Mader's Understanding Human Anatomy & Physiology

NINTH EDITION

Susannah
Nelson Longenbaker

Mc Graw Hill Education

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Susannah Nelson Longenbaker

Columbus State Community College, Columbus, OH

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MADER'S UNDERSTANDING HUMAN ANATOMY & PHYSIOLOGY, NINTH EDITION

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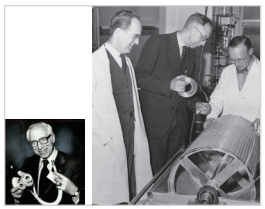
PART IV Maintenance of the Body



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About the Author

After earning a baccalaureate degree in biology from St. Mary's College (Notre Dame, Indiana) and a master's degree in physiology from the Ohio State University, Susannah Nelson Longenbaker began her teaching career at Columbus State Community College in Columbus, Ohio. She continues to teach anatomy and physiology courses there, as she has for over 30 years. During that time, she earned the college's Distinguished Teaching Award and *Ohio Magazine's* Excellence in Education award. She founded and serves as co-coordinator for Columbus State Community College *Fantastic Fridays* and *Fantastic Fridays Thinking Science*. These community outreach programs introduce middle school and high school students to the fun and excitement of laboratory science. In 2015, she was awarded the Columbus City Schools Community Excellence Award in recognition of her work in community outreach and science education.

In 2006, Sue was offered a unique opportunity by Dr. Sylvia Mader: to become the primary author for *Understanding Human Anatomy and Physiology*. Dr. Mader began her long career as a college biology professor, then left the classroom to become one of the most prolific authors of biology and human biology textbooks in the country. Her works are well known for their direct writing style and carefully crafted pedagogy. Dr. Mader's many titles have been published and enjoyed by students worldwide for almost 40 years.

Sue is honored to continue Dr. Mader's legacy to education, as the writer for this ninth edition of the textbook. She looks forward to and appreciates suggestions or comments from instructors and students alike. Feel free to contact her at the following address:

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Preface

Welcome to the ninth edition of *Mader's Understanding Human Anatomy and Physiology*! It is a joy and a privilege to work on this project, which is so fulfilling to me as a scientist, educator, and creative artist. I am honored to continue the vision of the book's original author, Dr. Sylvia Mader, who introduced the book almost two decades ago. We believe that a book designed to introduce the fascinating workings of the human body should be creative, informative, accurate, and most important, *relevant* to today's students. This book is tailored to appeal to a wide audience, from students in pre-nursing and allied health fields, to non-science majors who want a clear and concise explanation of how their bodies work. As soon as the student opens the book for the very first time, I want to capture that student's interest. Then, I want to keep the reader's attention as he or she learns something new about how we humans work.

Mader's Understanding Human Anatomy and Physiology continues to be the perfect text for a one-semester course. Each chapter begins with a brief introduction, designed to seize attention and stimulate curiosity, while drawing the reader in for a more detailed exploration. For example, the introduction for Chapter 6 on the skeletal system answers an age-old and commonly asked question: Does repeatedly cracking one's knuckles result in arthritis? And who among us has not experienced a "brain-freeze" headache when eating very cold foods too rapidly? The introduction for Chapter 7 on the nervous system explains why it occurs. Historical anecdotes will also intrigue the reader. The brief story of Henrietta Lacks that begins Chapter 4 is a fascinating account of how one woman's cancer cells continue to benefit humanity. The profile of retired astronaut and Senator John Glenn in Chapter 12 gives a fascinating insight to the very beginning of America's space program, and some of the medical issues that arose when humans were put into space for the first time.

Next, each chapter's Learning Outcomes are carefully constructed to be achievable to students with no prior training in anatomy and physiology. These Learning Outcomes are repeated as each new section begins, so that the reader never loses sight of what he or she is expected to learn. At the conclusion of each topic, the Content Check-Up feature allows the reader to test comprehension before continuing. Students who use the wonderful McGraw-Hill Connect® software with this text will be able to use this text's Learning Outcomes to check their progress. McGraw-Hill LearnSmart® is the most widely used and intelligent adaptive learning resource that is proven to strengthen memory recall, improve course retention, and boost grades.

Throughout the text, the Begin Thinking Clinically feature asks a student to do exactly that: start thinking as though he or she was already working in a clinic or hospital setting. Each question fosters critical thinking skills by requiring the student to conduct further investigation into the chapter's subject matter. A great deal of thought and attention have gone into the conclusion of each chapter. First, the Learning Outcomes are briefly summarized, and Key Terms and Clinical Key Terms are included, along with a pronunciation guide. Study Questions can be used as a checklist to ensure that important concepts are well understood. Each asks the student to craft a short essay. Learning Outcome Questions allow the student to "take the test" because they replicate the types of short answer questions often used in the classroom (matching, true-false, multiple choice, and the like). Finally, a Medical Terminology Exercise that concludes the chapter helps to build a working vocabulary, thus facilitating comprehension and increasing student confidence.

My own students love to relate examples about anatomy, physiology, and pathophysiology that they've seen in the media or come across on the job. For this reason, the many features in each chapter of this text are tailored toward the varied interests of today's students. The Focus on Forensics articles relate anatomy and physiology principles to the process of solving a crime. Every In Case of Emergency feature will be particularly relevant to those training to be first responders (emergency medical technicians and paramedics, for example), though everyone can benefit from knowing how to respond in a medical crisis situation. Each What's New reading describes a cutting-edge development in medicine and/or biotechnology. For example, you may have read in the popular media about the many uses of 3-D printers—but did you know that they can be used to craft a scaffolding to grow tissues, and may one day make it possible to grow entire organs? You can read about it in Chapter 4! New Medical Focus articles can be found throughout the book as well, and each existing Medical Focus article has been carefully researched and updated for this edition. However, perhaps the most important thing you'll notice throughout the book is the quality of the artwork. The new line drawings are realistic, detailed, and colorful; photographs are fresh and up-to-date. In addition, this ninth edition has been enriched by the incorporation of many fine images from McGraw-Hill Education's outstanding resource, *Anatomy & Physiology* REVEALED®. You'll find some of the best artwork in the industry in this edition of *Mader's Understanding Human Anatomy and Physiology.* Couple this with a completely redesigned layout, and I trust you'll find this book to be visually pleasing as well as accurate and informative.

I have been blessed to have the best job in the world—being a college professor teaching the biological sciences—for over 30 years. Being in the classroom daily helps me to understand the ways my students think, as well as what's happening in their world. Each semester's new batch of students has something to teach me, and I am fortunate to be able to learn something new every day. Further, I am privileged to work with a fine group of colleagues who are generous with both their expertise and their advice. I continue to develop new strategies to describe anatomical and physiological concepts, using more and better examples and analogies. In this book, it's my goal to share the ideas that work for me with both

students and teachers. I know that this text will help you, the instructor, to engage and excite your students in the fascinating study of the human body.

Acknowledgements

Every new edition of *Understanding Human Anatomy and Physiology* presents a unique challenge for me. It's my goal to create a work with content that is precisely correct, up-to-date, and worthwhile for an increasingly diverse and rapidly evolving student population. When you have an amazing support team like the one I have at McGraw-Hill Education, the task becomes much easier. I owe a tremendous debt of gratitude to two individuals who directly supported me and with whom I communicated on an almost daily basis: my Product Developer, Fran Simon, and Content Project Manager, April Southwood. Ladies, thanks for your patience, understanding, and good humor. I appreciate everything you've done for this edition.

Further, each of these individuals deserves special recognition for her hard work: Brand Managers, Chloe Bouxsein and Amy Reed; Marketing Managers, Jessica Cannavo and Jim Connely; Photo Researcher, Lori Hancock; Designer, Tara McDermott; and Buyer, Sandy Ludovissy. My copyeditor, Kevin Campbell, and proofreaders, Angie Sigwarth and Carey Lange, helped to ensure accuracy throughout the entire project. Photo researcher Jo Johnson contributed hours of effort to find just the right photo illustrations in each chapter.

I would also like to thank the many others who contributed to the ancillary products associated with this text: Morris Butcher, Jeanette Ferguson, Cindy Hansen, Susan Rohde, and Phillip Snider, Jr.

It's very gratifying to know that one's colleagues will take the time and make the effort to provide comments and suggestions for a new edition. I would like to thank the individuals listed below for the observations and detailed recommendations they shared with me. As an author, it's comforting to know that you have skilled and talented peer educators to review your content and help to improve it.

Finally, I'd like to express my profound thanks to my three coworkers, allies, and buddies at Columbus State Community College: Dr. Jeanette Ferguson, Professor Eric Kenz, and Professor Lyndsy Wolff. Each one generously contributed advice, evaluation and review for this edition. Guys, you are the best, and I'm proud to work with you. And to the folks who always have my back—my husband, Bill, and my family—I can't do anything that I do without your love and support, and I'll always remember that.

— Sue Longenbaker

Dedication:

To the One through whom all things are possible: *Ad majorem dei gloriam.* And for Claire, Molly, Maya, and Julia, and for all future students: may my efforts help you learn.

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Guided Tour Through a Chapter!

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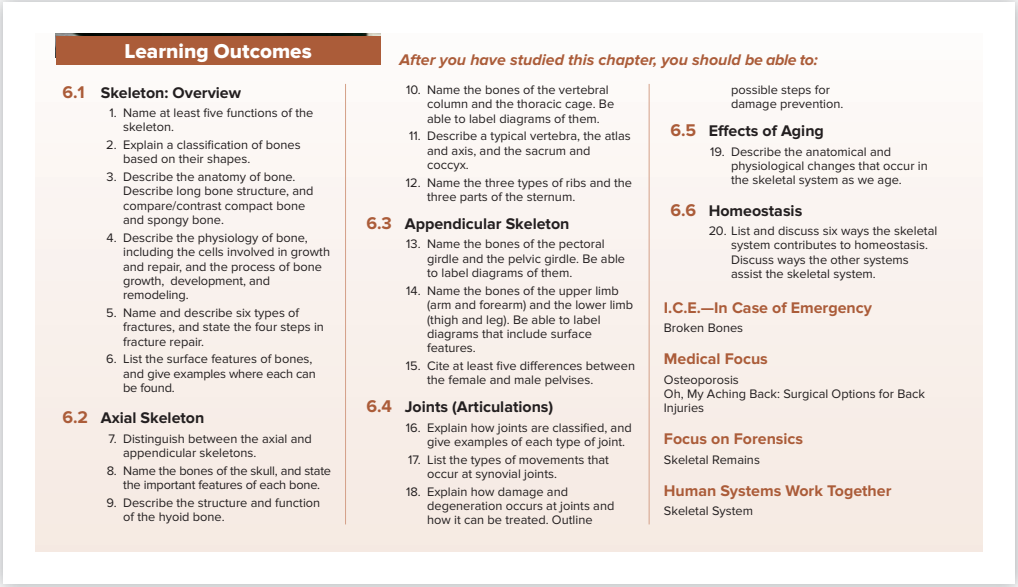
Learning Outcomes

at the beginning of every chapter will help students understand what they should know after studying the chapter.



Learning Outcomes

After you have studied this chapter, you should be able to:

6.1 Skeleton: Overview

1. Name at least five functions of the skeleton.
2. Explain a classification of bones based on their shapes.
3. Describe the anatomy of bone. Describe long bone structure, and compare/contrast compact bone and spongy bone.
4. Describe the physiology of bone, including the cells involved in growth and repair, and the process of bone growth, development, and remodeling.
5. Name and describe six types of fractures, and state the four steps in fracture repair.
6. List the surface features of bones, and give examples where each can be found.

6.2 Axial Skeleton

7. Distinguish between the axial and appendicular skeletons.
8. Name the bones of the skull, and state the important features of each bone.
9. Describe the structure and function of the hyoid bone.
10. Name the bones of the vertebral column and the thoracic cage. Be able to label diagrams of them.
11. Describe a typical vertebra, the atlas and axis, and the sacrum and coccyx.
12. Name the three types of ribs and the three parts of the sternum.

6.3 Appendicular Skeleton

13. Name the bones of the pectoral girdle and the pelvic girdle. Be able to label diagrams of them.
14. Name the bones of the upper limb (arm and forearm) and the lower limb (thigh and leg). Be able to label diagrams that include surface features.
15. Cite at least five differences between the female and male pelvises.

6.4 Joints (Articulations)

16. Explain how joints are classified, and give examples of each type of joint.
17. List the types of movements that occur at synovial joints.
18. Explain how damage and degeneration occurs at joints and how it can be treated. Outline possible steps for damage prevention.

6.5 Effects of Aging

19. Describe the anatomical and physiological changes that occur in the skeletal system as we age.

6.6 Homeostasis

20. List and discuss six ways the skeletal system contributes to homeostasis. Discuss ways the other systems assist the skeletal system.

I.C.E.—In Case of Emergency

Broken Bones

Medical Focus

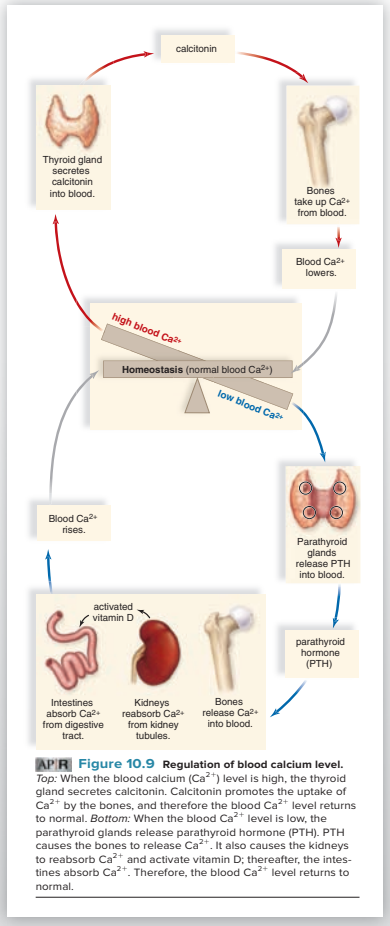
Osteoporosis
Oh, My Aching Back: Surgical Options for Back Injuries

Focus on Forensics

Skeletal Remains

Human Systems Work Together

Skeletal System



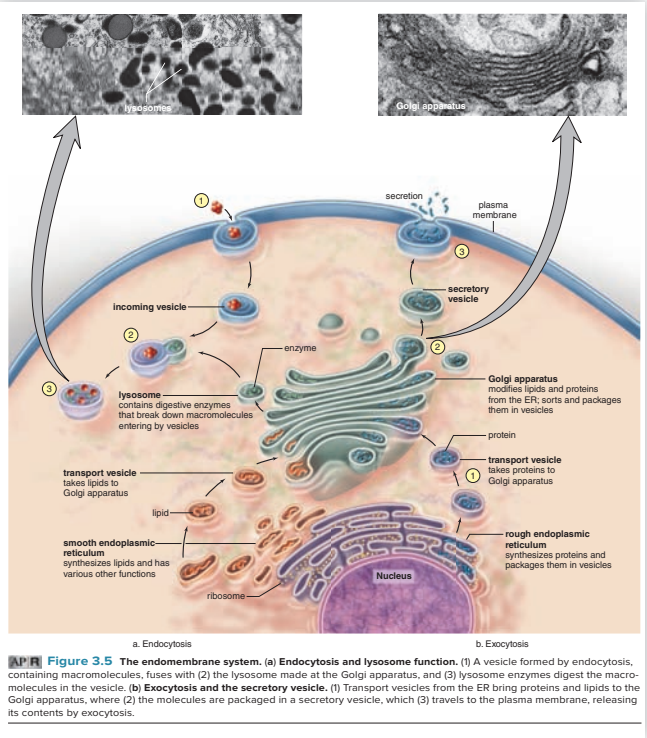
A|P|R Figure 10.9 Regulation of blood calcium level.
Top: When the blood calcium (Ca^{2+}) level is high, the thyroid gland secretes calcitonin. Calcitonin promotes the uptake of Ca^{2+} by the bones, and therefore the blood Ca^{2+} level returns to normal. *Bottom:* When the blood Ca^{2+} level is low, the parathyroid glands release parathyroid hormone (PTH). PTH causes the bones to release Ca^{2+}. It also causes the kidneys to reabsorb Ca^{2+} and activate vitamin D; thereafter, the intestines absorb Ca^{2+}. Therefore, the blood Ca^{2+} level returns to normal.

Accessible Writing Style More important than any other component of a textbook, the writing must be appropriate for the level of the reader. *Mader's Understanding Human Anatomy and Physiology* features the **perfect writing style for the one-semester course.** It has always been written and designed for the one-semester course, not adapted from a two-semester textbook. Paragraph introductions, explanations, comparisons, and relevant, everyday examples are used with these students in mind. The flow of the text is logical and accessible without being overly "chatty" and consistently makes use of relevant examples and analogies.

Easy-to-Understand Art covers what's important but leaves out unnecessary, confusing detail.

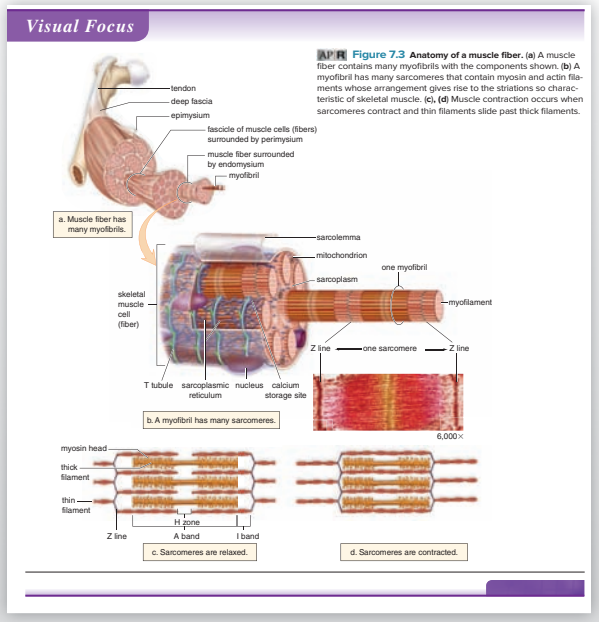
Good examples of this are the homeostasis illustrations – instead of lots of various colored arrows and boxes with explanations, these simple visual pieces get the message across beautifully.

Another example is stepped-out art, which shows key stages of an illustration identified by numbered circles. This type of explanation builds comprehension sequentially.



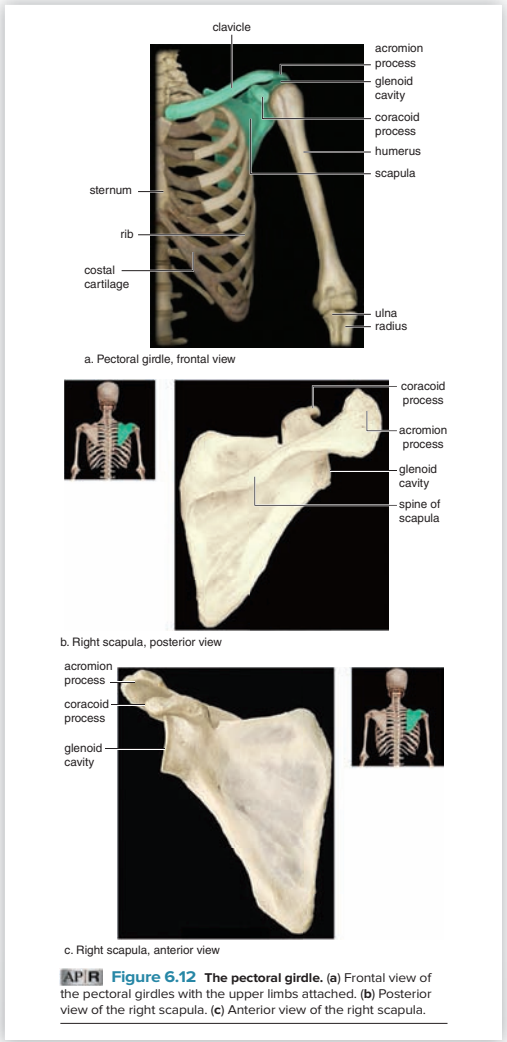
APR **Figure 3.5** **The endomembrane system.** **(a) Endocytosis and lysosome function.** (1) A vesicle formed by endocytosis, containing macromolecules, fuses with (2) the lysosome made at the Golgi apparatus, and (3) lysosome enzymes digest the macromolecules in the vesicle. **(b) Exocytosis and the secretory vesicle.** (1) Transport vesicles from the ER bring proteins and lipids to the Golgi apparatus, where (2) the molecules are packaged in a secretory vesicle, which (3) travels to the plasma membrane, releasing its contents by exocytosis.

Macro to micro figures give the students an overall perspective.



APR **Figure 7.3** **Anatomy of a muscle fiber.** **(a)** A muscle fiber contains many myofibrils with the components shown. **(b)** A myofibril has many sarcomeres that contain myosin and actin filaments whose arrangement gives rise to the striations so characteristic of skeletal muscle. **(c), (d)** Muscle contraction occurs when sarcomeres contract and thin filaments slide past thick filaments.

Several Anatomy & Physiology REVEALED® images have been added with icons from APR.



APR **Figure 6.12** **The pectoral girdle.** **(a)** Frontal view of the pectoral girdles with the upper limbs attached. **(b)** Posterior view of the right scapula. **(c)** Anterior view of the right scapula.

Learning Outcomes are listed within the chapter! Students will know what that specific section is covering.

6.2 Axial Skeleton

7. Distinguish between the axial and appendicular skeletons.
8. Name the bones of the skull, and state the important features of each bone.
9. Describe the structure and function of the hyoid bone.
10. Name the bones of the vertebral column and the thoracic cage. Be able to label diagrams of them.
11. Describe a typical vertebra, the atlas and axis, and the sacrum and coccyx.
12. Name the three types of ribs and the three parts of the sternum.

The skeleton is divided into the axial skeleton and the appendicular skeleton. The tissues of the axial and appendicular skeletons are bone (both compact and spongy), cartilage (hyaline, fibrocartilage, and elastic cartilage), and dense connective tissue, a type of fibrous connective tissue. (The various types of connective tissues were extensively discussed in Chapter 4.)

In Figure 6.4, the bones of the axial skeleton are colored gray, and the bones of the appendicular skeleton are colored tan for easy distinction. Notice that the **axial skeleton** lies in the midline of the body and contains the bones of the skull, the hyoid bone, the

Guided Tour Through a Chapter!

Built-in Study Aids such as the *Content Check-Up* and the *Begin Thinking Clinically* features allow students to test themselves over major sections of text before continuing. *Content Check-Up* questions will now be found after each major heading.

Content CHECK-UP!

1. The term for the expanded portions at the ends of a long bone is:
   a. diaphysis. c. periosteum.
   b. epiphysis. d. articular cartilage.
2. Osteons are associated with _____ bone.
3. Which type of bone cell breaks down bone and deposits calcium into the blood?
   a. osteoblast c. osteoprogenitor
   b. osteocyte d. osteoclast
4. The region in a long bone where growth occurs is the _____.
5. Imagine that an artery has to pass through bone to enter the skull. What is the feature through which the artery will pass? (Refer to Table 6.1.)

Answers in Appendix A.

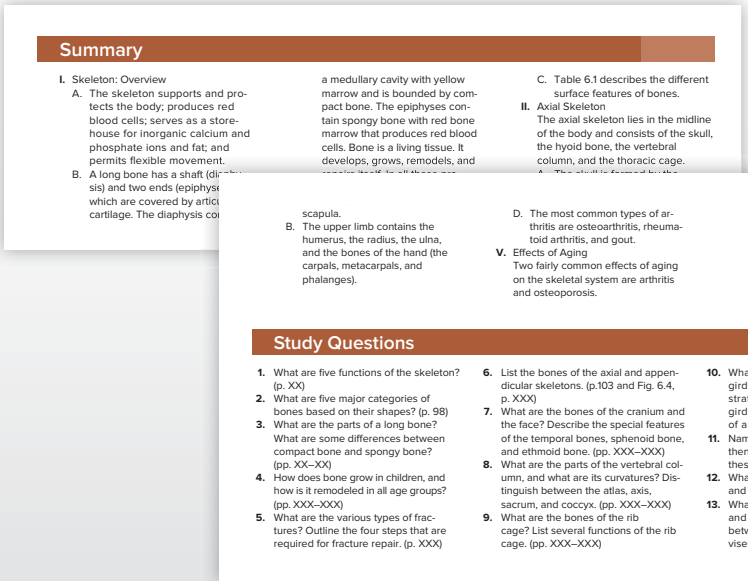
Begin Thinking Clinically

You're treating an 11-year-old patient in the emergency room. His right eye was struck by a baseball bat, and he's rapidly developing a nasty black eye. What bones might have been broken by the injury?

Answer and discussion in Appendix A.

End of Chapter

The end-of-chapter material has been newly organized with the Summary updated for every chapter. Key terms are divided into basic and clinical terms. Two levels of additional questions, along with exercises that reinforce medical terminology, are also included with every chapter.



Summary

I. Skeleton: Overview
A. The skeleton supports and protects the body; produces red blood cells; serves as a storehouse for inorganic calcium and phosphate ions and fat; and permits flexible movement.
B. A long bone has a shaft (diaphysis) and two ends (epiphyses) which are covered by articular cartilage. The diaphysis contains a medullary cavity with yellow marrow and is bounded by compact bone. The epiphyses contain spongy bone with red bone marrow that produces red blood cells. Bone is a living tissue. It develops, grows, remodels, and
C. Table 6.1 describes the different surface features of bones.
II. Axial Skeleton
The axial skeleton lies in the midline of the body and consists of the skull, the hyoid bone, the vertebral column, and the thoracic cage.

scapula.
B. The upper limb contains the humerus, the radius, the ulna, and the bones of the hand (the carpals, metacarpals, and phalanges).
D. The most common types of arthritis are osteoarthritis, rheumatoid arthritis, and gout.
V. Effects of Aging
Two fairly common effects of aging on the skeletal system are arthritis and osteoporosis.
storage and growth of bones. The cardiovascular system transports calcium to the skeleton, and muscles aid the skeleton in movement.

Study Questions

1. What are five functions of the skeleton? (p. XX)
2. What are five major categories of bones based on their shapes? (p. 98)
3. What are the parts of a long bone? What are some differences between compact bone and spongy bone? (pp. XX–XX)
4. How does bone grow in children, and how is it remodeled in all age groups? (pp. XXX–XXX)
5. What are the various types of fractures? Outline the four steps that are required for fracture repair. (p. XXX)
6. List the bones of the axial and appendicular skeletons. (p.103 and Fig. 6.4, p. XXX)
7. What are the bones of the cranium and the face? Describe the special features of the temporal bones, sphenoid bone, and ethmoid bone. (pp. XXX–XXX)
8. What are the parts of the vertebral column, and what are its curvatures? Distinguish between the atlas, axis, sacrum, and coccyx. (pp. XXX–XXX)
9. What are the bones of the rib cage? List several functions of the rib cage. (pp. XXX–XXX)
10. What are
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13. What are
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Learning Outcome Questions

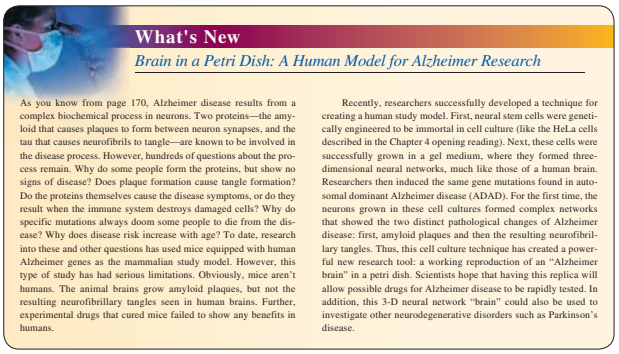
I. Match the items in the key to the bones listed in questions 1–6.
Key:
a. forehead
b. chin
c. cheekbone
d. elbow
e. shoulder blade
f. hip
g. leg
1. temporal and zygomatic bones
2. tibia and fibula
3. frontal bone
4. ulna
5. coxal bone
6. scapula

II. Match the items in the key to the bones listed in questions 7–13.
Key:
a. external acoustic meatus
b. cribriform plate
c. xiphoid process
d. glenoid cavity
e. olecranon process
f. acetabulum
g. greater and lesser trochanters
7. scapula
8. sternum
9. femur
10. temporal bone
11. coxal bone
12. ethmoid bone
13. ulna

III. Fill in the blanks.
14. Long bones are _____ than they are wide.
15. The epiphysis of a long bone contains _____ bone, where red blood cells are produced.
16. The _____ are the air-filled spaces in the cranium.
17. The sacrum is a part of the _____, and the sternum is a part of the _____.
18. The pectoral girdle is specialized for _____, while the pelvic girdle is specialized for _____.
19. The term *phalanges* is used for the bones of both the _____ and the _____.
20. The knee is a freely movable (synovial) joint of the _____ type.

IV. Match the movement with the description in questions 21–25.
a. extension
b. circumduction
c. adduction
d. flexion
e. abduction
21. moving a body part toward the midline
22. moving a body part away from the midline
23. moving a body part in a circle
24. decreasing the angle of a joint
25. increasing the angle of the joint

Unsurpassed Clinical Coverage is evident all through this text. What's New, Medical Focus, Begin Thinking Clinically, I.C.E.: In Case of Emergency, and Focus on Forensics readings and study aids to relate the very latest research and developments in applied aspects of anatomy and physiology to important concepts in the text. Examples include "Novel Stent for the Severest Strokes," "Brain in a Petri Dish: A Human Model for Alzheimer Research," "Improvements in Transfusion Technology," "Necrotizing Fasciitis," and "Influenza: A Constant Threat of Pandemic." The Focus on Forensics and I.C.E.: In Case of Emergency readings engage students in real-life scenarios that challenge them to use, and expand upon, their recently acquired knowledge.



What's New

Brain in a Petri Dish: A Human Model for Alzheimer Research

As you know from page 170, Alzheimer disease results from a complex biochemical process in neurons. Two proteins—the amyloid that causes plaques to form between neuron synapses, and the tau that causes neurofibrils to tangle—are known to be involved in the disease process. However, hundreds of questions about the process remain. Why do some people form the proteins, but show no signs of disease? Does plaque formation cause tangle formation? Do the proteins themselves cause the disease symptoms, or do they result when the immune system destroys damaged cells? Why do specific mutations always doom some people to die from the disease? Why does disease risk increase with age? To date, research into these and other questions has used mice equipped with human Alzheimer genes as the mammalian study model. However, this type of study has had serious limitations. Obviously, mice aren't humans. The animal brains grow amyloid plaques, but not the resulting neurofibrillary tangles seen in human brains. Further, experimental drugs that cured mice failed to show any benefits in humans.

Recently, researchers successfully developed a technique for creating a human study model. First, neural stem cells were genetically engineered to be immortal in cell culture (like the HeLa cells described in the Chapter 4 opening reading). Next, these cells were successfully grown in a gel medium, where they formed three-dimensional neural networks, much like those of a human brain. Researchers then induced the same gene mutations found in autosomal dominant Alzheimer disease (ADAD). For the first time, the neurons grown in these cell cultures formed complex networks that showed the two distinct pathological changes of Alzheimer disease: first, amyloid plaques and then the resulting neurofibrillary tangles. Thus, this cell culture technique has created a powerful new research tool: a working reproduction of an "Alzheimer brain" in a petri dish. Scientists hope that having this replica will allow possible drugs for Alzheimer disease to be rapidly tested. In addition, this 3-D neural network "brain" could also be used to investigate other neurodegenerative disorders such as Parkinson's disease.

MEDICAL FOCUS

Research on Alzheimer Disease: Causes, Treatments, Prevention, and Hop

Alzheimer disease (AD) is an irreversible, fatal disorder characterized by a gradual loss of reason that begins with memory lapses and ends with the inability to perform any activities. Personality changes such agitation and hostility, and memory deficits that affect daily routines often signal the onset of AD. For example, a normal 60- to 70-year-old might forget the name of a friend not seen for years, but someone with AD forgets the name of a neighbor who visits daily. Likewise, a healthy senior might forget where he placed his car keys, while a person with AD will forget what those keys are for. People afflicted with AD become confused and tend to repeat the same question. Signs of mental disturbance eventually appear, and patients gradually become bedridden and die of a complication, such as pneumonia. At the cellular level, AD is characterized by the presence of abnormally structured neurons and a reduced amount of the neurotransmitter acetylcholine (see p. xxx). These defective neurons are especially seen in the portions of the brain involved in reason and memory. The AD neuron has two pathological features. The first consists of bundles of fibrous protein, called neurofibrillary tangles, which surround the nucleus in the cells. The tangles are due to an abnormal form of *tau*, a protein molecule that normally helps to stabilize microtubules that form the cell's cytoskeleton. In addition to these tangles, protein-rich accumulations, called amyloid plaques, envelop the axon branches. Over time, affected neurons will die. The cortex and hippocampus shrivel, the brain shrinks in volume, and the ventricles become enlarged.

Research Regarding Its Causes

As techniques for genetic study continue to improve, several genetic mutations specific to Alzheimer have been identified. One set, designated by the acronyms APP, PS1, and PS2, are termed *deterministic*. People who inherit one of these three mutated genes will always develop the disease, called autosomal dominant Alzheimer disease (ADAD). It's interesting to note that APP, the first of these defective genes to be discovered, is found on chromosome 21. Down syndrome results from the inheritance of three copies of chromosome 21, and people with Down syndrome tend to develop AD. (You will learn more about autosomal dominant disorders in Chapter 19.) Mutation of a fourth gene, designated APO, puts patients at risk but does not always result in disease. Scientists are now studying victims with mutations to try to discover the exact cause for the disease. Recent findings have led researchers to believe that the neuron deterioration seen in Alzheimer disease patients may be caused by the spread of the tau protein from one cell to the next, much as a virus is spread from one infected cell to another. Other studies have implicated a second protein, striatal-enriched tyrosine phosphatase, or STEP, in the cell destruction found in Alzheimer sufferers. Further, other investigators are exploring the role of cell lysosomes in AD, suspecting that these essential organelles may be failing to destroy the abnormal proteins found in diseased cells.

Research into Its Treatment

Each new finding about what causes Alzheimer disease creates new possibilities for its treatment as well. Researchers are now conducting clinical testing on antibodies that block cell-to-cell transmission of the tau protein. (You can read more about antibodies in Chapter 13.) A second treatment might involve the creation of drugs that block formation of the STEP protein. Boosting lysosomal degradation of the abnormal Alzheimer cell protein is another p
time, only five drugs are accepted f
cholinesterase inhibitors (Aricept®,
works at neuron synapses in the brai
that breaks down acetylcholine (AC
synapses keeps memory pathways
period of time. The newest drug, me
toxicity: the tendency of diseased ne
tion is used only in moderately to s
drug allows neurons involved in me
affected patients. However, it's impe
medication cures AD. Both merely
toms, allowing the patient to functio
of time. Additional research is curre
ness of anticholesterol statin drugs, a
tions, in slowing the progress of the

Research on Prevention

Much of current research on AD fo
have shown that risk factors for cardi
stroke—also contribute to an increa
elevated blood cholesterol and bloo
tary lifestyle, and diabetes mellitus (
caused by gum disease has also been
developing heart disease, and by e
evidence suggests that a lifestyle tai
may also prevent AD. Slight changes
developing AD: boosting vitamins
salmon, and drinking coffee. Further
blows to the head. It's been shown that head injuries (such as those expe
rienced by football players) can increase the risk of developing AD it
later life 19-fold. Wearing seat belts and helmets and taking steps to pre
vent falls are commonsense, easy ways to prevent head injury. Finally,
staying mentally, physically, and socially active—as long as possible—
will help to slow the course of mental impairment for AD sufferers.

Early Detection and Hope for a Cure

Currently, researchers are testing vaccines for AD that would target the
patient's immune system to destroy amyloid protein. Early study results
show some promising outcomes of this treatment in early-stage patients.
However, scientists believe that curing AD will require an early diagnosis
because it's thought that the disease may begin in the brain 15 to 20 years
before symptoms ever develop. At present, diagnosis can't be made with
absolute certainty until the brain is examined at autopsy. In the future,
cerebrospinal fluid testing may allow amyloid proteins to be detected
before disease symptoms appear. Researchers are also developing ways
to tag the amyloid protein with radioactive molecules, which will allow
detection of the protein using a PET scan. (You learned about PET and
other imaging techniques in Chapter 1.) The Medical Focus reading in
Chapter 9 describes an eye scan technique that might allow an earlier
diagnosis, and the What's New reading on page XXX describes an
exciting breakthrough in cell culture that will create new options for
studying neurons and drug therapies in the laboratory.

I.C.E. — IN CASE OF EMERGENCY

Traumatic Brain Injury

In March 2009, Natasha Richardson, actress and wife of actor Liam Neeson, lost consciousness while she was on the beginner slope of a Montreal ski resort, after a seemingly minor fall. After regaining consciousness, she insisted that she was fine, even turning away EMS personnel. However, she complained of a severe headache hours later, and her condition rapidly deteriorated. After being declared brain dead, Richardson died in a New York hospital two days later.

Richardson's accident focused attention on the need for immediate medical attention when a traumatic brain injury (TBI) is suspected. Traumatic brain injuries cause swelling of the brain and meninges, which reduces blood supply to the brain. *Concussion* is often the first symptom of TBI. Patients who suffer a concussion become dizzy, confused or disoriented, suffer short-term memory loss, or lose consciousness. Bleeding inside the brain or skull, called *hematoma*, or bruising of the brain, called a *contusion*, may follow concussion. These are life-threatening and often fatal injuries that may not be immediately evident, but develop in the hours to days after the initial loss of consciousness. In Ms. Richardson's case, her fall resulted in an epidural hematoma: bleeding between the skull and dura mater. Had she received prompt medical treatment, the hematoma could have been surgically repaired.

Patients who have had a concussion should always be examined by an emergency room physician to rule out a critical injury. Before first responders transport the person to the hospital, they should quickly assess whether the patient is alert and able to respond to person, place, and time—in the language of the emergency room, "oriented times three." The individual should be able to identify himself (person), tell where he is (place), and correctly name the day of the week (time). Next, the victim's pupillary reflex is tested to ensure that both pupils react similarly and quickly in response to light. Emergency care providers and family members must be aware of the signs of brain damage: severe headache, nausea and vomiting, slow heartbeat and breathing rate, and decreasing consciousness. In babies and small children, the early signs of TBI include crying inconsolably and refusal to nurse or eat. In these situations, immediate medical and surgical treatment will hopefully lessen or prevent brain damage.

Athletes (and their parents and coaches) must be aware that no concussion should be considered minor; each is a traumatic brain injury. Further, repeated concussions in young people can result in permanent brain damage and predispose the victim to neurodegenerative diseases, including Alzheimer and Parkinson's disease. Under no circumstances should an athlete be returned to play in that day's game following a concussion.

FOCUS on FORENSICS

Retinal Hemorrhage in Shaken Baby Syndrome

It's one of the fastest-growing epidemics in children in North America, and the fifteenth-leading cause of death to young children—child abuse. Approximately 1,600 American children die every year at the hands of a parent or other caregiver, and 75% of those fatalities occur in children four years old or younger. In babies up to a year old, the leading cause of child abuse death is a phenomenon called "shaken baby syndrome," or SBS. As the name implies, the affected infant has been shaken violently by a caregiver. As little as 5 seconds of violent shaking can permanently injure or kill a baby.

Shaking an infant produces the same effect as whiplash in an adult because an infant's head is very large in proportion to the rest of its body and the neck muscles are weak. However, in the infant the whiplash effect occurs over and over. Like an adult whiplash injury, a shaken baby's brain slams back and forth inside the skull. This extreme force damages nerve tissue and tears delicate blood vessels throughout the brain and in the eyes.

One key to making a correct diagnosis of SBS is a retinal exam. The retina is a highly vascular tissue with a complex system of blood vessels. A healthy retina shows distinct blood vessels in a lacy network. The retina of an infant with SBS shows irregular, blotchy areas of hemorrhaged blood. Evidence of retinal hemorrhage should always lead to suspicion of abuse—this injury does not occur in a typical accidental fall.

Studies of adult abusers have shown that child abuse is rarely premeditated; the adult simply loses control while trying to stop a particular behavior, such as excessive crying. Because adult caregivers routinely deny involvement in a child's injury, health-care workers must be vigilant and observant to detect and stop SBS. Unexplained drowsiness, unconciousness, or seizures in an infant should always be investigated with an eye exam, using eye drops to dilate the pupil and examine the retina.

Changes to This Edition

Each chapter contains updated and improved line art and new, more current photos. Images from McGraw-Hill Education's award-winning interactive learning software, *Anatomy and Physiology* REVEALED®, have been incorporated throughout the text.

All information regarding signs, symptoms, diagnosis, and treatment of disease has been carefully investigated using **Up To Date®**, a professional peer-reviewed overview of current research in each respective field. This service is utilized throughout the nation by many universities and hospitals, including the Mayo Clinic.

Each section of a chapter ends with a **Content Check-Up!** to test student knowledge. In response to reviewer requests, selected **Content Check-Up!** questions throughout the chapters have been replaced with higher-level questions requiring critical thinking and assimilation of ideas.

Chapter 1:

- Updated **Medical Focus: Imaging the Body** to include latest technologies used for imaging, including functional magnetic resonance imaging and diffusion tensor imaging.

Chapter 2:

- New chapter opener about toxins as medication, with new photographs.
- Updated **Medical Focus: Prions: Malicious Proteins?** to incorporate latest diagnostic technology.
- Updated **Medical Focus: The Deadly Effects of High-Level Radiation** to contain current information regarding the effects of radiation on cell-cell junctions.
- In response to reviewer commentary: revised explanations for mass number; low levels of radiation; atomic structure, ionization, buffers.
- Based on heat map analysis, revised discussion of dehydration reaction, cation and anion structure, disaccharides, glycogen storage, phospholipid cell membrane structure, protein function.

Chapter 3:

- Based on heat map analysis: revised description of chromatin and chromosomes, simple diffusion.

Chapter 4:

- Updated **What's New: Targeting the Traitor Inside**, which now features the most current available information regarding cancer therapies.
- New Reading: **What's New: 3-D Printing to Create Complex Tissues.**
- Updated the story of Henrietta Lacks, the subject of the chapter introduction. Her gravesite has recently been located, and after many decades has been permanently identified with an appropriate grave marker.
- Based on heat map analysis, revised description of epithelial tissues to make it more complete.

Chapter 5:

- New chapter opener, featuring new photos.
- Per reviewer request, relocated and revised the section on Functions of the Skin.
- Completely revised sections on homeostasis to improve readability.
- Based on heat map analysis, revised description of sebaceous gland function.
- Based on heat map analysis, revised descriptions of temperature regulation.

Chapter 6:

- New artwork throughout, incorporating multiple images from *Anatomy and Physiology* REVEALED®.
- Updated **Medical Focus: Osteoporosis** to reflect state-of-the-art knowledge about medical research in the field.
- Reviewed current findings on causes and therapies to update **Medical Focus: Oh, My Aching Back—Options for Back Injuries.**
- Based on heat map analysis, revised description of lacunae and canaliculi.
- Based on heat map analysis, revised description of transverse foramina.

Chapter 7:

- Completely reworked Figure 7.6.
- Researched current findings and professional recommendations to overhaul **Medical Focus: Benefits of Exercise**. The article features a table of practical, real-world recommendations about incorporating exercise into daily living.
- Based on reviewer feedback, updated discussion of all-or-none law, recruitment, muscle tone.
- Based on reviewer feedback, updated discussion of twitch, tetanus, fatigue.

- Based on heat map analysis, revised description of the neuromuscular junction.
- Based on heat map analysis, revised discussion of myosin power stroke.

Chapter 8:

- Updated articles: **Medical Focus: Research on Alzheimer Disease**, and **In Case of Emergency: Traumatic Brain Injury**. Both readings now feature current research and recommendations from the Alzheimer's Association and the American Heart Association, respectively.
- Two new articles added:
  What's New: Epidural Stimulation in Spinal Cord Injuries: Cause for Hope What's New: Brain in a Petri Dish: A Human Model for Alzheimer Research
- New figures added: Figure 8.4, 8.15.
- Based on heat map analysis, added more detail to description of peripheral nervous system, neuron structure, all-or-none property of the neuron, meninges, pia mater, ventricles, brainstem functions.

Chapter 9:

- Updated statistics for child abuse, hearing loss, and ototoxicity.

Chapter 10:

- Updated all statistics regarding diabetes mellitus.
- New reading: **What's New: Options for Type I Diabetics: The Artificial Pancreas System, Beta Cell Transplants, and the BioHub**
- Updated **Medical Focus: Side Effects of Anabolic Steroids.**
- Based on heat map analysis, added more detail regarding Cushing's syndrome, ketoacidosis.

Chapter 11:

- Updated **What's New: Improvements in Transfusion Technology** to reflect new developments in this field.
- Based on heat map analysis, added more detail to the discussion of hemoglobin breakdown; positive feedback in blood clotting.

Chapter 12:

- In response to reviewer feedback: updated and revised discussion of intercalated disks and gap junctions.
- Updated **Medical Focus: Arteriosclerosis, Atherosclerosis, and Coronary Artery Disease** to contain up-to-date findings in diagnosis and therapy.
- Updated **I.C.E.—IN CASE OF EMERGENCY: Cardiopulmonary Resuscitation and Automated External Defibrillation** to include most current recommendations from the American Heart Association.
- New article: **What's New: Novel Stent for the Severest Strokes.**

Chapter 13:

- Updated **Medical Focus: AIDS Epidemic.**
- Updated **Medical Focus: Immunization: The Great Protector.**
- Updated **Medical Focus: Influenza: A Constant Threat of Pandemic.**
- Updated **What's New: Parasite Prescription for Autoimmune Disease.**
- Based on heat map analysis, added more detail about first, second and third lines of defense against infection, and antibody actions.

Chapter 14:

- Updated **Medical Focus: The Most-Often-Asked Questions About Tobacco and Health** to include current statistics and information about electronic cigarettes.
- Based on heat map analysis, added more detail about paranasal sinuses, muscles of forced expiration, respiratory volumes and capacities.

Chapter 15:

- New article: **Medical Focus: Disorders of the Digestive Tract** presents information about causes, signs and symptoms, and treatment of gastrointestinal disease.
- Revised and updated **Medical Focus: Tips for Effectively Using Nutrition Labels.**
- Researched and incorporated information about the most current pharmaceutical treatments for obesity.

- Researched and incorporated the latest statistics regarding obesity rates in the United States.
- Based on heat map analysis, improved explanations about salivary enzymes and lysozyme and anatomy of the esophagus.

Chapter 16:

- New chapter opener, featuring a fascinating historical account of the first renal dialysis machine and its developer.
- Based on reviewer request, included a section on lifetime renal function.
- In response to reviewer feedback, added greater detail regarding the two types of nephrons and the juxtaglomerular apparatus.

Chapter 17:

- In response to reviewer feedback, added more details to the explanation of the process of meiosis.
- Researched and updated diagnostic criteria for ovarian cancer, incorporating findings and recommendations by the American Cancer Society.
- Thorough review and revision of all information regarding contraceptive methods available in the United States, including statistics about success/failure rates and health precautions for each one.
- Incorporated up-to-date descriptions of the proper techniques for breast and testicular self-examination, using information from the American Cancer Society.
- Investigated newest research regarding endocrine-disrupting contaminants, and included novel recommendations from the United States Environmental Protection Agency (EPA).
- Revised information regarding causes and treatment of infertility to include contemporary findings and recommendations.

Chapter 18:

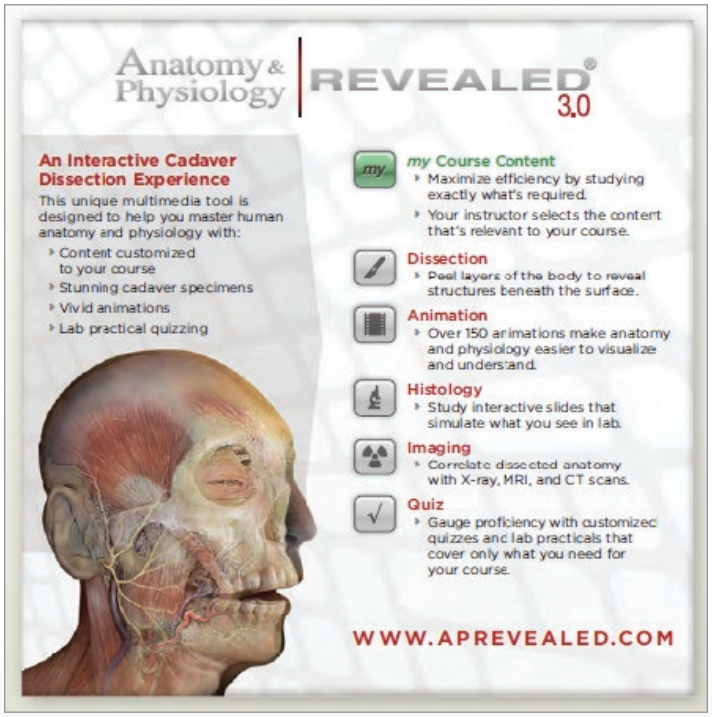
- Updated information regarding prevention of birth defects, utilizing information from the March of Dimes U.S.A.©
- Based on reviewer recommendation, revised description of implantation and the basis for a positive pregnancy test.

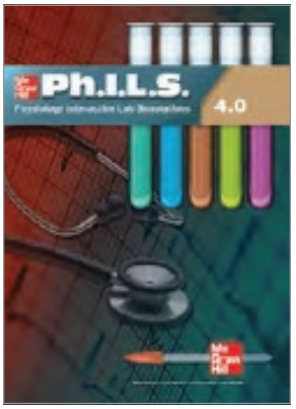
Chapter 19:

- NEW article: **What's New: A Profound Dilemma: Bioengineered Babies.**
- Added information about cell-free DNA analysis to the explanation of karyotyping.
- Revised **Medical Focus: Preimplantation Genetic Studies** to include information regarding polar body testing.
- Updated statistics for **Focus on Forensics: The Innocence Project**.
- Incorporated information about DNA repair into the section on Gene Therapy.

McGraw-Hill Education Teaching and Learning Tools

LearnSmart® Prep is an adaptive learning tool that prepares students for college-level work in Anatomy & Physiology. **Prep for Anatomy & Physiology now comes standard to students with Connect.** The tool individually identifies concepts the student does not fully understand and provides learning resources to teach essential concepts so he or she enters the classroom prepared. Data-driven reports highlight areas where students are struggling, helping to accurately identify weak areas.





Ph.I.L.S. 4.0 has been updated! Users have requested and we are providing five new exercises (Respiratory Quotient, Weight & Contraction, Insulin and Glucose Tolerance, Blood Typing, and Anti-Diuretic Hormone). Ph.I.L.S. 4.0 is the perfect way to reinforce key physiology concepts with powerful lab experiments. Created by Dr. Phil Stephens at Villanova University, this program offers 42 laboratory simulations that may be used to supplement or substitute for wet labs. All 42 labs are self-contained experiments—no lengthy instruction manual required. Users can adjust variables, view outcomes, make predictions, draw conclusions, and print lab reports. This easy-to-use software offers the flexibility to change the parameters of the lab experiment. There is no limit!

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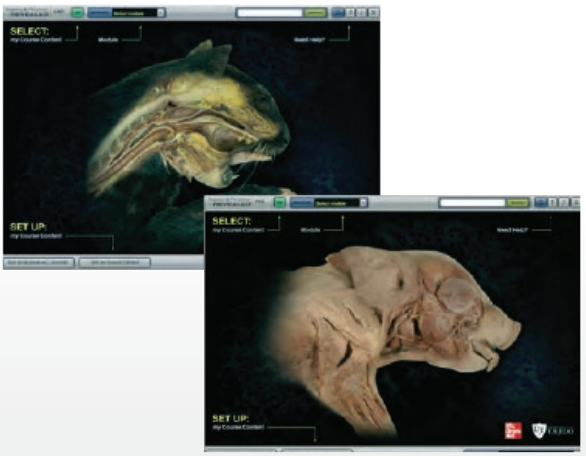

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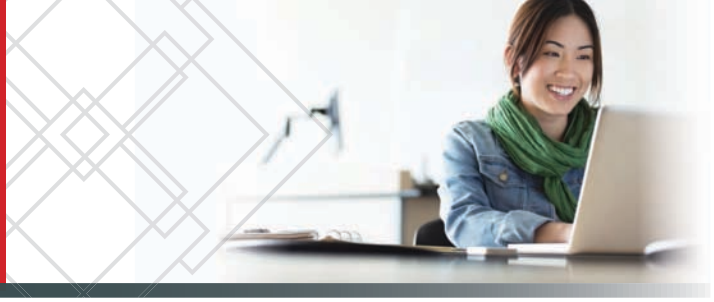

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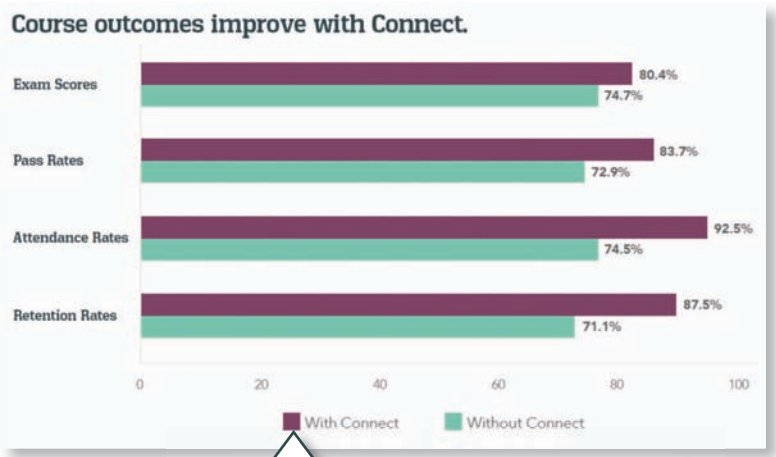

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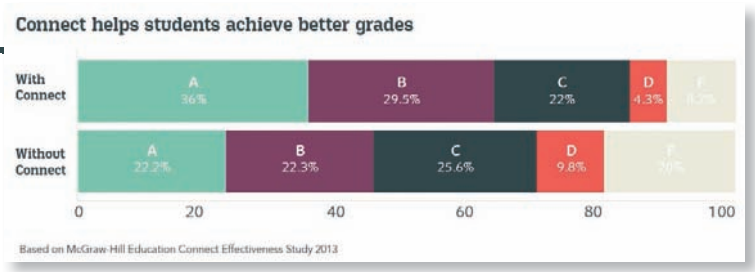

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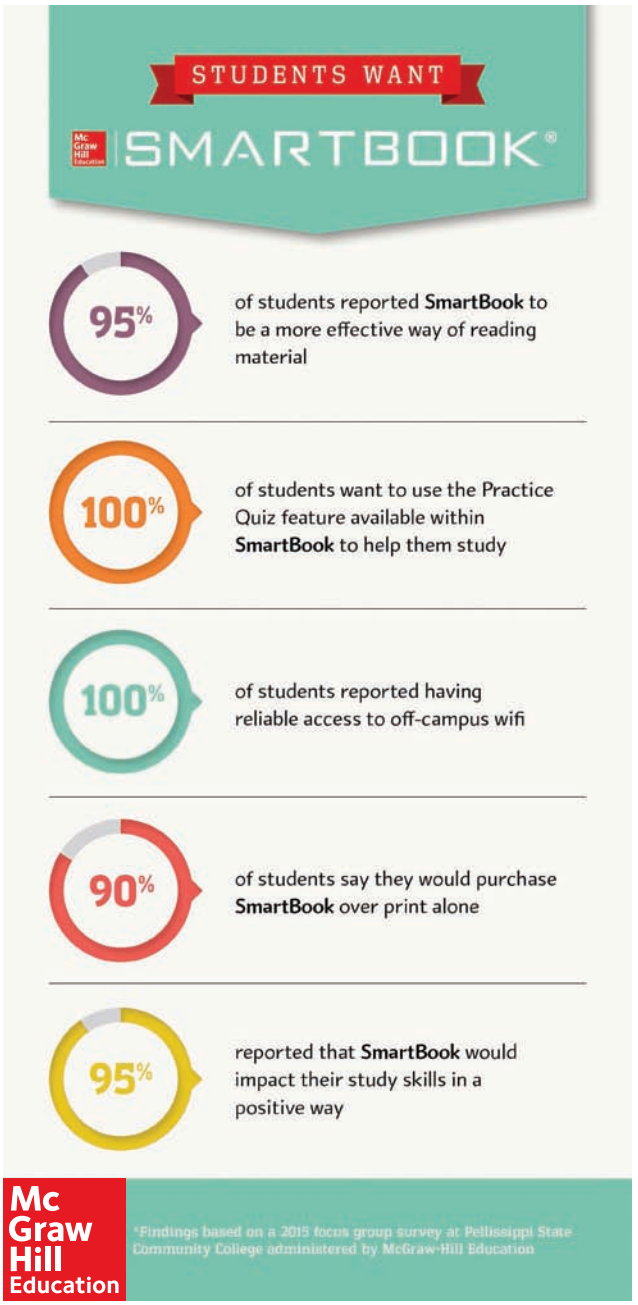


PART I

1 Organization of the Body

Recognize anything familiar? The little face, chest, and hands shown here belong to a baby in the womb, detailed using ultrasound, one of several imaging techniques described on page 16. All modern imaging methods have evolved from simple two-dimensional X rays, invented in 1895. The three-dimensional ultrasound procedure used to create this photo reveals structures with great detail and clarity. Ultrasound technology can monitor the infant's development and help to ensure a safe delivery for baby and mother. It can even enable physicians to diagnose fetal abnormalities and treat the baby while still in the womb!

Learning Outcomes

After you have studied this chapter, you should be able to:

1.1 The Human Body

1. Define anatomy and physiology, and explain how they are related.
2. Describe and give examples for each level of organization of the body.

1.2 Anatomical Terms

3. Use anatomical terms to describe the relative positions of the body parts, the regions of the body, and the planes that can be used to section the body.

1.3 Body Cavities and Membranes

4. List the cavities of the body, and state their locations.
5. Name the organs located in each of the body cavities.
6. Name the membranes that line each body cavity, and the membranes that cover the organs.

1.4 Organ Systems

7. List the organ systems of the body, and state the major organs associated with each.
8. Describe in general the functions of each organ system.

1.5 Homeostasis

9. Describe how a feedback system maintains homeostasis.
10. Describe the role of each body system in the maintenance of homeostasis.

Medical Focus

Meningitis and Serositis

Imaging the Body

1.1 The Human Body

1. Define anatomy and physiology, and explain how they are related.
2. Describe and give examples for each level of organization of the body.

Anatomy and physiology both involve the study of the human body. **Anatomy** is concerned with the structure of a part, as well as its relationship with other structures. For example, the stomach is a J-shaped, pouchlike organ, found between the esophagus and the small intestine, two other digestive system structures (Fig. 1.1). The stomach wall has thick folds, which disappear as the stomach expands to increase its capacity. **Physiology** is concerned with a body part's function, both individually and as a component of an entire system. For example, the stomach receives food from the esophagus, temporarily stores it and secretes digestive juices, then passes on partially digested food to the small intestine. Signals from the nervous system and the endocrine, or hormone system, direct stomach activities.

Anatomy and physiology are closely connected because the structure of an organ suits its function. For example, the stomach's pouchlike shape and ability to expand are well-suited to its function of storing food. In addition, the microscopic structure of the stomach wall is suitable to its secretion of digestive juices, as we will see in Chapter 15.

The Body's Organization Levels

The structure of the body can be studied at different *levels of organization* (Fig. 1.1). Initially, all substances, including body parts, are composed of chemicals made up of submicroscopic particles called **atoms.** Atoms join to form **molecules,** which can in turn join to form **macromolecules.** For example, molecules called amino acids join to form macromolecules called proteins. Different proteins make up the bulk of our muscles.

Macromolecules compose the cellular **organelles,** which are found within all cells. Organelles are tiny structures that perform cellular functions. For example, the organelle called the nucleus acts as a "control center" by directing cellular activity. Another organelle, called the mitochondrion, supplies the cell with energy. **Cells** are the basic units of living things.

Tissues are the next level of organization. A **tissue** is composed of similar types of cells and performs a specific function. An **organ** is composed of several types of tissues and performs a particular function within an **organ system.** For example, the stomach is an organ that is a part of the digestive system. It has a specific role in this system, whose overall function is to supply the body with the nutrients needed for growth and repair. The other systems of the body (see pages 12–15) also have specific functions.

All of the body systems together make up the **organism**—for example, a human being. Human beings are complex animals, but this complexity can be broken down and studied at ever simpler levels. Each simpler level is organized and constructed in a particular way.

Content CHECK UP!

1. Which would an anatomy student be studying: the structural organization of the skin, or functions of the skin?
2. Groups of organs are organized into _____.
3. Cells contain small structures called _____ that each perform a specific function.

Answers in Appendix A.

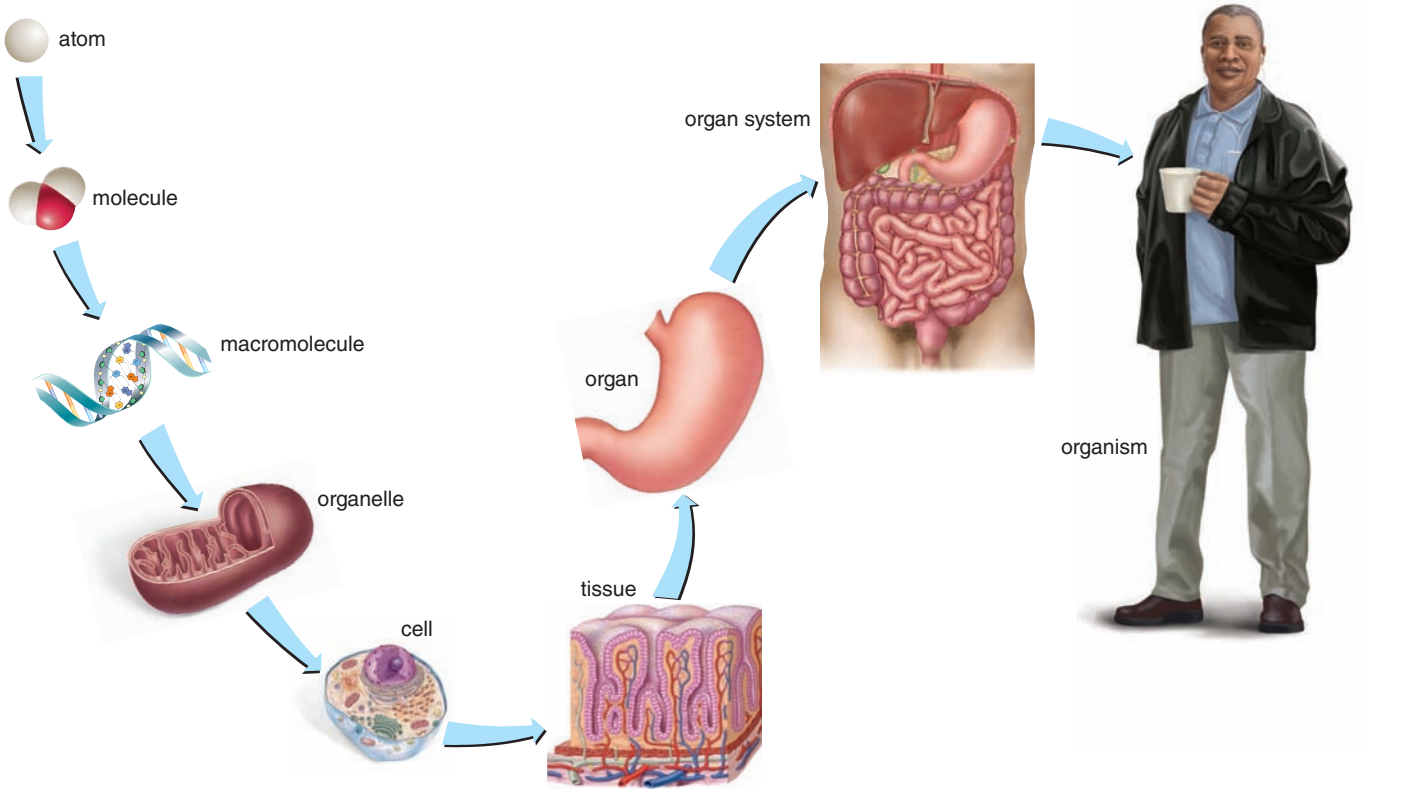


Figure 1.1 Levels of organization of the human body. Each level is more complex than the previous level.

1.2 Anatomical Terms

3. Use anatomical terms to describe the relative positions of the body parts, the regions of the body, and the planes that can be used to section the body.

Certain terms are used to describe the location of body parts, regions of the body, and imaginary planes that can be used to section the body. You should become familiar with these terms before your study of anatomy and physiology begins. Anatomical terms are useful only if everyone has in mind the same position of the body and is using the same reference points. Therefore, we will assume that the body is in the **anatomical position:** standing erect, with face forward, arms at the sides, and palms and toes directed forward, as illustrated in Figure 1.2.

Directional Terms

Directional terms are used to describe the location of one body part in relation to another (Fig. 1.2):

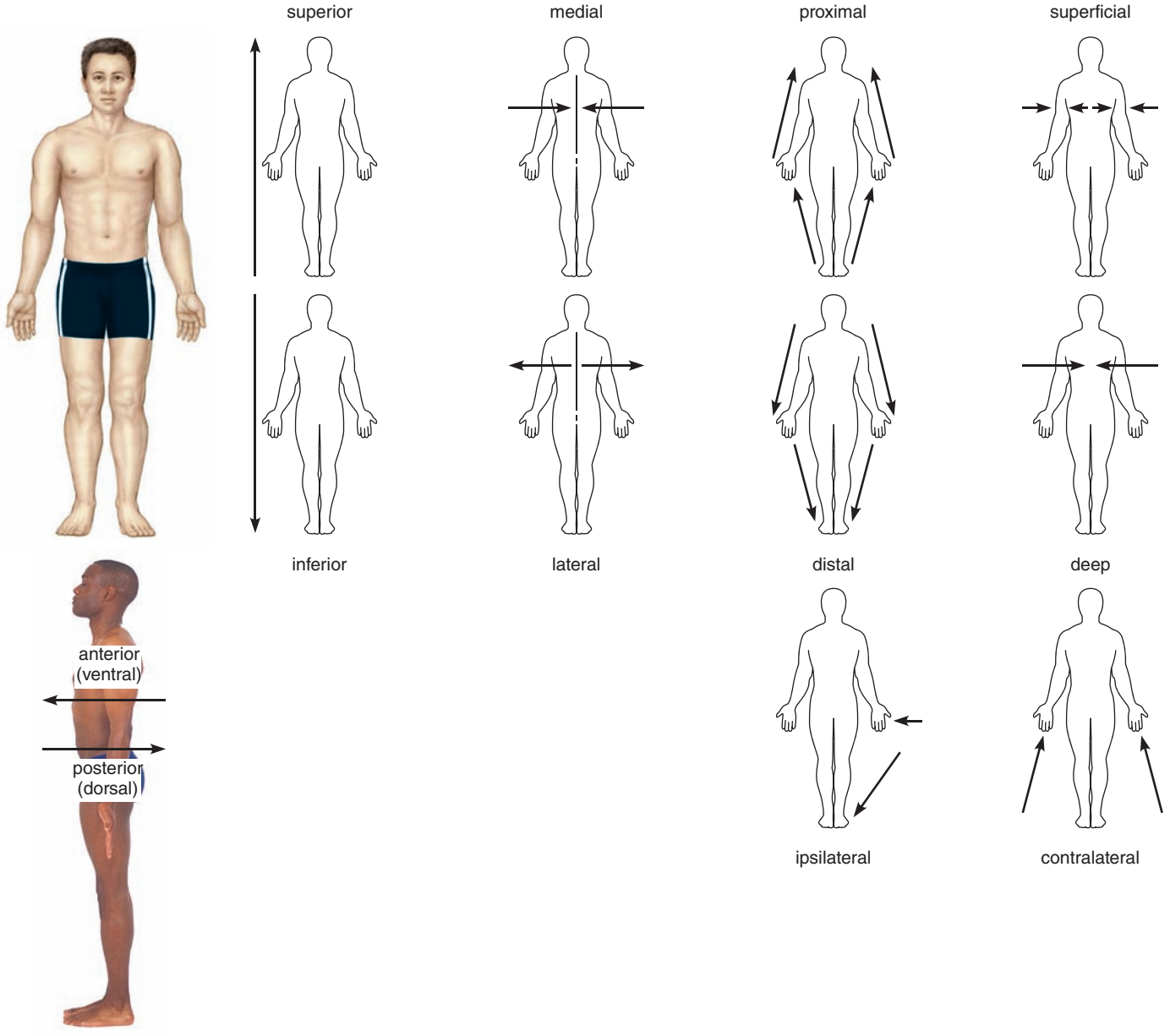
Anterior (ventral)—a body part is located toward the front. The windpipe (trachea) is *anterior* to the esophagus.

Posterior (dorsal)—a body part is located toward the back. The heart is *posterior* to the sternum (breastbone).

Superior—a body part is located above another part, or toward the head. The face is *superior* to the neck.

Inferior—a body part is below another part, or toward the feet. The navel is *inferior* to the chin.

Medial—a body part is nearer than another part to an imaginary midline of the body. The bridge of the nose is *medial* to the eyes.



AP|R **Figure 1.2** **Directional terms.** Directional terms tell us where body parts are located with reference to the body in anatomical position.

Lateral—a body part is farther away from the midline. The eyes are *lateral* to the nose.

Proximal—a body part is closer to a specific point of origin or attachment, or closer to the trunk of the entire body. For example, if the point of attachment is the shoulder, it is correct to say the elbow is *proximal* to the hand.

Distal—a body part is farther from a specific point of origin or attachment, or farther from the trunk of the entire body. For example, if the point of attachment is the hip, it is correct to say the foot is *distal* to the knee.

Superficial (external)—a body part is located closer to the surface than another. The skin is *superficial* to the muscles.

Deep (internal)—a body part is located farther from the surface than another. The intestines are *deep* to the spine.

Central—a body part is situated at the center of the body or an organ. The *central* nervous system is *centrally* located along the main axis of the body.

Peripheral—a body part is situated away from the center of the body or an organ. The *peripheral* nervous system is located outside the central nervous system.

Ipsilateral—a body part is on the same side of the body as another body part. The right hand is *ipsilateral* to the right foot.

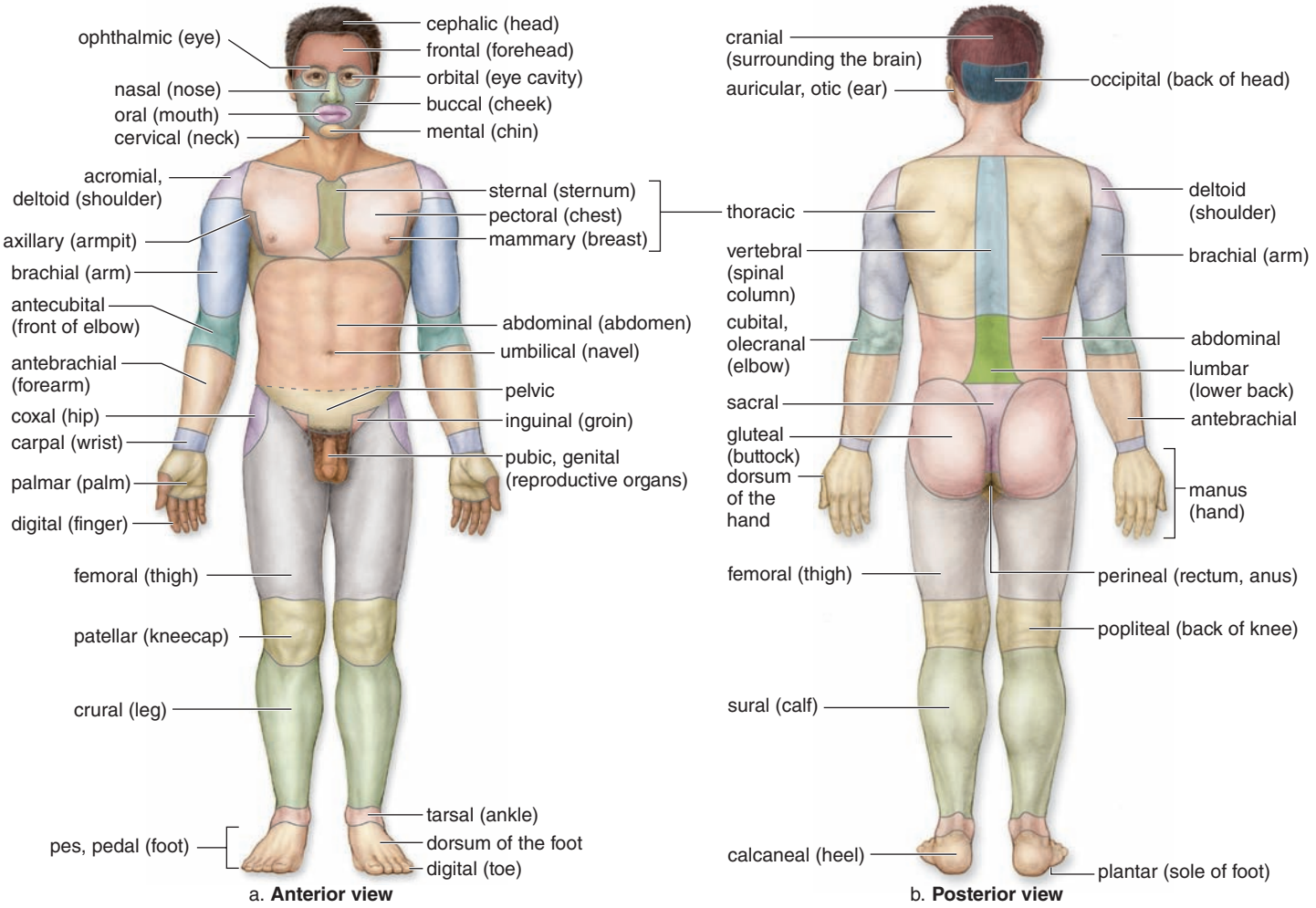
Contralateral—a body part is on the opposite side of the body from another body part. The right hand is *contralateral* to the left hand.

Regions of the Body

The human body can be divided into axial and appendicular portions. The **axial portion** includes the head, neck, spinal column, and ribs. The trunk can be divided into the thorax, abdomen, and pelvis. The pelvis is that part of the trunk associated with the hips. The **appendicular portion** of the human body includes the limbs—that is, the upper limbs and the lower limbs.

The human body is further divided as shown in Figure 1.3. The labels in Figure 1.3 don't include the word "region." It is understood that you will supply the word *region* in each case. The anatomical term for each region is followed by the common name for that region. For example, the cephalic region is commonly called the head.

Notice that the upper limb includes (among other parts) the brachial region (arm) and the antebrachial region (forearm). Similarly, the lower limb includes the femoral region (thigh), the crural



AP|R **Figure 1.3** **Terms for body parts and areas.** (**a**) Anterior. (**b**) Posterior.

region (leg), and the pedal region (foot). In other words, contrary to common usage, the terms *arm* and *leg* refer only to a part of the upper limb and lower limb, respectively.

Most likely, it will take practice to learn the terms in Figure 1.3, but you'll be glad you did. Try pointing to various regions of your own body and see if you can give the scientific name for that region. Check your answer against the figure.

Planes and Sections of the Body

To observe the structure of an internal body part, it is customary to section (cut) the body along a plane. A plane is an imaginary flat surface passing through the body. The body is customarily sectioned along the following planes (Fig. 1.4):

A **sagittal** (median) **plane** extends lengthwise and divides the body into right and left portions. A midsagittal plane passes exactly through the midline of the body. The head and neck are shown in a midsagittal section (Fig. 1.4*a*). Sagittal cuts that are not along the midline are called parasagittal (paramedian) sections.

A **frontal** (coronal) **plane** also extends lengthwise, but it is perpendicular to a sagittal plane and divides the body or an organ into anterior and posterior portions. Here, the knee joint is shown in frontal section (Fig. 1.4*b*).

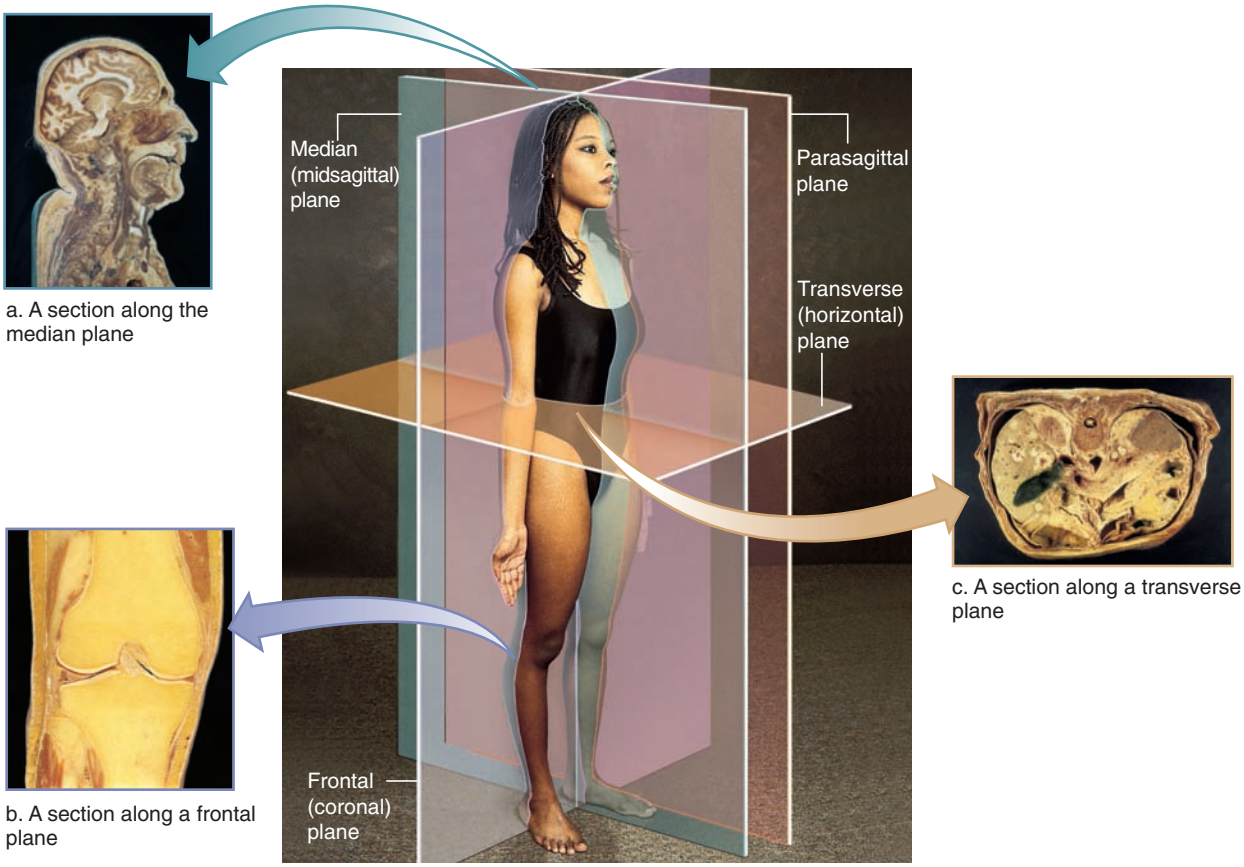
A **transverse** (horizontal) **plane** is perpendicular to the body's long axis and therefore divides the body horizontally to produce a cross section. A transverse cut divides the body or an organ into superior and inferior portions. Figure 1.4*c* is a transverse section of abdomen at the level of the umbilicus (navel).

The terms *longitudinal section* and *cross section* are often applied to individual body parts that have been removed and cut either lengthwise or straight across, respectively.

Content CHECK-UP!

4. Choose the correct directional term and finish the sentence: The chin is _____ to the navel.
5. If you point to your cheek, what region of the body are you identifying?
6. Suppose a CT scan creates images showing transverse sections of the head in a migraine headache patient. Are these horizontal or vertical images?

Answers in Appendix A.



AP|R **Figure 1.4 Body planes and sections.** Observation of internal parts requires sectioning the body along various planes.

1.3 Body Cavities and Membranes

4. List the cavities of the body, and state their locations.
5. Name the organs located in each of the body cavities.
6. Name the membranes that line each body cavity, and the membranes that cover the organs.

During embryonic development, the body is first divided into two internal cavities: the posterior (dorsal) body cavity and the anterior (ventral) body cavity. Each of these major cavities is then subdivided into smaller cavities. The cavities, as well as the organs in the cavities (called the **viscera**), are lined by membranes.

Posterior (Dorsal) Body Cavity

The posterior body cavity is subdivided into two parts: (1) The **cranial cavity,** enclosed by the bony cranium, contains the brain; (2) the **vertebral canal,** enclosed by vertebrae, contains the spinal cord (Fig. 1.5*a*).

The posterior body cavity is lined by three membranous layers collectively called the **meninges** (sing., *men´inx*). The innermost, or deepest, of the meninges is tightly bound to the surface of the brain and the spinal cord. The space between this layer and the next layer is filled with cerebrospinal fluid. Cerebrospinal fluid supports and nourishes the brain and the spinal cord and enables their cells to transmit electrical signals. In the skull, the most superficial of the three meninges lies directly under the skull bone. In the vertebral column, the outermost meninx is deep to a layer of fat and connective tissue, as you'll see in Chapter 8.

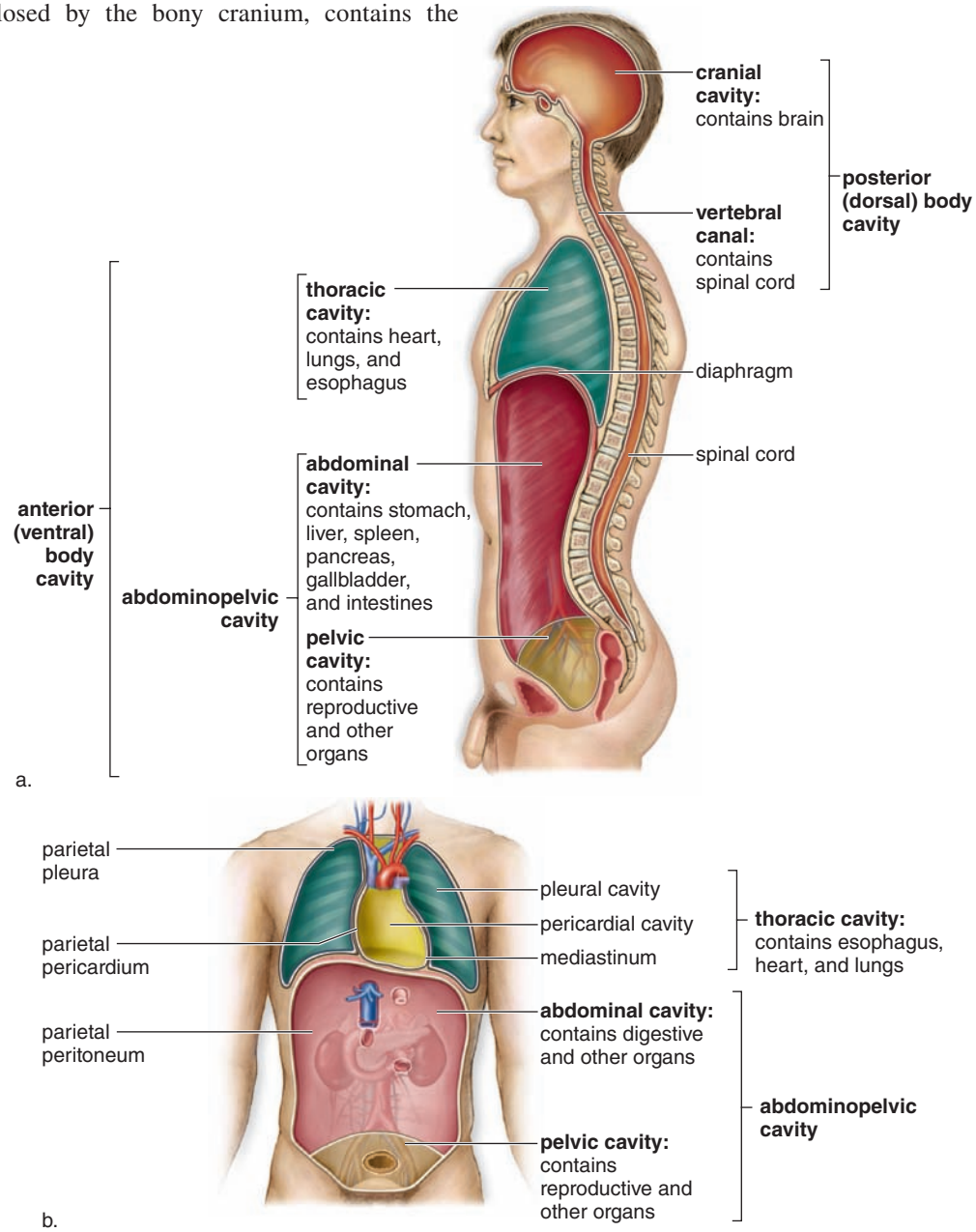


Figure 1.5 The two major body cavities and their subdivisions. (**a**) Left lateral view (**b**) Frontal view.

Anterior (Ventral) Body Cavity

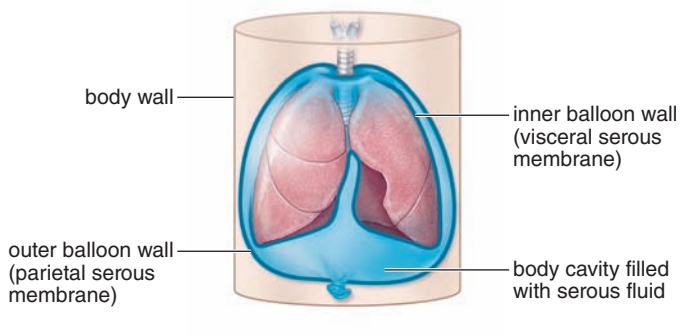
The large anterior body cavity is subdivided into the superior **thoracic cavity** and the inferior **abdominopelvic cavity** (Fig. 1.5*a*). A muscular partition called the **diaphragm** separates the two cavities. Membranes that line these cavities are called **serous membranes** because they secrete a fluid that is similar to blood **serum.** Serum is the fluid that remains if all of the clotting proteins are removed from the blood. **Serous fluid** between the smooth serous membranes reduces friction when the viscera rub against each other or against the body wall.

To understand the relationship among serous membranes, the outer body wall, and an organ, consider the following example: Imagine a soft, pliable balloon (the serous membrane) filled with a small amount of fluid (serous fluid). The balloon sits inside a container (the inner body wall), tightly pressed to all sides of the container. An organ (the lung, for example) is pushed into this balloon and is then covered by the balloon (Fig. 1.6). As a result, two layers of serous membrane are created, separated from each other by the serous fluid. The balloon's outermost layer (lining the inner body wall) is termed the **parietal serous membrane.** The inner layer covering the organ is the **visceral serous membrane.** Thus, the parietal membrane is a cavity lining, and the visceral membrane is an organ covering. Inflammation of the serous membrane or infection of the serous fluid in the body cavities causes serious and potentially fatal illness (see Medical Focus, p. 9).

Thoracic Cavity

The thoracic cavity is enclosed by the rib cage and has three portions: the left, right, and medial portions. The medial portion, called the **mediastinum,** contains the heart, thymus gland, trachea, esophagus, and other structures (Fig. 1.5*b*).

The right and left portions of the thoracic cavity contain the lungs. The lung tissue is covered by a serous membrane—the **visceral pleura.** The **parietal pleura** lines the thoracic cavity. In between these two **pleurae** is the pleural cavity, which contains a small amount of pleural fluid. Similarly, in the medial thoracic cavity, the heart is covered by the **visceral pericardium.** The visceral pericardium contributes to the outermost connective tissue layer of the heart. Forming a tough connective tissue sac around the heart is the **fibrous pericardium,** whose inner lining is the **parietal pericardium**. Together, these structures create the **pericardial cavity.** The heart, inside its visceral pericardial sac, is separated from the outer parietal pericardium by a small amount of pericardial fluid.



AP\|R Figure 1.6 Relationship between the body wall, serous membranes, and organs.

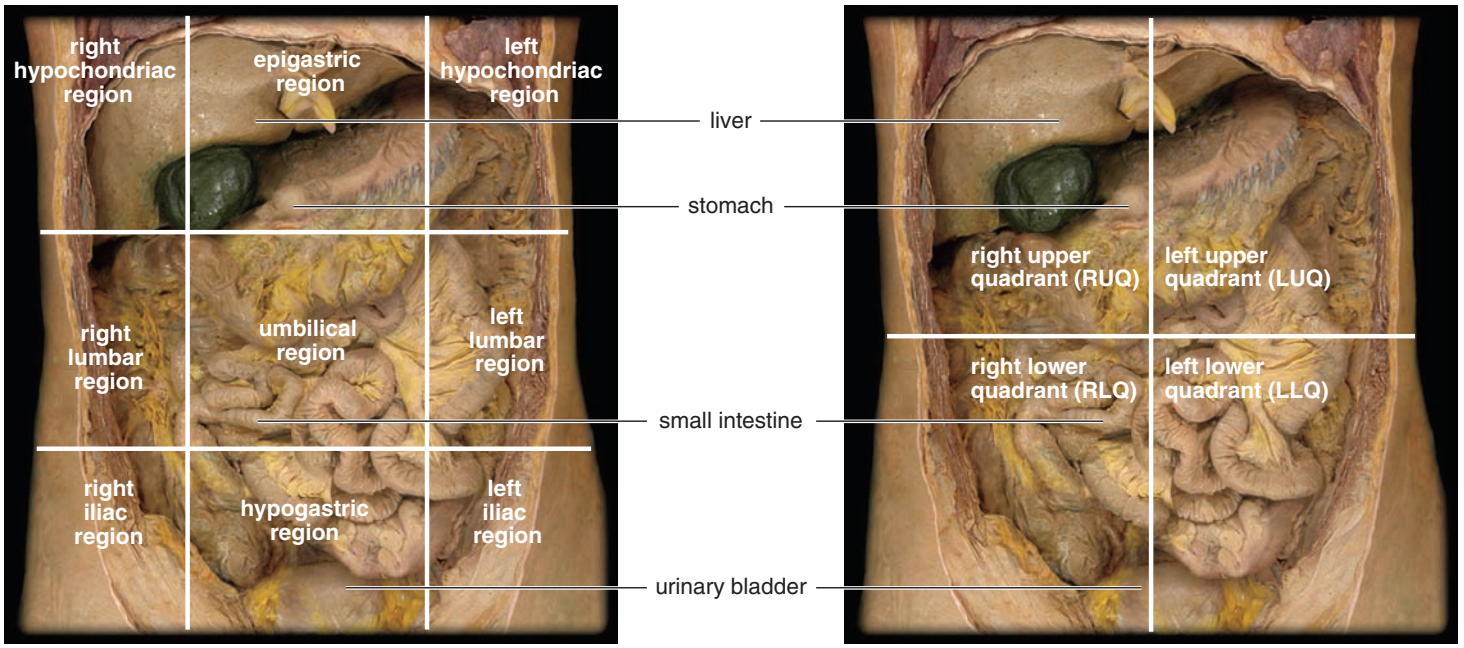
Abdominopelvic Cavity

The abdominopelvic cavity has two portions: the superior **abdominal cavity** and the inferior **pelvic cavity.** The stomach, liver, spleen, gallbladder, and most of the small and large intestines are in the abdominal cavity. The pelvic cavity contains the rectum, the urinary bladder, the internal reproductive organs, and the rest of the large intestine. Males have an external extension of the abdominal wall, called the **scrotum,** where the testes are located.

Many of the organs of the abdominopelvic cavity are covered by the **visceral peritoneum,** whereas the wall of the abdominal cavity is lined with the **parietal peritoneum.** Peritoneal fluid fills the cavity between the visceral and parietal peritoneum. Table 1.1 summarizes our discussion of body cavities and membranes.

TABLE 1.1 Body Cavities and Membranes

Name of Cavity	Contents of Cavity	Membranes	
POSTERIOR BODY CAVITY			
Cranial cavity	Brain	Meninges	
Vertebral canal	Spinal cord	Meninges	
ANTERIOR BODY CAVITY			
Thoracic Cavity		*Parietal Membrane*	*Visceral Membrane*
Pleural cavity	Lungs, serous fluid	Parietal pleura	Visceral pleura
Pericardial cavity	Heart, serous fluid	Fibrous pericardium and parietal pericardium	Visceral pericardium (epicardium)
Abdominopelvic Cavity			
Abdominal cavity	Stomach, intestines, liver	Parietal peritoneum	Visceral peritoneum
Pelvic cavity	Reproductive organs, urinary bladder, rectum	Parietal peritoneum	Visceral peritoneum



a. **Abdominopelvic regions** b. **Abdominopelvic quadrants**

AP|R **Figure 1.7** **The abdominopelvic cavity.** The abdominopelvic cavity can be subdivided into **(a)** nine regions or **(b)** four quadrants.

It's important that clinicians use the same terminology to reference various regions of the abdominopelvic cavity. Either of two systems can be used. The first uses nine regions (imagine a "tic-tac-toe" grid, with the umbilicus [navel] in the center square). The upper regions are right hypochondriac, epigastric, and left hypochondriac. The center regions are right lumbar, umbilical, and left lumbar. The lower regions are right inguinal (iliac), pubic, and left inguinal (iliac) (Fig. 1.7*a*). Note that the terms used are those for each body area, as illustrated in Figure 1.3.

Alternatively, the abdominopelvic cavity can be divided into four quadrants by running a horizontal plane across the median plane at the point of the navel (Fig. 1.7*b*).

Begin Thinking Clinically

Imagine that you are caring for a small child, who tells you that his stomach hurts. However, he points to his umbilical region, immediately below his navel. What organ is more likely the source of his pain?

Answer and discussion in Appendix A.

Physicians commonly use these quadrants to identify the locations of patients' symptoms. The four quadrants are: (1) right upper quadrant, (2) left upper quadrant, (3) right lower quadrant, and (4) left lower quadrant.

Figure 1.7 compares the two methods of referencing the abdominopelvic region and shows the organs within each region.

Content CHECK-UP!

7. Match each of the serous membranes to its function.

parietal pleura _____	A. covers the heart
visceral pericardium _____	B. lines walls of right and left portions of thoracic cavity
visceral peritoneum _____	C. covers the abdominal organs

8. Pleurisy refers to infection or inflammation of the pleurae. You might expect a common symptom of pleurisy to be _____.

Answers in Appendix A.

1.4 Organ Systems

7. List the organ systems of the body, and state the major organs associated with each.

8. Describe in general the functions of each organ system.

The organs of the body work together in systems. The reference figures found on pages 14 and 15 summarize the functions of each of these systems. Corresponding figures that complete each organ system chapter show how that particular system interacts with all the other systems. In this text, the organ systems of the body have been divided into four categories, as discussed next.

Support, Movement, and Protection

The **integumentary system,** discussed in Chapter 5, includes the skin and accessory organs, such as the hair, nails, sweat glands, and sebaceous glands. The skin protects underlying tissues, prevents

MEDICAL FOCUS

Meningitis and Serositis

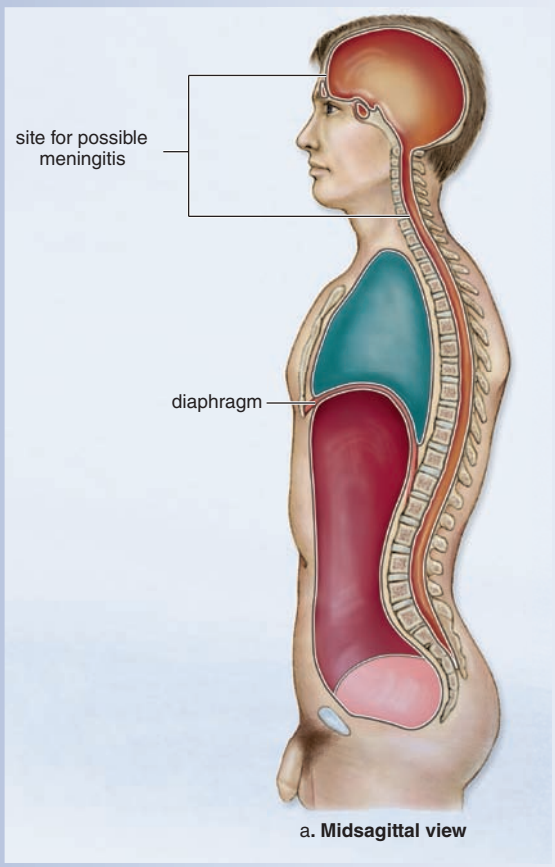
The anterior and posterior body cavities are enclosed areas that are protected by bone, muscle, connective tissues, and skin. Inflammation of the membranes lining these cavities is a fairly rare, but serious, illness. If body defenses are overcome by bacteria, viruses, or other microbes, the result is a serious, potentially fatal infection and inflammation of the meninges (meningitis) or the serous membranes (**serositis**). Pleurisy, pericarditis, and peritonitis are all forms of serositis.

Meningitis is the term for inflammation of the meninges—linings of the posterior body cavity that cover the brain and spinal cord. The most dangerous form is caused by bacteria that commonly inhabit the nose. In the bacterial meningitis patient, a previous viral infection (which may be a simple common cold) allows these bacteria to enter the bloodstream and infect the meninges. Symptoms of bacterial meningitis include a severe headache and stiff neck, sensitivity to light, fever, weakness, and fatigue. Even with aggressive antibiotic treatment, bacterial meningitis is fatal in 25% of adults. The best treatment is prevention by immunization—especially important for young college students living in the close quarters of a college dorm.

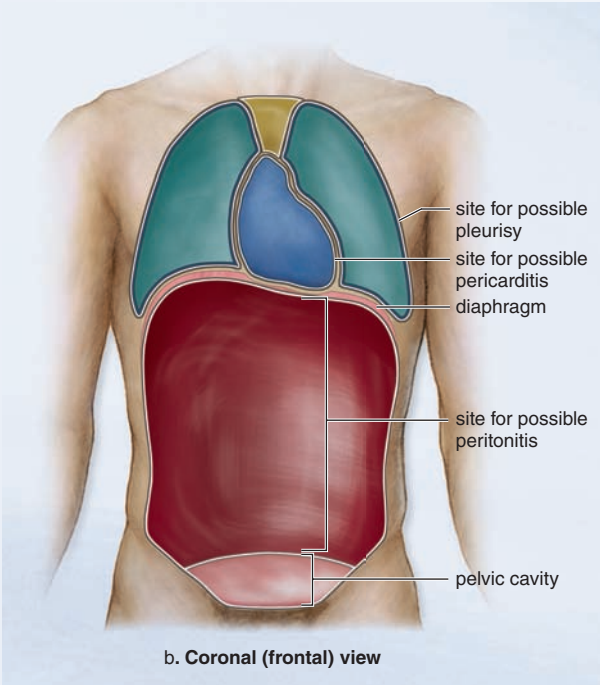
Pleurisy is an inflammation of the pleurae—linings of the thoracic cavity that also cover the lungs. It is often caused by a cold virus, although it can signal the presence of more serious infections or even lung cancer. Its symptoms include chest pain that worsens with deep breathing, and *pleural friction rub*—a rough, grating sound in the chest that can be heard with a stethoscope placed over the painful area. Treatment for pleurisy depends on its cause; most often, pleurisy that results from a common cold requires only pain medication such as aspirin or ibuprofen. Treatment for bacterial infection requires antibiotics.

Pericarditis affects the linings surrounding the heart. Like meningitis, it often results from previous infections and can be extremely dangerous. It is a common complication in drug abusers who use dirty needles for injections. Symptoms include severe chest pain (which may be mistaken for a heart attack), fever, and weakness. Physicians can hear *pericardial friction rub* by placing a stethoscope over the patient's heart. Fluid accumulation inside the pericardial sac surrounding the heart may interfere with blood flow to and from the heart. Bacterial pericarditis is treated with antibiotics, pain medications, and drugs that reduce swelling.

Peritonitis affects the lining of the abdominopelvic cavity. It usually results from bacterial infection; a common cause of infection is a ruptured appendix from appendicitis. Severe pain, fever, elevated white blood cell counts, and tenderness are common symptoms. Aggressive treatment with antibiotics is necessary to prevent bacteria from invading the blood.



a. **Midsagittal view**



b. **Coronal (frontal) view**

Figure 1A **Meningitis and serositis.** (**a**) Meningitis is infection or inflammation of the linings of the cranial cavity and vertebral canal. (**b**) Serositis is infection or inflammation of the ventral body cavities. Pleurisy affects the pleural cavities, pericarditis affects the pericardial cavity, and peritonitis affects the abdominopelvic cavities.