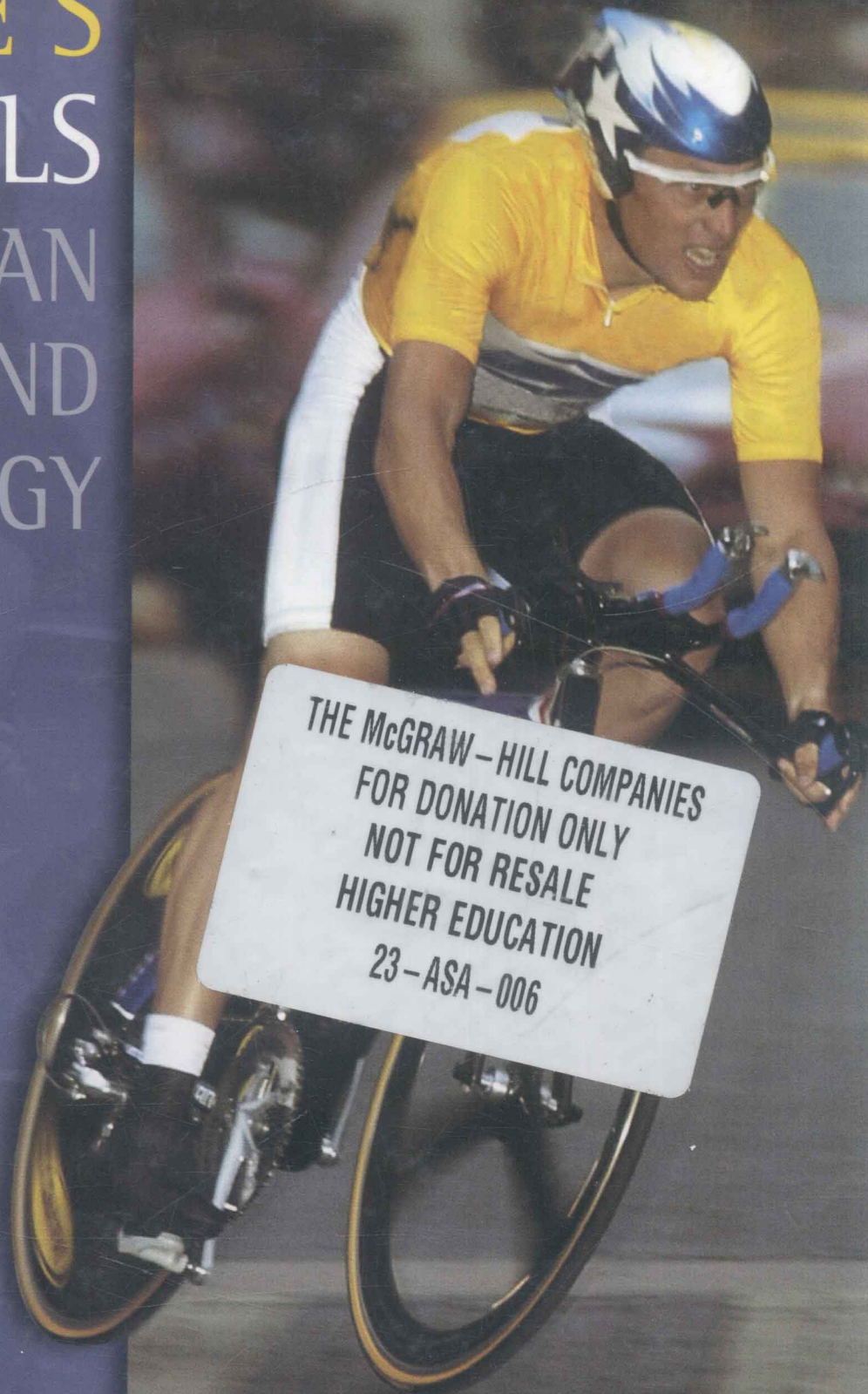


EIGHTH EDITION

# HOLE'S ESSENTIALS OF HUMAN ANATOMY AND PHYSIOLOGY

DAVID SHIER  
JACKIE BUTLER  
RICKI LEWIS



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EIGHTH  
EDITION

HOLE'S  
ESSENTIALS  
OF HUMAN  
ANATOMY AND  
PHYSIOLOGY

DAVID SHIER

*Washtenaw Community College*

JACKIE BUTLER

*Grayson County College*

RICKI LEWIS

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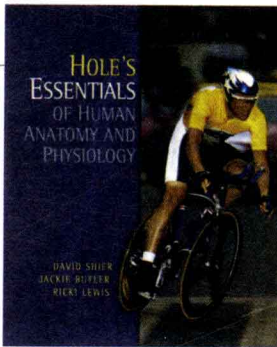
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David N. Shier, Washburn Community College  
Jackie L. Butler, Grayson County College  
Ricki Lewis, SUNY - Albany

**Student Center**

**Contents:**

Chapter 1: Introduction to Human Anatomy and Physiology  
Chapter 2: Chemical Basis of Life  
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Chapter 17: Urinary System  
Chapter 18: Water, Electrolyte, and Acid-Base Balance  
Chapter 19: Reproductive Systems  
Chapter 20: Pregnancy, Growth, and Development



## Online Learning Center (OLC)

The Online Learning Center that accompanies *Hole's Essentials of Human Anatomy and Physiology* is found at [www.mhhe.com/shieress8](http://www.mhhe.com/shieress8). This online resource offers an extensive array of quizzing and learning tools that will help you master the topics covered in your textbook.

## Interactive Activities

Fun and exciting learning experiences await you at the *Hole's Essentials of Human Anatomy and Physiology* Online Learning Center! Each chapter offers a series of interactive crossword puzzles, art labeling exercises, vocabulary flashcards, animation-based quizzes, and other engaging activities designed to reinforce learning. For a real challenge, tackle a case study or clinical application to put your knowledge into practice.

**TERMS**

**ENDOSTEUM**

DEFINITION  
NEXT  
REMOVE CARD

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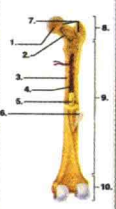
**DEFINITION**

**TISSUE LINING THE MEDULLARY CAVITY WITHIN THE BONE.**

TERM  
NEXT  
REMOVE CARD  
RANDOMIZE DECK  
CARDS REMAINING 73

Click and hold on the answer space to see the possible answers. Then select the correct answer and release. Answer all questions and the the "Score Test" button at the bottom.

1. Spongy bone
2. Space occupied by red marrow
3. Compact bone
4. Medullary cavity
5. Yellow marrow
6. Periosteum
7. Epiphyseal disk
8. Proximal epiphysis
9. Diaphysis
10. Distal epiphysis



**Summary of Answers**

If there are any blanks, it means that you didn't answer the question. You can go back and make changes before you hit the "Score Test" button.

Your answer	Correct Answer
1. Spongy bone	1. Spongy bone

Peek Errors?

About Crossword Express Help Time 2:52

**Hole's Essentials of Human Anatomy and Physiology**  
8th Edition  
Shier, Butler, Lewis  
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**A** 14 A cylinder-shaped unit containing bone cells that surround an osteonic canal, Haversian system.

**D** 7 Bone that consists of bars and plates separated by irregular spaces, cancellous bone.

Chapter 7: Skeletal System

E	H	O	M	E						
B	O	N	E							
C	O	M	P	A	C	T	I	O	N	E
H	O	M	E							
B	O	N	E							
R	A	L	B	O	N	E				
B	O	N	E							

**Interactive Case Studies and the Human Body**

**The Male Body**

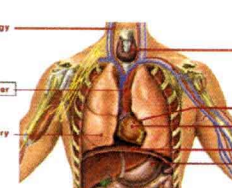
(Click on the label to begin the case study)

11. Hematology

12. Cardiovascular

13. Respiratory

14. Gastrointestinal



15. Endocrine

16. Cardiovascular

17. Cardiovascular

18. Respiratory

19. Gastrointestinal

## Test Yourself

Take a quiz at the *Hole's Essentials of Human Anatomy and Physiology* Online Learning Center to gauge your mastery of chapter content.

Each chapter quiz is specially constructed to test your comprehension of key concepts. Feedback on your responses explains why an answer is correct or incorrect. You can even e-mail your quiz results to your professor!

### Your Results:

The correct answer for each question is indicated by a ✓.

- 1 CORRECT** The outer covering of each bone, made from fibrous connective tissue, is called the \_\_\_\_\_.  
 A) epiphysis  
 B) diaphysis  
 C) articular cartilage  
 D) periosteum
- 2 CORRECT** Inside the epiphysis of each long bone, mostly \_\_\_\_\_ can be found.  
 A) compact bone  
 B) spongy bone  
 C) cartilage  
 D) marrow
- 3 CORRECT** Compact bone is made up of \_\_\_\_\_ cemented together.  
 A) osteocytes  
 B) perforating canals  
 C) osteons  
 D) trabeculae
- 4 CORRECT** Which of these statements is not true about intramembranous bones?  
 A) They begin with a cartilage model.  
 B) They form between flat sheets of connective tissue.  
 C) Skull bones are formed in this way.  
 D) Osteoblasts deposit new bone along blood vessels within the layers.
- 5 UNANSWERED** Several layers of cells reside within epiphyseal disks of developing long bones. Which layer is responsible for anchoring the disk to the bony epiphysis?  
 A) cells undergoing mitosis  
 B) cells enlarging and becoming calcified

## Course Tools

Here you'll find chapter-specific study outlines and a listing of relevant websites, along with links to interactive lab activities. The *Hole's Essentials of Human Anatomy and Physiology* Online Learning Center also features cutting-edge online histology and anatomy atlases plus general study tips and career information.

**Systemic Descriptions**  
**Cardiovascular System**  
 For describing (labelled) parts (13) (pink labels).

**SECTION 17**

**SECTION 18**

**CT Image:** The stomach, transverse colon (2), descending colon (6) and spleen (8) are seen in both the coronal and CT. Because the person is lying down, the constant motions (related to the stomach) form a level interface with the air (10) in the stomach. The liver in this CT is more like the liver in cadaver Section 15, including the falciform ligament (27) and the hepatic portal vein (18). The pancreas (22) and adrenal gland (20) in this CT can be seen in cadaver Section 17. The kidney (20) in this CT can be seen in cadaver Section 18.

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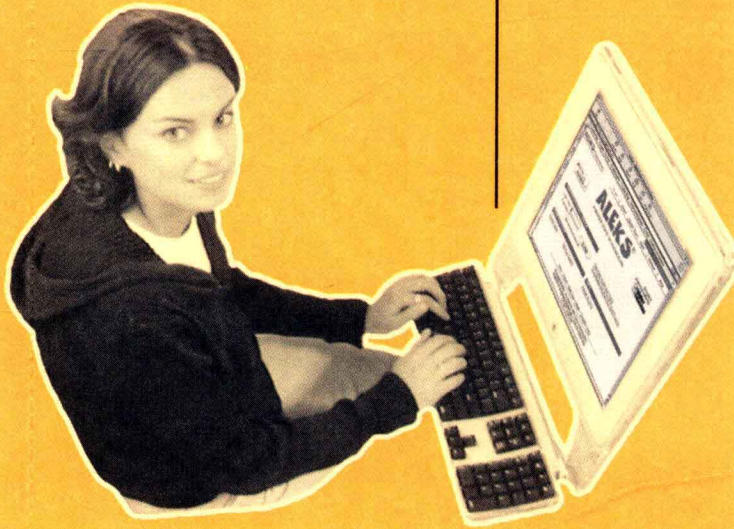
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# About the Authors



**David Shier**

David Shier has accumulated twenty-five years of experience teaching anatomy and physiology,

primarily to premedical, nursing, dental, and allied health students. He has effectively incorporated his extensive teaching experience into another student-friendly revision of *Hole's Essentials of Human Anatomy and Physiology* and *Hole's Anatomy and Physiology*. David has published numerous papers and abstracts in the areas of renal and cardiovascular physiology, the endocrinology of fluid and electrolyte balance, and hypertension. A faculty member in the Life Science Department at Washtenaw Community College, he is actively involved in a number of projects dealing with assessment, articulation, and the incorporation of technology into instructional design. David holds a Ph.D. in physiology from the University of Michigan.



**Jackie Butler**

Jackie Butler's professional background includes work at the University of Texas Health Science Center

conducting research about the genetics of bilateral retinoblastoma. She later worked at Houston's M. D. Anderson Hospital conducting research on remission in leukemia patients. Now a popular educator at Grayson County College, Jackie teaches microbiology and human anatomy and physiology for health science majors. Her experience and work with students of various educational backgrounds have contributed significantly to another revision of *Hole's Essentials of Human Anatomy and Physiology* and *Hole's Human Anatomy and Physiology*. Jackie Butler received her B.S. and M.S. degrees from Texas A&M University, focusing on microbiology, including courses in immunology and epidemiology.



**Ricki Lewis**

Ricki Lewis, author of the WCB/McGraw-Hill textbooks *Life* and *Human Genetics*,

combines the skills of

scientist and journalist. Since earning her Ph.D. in genetics from Indiana University in 1980, she has published more than 3,000 articles in scientific and popular publications. Today Ricki contributes regularly to *The Scientist* and *Biophotonics International*, and has published an essay collection, *Discovery: Windows on the Life Sciences*. She is a genetic counselor for a private medical practice in upstate New York, and is an adjunct professor of biology at the University at Albany and at Miami University. Ricki brings a molecular, cellular, and genetics perspective, with a journalistic flair, to *Hole's Essentials of Human Anatomy and Physiology* and *Hole's Human Anatomy and Physiology*.



# Preface

## To the Student

Welcome to the eighth edition of *Hole's Essentials of Human Anatomy and Physiology*. We continue our commitment to introduce the structure and function of the human body in an interesting and highly readable manner.

Many of you are planning careers in health care, athletics, science, or education. We understand that you face the challenge of balancing family, work, and academics. This text provides you with many helpful tools that will prepare you for success in the study of human anatomy and physiology.

**The Guided Tour to Top Performance**, p. ix, highlights the integrated study tools of your text.

- Take the lead with chapter vignettes, objectives, and key terms.
- Attack the chapter content with *Check Your Recall Questions* and *A&P Trivia*.
- Pull concepts together with real-life *Clinical Connections* and *Topics of Interest*.
- Prepare for top performance with *Review Exercises* and *Critical Thinking Questions*.
- Cruise online to a *Learning Center* packed full of activities to complement the text.

Your next step to effective learning begins with a solid study strategy. Many first year students feel overwhelmed by the amount of material in Anatomy and Physiology. Be assured that you can do the work, and you can be successful. Studying anatomy and physiology is like preparing for the Tour de France. Practice, diligence, and perseverance will pay off. Professor Susan Allen of North Harris College, Houston, Texas, offers the following study tips to assist you in preparation for the ride ahead.

1. Go over your notes and handouts everyday.
  - Review material in the first 24 hours after it is presented. You will learn faster and remember longer.
  - Go over your notes at least once a day, seven days a week.
  - Read over all notes taken to date, and read the notes out loud. Seeing, saying, and hearing helps.
  - Tape-record the lectures (after getting permission), and listen to the lectures.
2. Rewrite your notes.
  - Use block letters and an outline form.
  - Put a small amount of material on each page and illustrate facts with drawings. A picture is worth a thousand words.
  - Color code headings.
3. Read each chapter or unit before going to class.
  - Use the SQ3R method when you read: Survey, Question, Read, Recite, Review.
  - Use the chapter outline at the end of each of the chapters in *Hole's Essentials* text.
  - Answer the questions at the end of the chapter.
  - Pay particular attention to the diagrams and charts.
4. Form study groups.
  - Plan regular times to meet and go over the material.
  - Explain the material to someone else.
  - Talk through a concept to gain a thorough understanding.
  - Make up an exam over the material.
5. Use the Cornell Method of note taking.
  - Organizing the material will cut down on your study time.
  - (For further information on this great method of note taking, refer to the study tips page under Biology on the North Harris College Web Page: <http://science.nhmccd.edu/biol>)
6. Budget your time.
  - Study for short periods of time with breaks in between. Short repeated study sessions are much more effective than one long session.
  - For every hour you are in class, spend two to three hours studying outside of class.
7. Make flashcards of terms and definitions.
  - Make up meaningful acronyms and word combination to help you remember information.
  - Sound out difficult words and practice spelling them.
  - Learn the meanings of the prefixes and suffixes of words. Check out the inside back cover of the text for meanings of these words.

8. Use effective ways to learn terminology.
  - Look at the word.
  - Say the word out loud and repeat the word often during the day.
  - Touch the area on a model or torso, or touch the area on your own body (when possible).
  - Write the word.
  - Color the region represented by the term in an Anatomy Coloring Book.
9. Make models of the chemical structures in chapter 2.
  - Use gumdrops, marshmallows, toothpicks, etc.
  - Look at a diagram and build a model. It will help you learn the material faster and remember it longer.
10. Use additional study aids that are available:
  - *Student Study Guide*
  - *The Dynamic Human* CD-Rom
  - *Essential Study Partner* found in the Online Learning Center
  - Film clips or videos recommended by the professor

The cover image of Lance Armstrong, three-time Tour de France cycling champion, husband, father, and cancer survivor sends a message of encouragement, inspiration, and determination to all. This is your life; don't spend it at the back of the pack. Enjoy the ride; use the study tools provided and sprint to success in anatomy and physiology.

*David Shier*

*Jackie Butler*

*Ricki Lewis*



# Guided Tour

## to Top Performance

### HOLE'S ESSENTIALS OF HUMAN ANATOMY AND PHYSIOLOGY

- Maintains commitment to readability
- Applies concepts to everyday examples
- Emphasizes the interrelatedness and interdependence of organ systems
- Provides you with the right tools to cross the anatomy and physiology finish line

### VIGNETTES

take the lead to chapter content. They connect you to many areas of health care including technology, physiology, medical conditions, historical perspectives, and careers.

### CHAPTER OBJECTIVES

help you stay on course as you master the information within the narrative. Use them as guides to identify important chapter topics.

CHAPTER 7: Skeletal System 127

**Chapter Objectives**  
After studying this chapter, you should be able to do the following:

**7.1 Introduction**  
1. List the active tissues in a bone. (p. 129)

**7.2 Bone Structure**  
2. Describe the general structure of a bone, and list the functions of its parts. (p. 129)

**7.4 Bone Development and Growth**  
3. Distinguish between intramembranous and endochondral ossification.

**7.4 Bones, and explain how such bones develop and grow. (p. 130)**

**7.4 Bone Function**  
4. Discuss the major functions of bones. (p. 131)

**7.5 Skeletal Organization**  
5. Distinguish between the axial and appendicular skeletons, and name the major parts of each. (p. 135)

**7.6–7.12 Skull—Lower Limb**  
6. Locate and identify the bones and the major features of the bones that

comprise the skull, vertebral column, thoracic cage, pectoral girdle, upper limb, pelvic girdle, and lower limb. (p. 136)

**7.13 Joints**  
7. List three classes of joints, describe their characteristics, and name an example of each. (p. 150)

8. List six types of synovial joints, and describe the actions of each. (p. 157)

9. Explain how skeletal muscles produce movements at joints, and identify several types of joint movements. (p. 159)

**126**

**Key Terms**

**articular cartilage** (ar-ti-ku-lar kar-ti-laj) Hip  
**acromioclavicular joint** (ak-ro-mee-oh-klav-uh-ku-lar-toe-klav-uh-ku-lar) Shoulder  
**axial skeleton** (ak-si-ah-l skeletal) Front portion of the skeleton that supports the head, neck, and trunk.  
**blast** (blast) Osteoblast: Cell that will form bone tissue.  
**carp** (karp) Carpals: Wrist bones.  
**clavicle** (klav-uh-ku-l) Collarbone.  
**condyle** (kond-uh-ku-l) Rounded, bony process.  
**coracoclavicular ligament** (kora-oh-ku-lav-uh-ku-lar) Ligament between the coracoid process of the scapula and the clavicle.  
**cribra** (kri-bra) Foramina: Small openings in the ethmoid bone.  
**crest** (krest) Crista galli: Bony ridge that projects up into the cranial cavity.  
**fovea** (fo-ve-ah) Small pit or depression.  
**glenoid fossa** (gle-noy-ee-oh) Depression in the scapula that articulates with the head of the humerus.  
**hemopoiesis** (he-mee-oh-pee-ee-sis) Blood cell formation.  
**intercondylar notch** (in-ter-kond-uh-lar notch) Notch between the condyles of the femur.  
**intra-articular ligament** (in-trah-ah-tye-ku-lar) Ligament within the joint.  
**meatus** (me-ah-tyus) Opening or canal.  
**odontoid process** (oh-don-uh-eyd) Process of the second cervical vertebra.  
**poikilothermic** (poy-kuil-oh-ther-mik) Cold-blooded.  
**pyramidal lobe** (puy-rah-mee-dal) Small lobe of the tongue.  
**synovial joint** (sin-oh-vee-ah-ku-lar) Joint with a synovial cavity.  
**epiphysis** (ep-uh-fuh-sis) End of a long bone.  
**fibrous joint** (fay-broo-ee-oh) Joint between two bones.  
**hemopoiesis** (he-mee-oh-pee-ee-sis) Blood cell formation.  
**intra-articular ligament** (in-trah-ah-tye-ku-lar) Ligament within the joint.  
**lever** (lev-er) One of the three classes of levers.  
**marrow** (mar-oh) Soft tissue in the center of a bone.  
**medullary cavity** (med-uh-lar-ee-ku-lar) Cavity in the center of a long bone.  
**meniscus** (men-uh-sus) Wedge-shaped piece of cartilage between two bones.  
**osteoblast** (oh-tee-oh-blast) Cell that forms bone.  
**osteoclast** (oh-tee-oh-klast) Cell that breaks down bone.  
**osteocyte** (oh-tee-oh-sayt) Mature bone cell.  
**periosteum** (per-ee-oh-tee-oh-ee-um) Membrane covering the bone.  
**spongy bone** (spun-juh-ee-oh) Bone with many air spaces.  
**synovial joint** (sin-oh-vee-ah-ku-lar) Joint with a synovial cavity.

### chapter 7

## Skeletal System

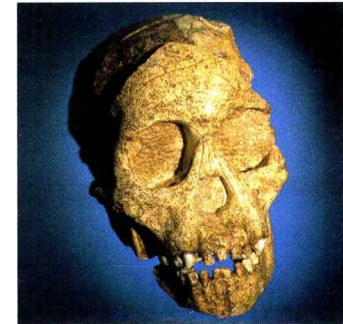
**CLUES FROM SKELETONS PAST** As the hardest and therefore most enduring of human tissues, bone has persisted over time to provide clues to early humans and their forebears. Some glimpses into the past, composed of skeletal remains or fossils, include:

**200,000–250,000 years ago** Skulls with circular holes are the earliest evidence of trepanation, a technique used to relieve pressure following a skull fracture or as a spiritual treatment for headache, tumors, or mental illness. A test of the people treated with trepanation were lucky—they survived, as evidenced by new bony growth over the holes made in their skulls. However, most trepanned skulls have gaping, drilled holes, indicating that the treatment was lethal.

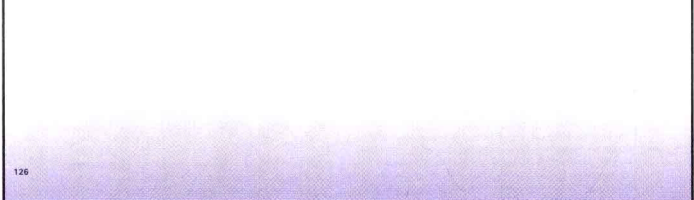
**2.8–2.6 million years ago** “Mr. Ples,” as the name anthropologists have given to the face and left side of a skull from Sterkfontein, South Africa, who once belonged to a member of *Australopithecus africanus* (see photo), a type of primate that preceded *Homo sapiens*. Using computer modeling to fashion a “virtual endocast” of the entire skull contents, researchers have estimated the cranial capacity of *A. africanus* at 515 cubic centimeters (cc). By comparison, a chimpanzee’s cranial capacity averages 370 cc, and a modern human’s, 1,500. Expanded cranial capacity correlates to increases in intelligence.

**1.5 million years ago** Not all evidence of a skeletal system is in the form of preserved bone. On the Serengeti Plain are clues to our ancestors who first began to walk upright: a stance that freed their hands, perhaps making possible the development of

tools. This evidence consists of shallow footprints where an animal called *Australopithecus africanus* once lived. The prints reveal that it had long big toes and arched feet.



**Photo:** *Australopithecus africanus* lived from 2.8 to 2.6 million years ago. Our knowledge of this primate comes from skeletal evidence.



### AIDS TO UNDERSTANDING WORDS

increase your pace in understanding and remembering scientific word meanings. Examine root words, stems, prefixes, suffixes, pronunciations and build a solid A&P vocabulary.

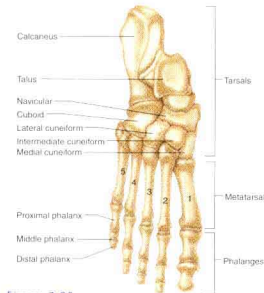
### KEY TERMS

are part of your basic training in building a solid science vocabulary. Phonetic pronunciations and definitions can be found at the beginning of the chapter, within the text, and in the glossary.

## GENETICS CONNECTIONS

lead the standings by exploring the molecular underpinnings of familiar as well as not so familiar illnesses. Read about such topics as ion channel disorders, muscular dystrophies, and cystic fibrosis.

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**Figure 7.32**  
The right foot viewed superiorly.

The metatarsals consist of five elongated **metatarsal bones**, that articulate with the tarsals. They are numbered 1–5, beginning on the medial side (fig. 7.32). The heads at the distal ends of these bones form the ball of the foot. The tarsals and metatarsals are arranged and bound by ligaments to form the arches of the foot. A longitudinal arch extends from the heel to the toe, and a transverse arch stretches across the foot. These arches provide a stable, springy base for the body. Sometimes, however, the tissues that bind the metatarsals weaken, producing fallen arches, or flat feet.

The **phalanges** of the toes are similar to those of the fingers and align and articulate with the metatarsals. Each toe has three phalanges—a proximal, a middle, and a distal phalanx—except the great toe, which lacks a middle phalanx.

**CHECK YOUR RECALL**

1. Locate and name each of the bones of the lower limb.
2. Explain how the bones of the lower limb articulate with one another.
3. Describe how the foot is adapted to support the body.

**7.13 Joints**

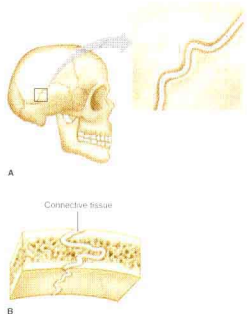
**Joints** (articulations) are functional junctions between bones. They bind parts of the skeletal system, make possible bone growth, permit parts of the skeleton to

change shape during childbirth, and enable the body to move in response to skeletal muscle contractions. Joints vary considerably in structure and function. If classified according to the degree of movement they make possible, joints can be immovable, slightly movable, or freely movable. Joints also can be grouped by the type of tissue (fibrous, cartilaginous, or synovial) that binds the bones together at each junction. Currently, structural classification by tissue type is more commonly used.

There are 230 joints in the body.

**Fibrous Joints**

**Fibrous (or bony) joints** lie between bones that closely contact one another. A thin layer of dense connective tissue joins the bones at such joints, as in the case of a **suture** between a pair of flat bones of the skull (fig. 7.33). No appreciable movement takes place at a fibrous joint. Some fibrous joints, such as the joint in the leg between the distal ends of the tibia and fibula, have limited movement.



**Figure 7.33**  
Fibrous joints. (A) The fibrous joints between the bones of the skull are immovable and are called sutures. (B) A thin layer of connective tissue connects the bones at the suture.

## CHECK YOUR RECALL QUESTIONS

attack the material covered in major sections by testing your understanding of key concepts.

## ORGANIZATION ILLUSTRATIONS

found at the end of selected chapters, conceptually link the highlighted body system to every other system and reinforce the dynamic interplays between groups and organs. These illustrations help you review chapter concepts and reinforce the "big picture" in learning and applying the principles of anatomy and physiology.

### Genetics Connection

### INHERITED DISEASES OF MUSCLE

A variety of inherited conditions affect muscle tissue. These disorders differ in the nature of the genetic defect, the type of protein that is abnormal in form or function, and the particular muscles in the body that are impaired.

#### The Muscular Dystrophies—Missing Proteins

A muscle cell is packed with filaments of actin and myosin. Less abundant, but no less important, is a protein called **dystrophin**. It literally holds skeletal muscle cells together by linking actin in the cell to glycoproteins called **dystroglycan-associated glycoproteins**, or DAGs that are part of the cell membrane. This helps attach the cell to the surrounding matrix. Missing or abnormal dystrophin or DAGs cause muscular dystrophies. These illnesses vary in severity and age of onset, but in all cases, muscles weaken and degenerate. Eventually, fat and connective tissue replace muscle.

Duchenne muscular dystrophy (DMD) is the most severe type of the illness (fig. 8B). Symptoms begin by age five and affect only boys. By age fifteen, the person cannot walk, and by early adulthood he usually dies from failure of the respiratory muscles. In DMD, dystrophin is often missing. In Becker muscular dystrophy, symptoms begin in early adulthood, are less severe, and result from underproduction of dystrophin. Limb-girdle muscular dys-

trophy causes weakness in the upper limbs, usually noticeable in a person's thirties. This form of muscular dystrophy is often the result of a missing or abnormal DAG, which causes the other DAGs to be deficient too.

#### Charcot-Marie-Tooth Disease—A Duplicate Gene

Charcot-Marie-Tooth disease causes a slowly progressing weakness in the muscles of the hands and feet and a decrease in tendon reflexes in these parts. In this illness, an extra gene impairs the insulating sheath around affected nerve cells, so that nerve cells cannot adequately stimulate the involved muscles. Symptoms resemble those of diverse other conditions, including AIDS, alcoholism, vitamin B<sub>12</sub> deficiency, diabetes mellitus, and heavy metal poisoning. Therefore, physicians perform two tests—electromyography and nerve conduction velocities—to diagnose Charcot-Marie-Tooth disease. It is also possible to test for the gene mutation to establish a diagnosis.

#### Mitotic Dystrophy—An Expanding Gene

Mitotic dystrophy causes delayed muscle relaxation following contraction (myotonia), which causes facial and limb weakness, cataracts, and an irregular heartbeat. It is caused by inheriting either of two "expanding genes" that actually grow with each generation. As the gene enlarges, symptoms increase in severity or begin at an earlier age. For example, a grandfather might experience only mild weakness in his forearms, but his daughter might have more noticeable arm and leg weakness. By the third generation, affected children might suffer severe muscle impairment. For many years, physicians attributed the worsening of symptoms over generations to psychological causes. We know now there is a physical basis for the phenomenon. The expanded genes are actually transcribed into messenger RNA molecules that are too large to leave the nucleus, so that the proteins that they encode are not synthesized.

#### Hereditary Idiopathic Dilated Cardiomyopathy—A Tiny Glitch

This very rare inherited form of heart failure begins usually in a person's forties and is lethal in 50% of cases within five years of diagnosis, unless a heart transplant can be performed. The condition is caused by a tiny genetic error in a form of actin found only in cardiac muscle, where it is the predominant component of the thin filaments. Change of a single DNA building block (nucleotide base) apparently disturbs actin's ability to anchor to the Z bands in heart muscle cells. The mutation prevents actin from effectively transmitting the force of contraction, which gradually causes the heart chambers to enlarge and eventually to fail to function.




**Figure 8B**  
This young man has Duchenne muscular dystrophy. The condition has not yet severely limited his activities, but he shows the hyperreflexial (overdeveloped) calf muscles that result from his inability to use them in a sitting position (the usual way an early sign of the illness).

## FACTS OF LIFE

go all out with amazing bits of anatomy and physiology trivia, adding a touch of wonder to chapter topics.

# Organization



**Integumentary System**  
Vitamin D, activated in the skin, plays a role in calcium availability for bone matrix.

**Lymphatic System**  
Cells of the immune system originate in the bone marrow.

**Muscular System**  
Muscles pull on bones to cause movement.

**Digestive System**  
Absorption of dietary calcium provides material for bone matrix.

**Nervous System**  
Proprioceptors sense the position of body parts. Pain receptors warn of trauma to bone. Bones protect the brain and spinal cord.

**Respiratory System**  
Ribs and muscles work together in breathing.

**Endocrine System**  
Some hormones act on bone to help regulate blood calcium levels.

**Urinary System**  
The kidneys and bones work together to help regulate blood calcium levels.

**Cardiovascular System**  
Blood transports nutrients to bone cells. Bone helps regulate plasma calcium levels, important to heart function.

**Reproductive System**  
The pelvis helps support the uterus during pregnancy. Bone may provide a source of calcium during lactation.

**Skeletal System**  
Bones provide support, protection, and movement and also play a role in calcium balance.

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TOPICS OF INTEREST

are proven performers in presenting disorders, physiological responses to environmental factors, and other topics of general interest.

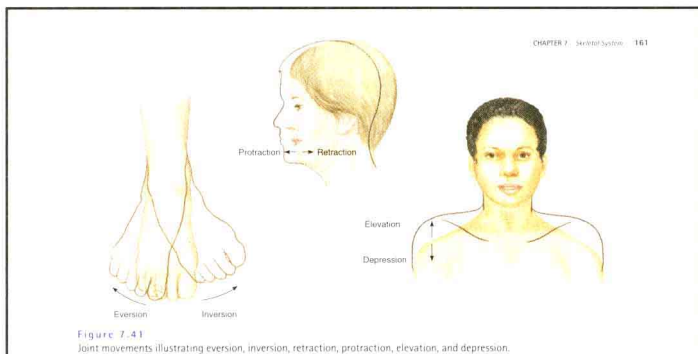


Figure 7.41 Joint movements illustrating eversion, inversion, retraction, protraction, elevation, and depression.

CHECK YOUR RECALL

1. Describe the characteristics of the three major types of joints.
2. Name six types of synovial joints.
3. What terms describe the movements possible at synovial joints?

Injuries to the elbow, shoulder, and knee are commonly diagnosed and treated using a procedure called arthroscopy. Arthroscopy enables a surgeon to visualize a joint's interior and even perform diagnostic or therapeutic procedures, guided by the image on a video screen. An arthroscope is a thin, tubular instrument about 25 centimeters long containing optical fibers that transmit an image. The surgeon inserts the device through a small incision in the joint capsule. Arthroscopy is far less invasive than conventional surgery. Many runners have undergone uncomplicated arthroscopy and raced just weeks later.

Clinical Terms Related to the Skeletal System

- acromegaly** (ak-ro-meg-ah-lee) Abnormal enlargement of facial features, hands, and feet in adults as a result of overproduction of growth hormone.
- ankylosis** (ang-ki-lo-sis) Abnormal stiffness of a joint or fusion of bones at a joint, often due to damage to the joint membranes from trauma, rheumatoid arthritis, or osteoarthritis.
- arthralgia** (ar-thal-jah-lee) Pain in a joint.
- arthrocentesis** (ar-thro-sen-tis) Puncture of and removal of fluid from a joint cavity.

- arthrodesis** (ar-thro-dee-sis) Surgery to fuse the bones at a joint.
- arthroplasty** (ar-thro-plas-tee) Surgery to make a joint more movable.
- Colles fracture** (kol-eh-frak-choor) Fracture at the distal end of the radius that displaces the smaller fragment posteriorly.
- epiphysiolysis** (ep-ih-fiz-ee-oh-sis) Separation or loosening of the epiphysis from the diaphysis of a bone.
- hemarthrosis** (hem-ar-thro-sis) Blood in a joint cavity.
- laminectomy** (lam-eh-nek-to-me) Surgical removal of the posterior arch of a vertebra, usually to relieve symptoms of a ruptured intervertebral disc.
- lumbago** (lum-bah-goh) Dull ache in the lumbar region of the back.
- orthopedics** (or-tho-pee-dee-ks) Medical specialty that prevents, diagnoses, and treats diseases and abnormalities of the skeletal and muscular systems.
- ostealgia** (os-te-ah-jah) Pain in a bone.
- osteotomy** (os-teck-to-me) Surgical removal of a bone.
- osteitis** (os-te-ah-tis) Inflammation of bone tissue.
- osteochondritis** (os-tes-keh-n-dri-tis) Inflammation of bone and cartilage tissues.
- osteogenesis** (os-tes-oh-jen-eh-sis) Bone development.
- osteogenesis imperfecta** (os-tes-oh-jen-eh-sis-im-per-ek-to) Inherited condition of deformed and abnormally brittle bones.
- osteoma** (os-te-o-mah) Tumor composed of bone tissue.
- osteomalacia** (os-tes-oh-mah-lee-shah-lee) Softening of adult bone due to a disorder in calcium and phosphorus metabolism, usually caused by vitamin D deficiency.

CLINICAL CONNECTIONS

help you go even further by "pulling the chapter concepts together." These short vignettes at the end of the chapter give you a real-life connection to the material covered. Short paragraphs in colored boxes also apply ideas and facts in the narrative to clinical situations.

CHAPTER SUMMARY OUTLINES

prepare you for another top performance by helping you review the chapter's main ideas.

Topic of Interest

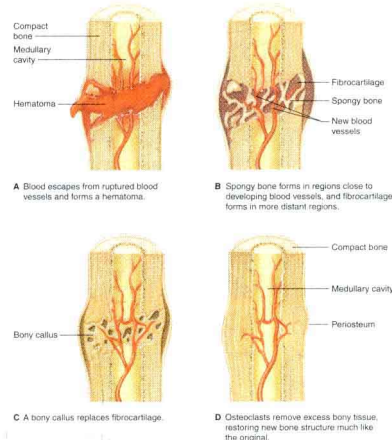
REPAIR OF A BONE FRACTURE

A fracture is a break in a bone. Whenever a bone breaks, blood vessels within it and its periosteum rupture, and the perosteum is likely to tear. Blood escaping from the broken vessels spreads through the damaged area and soon forms a blood clot, or *hematoma*. Vessels in surrounding tissues dilate, swelling and inflaming the tissues. Within days or weeks, developing blood vessels and large numbers of osteoblasts from the periosteum invade the hematoma. The osteoblasts rapidly divide in the regions close to the new blood vessels, building spongy bone nearby. Granulation tissue develops, and in regions further from a blood supply, fibroblasts produce masses of fibrocartilage. Meanwhile, phagocytic cells begin to remove the blood clot, as well as any dead or damaged cells in the affected area. Osteoclasts also appear and resorb bone fragments, aiding in "cleaning up" debris. In time, fibrocartilage fills the gap between the ends of the broken bone. This mass, termed a *cartilaginous callus*, is later replaced by bone tissue in much the same

way that the hyaline cartilage of a developing endochondral bone is replaced. That is, the cartilaginous callus breaks down, blood vessels and osteoblasts invade the area, and a *bony callus* fills the space. Typically, more bone is produced at the site of a healing fracture than is required to replace the damaged tissues. Osteoclasts remove the excess, and the final result is a bone shaped very much like the original (Fig. 7A). Physicians can help the bone-healing process. The first casts to immobilize fractured bones were introduced in Philadelphia in 1876, and soon after, doctors began using screws and plates internally to align healing bone parts. Today, orthopedic surgeons also use rods, wires, and nails. These devices have become lighter and smaller; many are built of titanium. A new approach, called a hybrid fixator, treats a broken leg using metal pins internally to align bone pieces. The pins are anchored to a metal ring device worn outside the leg.

Figure 7A

Major steps (A-D) in repair of a fracture.



CLINICAL TERMS

help you sprint ahead in understanding medical terminology. Lists of related terms often used in clinical situations are found at the end of several chapters.

162 UNIT 2 Support and Movement

- osteomyelitis** (os-tes-oh-mi-eh-ah-tis) Bone inflammation caused by the body's reaction to bacterial or fungal infection.
- osteonecrosis** (os-tes-oh-nek-ro-sis) Death of bone tissue. This condition occurs most commonly in the femur head in elderly persons and may be due to obstructed arteries supplying the bone.
- osteopathology** (os-tes-oh-path-oh-logy) Study of bone diseases.
- ostotomy** (os-tes-oh-to-me) Cutting a bone.
- synovectomy** (sin-oh-vek-to-me) Surgical removal of the synovial membrane of a joint.

such injuries usually do. This time, the injured toe started to turn bluish red immediately, as a hematoma formed beneath the nail. The pain continued, for weeks. Pus swelled from beneath the darkened nail. Finally barely able to walk let alone continuing playing his sport, the athlete consulted a physician, who, assuming the wound was infected, prescribed antibiotics and an anti-inflammatory cream. But the unhealing pain was not due to infection. The young man finally went to an emergency room, where a sample of the pus revealed no bacteria. X-rays instead clearly indicated an osteochondroma, a spike of bone emerging 7 millimeters from the distal terminal phalanx of the left great toe, capped with cartilage. Usually an osteochondroma is a benign bone tumor that arises during fetal development. The physician in charge, however, suspected that the soccer player's spike was a response to trauma—and then failure to rest afterwards. Surgery removed the spike, and a month later, the athlete was back on the field.

Clinical Connection

When the 20-year-old professional soccer player jammed his left toe at high speed against the ball and hocked in pain, he thought it would just get better in a few days, as

SUMMARY OUTLINE

- 7.1 Introduction (p. 128)** Individual bones are the organs of the skeletal system. A bone contains very active tissues.
- 7.2 Bone Structure (p. 128)** Bone structure reflects its function.
  1. Parts of a long bone
    - a. Epiphyses at each end are covered with articular cartilage and articulate with other bones.
    - b. The shaft of a bone is called the diaphysis.
    - c. Except for the articular cartilage, a bone is covered by a periosteum.
    - d. Compact bone has a continuous matrix with no gaps.
    - e. Spongy bone has irregular interconnecting spaces between bony plates that reduce the weight of bone.
  2. Microscopic structure
    - a. Compact bone contains osteons cemented together.
    - b. Central canals contain blood vessels that nourish the cells of osteons.
    - c. Diffusion from the surface of the thin, bony plates nourishes the cells of spongy bone.
- 7.3 Bone Development and Growth (p. 130)**
  1. Intramembranous bones
    - a. Intramembranous bones develop from layers of connective tissues.
    - b. Osteoblasts within the membranous layers form bone tissue.
    - c. Mature bone cells are called osteocytes.
  2. Endochondral bones
    - a. Endochondral bones develop as hyaline cartilage that is later replaced by bone tissue.
    - b. The primary ossification center appears in the diaphysis, whereas secondary ossification centers appear in the epiphyses.
    - c. An epiphyseal plate remains between the primary and secondary ossification centers.

3. Homeostasis of bone tissue
  - a. Osteoclasts and osteoblasts continually remodel bone.
  - b. The total mass of bone remains nearly constant.
- 7.4 Bone Function (p. 131)**
  1. Support and protection
    - a. Bones shape and form body structures.
    - b. Bones support and protect softer, underlying tissues.
  2. Body movement
    - a. Bones and muscles function together as levers.
    - b. A lever consists of a rigid, a pivot (fulcrum), a resistance, and a force that supplies energy.
  3. Blood cell formation
    - a. At different ages, hemopoiesis occurs in the yolk sac, liver and spleen, and red bone marrow.
    - b. Red marrow houses developing red blood cells, white blood cells, and blood platelets. Yellow marrow stores fat.
  4. Storage of inorganic salts
    - a. The intercellular material of bone tissue contains large quantities of calcium phosphate.
    - b. When blood calcium is low, osteoclasts break down bone, releasing calcium salts. When blood calcium is high, osteoblasts form bone tissue and store calcium salts.
    - c. Bone stores small amounts of magnesium, sodium, potassium, and carbonate ions.
- 7.5 Skeletal Organization (p. 135)**
  1. The skeleton can be divided into axial and appendicular portions.
  2. The axial skeleton consists of the skull, hyoid bone, vertebral column, and thoracic cage.
  3. The appendicular skeleton consists of the pectoral girdle, upper limbs, pelvic girdle, and lower limbs.

**REVIEW EXERCISES AND CRITICAL THINKING**  
 check your understanding of the chapter's major ideas. Critical thinking questions encourage you to apply information to clinical situations.

164 UNIT 2 Support and Movement

4. Ankle and foot
  - a. The ankle and foot consist of the tarsus, metatarsus, and five toes.
  - b. Included are the talus that helps form the ankle, six other tarsals, five metatarsals, and fourteen phalanges.

7.13 Joints (p. 156)

Joints can be classified according to the type of tissue that binds the bones together.

1. Fibrous joints
  - a. Bones at fibrous joints are tightly joined by a layer of dense connective tissue.
  - b. Little or no movement occurs at a fibrous joint.
2. Cartilaginous joints
  - a. A layer of cartilage joins bones of cartilaginous joints.
  - b. Such joints allow limited movement.
3. Synovial joints
  - a. The bones of a synovial joint are covered with hyaline cartilage and held together by a fibrous joint capsule.
  - b. The joint capsule consists of an outer layer of ligaments and an inner lining of synovial membrane.
  - c. Bursae are located between the skin and underlying bony prominences.
  - d. Types of synovial joints include: ball-and-socket, condyloid, gliding, hinge, pivot, and saddle.
4. Types of joint movements
  - a. Muscles fastened on either side of a joint produce movements of synovial joints.
  - b. Joint movements include flexion, extension, dorsiflexion, plantar flexion, hyperextension, abduction, adduction, rotation, circumduction, pronation, supination, eversion, inversion, retraction, protraction, elevation, and depression.

18. Name the bones that comprise the thoracic cage. (p. 147)
19. List the bones that form the pectoral and pelvic girdles. (p. 147)
20. Name the bones of the upper limb. (p. 148)
21. Name the bones that comprise a coxa. (p. 152)
22. List the bones of the lower limb. (p. 154)
23. Define *joint*. (p. 156)
24. Describe a fibrous joint, a cartilaginous joint, and a synovial joint. (p. 156)
25. Define *bursa*. (p. 157)
26. List six types of synovial joints, and name an example of each type. (p. 158)

Part B

Match the parts listed in column I with the bones listed in column II.

- | I                       | II                |
|-------------------------|-------------------|
| 1. Coronoid process     | a. Ethmoid bone   |
| 2. Cribriform plate     | b. Frontal bone   |
| 3. Foramen magnum       | c. Mandible       |
| 4. Mastoid process      | d. Maxilla        |
| 5. Palatine process     | e. Occipital bone |
| 6. Sella turcica        | f. Temporal bone  |
| 7. Supraorbital foramen | g. Sphenoid bone  |
| 8. Temporal process     | h. Zygomatic bone |
| 9. Acromion process     | i. Femur          |
| 10. Deltoid tuberosity  | j. Fibula         |
| 11. Greater trochanter  | k. Humerus        |
| 12. Lateral malleolus   | l. Radius         |
| 13. Medial malleolus    | m. Scapula        |
| 14. Olecranon process   | n. Sternum        |
| 15. Radial tuberosity   | o. Tibia          |
| 16. Xiphoid process     | p. Ulna           |

Part C

Match the movements in column I with the descriptions in column II.

- | I              | II  |
|----------------|---|
| 1. Rotation    | a. Turning palm upward                    |
| 2. Supination  | b. Decreasing angle between parts         |
| 3. Extension   | c. Moving part forward                    |
| 4. Eversion    | d. Moving part around an axis             |
| 5. Protraction | e. Turning sole of foot to face laterally |
| 6. Flexion     | f. Increasing angle between parts         |
| 7. Pronation   | g. Lowering a part                        |
| 8. Abduction   | h. Turning palm downward                  |
| 9. Depression  | i. Moving part away from midline          |

CRITICAL THINKING

1. How does the structure of a bone make it strong yet lightweight?
2. Archaeologists discover skeletal remains of hominid animals in Ethiopia. Examination of the bones suggests that the remains represent four types of individuals. Two of the skeletons have bone densities that are 30% less than those of the other two skeletons. The skeletons with the lower bone mass also have broader front

REVIEW EXERCISES

Part A

1. Sketch a typical long bone, and label its epiphysis, diaphysis, medullary cavity, periosteum, and articular cartilages. (p. 128)
2. Distinguish between spongy and compact bone. (p. 128)
3. Explain how central canals and perforating canals are related. (p. 129)
4. Explain how the development of intramembranous bone differs from that of endochondral bone. (p. 130)
5. Distinguish between osteoblasts and osteocytes. (p. 130)
6. Explain the function of an epiphyseal plate. (p. 130)
7. Explain how a bone thickens. (p. 131)
8. Provide several examples to illustrate how bones support and protect body parts. (p. 131)
9. Describe a lever. (p. 133)
10. Explain how upper limb movements function as levers. (p. 133)
11. Describe the functions of red and yellow bone marrow. (p. 133)
12. Explain the mechanism that regulates the concentration of blood calcium ions. (p. 134)

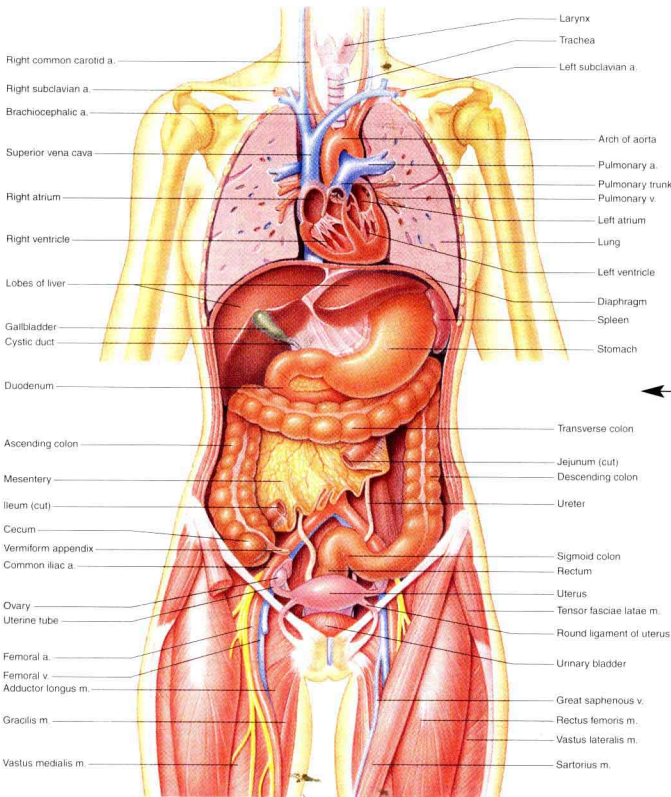


PLATE 5

Human female torso with the lungs, heart, and small intestine sectioned.

REFERENCE PLATES

continue to offer vibrant detail of body structures.

# Preface

## To the Instructor

In this eighth edition of *Hole's Essentials of Human Anatomy and Physiology* we continue our commitment to introduce the structure and function of the human body in an interesting and highly readable manner. We have added content only when it can be integrated into the larger concept of homeostasis and maintenance of the internal environment. Indeed, a book at this level is almost a metaphor of the human body itself—nothing unnecessary is retained, and every component contributes to the final purpose.

Given the immensely varied population of most universities and colleges, particularly two-year and community colleges, we have continued to devote top priority to the readability of this text. Our challenge has been to do so while at the same time responding to requests to enhance physiology coverage. We have accomplished this through thoughtful changes in the text and art, carefully designed and implemented pedagogical features, and a wide choice of ancillaries designed to review and augment both in-class and out-of-class student activities.

The level of this text is geared toward students in one-semester courses in anatomy and physiology who are pursuing careers in allied health fields and who have minimal background in physical and biological sciences. The first four chapters cover the chemistry and cell physiology necessary to understand biological processes. Students who have studied this material previously will view it as a welcomed review, but newcomers will not find it intimidating.

## General Themes

### *Commitment to Readability*

Even the most basic concepts of human anatomy and physiology can be challenging to the uninitiated, and most of the students in introductory anatomy and physiology courses fall into this category. Students and instructors both are faced with an enormous amount of material to cover in a short period of time. Our approach is to never add unnecessary content, and to maintain readability as our top priority.

### *Clear Application of Concepts*

The content carefully balances structure and function to provide an integrated view of how the human body works. In striking this balance we recognize a clear trend toward a greater emphasis on physiology across the board in the health care professions. All physiological concepts are tied to some level of body structure and organization and presented in a student-accessible way. Numerous practical applications and everyday examples are provided.

### *Emphasis of the Interrelatedness and Interdependency of Organ Systems*

Chapter 1 introduces the concept of the internal environment, along with homeostasis, the mechanism that keeps the internal environment relatively constant. The book reinforces this theme throughout, most strikingly in the end-of-chapter “ORGANization” figures that hammer home the interrelatedness and interdependency of organ systems.

### *Enhancing the Text with Consistent Illustrations*

Detail, clarity, accuracy, and consistency prevail, with frequent use of icons for orientation and to establish a sense of scale. Color is consistent from chapter to chapter—a cell is not blue in one chapter, orange in another.

## What's New?

*Hole's Essentials of Human Anatomy and Physiology* is written with the student in mind. Several new features accompany the eighth edition.

### *Key Term Pronunciations within the Text*

A list of key terms and their phonetic pronunciations at the beginning of each chapter helps build science vocabulary. The key terms are boldfaced, defined within the chapter and followed again by pronunciations when the term is first introduced in the text. These terms are likely

to be found in subsequent chapters. The glossary at the end of the book explains phonetic pronunciations.

## *Chapter Opening Vignettes*

Interesting, creative, and thought-provoking vignettes introduce the chapter topics.

## *Check Your Recall Review Questions*

This edition offers review questions at the ends of major sections in each chapter to test understanding of the material just covered.

## *Design*

The revitalized text design injects new life into the study of Anatomy and Physiology. Bright, bold, modern colors are used throughout the feature boxes, tables, and chapter openers making them easy to recognize.

## *Illustrations*

The new art program is designed to support the text and beyond. Labels and legends go only as far as the text itself. However, the detail of the figures is accurate enough to support more detailed discussion if the instructor or the student chooses further investigation.

## *Facts of Life*

These briefs are fun bits of A&P trivia information scattered throughout the text adding a touch of wonder to chapter topics and concepts.

## *Clinical Connections*

These new clinical connections are integrated at the end of several chapters to “pull the concepts together”. The short vignettes help students make a vital real-life connection to the chapter material.

## *Review Exercises and Critical Thinking*

Updated end-of-chapter review exercises help the student check understanding of the chapter’s major ideas. Critical thinking questions encourage the student to apply information to clinical situations.

## *Online Learning Center*

New OLC activities and resources are available for students and instructors.

## *Digital Content Manager*

This multimedia collection of visual resources allows instructors to utilize artwork from the text in multiple

formats to create customized classroom presentations, visually-based tests and quizzes, dynamic course website content, or attractive printed support materials. The digital assets on this cross-platform CD-ROM are grouped by chapter within the following easy-to-use folders.

**Active Art Library** Key figures from the text are saved in manipulable layers that can be isolated and customized to meet the needs of the lecture environment.

**Animations Library** Numerous full-color animations of key physiological processes are provided. Harness the visual impact of processes in motion by importing these files into classroom presentations or course websites.

**Art Libraries** Full-color digital files of all illustrations in the book, plus the same art saved in unlabeled and gray scale versions, can be readily incorporated into lecture presentations, exams, or custom-made classroom materials. These images are also pre-inserted into blank PowerPoint slides for ease of use.

**Photo Libraries** Digital files of instructionally significant photographs from the text—including cadaver, bone, histology, and surface anatomy images—can be reproduced for multiple classroom uses.

**PowerPoint Lectures** Ready-made presentations that combine art and lecture notes have been specifically written to cover each of the 20 chapters of the text. Use the PowerPoint lectures as they are, or tailor them to reflect your preferred lecture topics and sequences.

**Tables Library** Every table appearing in the text is provided in electronic form.

You can quickly preview images and incorporate them into PowerPoint or other presentation programs to create your own multimedia presentations. You can also remove and replace labels to suit your own preferences in terminology or level of detail.

## **Teaching and Learning Supplements**

**Online Learning Center** (<http://www.mhhe.com/shieress8>) The OLC offers an extensive array of learning and teaching tools. The site includes quizzes for each chapter, links to websites related to each chapter, supplemental reading lists, clinical applications, interactive activities, art labelling exercises, and case studies. Students can click on a diagram of the human body and get case studies related to the regions they select. Instructor resources at the site include lecture outlines, supplemental reading lists, technology resources, clinical applications, and case studies.



- **Essential Study Partner** The ESP contains 120 animations and more than 800 learning activities to help your students grasp complex concepts. Interactive diagrams and quizzes will make learning stimulating and fun for your students. The Essential Study Partner can be accessed via the Online Learning Center.
- **PowerWeb** is an online supplement that offers access to course-specific current articles referred by content experts, course-specific real-time news, weekly course updates, referred and updated research links, daily news, and the Northernlight.com Special Collection™ of journals and articles.

The **Laboratory Manual for Hole's Essentials of Human Anatomy and Physiology**, 0-07-235120-9, by Terry R. Martin, Kishwaukee College, is designed to accompany the eighth edition of *Hole's Essentials of Human Anatomy and Physiology*.

**Student Study Guide**, 0-07-243813-4, by Nancy A. Sickels Corbett contains chapter overviews, chapter objectives, focus questions, mastery tests, study activities, and mastery test answers.

The **Instructor's Manual**, 0-07-242523-7, by Michael F. Peters includes supplemental topics and demonstration ideas for your lectures, suggested readings, critical thinking questions, and teaching strategies. The Instructor's Manual is available online through the Instructor Resources of the Online Learning Center.

**Computerized Test Bank t/a Hole's Essentials of Human A&P**, 0-07-242528-8, is a computerized test generator free upon request to qualified adopters. A test bank of questions contains matching, true/false, and essay questions. The test generator contains the complete test item file on CD-ROM.

McGraw-Hill provides over 400 **Overhead Transparencies**, 0-07-235122-5, of all text line art including fully labeled and unlabeled duplicates of many of them for testing purposes or custom labeling.

**The Digital Content Manager**, 0-07-242524-5, is a multimedia collection of visual resources that allows instructors to utilize artwork from the text in multiple formats to create customized classroom presentations, visually-based tests and quizzes, dynamic course website content, or attractive printed support materials. The digital assets on this cross-platform CD-ROM are grouped by chapter within easy-to-use folders.

**PageOut** is McGraw-Hill's exclusive tool for creating your own website for your A&P course. It requires no knowledge of coding. Simply type your course information into the templates provided. PageOut is hosted by McGraw-Hill.

**MediaPhys CD-Rom**, 0-07-255140-2, combines incredible multimedia and powerful visuals with in-depth textual content. This interactive program provides a friendly and educational environment that allows you to:

- navigate through body systems via detailed graphics, animations, and sound
- explore concepts in a logical order from simple to more complex
- visualize physiological processes and their relationships

#### **Human Anatomy and Physiology Laboratory**

**Manual-Fetal Pig Dissection**, 0-07-231199-1, by Terry R. Martin, provides excellent full-color photos of the dissected fetal pig with corresponding labeled art. It includes World Wide Web activities for many chapters.

#### **Web-Based Cat Dissection Review for Human**

**Anatomy and Physiology**, 0-07-232157-1, by John Waters, Pennsylvania State University. This online multimedia program contains vivid, high-quality labeled cat dissection photographs. The program helps students easily identify and review the corresponding structures and functions between the cat and the human body.

**Dynamic Human Version 2.0**, 0-07-235476-3. This set of two interactive CD-ROMs covers each body system and demonstrates clinical concepts, histology, and physiology with animated three-dimensional and other images.

**Interactive Histology CD-ROM**, 0-07-237308-3, by Bruce Wingerd and Paul Paolini, San Diego State University. This CD contains 135 full-color, high-resolution LM images and 35 SEM images of selected tissue sections typically studied in A&P. Each image has labels that can be clicked on or off, has full explanatory legends, offers views at two magnifications, and has links to study questions. The CD also has a glossary with pronunciation guides.

**Life Science Animation CD-ROM**, 0-07-234296-X, contains 125 animations of major biological concepts and processes such as the sliding filament mechanism, active transport, genetic transcription and translation, and other topics that may be difficult for students to visualize.

**Life Science Animations 3D Videotape**, 0-07-290652-9, contains 42 key biological processes that are narrated and animated in vibrant full color with dynamic three-dimensional graphics.

**Life Science Animations (LSA)** videotape series contains 53 animations on five VHS videocassettes; Chemistry, The Cell, and Energetics, 0-697-25068-7; Cell Division, Heredity, Genetics, Reproduction, and