in the English language are, in turn, composed of various combinations of just 26 letters. Between the alphabet and a book are successively more complex levels of organization: syllables, words, sentences, paragraphs, and chapters. Humans have an analogous hierarchy of complexity (fig. 1.6), as follows:

The organism is composed of organ systems,
organ systems are composed of organs,
organs are composed of tissues,
tissues are composed of cells,
cells are composed (in part) of organelles,
organelles are composed of molecules, and
molecules are composed of atoms.

The **organism** is a single, complete individual, capable of acting separately from other individuals.

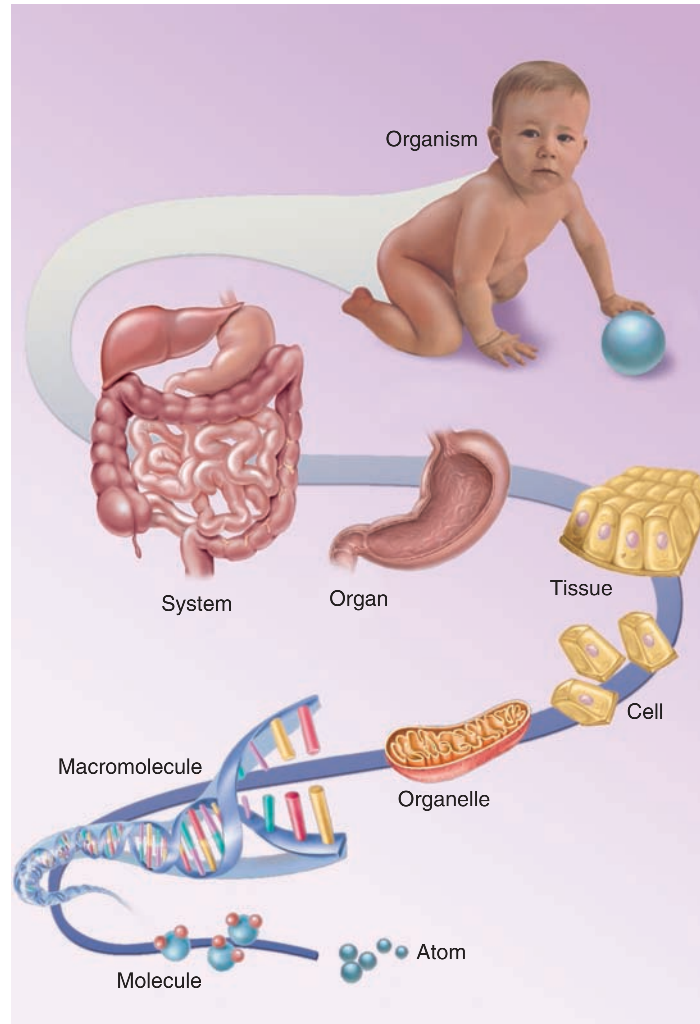


Figure 1.6 The Body's Structural Hierarchy from the Level of Organism to Atom. Each level depends on the structure and function of the level below it.

An **organ system** is a group of organs that carries out a basic function of the organism such as circulation, respiration, or digestion. The human body has 11 organ systems, defined and illustrated in the next section. Usually, the organs of a system are physically interconnected, such as the kidneys, ureters, urinary bladder, and urethra that compose the urinary system. The endocrine system, however, is a group of hormone-secreting glands and tissues that, for the most part, have no physical connection to each other.

An **organ** is any structure that has definite anatomical boundaries, is visually distinguishable from adjacent organs, and is composed of two or more tissue types working together to carry out a particular function. Most organs and higher levels of structure are within the domain of gross anatomy. However, there are organs within organs—the large organs visible to the naked eye contain smaller organs, some of which are visible only with the microscope. The skin, for example, is the body's largest organ. Included within it are thousands of smaller organs: Each hair follicle, nail, sweat gland, nerve, and blood vessel of the skin is an organ in itself.

A **tissue** is a mass of similar cells and cell products that forms a discrete region of an organ and performs a specific function. The body is composed of only four primary classes of tissue—epithelial, connective, nervous, and muscular tissue. *Histology,* the study of tissues, is the subject of chapter 3.

Cells are the smallest units of an organism considered to be alive. A cell is enclosed in a *plasma membrane* composed of lipids and protein, and it usually has one nucleus, an organelle that contains most of its DNA. *Cytology,* the study of cells and organelles, is the subject of chapter 2.

Organelles[10] are microscopic structures in a cell that carry out its individual functions, much like organs such as the heart, liver, and kidneys carry out individual functions of the whole body. Organelles include the nucleus, mitochondria, lysosomes, centrioles, and others.

Organelles and other cellular components are composed of **molecules**—particles of at least two **atoms** joined by chemical bonds. The largest molecules, such as proteins, fats, and DNA, are called *macromolecules.*

The Human Organ Systems

As remarked earlier, human structure can be learned from the perspective of regional anatomy or systemic anatomy. This book takes the systemic approach, in which we will fully examine one organ system at a time. There are 11 organ systems in the human body, as well as an *immune system,* which is better described as a population of cells that inhabit multiple organs rather than as an organ system. The organ systems are illustrated and summarized in figure 1.7 in the order that they are covered by this book. They are classified in the following list by their principal functions, although this is an unavoidably flawed classification. Some organs belong to two or more systems—for example, the male urethra is part of both the urinary and reproductive systems; the pharynx is part of the digestive and respiratory systems; and the mammary glands belong to both the integumentary and female reproductive systems.

Systems of Protection, Support, and Movement

- Integumentary system
- Skeletal system
- Muscular system

Systems of Internal Communication and Integration

- Nervous system
- Endocrine system

Systems of Fluid Transport

- Circulatory system
- Lymphatic system

[10] *elle* = little

Systems of Intake and Output

- Respiratory system
- Digestive system
- Urinary system

Systems of Reproduction

- Male reproductive system
- Female reproductive system

Some medical terms combine the names of two functionally related systems—for example, the *musculoskeletal system, cardiopulmonary system,* and *urogenital (genitourinary) system.* Such terms serve to call attention to the close anatomical or physiological relationship between two systems, but these are not literally individual organ systems.

The Terminology of Body Orientation

When anatomists describe the body, they must indicate where one structure is relative to another, the direction in which a nerve or blood vessel travels, the directions in which body parts move, and so forth. Clear communication on such points requires a universal terminology and frame of reference.

Anatomical Position

In describing the human body, anatomists assume that it is in **anatomical position**—that of a person standing upright with the feet flat on the floor and close together, arms at the sides, and the palms and face directed forward (fig. 1.8). Without such a frame of reference, to say that a structure such as the sternum, thymus, or aorta is "above the heart" would be vague, since it would depend on whether the subject was standing, lying face down, or lying face up. From the perspective of anatomical position, however, we can describe the thyroid gland as *superior* to the heart, the sternum as *anterior (ventral)* to it, and the aorta as *posterior (dorsal)* to it. These descriptions remain valid regardless of the subject's position. Even if the body is lying down, such as a cadaver on the medical student's dissection table, to say that the sternum is anterior to the heart invites the viewer to imagine the body standing in anatomical position and not to call it "above the heart" simply because that is the way the body happens to be lying.

Unless stated otherwise, assume that all anatomical descriptions refer to anatomical position. Bear in mind that if a subject is facing you in anatomical position, the subject's left will be on your right and vice versa. In most anatomical illustrations, for example, the left atrium of the heart appears toward the right side of the page, and although the appendix is located in the right lower quadrant of the abdomen, it appears on the left side of most illustrations.

The forearm is said to be **supinated** when the palms face up or anteriorly and **pronated** when they face down or posteriorly (see fig. 9.13, p. 217); in anatomical position, the forearm is supinated. The words *prone* and *supine* seem similar to these but have an entirely different meaning. A person is **prone** if lying face down, and **supine** if lying face up.