

Human Understanding & Anatomy Physiology

FIFTH EDITION

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Sylvia S.

Mader



FIFTH EDITION

Understanding Human Anatomy & Physiology

Sylvia S. Mader

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UNDERSTANDING HUMAN ANATOMY & PHYSIOLOGY, FIFTH EDITION

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Preface

We cannot teach people anything; we can only help them discover it within themselves. Galileo Galilei

Over the years, it has been my privilege to meet many of the adopters of my texts at various meetings around the country. At one such meeting, I met a professor who told me that he and his colleagues were using my book, *Human Biology* for an anatomy and physiology course because they wanted to use a Mader text. When I returned home, I pondered over this and decided that I would write an anatomy and physiology text so that professors teaching that course would have a more appropriate Mader textbook. Thus, began the development of this text, *Understanding Human Anatomy and Physiology*, which is now in its fifth edition.

I wanted to write a text that would appeal to a wide audience—from those in traditional allied health fields to others who are a bit removed from traditional endeavors. The book should be clear and direct, with objectives that are achievable by students who have no previous science background and even by those who are science shy. This goal was reached.

Diane Kelly, of Broome Community College, writes, “I think the text is very readable, clear, and user friendly. The art is a wonderful complement to the author’s writing; together, the information is clearly presented.”

Mader texts are well known for their pedagogical features, and those for this text are described in the Guided Tour on pages xv–xx. Also, as with other Mader texts, the illustrations are excellent.

William J. Burke, of Madison Area Technical College, states, “This text has some very good art. It is well labeled and has a good color scheme that helps it stand out. The inclusion of the many tables and charts is also an excellent learning tool for the students.”

My vision for *Understanding Human Anatomy and Physiology* encompasses three goals. I want students to develop a working knowledge of (1) anatomy and physiology that is based on conceptual understanding rather than rote memory; (2) medical terminology that will increase the student’s confidence in their chosen field; and (3) clinical applications to broaden their horizons beyond the core principles.

Dr. Philip Swartz, of Houston Community College system, writes, “Each chapter includes salient clinical concepts that will be fascinating to the reader and enhance his or her understanding of the material being presented.”

About the Author

Sylvia S. Mader

In her 20-year career with McGraw-Hill, Dr. Mader has written an impressive collection of textbooks. Aside from *Understanding Human Anatomy and Physiology*, now in its fifth edition, Dr. Mader has written *Biology*, eighth edition; *Human Biology*, eighth edition, and *Inquiry into Life*, tenth edition, through which Dr. Mader has successfully helped innumerable students learn biology as well as human anatomy and physiology.

Dr. Mader’s interest in anatomy and physiology began when she took courses at the Medical School of St. Andrews University, in Scotland, during her junior year abroad. As a fledgling faculty member, she was called upon to teach a variety of courses, among them was human anatomy and physiology. As a textbook writer she discovered that the teaching and learning techniques she so successfully used in the classroom were appropriate for her biology texts and then later for her anatomy and physiology text. Dr. Mader’s direct writing style and carefully constructed pedagogy provide students with an opportunity to learn the basics of biology and anatomy and physiology.

What's New to This Edition?

New Design and Illustrations

A new, colorful design and revised illustrations enhance the features of *Understanding Human Anatomy and Physiology*, fifth edition.

Organization

This edition follows the same general sequence as the earlier editions. It is divided into five parts:

Part I, "Human Organization," provides an understanding of how the body is organized and the terminology used to refer to various body parts and their locations. Chapters 2 through 4 describe the chemistry of the cell, cell structure and function, and the tissues and membranes of the body.

Part II, "Support, Movement, and Protection," includes the integumentary system in addition to the skeletal and muscular systems.

Part III, "Integration and Coordination," explains that the nervous and endocrine systems are vitally important to the coordination of body systems, and therefore homeostasis, while the sensory system provides the nervous system with information about the internal and external environments.

Part IV, "Maintenance of the Body," describes how the cardiovascular, lymphatic, respiratory, digestive, and urinary systems contribute to the maintenance of homeostasis.

Part V, "Reproduction and Development," concerns the reproductive systems, development, and the basics of human genetics, including modern advances.

Homeostasis

The theme of homeostasis is strengthened in this edition. As before, Chapter 1 describes how various feedback mechanisms work to maintain the internal environment within a narrow range. New to this edition, each systems chapter ends with a major section on homeostasis to accompany the "Human Systems Work Together" illustration. This section describes how the system under discussion, with the help of the other systems, maintains homeostasis.

New Readings

Understanding Human Anatomy and Physiology, fifth edition, has two types of readings. Previously, the book had two types of readings called Medical Focus and MedAlert. In this edition, the readings are Medical Focus and What's New. Some of the Medical Focus readings from the fourth edition have been removed, and most of the others have been revised. The What's New readings, which are new to this edition, tell of treatments

that are now experimental but promise to be particularly helpful in the future. For example, a What's New box in the first chapter tells about organs made in the laboratory that are now being transplanted into patients. The What's New reading in Chapter 8 describes a "pacemaker" for Parkinson disease.

Chapter Openers

Scanning electron micrographs, X-rays, and MRI images open the chapters for a closer look into the wonders of the human body. The integrated outline has been retained with the addition of a numbering system for each major concept found in the chapter, including the summary.

Visual Focus

Visual Focus illustrations are included in several chapters. With the addition of boxed statements, these in-depth illustrations, which contain several art pieces, cover a process from start to finish. For example, Figure 7.3 outlines contraction of a muscle from the macroscopic to the microscopic perspective.

Chapter End Matter

This edition includes updated Selected New Terms, Summaries, Study Questions, Objective Questions, Medical Terminology Reinforcement Exercises, and Website Links to the Online Learning Center.

Objective Questions

Labeling exercises have been added to chapters 8, 11, 14, and 18 to reinforce the concepts of the chapter.

Chapter Updates and Additions

Chapter 1: Organization of the Body

New illustrations, tables, and a reading titled "Organs for Transplant" introduce the student to the human body. The discussion of negative feedback now includes temperature control as an example and also includes a discussion of positive feedback, as requested by reviewers.

Chapter 2: Chemistry of Life

This chapter has been reorganized and rewritten to help students understand fundamental chemistry concepts. Carbohydrates, lipids, proteins, and nucleic acids each have their own major section.

Chapter 3: Cell Structure and Function

Cellular Organization, Crossing the Plasma Membrane, and The Cell Cycle are clearly defined as chapter sections. Tables

3.1, 3.2, and all art are new to this edition. The Medical Focus reading, “Dehydration and Water Intoxication” is also new to this edition.

Chapter 4: Body Tissues and Membranes

Each type of tissue now has its own major section. In addition to body membranes, connections between cells and different types of glands are discussed in respective sections. Art and tables have been revised for this chapter.

Chapter 5: The Integumentary System

Section 5.5. Homeostasis is new to this edition. It shows how the various functions of the skin assist the body in maintaining homeostasis. Also discussed are hyperthermia and hypothermia, which occur when homeostasis has been overcome. The section is accompanied by an updated Human Systems Work Together illustration.

Chapter 6: The Skeletal System

New illustrations, each of which is on the same or a facing page to its reference, much improve this chapter. More information is given about each bone and joint discussed. The chapter ends with a review of the many ways the skeletal system helps maintain homeostasis.

Chapter 7: The Muscular System

The first two illustrations in this chapter are new: The first shows the three types of muscles, and the second describes the connective tissue coverings within and around a skeletal muscle. Instructors and students will appreciate the new in-depth discussion of the sources of energy for muscle contraction, which is also accompanied by a new illustration.

Chapter 8: The Nervous System

This chapter was rewritten. In particular, the discussion of the cerebrum has been expanded to include not only the various lobes but also the areas within these lobes. The somatic system of the peripheral nervous system is now clearly defined, and the spinal reflex has been moved to this section. New illustrations support improved discussions of all aspects of the nervous system.

Chapter 9: The Sensory System

Types of senses, rather than types of receptors, are now used to organize this chapter. The discussions of the anatomy and physiology of the eye and ear are better organized, with an emphasis on how information regarding vision and sound is generated and transmitted to the brain. The sense of equilibrium is now divided into rotational and gravitational equilibrium.

Chapter 10: The Endocrine System

An overview of the endocrine glands now precedes an improved discussion of each gland. A new illustration shows how the adrenal medulla and the adrenal cortex are involved in short-term and long-term stress, respectively. Other new illustrations pertain to regulation of blood calcium, regulation of blood pressure, Addison disease, and Cushing syndrome. The chapter also includes a discussion of chemical signals in general and how hormones affect cellular metabolism.

Chapter 11: Blood

A detailed description of the composition and function of blood now opens the chapter. There follows a more comprehensive look at the formed elements. The section on platelets centers around hemostasis, including coagulation. The transport function of blood is illustrated by considering capillary exchange. The last section of the chapter, Blood Typing and Transfusions, is supported by new art that clearly illustrates blood types and agglutination.

Chapter 12: The Cardiovascular System

An overview of the cardiovascular system, supported by an illustration, offers a much-improved introduction to the chapter, which has been reorganized into five parts: the anatomy of the heart, the physiology of the heart, the anatomy of blood vessels, the physiology of circulation, and circulatory routes. A better discussion of cardiac output and peripheral resistance improves the presentation of the chapter.

Chapter 13: The Lymphatic System and Body Defenses

As requested by reviewers, the lymphatic organs are now divided into those that are primary and those that are secondary. The discussion of specific immunity is much improved by new illustrations depicting the action of B cells and T cells. A new reading on emerging diseases modernizes the chapter.

Chapter 14: The Respiratory System

An improved Table 14.1, which includes a description of the respiratory organs, adds to the discussion of the respiratory system. The respiratory membrane is better described and is accompanied by a new illustration. The section entitled Mechanism of Breathing is better organized so that regulation of breathing rates now has its own subsection. Following reviewers' suggestions, the chapter is more student friendly because gas exchange and transport no longer require a knowledge of partial pressures. All readings are new or extensively revised.

Chapter 15: The Digestive System

New illustrations of stomach and small intestine anatomy add to the improved and extended discussion of these topics. Chemical digestion now benefits by having its own separate section. The Medical Focus reading “Human Teeth” has been moved to a logical location early in the chapter. Liver structure, function, and disorders are more logically and thoroughly presented. The chapter ends with an added discussion of three eating disorders: obesity, bulimia nervosa, and anorexia nervosa.

Chapter 16: The Urinary System and Excretion

The functions of the urinary system are discussed more thoroughly than in the fourth edition. The discussion of a nephron has been improved by the addition of micrographs. The role of the loop of the nephron and various hormones in water reabsorption is better explained, and the topic of acid-base balance has been expanded to discuss all the ways the body can adjust the pH of the blood. The chapter ends with a discussion of treatments for kidney failure.

Chapter 17: The Reproductive System

The topic of meiosis has been moved to this chapter so that spermatogenesis and oogenesis can be better understood by students. Coverage of the reproductive organs has been improved by the inclusion of both sagittal and posterior views of the systems. Following reviewers’ suggestions, the menstrual (instead of the ovarian and uterine cycles) is discussed. New Health Focuses are provided on endocrine-disrupting contaminants, shower checks for cancer, and preventing transmission of STDs.

Chapter 18: Human Development and Birth

The addition of new figures depicting fertilization, extraembryonic membranes, and the primary germ layers improves this chapter. Extensive revision is obvious due to the addition of new readings entitled “Therapeutic Cloning” and “Preventing Birth Defects.” A discussion of the development of male and female organs has been added, and the chapter ends with a new and extended discussion of the effects of pregnancy on the mother.

Chapter 19: Human Genetics

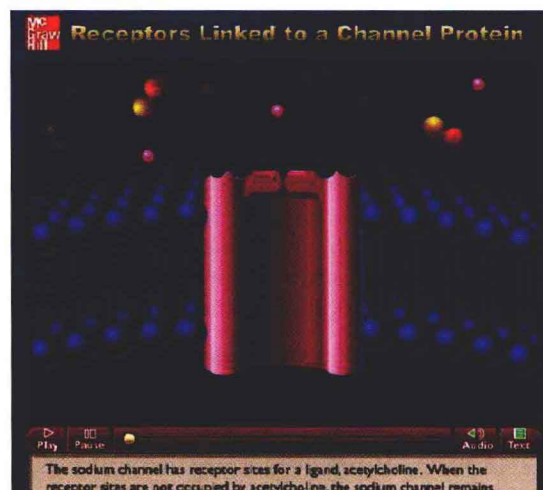
Aside from having all sections revised and updated, the chapter uses cystic fibrosis to show the connection between a genetic disorder and the function of a protein and to illustrate the levels of genetic counseling, from doing a pedigree to performing a preimplantation genetic study. The chapter ends with a Medical Focus outlining the future benefits from the modern field of genomics.

Teaching and Learning Supplements

McGraw-Hill offers various tools and teaching products to support the fifth edition of *Understanding Human Anatomy & Physiology*. Students can order supplemental study materials by contacting their local bookstore. Instructors can obtain teaching aids by calling the Customer Service Department at 800-338-3987, visiting our A & P website at www.mhhe.com, or contacting their local McGraw-Hill sales representative.

The *Digital Content Manager*, 0-07-246443-7, 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 the following easy-to-use folders.

- **Active Art Library** Key Process Figures 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.

- **PowerPoints** Ready-made image presentations cover each of the 19 chapters of the text. Tailor the PowerPoints to reflect your preferred lecture topics and sequences.
- **Tables Library** Every table that appears 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.

Instructor Testing and Resource CD-ROM, 0-07-246441-0, is a cross-platform CD-ROM providing a wealth of resources for the instructor. Supplements featured on this CD-ROM include a computerized test bank utilizing Brownstone Diploma® testing software to quickly create customized exams. This user-friendly program allows instructors to search for questions by topic or format, edit existing questions or add new ones, and scramble questions and answer keys for multiple versions of the same test.

Other assets on the Instructor's Testing and Resource CD-ROM are grouped within easy-to-use folders. The Instructor's Manual and Clinical Applications Manual are available in both Word and PDF formats. Word files of the test bank are included for those instructors who prefer to work outside of the test generator software.

The *Instructor's Manual*, by Dr. Patrick Gallart includes chapter summaries and outlines, suggested student activities, answers to objective questions and to medical terminology reinforcement exercises, and a list of audiovisual materials. The Instructor's Manual is available on Instructor Testing and Resource CD-ROM and the Instructor Edition of the Online Learning Center.

McGraw-Hill provides 200 *Overhead Transparencies*, 0-07-246438-0 of key text line art and photographs.

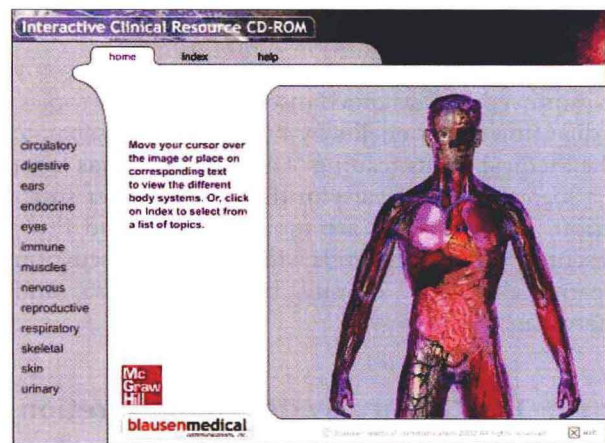
English/Spanish Glossary for Anatomy and Physiology, 0-07-283118-9, is a complete glossary that includes every key term used in a typical anatomy and physiology course. Definitions are provided in both English and Spanish. A phonetic guide to pronunciation follows each word in the glossary.

Course Delivery Systems With help from our partners, WebCT, Blackboard, TopClass, eCollege, and other course management systems, professors can take complete control over their course content. These course cartridges also provide online testing and powerful student tracking features. *Understanding Human Anatomy & Physiology* Online Learning Center is available within all of these platforms.

For the Student

Interactive Clinical Resource CD-ROM

The *Interactive Clinical Resource CD-ROM* offers one hundred fifty-one 3D animations and 3D models of human disease and disorders. It also contains 13 sections of clinical

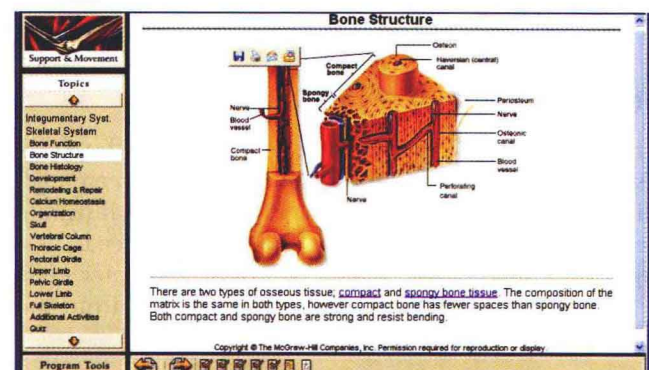


content (and nearly every body system) including Urinary, Skeletal, Reproductive, Nervous, Muscular, Immune, Digestive, Circulatory, and Endocrine. The *Interactive Clinical Resource CD-ROM* may be used as a classroom lecture tool or study guide for students post lecture. Students can use the *Interactive Clinical Resource CD-ROM* to play the 3D animations, explore the 3D models, print the associated text, and view the slides with labels and definitions of key structures related to the disease/disorder. Students will learn how the various diseases/disorders affect the human body system along with possible treatments. The *Interactive Clinical Resource CD-ROM* is the perfect way to reinforce and relate the physiological concepts taught in the classroom to real life.

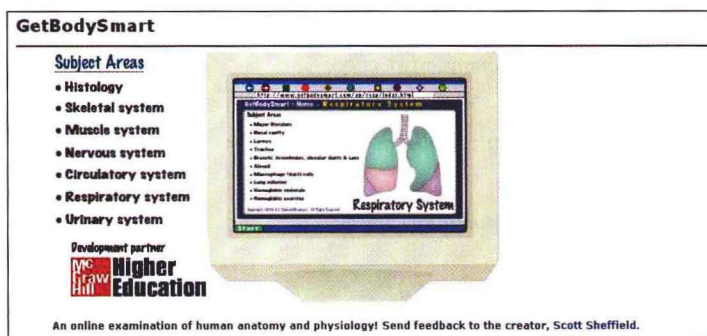
Online Learning Center (<http://www.mhhe.com/maderap5>)

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, clinical applications, interactive activities, art labeling exercises, and case studies. Instructor resources at the site include lecture outlines, technology resources, clinical applications, and case studies.

- **Student Center, Online 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 Essentials Study Partner can be accessed via the Online Learning Center.



- **Live News Feeds**
The OLC offers course specific real-time news articles to help students stay current with the latest topics in anatomy and physiology.
- **Tutorial Service**
This free “homework hotline” offers you the opportunity to discuss text questions with our A&P consultant.
- **GetBodySmart.com** is an online examination of human anatomy and physiology. This program is available on the Student Edition of the Online Learning Center.

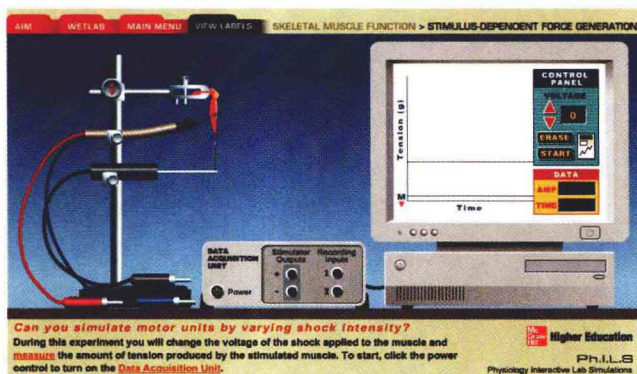


- **Access Science** is the online version of McGraw-Hill's Encyclopedia of Science & Technology. Link to this site free of charge from the Online Learning Center.

Physiology Interactive Lab Simulations (Ph.I.L.S)

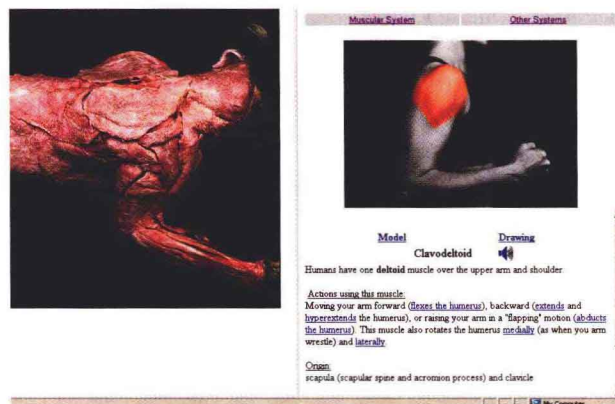
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The Ph.I.L.S CD-ROM contains eleven laboratory simulations that allow students to perform experiments without using expensive lab equipment or live animals. This easy-to-use software offers students the flexibility to change the parameters of every lab experiment, with no limit to the amount of times a student can repeat experiments or modify variables. This power to manipulate each experiment reinforces key physiology concepts by helping students to view outcomes, make predictions, and draw conclusions.



The *Anatomy and Physiology Laboratory Textbook Essentials Version*, 0-07-232363-9, by Gunstream, contains several frog dissections and may be used with any anatomy and physiology text.

Human Anatomy and Physiology Laboratory Manual-Fetal Pig Dissection, Second Edition 0-07-243814-2, by Terry R. Martin, Kishwaukee College, provides excellent full-color photos of the dissected fetal pig with corresponding labeled art. It includes World Wide Web activities for many chapters.



Virtual Anatomy Dissection Review, CD-ROM,

0-07-285621-1, by John Waters, Pennsylvania State University. This 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.

Laboratory Atlas of Anatomy and Physiology, fourth edition, 0-07-243810-X, by Eder et al., is a full-color atlas containing histology, human skeletal anatomy, human muscular anatomy, dissections, and reference tables.

I would like to acknowledge the valuable contributions of all professors and their students who have provided detailed recommendations for improving chapter content and illustrations for the fifth edition.

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The Focus is Understanding . . .

- Students develop a working knowledge of anatomy and physiology based upon conceptual understanding.
- Clinical Applications broaden students' horizons beyond the core principles.
- Self-confidence increases as students master medical terminology and key concepts.

Art Program

Art presents and reinforces the dynamic processes within the human body.

Dynamic Photos

give students a closer look inside the wonders of the human body through the technology of scanning electron micrographs.

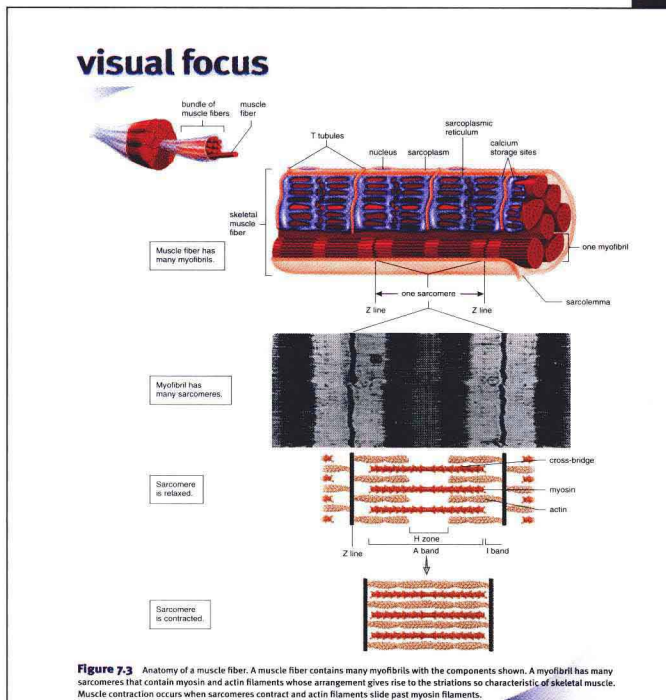
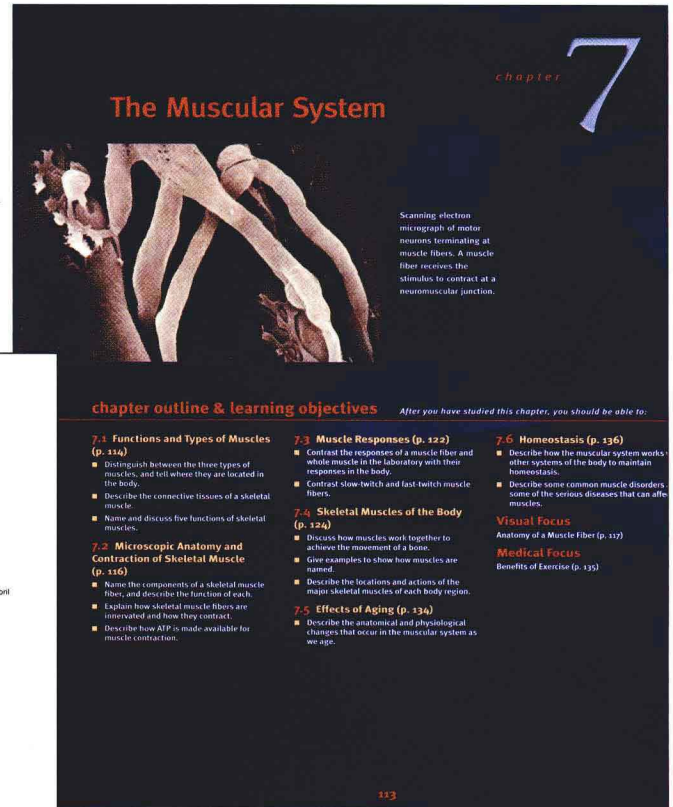


Figure 7-3 Anatomy of a muscle fiber. A muscle fiber contains many myofibrils with the components shown. A myofibril has many sarcomeres that contain myosin and actin filaments whose arrangement gives rise to the striations so characteristic of skeletal muscle. Muscle contraction occurs when sarcomeres contract and actin filaments slide past myosin filaments.

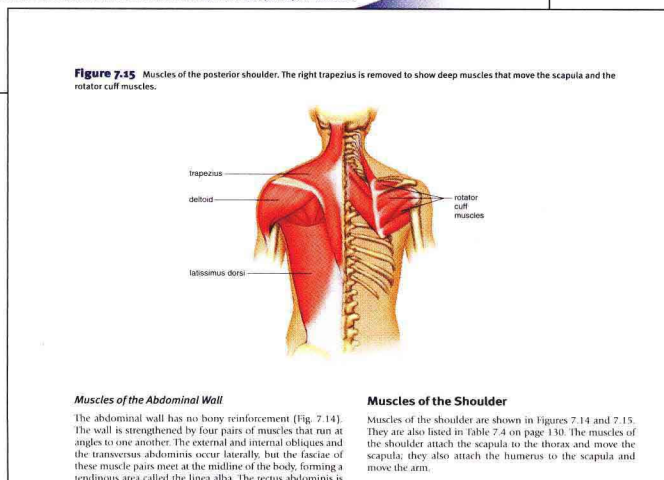


Figure 7-15 Muscles of the posterior shoulder. The right trapezius is removed to show deep muscles that move the scapula and the rotator cuff muscles.

Muscles of the Abdominal Wall

The abdominal wall has no bony reinforcement (Fig. 7.14). The wall is strengthened by four pairs of muscles that run at angles to one another. The external and internal obliques and the transversus abdominis occur laterally, but the fasciae of these muscle pairs meet at the midline of the body, forming a tendinous area called the linea alba. The rectus abdominis is

Muscles of the Shoulder

Muscles of the shoulder are shown in Figures 7.14 and 7.15. They are also listed in Table 7.4 on page 130. The muscles of the shoulder attach the scapula to the thorax and move the scapula; they also attach the humerus to the scapula and move the arm.

Visual Focus

illustrates difficult concepts that relate structure to function, using a step-by-step process.

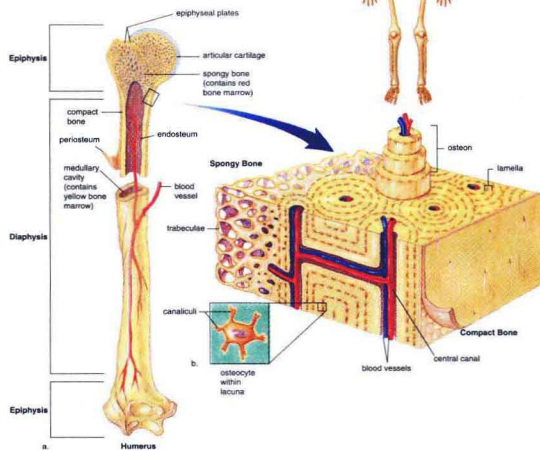
New and Revised Art

focuses on the main concepts by using concise labeling methodology that keeps students from getting bogged down with excessive detail.

"The most beautiful thing we can experience is the mysterious. It is the source of all true art and science."

– Albert Einstein

Figure 6.2 Anatomy of a long bone. **a.** A long bone is encased by the periosteum except at the epiphyses, which are covered by articular cartilage. Spongy bone of the epiphyses contains red bone marrow. The diaphysis contains yellow bone marrow and is bordered by compact bone. **b.** The detailed anatomy of spongy bone and compact bone is shown in the enlargement, along with a blowup of an osteocyte in a lacuna.



Chapter 6 The Skeletal System 85

Macro to Micro Presentation

helps students make the connection between gross anatomy and microscopic anatomy.

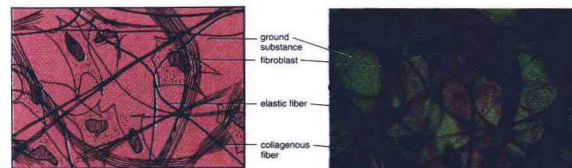
4.2 Connective Tissue

Connective tissue binds structures together, provides support and protection, fills spaces, produces blood cells, and stores fat. The body uses this stored fat for energy, insulation, and organ protection. As a rule, connective tissue cells are widely separated by an extracellular matrix composed of an *organic ground substance* that contains *fibers* and varies in consistency from solid to semifluid to fluid. Whereas the functional and

physical properties of epithelial tissues are derived from its cells, connective tissue properties are largely derived from the characteristics of the matrix (Table 4.2).

The fibers within the matrix are of three types. White fibers contain *collagen*, a substance that gives the fibers flexibility and strength. Yellow fibers contain *elastin*, which is not as strong as collagen but is more elastic. *Reticular fibers* are very thin, highly branched, collagenous fibers that form delicate supporting networks.

Figure 4.5 Loose (areolar) connective tissue. This tissue has a loose network of fibers.



Loose (Areolar) Connective Tissue

Location:
Between muscles; beneath the skin;
beneath most epithelial layers
Function:
Binds organs together

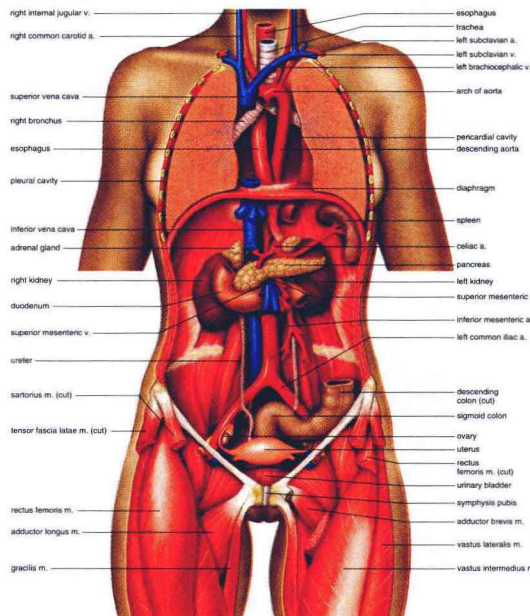
Correlation of Photomicrographs with Line Art

makes it easier for students to identify specific structures.

Reference Figures

of the human body have been added to give students an additional resource in the study of body structure.

Plate 6 The torso as viewed with the heart, liver, stomach, and portions of the small and large intestines removed. (a. = artery; m. = muscle; v. = vein.)



Appendix A 409

Clinical Connections

Additional readings engage the students by creating a richer understanding of the concepts presented and provide a real life connection to anatomy and physiology.

Medical Focus Readings

encourage students to explore clinical examples that they may see throughout their health care career or within their own family.

Osteoporosis

Osteoporosis is a condition in which the bones are weakened due to a decrease in the bone mass that makes up the skeleton. Throughout life, bones are continuously remodeled. While a child is growing, the rate of bone formation is greater than the rate of bone breakdown. The skeletal mass continues to increase until ages 20 to 30. After that, the rates of formation and breakdown of bone mass are equal until ages 40 to 50. Then, resorption begins to exceed formation, and the total bone mass slowly decreases.

Over time, men are apt to lose 25% and women 35% of their bone mass. But we have to consider that men tend to have denser bones than women anyway, and their testosterone (male sex hormone) level generally does not begin to decline significantly until after age 65. In contrast, the estrogen (female sex hormone) level in women begins to decline at about age 45. Because sex hormones play an important role in maintaining bone strength, this difference means that women are more likely than men to suffer fractures, involving especially the hip, vertebrae, long bones, and pelvis. Although osteoporosis may at times be the result of various disease processes, it is essentially a disease of aging.

Everyone can take measures to avoid having osteoporosis when they get older. Adequate dietary calcium throughout life is an important protection against osteoporosis. The U.S. National Institutes of Health recommend a calcium intake of 1,200–1,500 mg per day during puberty. Males and females require 1,000 mg per day until age 65 and 1,500 mg per day after age 65, because the intestinal tract has fewer vitamin D receptors in the elderly.

A small daily amount of vitamin D is also necessary to absorb calcium from the digestive tract. Exposure to sunlight is required to allow skin to synthesize vitamin D. If you reside on or north of a "line" drawn from Boston to Milwaukee, to Minneapolis, to Boise, chances are, you're not getting enough vitamin D during the winter months. Therefore, you should avail yourself of the vitamin D in fortified foods such as low-fat milk and cereal.

Postmenopausal women should have an evaluation of their bone density. Presently, bone density is measured by a method called dual energy X-ray absorptiometry (DEXA). This test measures bone density based on the absorption of photons generated by an X-ray tube. Soon, a blood and urine test may be able to detect the biochemical markers of bone loss, making it possible for physicians to screen all older women and at-risk men for osteoporosis.

Medical Focus

If the bones are thin, it is worthwhile to take measures to gain bone density because even a slight increase can significantly reduce fracture risk. Regular, moderate, weight-bearing exercise such as walking or jogging is a good way to maintain bone strength (Fig. 6A). A combination of exercise and drug treatment, as recommended by a physician, may yield the best results.

A wide variety of prescribed drugs that have different modes of action are available. Hormone therapy includes black cohosh, which is a phytoestrogen (estrogen made by a plant as opposed to an animal). Calcitonin is a naturally occurring hormone whose main site of action is the skeleton where it inhibits the action of osteoclasts, the cells that break down bone. Promising new drugs include slow-release fluoride therapy and certain growth hormones. These medications stimulate the formation of new bone.

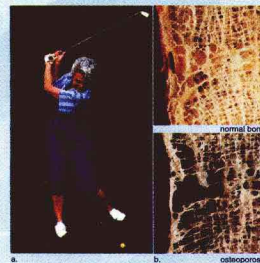


Figure 6A Preventing osteoporosis. **a.** Exercise can help prevent osteoporosis, but when playing golf, you should carry your own clubs and walk instead of using a golf cart. **b.** Normal bone growth compared to bone from a person with osteoporosis.

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What's New Readings

offer fascinating information on treatments that are now experimental but promise to be particularly helpful in the future.

Coaxing the Chondrocytes for Knee Repair

To the young, otherwise healthy, 30-something athlete on the physician's exam table, the diagnosis must seem completely unfair. Perhaps he's a former football player, or she's a trained dancer. Whatever the sport or activity, the patient is slender and fit, but knee pain and swelling are this athlete's constant companions. Examination of the knee shows the result of decades of use and abuse while performing a sport: The hyaline cartilage, also called articular cartilage, of the knee joint has degenerated. Hyaline cartilage (see page 84) is the "Teflon coating" for the bones of freely movable joints such as the knee. Hyaline cartilage allows easy, frictionless movement between the bones of the joint. Once repeated use has worn it away, hyaline cartilage does not grow back naturally. Exposed bone ends can grind against one another, resulting in pain, swelling, and restricted movements that can cripple the athlete. In severe cases, total knee replacement with a prosthetic joint is the athlete's only option (Fig. 6B).

As with all injuries to the knee, once the cartilage cells are firmly established, the patient still faces a lengthy rehabilitation. The patient must use crutches or a cane for three to four months to protect the joint. Physical therapy will stimulate cartilage growth without oversteering the area being repaired. In six months, the athlete can return to light-impact training and jogging. Full workouts can be resumed in about one year after surgery. However, most patients regain full mobility and a pain-free life after ACI surgery and do not have to undergo total knee replacement.

ACI surgery can't be used for the elderly or for overweight patients with osteoarthritis. Muscle or bone defects in the knee joint must be corrected before the surgery can be attempted. As with all surgeries, there is a risk for postoperative complications, such as bleeding or infection. However, ACI may offer young athletes the chance to restore essential hyaline cartilage and regain a healthy, functional knee joint.

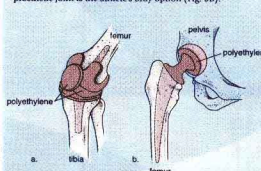


Figure 6B Artificial joints in which polyethylene replaces articular cartilage. **a.** Knee. **b.** Hip.

What's New

Now the technique of tissue culture (growing cells outside of the patient's body in a special medium) can help young athletes with cartilage injuries regenerate their own hyaline cartilage. In an autologous chondrocyte implantation (ACI) surgery, a piece of healthy hyaline cartilage from the patient's knee is first removed surgically. This piece of cartilage, about the size of a pencil eraser, is typically taken from an undamaged area at the top edge of the knee. The chondrocytes, living cells of hyaline cartilage, are grown outside the body in tissue culture medium. Millions of the patient's own cells can be grown to create a "patch" of living cartilage. Growing these cells takes two to three weeks. Once the chondrocytes have grown, a pocket is created over the damaged area using the patient's own perosteum, the connective tissue that surrounds the bone (see page 84). The perosteum pocket will hold the hyaline cartilage cells in place. The cells are injected into the pocket and left to grow.

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Effects of Aging

presents some of the age-related physical and functional changes that occur in the body.

6.5 Effects of Aging

Both cartilage and bone tend to deteriorate as a person ages. The chemical nature of cartilage changes, and the bluish color typical of young cartilage changes to an opaque, yellowish color. The chondrocytes die, and resorption occurs as the cartilage undergoes calcification, becoming hard and brittle. Calcification interferes with the ready diffusion of nutrients and waste products through the matrix. The articular cartilage may no longer function properly, and the symptoms of arthritis can appear. There are three common types of arthritis:

(1) Osteoarthritis is accompanied by deterioration of the articular cartilage. (2) In rheumatoid arthritis, the synovial membrane becomes inflamed and grows thicker cartilage, possibly due to an autoimmune reaction. (3) Gout, or gouty arthritis, is caused by an excessive buildup of uric acid (a metabolic waste) in the blood. Rather than being excreted in the urine, the acid is deposited as crystals in the joints, where it causes inflammation and pain.

Osteoporosis, discussed in the Medical Focus on page 88, is present when weak and thin bones cause aches and pains. Such bones tend to fracture easily.

"Education is not preparation for life; education is life itself."

– John Dewey

Homeostasis

Each system chapter ends with a major section on homeostasis to accompany the “Human Systems Work Together” illustration. Together, they describe how the system under discussion, with the help of other body systems, maintains a stable internal environment.

Human Systems Work Together

Integumentary System

Bones provide support for skin.
Skin protects bones, helps provide vitamin D for Ca^{2+} absorption.

Muscular System

Bones provide attachment sites for muscles, store Ca^{2+} for muscle function.
Muscular contraction causes bones to move; joints; muscles help protect bones.

Nervous System

Bones protect sense organs, brain, and spinal cord; store Ca^{2+} for nerve function.
Receptors send sensory input from bones to joints.

Endocrine System

Bones provide protection for glands; store Ca^{2+} as second messenger.
Growth hormone regulates bone development; parathyroid hormone and calcitonin regulate Ca^{2+} content.

Cardiovascular System

Rib cage protects heart; red bone marrow produces blood cells; stores Ca^{2+} for blood clotting.
Blood vessels deliver oxygen and nutrients to bones; carry away wastes.

Lymphatic System/Immunity

Red bone marrow produces white blood cells involved in immunity.
Lymphatic vessels plus drainage system protect against infection.

Respiratory System

Rib cage protects lungs and assists breathing; bones provide attachment sites for muscles involved in breathing.
Gaseous exchange in lungs provides oxygen and ridges body of carbon dioxide.

Digestive System

Jaws contain teeth that chew food; hyoid bone assists swallowing.
Esophagus and stomach; Ca^{2+} and other nutrients for bone growth and repair.

Urinary System

Bones provide support and protection.
Parathyroid glands secrete vitamin D for Ca^{2+} absorption and help maintain blood level of Ca^{2+} ; needed for bone growth and repair.

Reproductive System

Bones provide support and protection of reproductive organs.
Sex hormones influence bone growth and density in males and females.

How the Skeletal System works with other body systems

Clinical Key Terms

expand students' understanding of medical terminology and offer the chance to brush up on phonetic pronunciations of terms often used in clinical situations.

6.6 Homeostasis

The illustration in Human Systems Work Together on page 109 tells how the skeletal system assists other systems (buff color) and how other systems assist the skeletal system (aqua color). Let's review again the functions of the skeletal system, but this time as they relate to the other systems of the body.

Functions of the Skeletal System

The bones protect the internal organs. The rib cage protects the heart and lungs; the skull protects the brain; and the vertebrae protect the spinal cord. The endocrine organs, such as the pituitary gland, pineal gland, thymus, and thyroid gland, are also protected by bone. The nervous system and the endocrine system work together to control the other organs and, ultimately, homeostasis.

The bones assist all phases of respiration (Fig. 6.23). The rib cage assists the breathing process, enabling oxygen to enter the blood, where it is transported by red blood cells to the tissues. Red bone marrow produces the blood cells, including the red blood cells that transport oxygen. Without a supply of oxygen, the cells of the body could not efficiently produce ATP. ATP is needed for the many synthesis reactions that occur in cells.

The bones store and release calcium. The storage of calcium in the bones is under hormonal control. A dynamic equilibrium is maintained between the concentrations of calcium in the bones and in the blood. Calcium ions play a major role in muscle contraction and nerve conduction. Calcium ions also help regulate cellular metabolism. Protein hormones, which cannot enter cells, are called the first messenger, and a second messenger such as calcium ions jump-starts cellular metabolism, directing it to proceed in a particular way.

The bones assist the lymphatic system and immunity. Red bone marrow produces not only the red blood cells but also the white blood cells. The white cells, which congregate in the lymphatic organs, are involved in defending the body against

pathogens and cancerous cells. Without the ability to withstand foreign invasion, the body may quickly succumb to disease and die.

The bones assist digestion. The jaws contain sockets for the teeth, which chew food, and a place of attachment for the muscles that move the jaws. Chewing breaks food into pieces small enough to be swallowed and chemically digested. Without digestion, nutrients would not enter the body to serve as building blocks for repair and a source of energy for the production of ATP.

The skeleton is necessary to locomotion. Locomotion is efficient in human beings because they have a jointed skeleton for the attachment of muscles that move the bones. Our jointed skeleton allows us to seek out and move to a more suitable external environment in order to maintain the internal environment within reasonable limits.

Functions of Other Systems

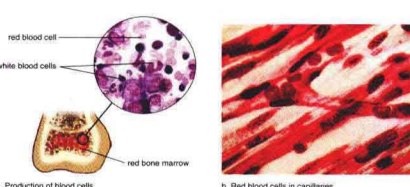
How do the other systems of the body help the skeletal system carry out its functions?

The integumentary system and the muscles help the skeletal system protect internal organs. For example, anteriorly, the abdominal organs are only protected by muscle and skin. The digestive system absorbs the calcium from food so that it enters the body. The plasma portion of blood transports calcium from the digestive system to the bones and any other organs that need it. The endocrine system regulates the storage of calcium in the bones.

The thyroid gland, a lymphatic organ, is instrumental in the maturity of certain white blood cells produced by the red bone marrow. The cardiovascular system transports the red blood cells as they deliver oxygen to the tissues and as they return to the lungs where they pick up oxygen.

Movement of the bones would be impossible without contraction of the muscles. In these and other ways, the systems of the body help the skeletal system carry out its functions.

Figure 6.23 The skeletal system and cardiovascular system work together. a. Red bone marrow produces the blood cells, including the red and white blood cells. b. As the red blood cells pass through the capillaries, they deliver oxygen to the body's cells. Some white blood cells exit blood and enter the tissues at capillaries, where they phagocytize pathogens. Others stay in the blood (and lymph), where they produce antibodies against invaders.



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Chapter 6 The Skeletal System

Selected New Terms

Basic Key Terms

- abduction (ab-duk-shun), p. 106
- adduction (uh-duk-shun), p. 106
- appendicular skeleton (ap-en-dik-yu-ler skel-e-ton), p. 97
- articular cartilage (ar-tik-yu-ler kar-ti-lij), p. 84
- articulation (ar-tik-yu-lu-shun), p. 84
- axial skeleton (ak-sal skel-e-ton), p. 89
- bursa (bur-suh), p. 104
- circumduction (ser-kum-duk-shun), p. 106
- compact bone (kom-pakt bon), p. 84
- diaphysis (di-af-i-sis), p. 84
- epiphyseal plate (ep-i-fi-se-al plat), p. 86
- epiphysis (e-pi-fi-sis), p. 84
- eversion (e-ver-zhun), p. 106
- extension (ek-sten-zhun), p. 106
- flexion (flek-shun), p. 106
- fontanel (fon-tuh-nel), p. 90
- hematopoiesis (hem-ah-to-poi-e-sis), p. 84
- intervertebral disk (in-ter-ver-bee-bral disk), p. 94
- inversion (in-ver-zhun), p. 106
- ligament (lig-uh-men), p. 104
- medullary cavity (med-yu-lar-e kav-i-te), p. 84
- meniscus (me-nis-kus), p. 104
- ossification (os-i-fi-ka-shun), p. 86
- osteoblast (os-ee-o-blast*), p. 86
- osteoclast (os-ee-o-klast*), p. 86

- osteocyte (os-ee-o-sit), p. 86
- pectoral girdle (pek-to-ral ger-dil), p. 97
- pelvic girdle (pel-vik ger-dil), p. 100
- periosteum (per-ee-o-ste-um), p. 84
- pronation (pro-nah-shun), p. 106
- red bone marrow (red bon mar-oh), p. 84
- rotation (ro-tah-shun), p. 106
- sinus (si-nus), p. 90
- spongy bone (spun-jee bon), p. 84
- supination (su-pi-nah-shun), p. 106
- suture (su-cher), p. 90
- synovial fluid (si-no-ve-al flu-id), p. 104
- synovial joint (si-no-ve-al joint), p. 104
- synovial membrane (si-no-ve-al mem-bran), p. 104
- vertebral column (ver-bee-bral kah-lum), p. 94

Clinical Key Terms

- bursitis (ber-si-tis), p. 104
- fracture (frak-cher), p. 87
- hemiated disk (her-ne-a-ted disk), p. 94
- kyphosis (ki-fuh-sis), p. 94
- lordosis (lor-do-sis), p. 94
- mastoiditis (mas-toi-di-tis), p. 90
- osteoarthritis (os-ee-o-ar-thri-tis), p. 107
- osteoporosis (os-ee-o-po-ro-sis), p. 107
- rheumatoid arthritis (ru-muh-toid ar-thri-tis), p. 107
- scoliosis (sko-le-o-sis), p. 94

Summary

6.1 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.
- C. Bone is a living tissue. It develops, grows, remodels, and repairs itself. In all these processes, osteoclasts

- break down bone, and osteoblasts build bone.
- D. Fractures are of various types, but repair requires four steps: (1) hematoma, (2) fibrocartilaginous callus, (3) bony callus, and (4) remodeling.

6.2 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.
- A. The skull is formed by the cranium and the facial bones. The cranium includes the frontal bone, two parietal bones, one occipital bone, two temporal bones, one sphenoid bone, and one ethmoid bone. The facial bones include two maxillae,

- two palatine bones, two zygomatic bones, two lacrimal bones, two nasal bones, the vomer bone, two inferior nasal conchae, and the mandible.
- B. The U-shaped hyoid bone is located in the neck. It anchors the tongue and does not articulate with any other bone.
- C. The typical vertebra has a body, a vertebral arch surrounding the vertebral foramen, and a spinous process. The first two vertebrae are the atlas and axis. The vertebral column has four curvatures and contains the cervical, thoracic, lumbar, sacral, and coccygeal vertebrae, which are separated by intervertebral disks.

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The Learning System

Students differ in how they learn best and how they respond to different learning situations. Effective instruction and lasting retention don't just happen; they result from materials that are carefully planned and organized in a logical sequence so that learning will occur.

Outline and Learning Objectives

An integrated outline and learning objectives that number the major topics of the chapter, give students the overall plan and sequence for the chapter.

Table 6.1 Surface Features of Bones

Term	Definition	Example
PROCESSES		
Articulating Surfaces		
Condyle (kon'dil)	A large, rounded, articulating knob	Mandibular condyle of the mandible (Fig. 6.6d)
Head	A prominent, rounded, articulating proximal end of a bone	Head of the femur (Fig. 6.1c)
Projections for Muscle Attachment		
Crest	A narrow, ridgelike projection	Iliac crest of the coxal bone (Fig. 6.1s)
Spine	A sharp, slender process	Spine of the scapula (Fig. 6.11b)
Trochanter (tro-kan'ter)	A massive process found only on the femur	Greater trochanter and lesser trochanter of the femur (Fig. 6.1c)
Tubercle (tu-ber-kul)	A small, rounded process	Greater tubercle of the humerus (Fig. 6.12)
Tuberosity (tu-ber-osi'tee)	A large, roughened process	Radial tuberosity of the radius (Fig. 6.13)
DEPRESSIONS AND OPENINGS		
Foramen (fo-ra'men)	A rounded opening through a bone	Foramen magnum of the occipital bone (Fig. 6.7d)
Fossa (fos'uh)	A flattened or shallow surface	Mandibular fossa of the temporal bone (Fig. 6.7d)
Meatus (me-a'tus)	A tubelike passageway through a bone	External auditory meatus of the temporal bone (Fig. 6.6d)
Sinus (s'i-nus)	A cavity or hollow space in a bone	Frontal sinus of the frontal bone (Fig. 6.5)

Source: Data from Marieb and Hoar, *Concepts of Human Anatomy and Physiology*, 10th ed., 1999, p. 187.

Chapter 6: The Skeletal System 87

Key points are emphasized using a **variety of presentation techniques**, photos, drawings, and tables.

Key Boldface Terms anchor students' understanding of chapter concepts.

"I hear and I forget. I see and I remember. I do and I understand."

— Confucius



14.1 The Respiratory System

The primary function of the respiratory system is to allow oxygen from the air to enter the blood and carbon dioxide from the blood to exit into the air. During inspiration, or inhalation (breathing in), and expiration, or exhalation (breathing out), air is conducted toward or away from the lungs by a series of cavities, tubes, and openings, illustrated in Figure 14.1.

The respiratory system also works with the cardiovascular system to accomplish these four respiratory events:

1. breathing, the entrance and exit of air into and out of the lungs;
2. external respiration, the exchange of gases (oxygen and carbon dioxide) between air and blood;
3. internal respiration, the exchange of gases between blood and tissue fluid;
4. transport of gases to and from the lungs and the tissues.

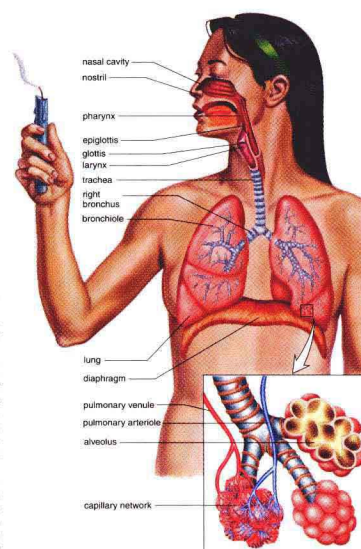
Cellular respiration, which produces ATP, uses the oxygen and produces the carbon dioxide that makes gas exchange with the environment necessary. Without a continuous supply of ATP, the cells cease to function. The four events listed here allow cellular respiration to continue.

The Respiratory Tract

Table 14.1 traces the path of air from the nose to the lungs. As air moves in along the airways, it is cleansed, warmed, and moistened. Cleansing is accomplished by coarse hairs just inside the nostrils and by cilia and mucus in the nasal cavities and the other airways of the respiratory tract. In the nose, the hairs and the cilia act as screening devices. In the trachea and other airways, the cilia beat upward, carrying mucus, dust, and occasional bits of food that "went down the wrong way" into the pharynx, where the accumulation can be swallowed or expectorated. The air is warmed by heat given off by the blood vessels lying close to the surface of the lining of the airways, and it is moistened by the wet surface of these passages.

Conversely, as air moves out during expiration, it cools and loses its moisture. As the air cools, it deposits its moisture on the lining of the trachea and the nose, and the nose may even drip as a result of this condensation. The air still retains so much moisture, however, that upon expiration on a cold day, it condenses and forms a small cloud.

Figure 14.1 The respiratory tract extends from the nasal cavities to the lungs, which are composed of air sacs called alveoli. Gas exchange occurs between the air in the alveoli and the blood within a capillary network that surrounds the alveoli. Notice in the blow-up that the pulmonary arteriole is colored blue—it carries O₂-poor blood away from the heart to the alveoli. Then carbon dioxide leaves the blood, and oxygen enters the blood. The pulmonary venule is colored red—it carries O₂-rich blood from the alveoli toward the heart.



Learners are actively involved in end of chapter **questions and reinforcement activities** to confirm mastery of the chapter objectives.

- D. The rib cage contains the thoracic vertebrae, ribs and associated cartilages, and the sternum.
- 6.3 **Appendicular Skeleton**
The appendicular skeleton consists of the bones of the pectoral girdle, upper limbs, pelvic girdle, and lower limbs.
- A. The pectoral (shoulder) girdle contains two clavicles and two scapulae.
- B. The upper limb contains the humerus, the radius, the ulna, and the bones of the hand (the carpals, metacarpals, and phalanges).
- C. The pelvic girdle contains two coxal bones, as well as the sacrum and coccyx. The female pelvis is generally wider and more shallow than the male pelvis.
- D. The lower limb contains the femur, the patella, the tibia, the fibula, and the bones of the foot (the tarsals, metatarsals, and phalanges).
- 6.4 **Joints (Articulations)**
A. Joints are regions of articulation between bones. They are classified according to their degree of movement. Some joints are immovable, some are slightly movable, and some are freely movable (synovial). The different kinds of synovial joints are ball-and-socket, hinge, condyloid, pivot, gliding, and saddle.
- B. Movements at joints are broadly classified as angular (flexion, extension, adduction, abduction); circular (circumduction, rotation, supination, and pronation); and special (inversion, eversion, elevation, and depression).
- 6.5 **Effects of Aging**
Two fairly common effects of aging on the skeletal system are arthritis and osteoporosis.
- 6.6 **Homeostasis**
A. The bones protect the internal organs. The rib cage protects the heart and lungs; the skull protects the brain; and the vertebrae protect the spinal cord.
- B. The bones assist all phases of respiration. The rib cage assists the breathing process, and red bone marrow produces the red blood cells that transport oxygen.
- C. The bones store and release calcium. Calcium ions play a major role in muscle contraction and nerve conduction. Calcium ions also help regulate cellular metabolism.
- D. The bones assist the lymphatic system and immunity. Red bone marrow produces not only the red blood cells but also the white blood cells.
- E. The bones assist digestion. The jaws contain sockets for the teeth, which chew food, and a place of attachment for the muscles that move the jaws.
- F. The skeleton is necessary for locomotion. Locomotion is efficient in human beings because they have a jointed skeleton for the attachment of muscles that move the bones.

Study Questions

- What are five functions of the skeleton? (p. 84)
- What are five major categories of bones based on their shapes? (p. 84)
- What are the parts of a long bone? What are some differences between compact bone and spongy bone? (pp. 84–85)
- How does bone grow in children, and how is it remodeled in all age groups? (pp. 86–87)
- What are the various types of fractures? What four steps are required for fracture repair? (p. 87)
- List the bones of the axial and appendicular skeletons. (Fig. 6.4, p. 89)
- What are the bones of the cranium and the face? What are the special features of the temporal bones, sphenoid bone, and ethmoid bone? (pp. 90–93)
- What are the parts of the vertebral column, and what are its curvatures? Distinguish between the atlas, axis, sacrum, and coccyx. (pp. 94–95)
- What are the bones of the rib cage, and what are several of its functions? (p. 96)
- What are the bones of the pectoral girdle? Give examples to demonstrate the flexibility of the pectoral girdle. What are the special features of a scapula? (p. 97)
- What are the bones of the upper limb? What are the special features of these bones? (pp. 98–100)
- What are the bones of the pelvic girdle, and what are their functions? (pp. 100–101)
- What are the false and true pelvises, and what are several differences between the male and female pelvises? (p. 101)
- What are the bones of the lower limb? Describe the special features of these bones. (pp. 102–3)
- How are joints classified? Give examples of each type of joint. (p. 104)
- How can joint movements permitted by synovial joints be categorized? Give an example of each category. (p. 106)
- How does aging affect the skeletal system? (p. 107)
- What functions of the skeletal system are particularly helpful in maintaining homeostasis? (pp. 108–9)

Objective Questions

I. Match the items in the key to the bones listed in questions 1–6.

Key:

- forehead
- chin
- cheekbone
- elbow
- shoulder blade
- hip
- ankle
- temporal and zygomatic bones
- tibia and fibula
- frontal bone
- ulna
- coxal bone
- scapula

II. Match the items in the key to the bones listed in questions 7–13.

Key:

- external auditory meatus
- cribriform plate
- xiphoid process
- glenoid cavity
- olecranon process
- acetabulum
- greater and lesser trochanters
- scapula
- sternum
- femur
- temporal bone
- ethmoid bone
- ulna

III. Fill in the blanks.

- Long bones are _____ than they are wide.
- The epiphysis of a long bone contains _____ bone,

where red blood cells are produced.

- The _____ are the air-filled spaces in the cranium.
- The sacrum is a part of the _____, and the sternum is a part of the _____.
- The pectoral girdle is specialized for _____, while the pelvic girdle is specialized for _____.
- The term *phalanges* is used for the bones of both the _____ and the _____.
- The knee is a freely movable (synovial) joint of the _____ type.

Medical Terminology Reinforcement Exercise

Consult Appendix B for help in pronouncing and analyzing the meaning of the terms that follow.

- chondromalacia (kon'dro-muh-lah'she-uh)
- osteomyelitis (os'te-o-mi'e-l'i'tis)
- craniostylosis (kra'ne-o-sin'os-to'sis)
- myelography (mi'e-log'ruh-fe)
- acrocyanosis (ak'ro-sai'uh-no'sis)
- syndactylism (sin-dak'ti-lizm)
- orthopedist (or'tho-pe'dist)
- prognathism (prog'nah-thizm)
- micropodia (mi'kro-po'de-uh)
- arthroscopic (ar'thro-skop'ik)
- bursectomy (ber-sek'to-me)
- synovitis (sin-o-vi'tis)
- accephaly (a-sef'uh-le)
- sphenoidostomy (sfen-noy-dos'to-me)
- acetabuloplasty (as-e-tab'yū-lo-plas-te)

Website Link

Visit the Student Edition of the Online Learning Center at <http://www.mhhe.com/maderap5> for additional quizzes, interactive learning exercises, and other study tools.

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