

# Hole's Human Anatomy & Physiology

TENTH EDITION

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## HOLE'S HUMAN ANATOMY &amp; PHYSIOLOGY, TENTH EDITION

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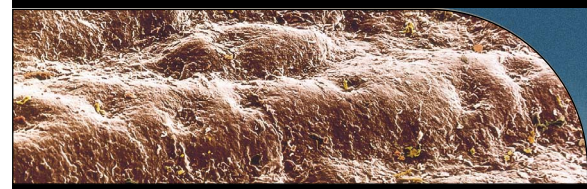
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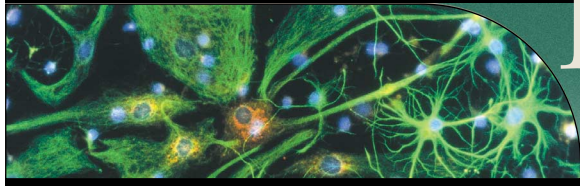
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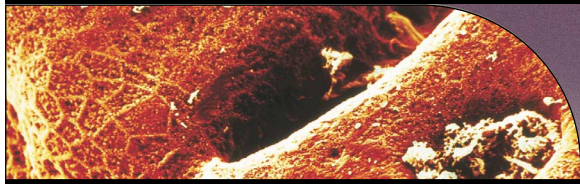
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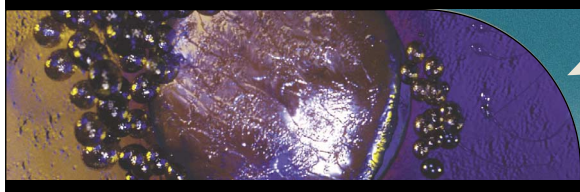
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David Shier has accumulated twenty-seven years of experience teaching anatomy and physiology, primarily to premedical, nursing, dental, and allied health students. He has effectively incorporated his extensive teaching experience into another student-friendly revision of *Hole's Human Anatomy & Physiology* and *Hole's Essentials of Human 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.

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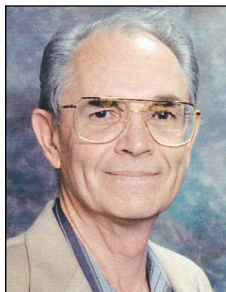
Ricki Lewis, David Shier, Jackie Butler

# Preface

## The Evolution of a Classic

In biological evolution, a population of organisms changes over time. Molded by natural selection, a successful species becomes the best suited that it can be for a particular environment. In a similar manner, this textbook has evolved over the past quarter century.

From its beginnings as a clear, concise, and exciting grand tour of the human body, John Hole's *Human Anatomy & Physiology* has matured into a modern exploration of the human, from its interacting organ systems to the cellular and molecular underpinnings of the functions of life. In our preface to the seventh edition, when we came on board to continue Dr. Hole's legacy, we termed his work "a classic." That it certainly is, with over one million copies sold worldwide over its 25-year history.



Dr. John W. Hole, Jr.

### Dr. Hole tells of his book's origin:

"When I began teaching human anatomy and physiology 35 years ago, the nation was entering an era of increased space exploration, advances in civil rights, and influences of the women's movement. In the 1970s, the floppy disc appeared, rocks were the pets of choice, and *Star Wars* transported us to a galaxy far, far away. Despite the advances made during this era, the available anatomy and phys-

iology textbooks were lacking in some of the features I felt were desirable for my students.

The first edition of Hole's *Human Anatomy & Physiology*, published in 1978, reflected our efforts to prepare a textbook that would engage students and involve them actively in the learning process. The text included information of particular interest to allied health students and devices to help them relate their classroom knowledge to their future clinical practice. Boxed information illustrated how theory is applied to clinical practice, lists of terms and word parts expanded understanding of technical and medical terminology, and review activities within as well as at the end of each chapter aided the reader in evaluating his or her progress in achieving the chapter objectives.

As I think about the many years of work involved in preparing the first edition of the textbook, I am reminded of how much of it was a team effort, and I will be forever grateful for the help and support from all who were part of

the text's development and production. With each edition, the current authors continue to include, expand and improve the features that define this text."

Success came quickly for *Hole's Human Anatomy & Physiology*. One early adopter wrote, "I think it is one of the finest books of its kind I have ever seen. It is an excellent teaching text, the organization is superb, and its explanatory style is highly effective." Such praise is rare indeed for a first edition. By fall 1978, sales confirmed that John Hole's approach had struck a chord, and the publisher declared the textbook "an overwhelming success." Work began on the second edition, and the success exploded. With each revision, the textbook grew. Much of the black-and-white art evolved into full color, and certain chapters underwent a binary fission of sorts, the nervous system expanding into two chapters, and bones and joints given their own turf. New clinical case studies, practical applications, and laboratory applications continued to complement the trademark of clear explanations.

When we took over with the seventh edition a decade ago, space travel had become more common place, pet rocks had vanished, and the Internet was beginning to link us all together. Powerful imaging technologies added new views of anatomy and physiology, as nonstop discoveries in molecular and cellular biology and genetics revealed the mechanisms behind body functions. To embrace new knowledge while at the same time making the material accessible, we introduced a personal touch—compelling vignettes to open chapters and more tales of real people. Coverage of pathology ranged from the tragic to the commonplace to the quirky, usually offset in small boxes or sidebars so as not to interrupt the narrative flow. We delved into historical anecdotes where appropriate for understanding the present, while introducing new biomedical technologies. At the same time, increased coverage of homeostasis and a new feature to end the systems chapters, called InnerConnections, wove the text into a tighter fabric.

Other changes streamlined the learning process. We reorganized the chapter sequence, and placed the clinical case studies, practical applications, and laboratory applications under the umbrella heading of clinical applications. Improvements in art, text, as well as content updating, continued through the eighth edition. The ninth edition introduced a "life-span changes" section at the ends of the systems chapters, and a "reconnect" fea-

ture throughout to help the reader integrate the information, and more extensive on-line student resources. The final chapter evolved to become “Genetics and Genomics” to reflect the sequencing of the human genome and the emergence of a new field.

Just as world events helped to inspire the first edition of the book, so too have they influenced this anniversary edition. The vignette for the integumentary system chapter addresses a possible reintroduction of smallpox; that for the respiratory system chapter examines air quality concerns at the World Trade Center site in the months following September 11, 2001. This edition also introduces a developmental backdrop by considering how stem cells contribute to tissues, including two spectacularly redone illustrations, vignettes, a basic section in the Cells chapter, and relevant mentions throughout. Stem cells also star in three of the *From Science to Technology* boxes, which highlight the origins of medical and biotechnologies.

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## Audience

The tenth edition brings new awareness and reveals a new set of rules. In our evolution as authors we are evolving as teachers. What we and our reviewers do in class is reflected more in this than in previous editions. Students have always come first in our approach to teaching and textbook authoring, but we now feel more excited than ever about the student-oriented, teacher-friendly quality of this text. We have never included detail for its own sake, but we have felt free to include extra detail if the end result is to clarify.

The level of this text is geared toward students in two-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 processes. Students who have studied this material previously will view it as a welcomed review, but newcomers will not find it intimidating.

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## What's New?

Over 25 years have passed, and *Hole's Human Anatomy & Physiology* is still *Hole's Human Anatomy & Physiology*—but with a sharper focus and appearance.

- **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**—All illustrations have been revised. New art incorporates cutting-edge technology

offering vivid depictions of complex processes while maintaining the conceptual base that has established Hole as the most effective “instructional tool” on the market, with a unique focus on the fundamentals. Hole’s art focuses on the main concepts by using concise labeling methodology that keeps students from getting bogged down with excessive detail. Difficult concepts are broken down into easy-to-understand illustrations.

- **Chapter Openers**—Chapter opener images give you a closer look inside the wonders of the human body through the technology of scanning electron micrographs, endoscopic photography, and immunofluorescent light micrographs. The authors provide interesting, creative, and thought-provoking vignettes that introduce the chapter topics with readings on such topics as smallpox, heart transplants, and defibrillator implants.
- **From Science to Technology**—The new “From Science to Technology” readings cover topics such as *Cloning to Produce Therapeutic Stem Cells* and *Replacing the Liver*.
- **Clinical Applications**—New topics have been added to the Clinical Application boxes in several chapters. Read updates on Parkinson disease treatment, asthma, and food supplements.
- **Review Exercises and Critical Thinking**—Updated end-of-chapter review exercises help the student check their 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**—The *Digital Content Manager*, a 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 easy-to-use folders.

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## Updates and Additions

Chapter 1 reorders topics to provide a more solid foundation for understanding by presenting the internal environment in more detail with unique figures and introducing hierarchy of organization and various organ systems first. New figures on homeostatic mechanisms have also been added.

Chapter 2 features a revised presentation of dissociation of salts in water, a revised presentation of protein structure, and an improved explanation of electron shells and octet rule, and polar bonds. The explanation of saturated/unsaturated fatty acids and fats has also been reordered.

Chapter 3 presents a revised figure on osmosis, which now allows for equilibrium to be reached, thus better illustrating the relationship between intracellular and extracellular fluids. A new section covers stem and progenitor cells.

Chapter 4 offers additional steps shown in translation and a better representation of the relationship between chromosome structure and DNA.

Chapter 5 presents a new vignette on building a blood vessel plus the addition of a *From Science to Technology* reading on tissue engineering. The “types of membranes” topic from chapter 6 has been moved to chapter 5.

Chapter 6 introduces a new, boxed reading on the causes as well as the anatomical and physiological effects of sunburn. A new vignette on smallpox has been added at the beginning of the chapter.

Chapter 7 features revised skeletal figures that present a consistent right side orientation. *Skeletons From the Past* is the new chapter opener vignette.

Chapter 9 presents a clearer relationship between thick and thin filaments, striation pattern, and the explanation of the sliding filament model. A new figure on muscle contraction shows the crossbridge cycle and the relationship to relaxed state. New art for muscles has been added throughout. Terminology is now more consistent with *Terminologia Anatomica*, except when such convention conflicts with current clinical usage.

Chapter 10 introduces a new figure showing the relationship between CNS and PNS, including motor and sensory divisions of PNS and the somatic and autonomic divisions of the motor portion. Unipolar neurons are now shown to have an axon with a central process and a peripheral process.

Chapter 11 features a revised presentation of neuroanatomy distinguishing between gray matter and white matter.

Chapter 12 offers new illustrations of the inner ear.

Chapter 13 provides a new illustration and a new table that compare the nervous and endocrine systems and highlights the importance of target cells.

Chapter 14 introduces the topic of blood with a new vignette on blood substitutes.

Chapter 15 provides added and expanded information on the control of blood pressure; end-diastolic volume, end-systolic volume, and preload. A new vignette on defibrillator implants opens the chapter.

Chapter 16 presents a new section on *Natural Killer Cells (NK)*, includes expanded information on MHC classes, and a new table on the comparison of T cells and B cells. The topic of peanut allergies is featured in the chapter-opening vignette.

Chapter 17 *From Science to Technology 17.1* features a new reading on liver replacement, and the introductory chapter vignette covers a brief history of constipation.

Chapter 18 features an expanded section on appetite control and a new vignette on preventing vitamin D deficiency.

Chapter 20 has improved art pieces presenting kidney anatomy, the countercurrent mechanism, and the mechanism of urine concentration.

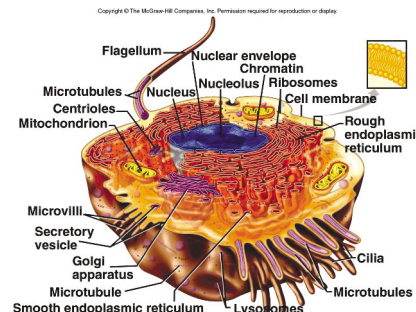
Chapter 23 presents a new vignette on multiple births and a new table on the stages and events of early human prenatal development. Pregnancy, the birth process and milk production are now included in this chapter.

Chapter 24 provides an update on human genome sequencing results and chromosomal abnormalities.

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## Teaching and Learning Supplements

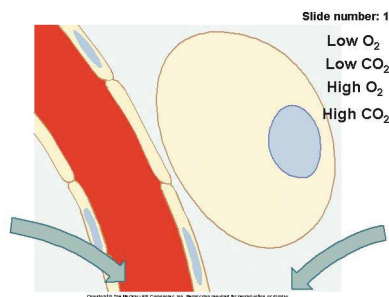
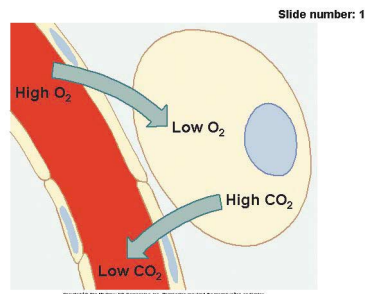
McGraw-Hill offers various tools and teaching products to support the tenth edition of *Hole's Human Anatomy & Physiology*. Students can order supplemental study materials by contacting your local bookstore. Instructors can obtain teaching aids by calling the Customer Service Department at 800-338-3987, visiting our A&P website at [www.mhhe.com](http://www.mhhe.com), or contacting your local McGraw-Hill sales representative.



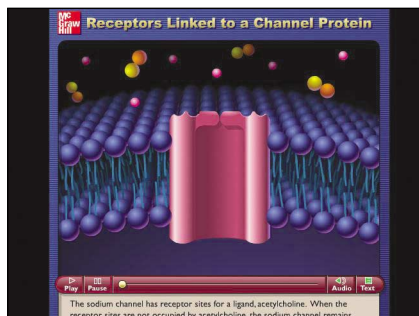
The **Digital Content Manager**, 0-07-243895-9, is a multimedia collection of visual resources that



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 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 24 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 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,***

0-07-282738-6, 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, format, or difficulty level; edit existing questions or add new ones; and scramble questions and answer keys for multiple versions of the same test.

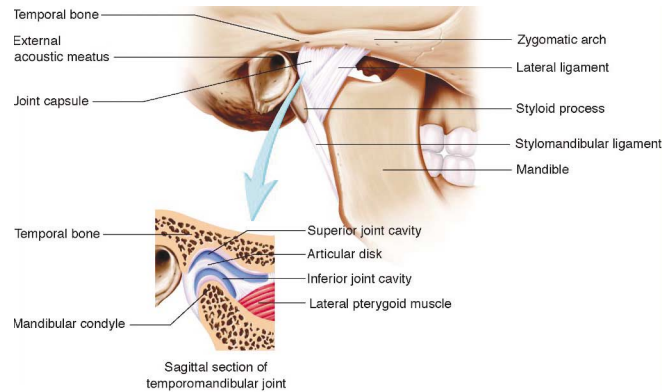
Other assets on the Instructor's Testing and Resource CD-ROM are grouped within easy-to-use folders. The Instructor's Manual and the Instructor's Manual to accompany the Laboratory Manual are available in both Word and PDF formats. Word files of the test bank are included for those instructors who prefer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

The ***Instructor's Manual***, by 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 through the Instructor Resources of the Online Learning Center and the Instructor Testing and Resource CD-ROM.

McGraw-Hill provides **Overhead Transparencies, Labeled** 0-07-243894-0, of all text line art and numerous photos and **Unlabeled** 0-07-284222-9, of key line art and photos.

***English/Spanish Glossary for Anatomy and Physiology,*** 0-07-283118-9, is a complete glossary that includes every key term used in a typical two-semester

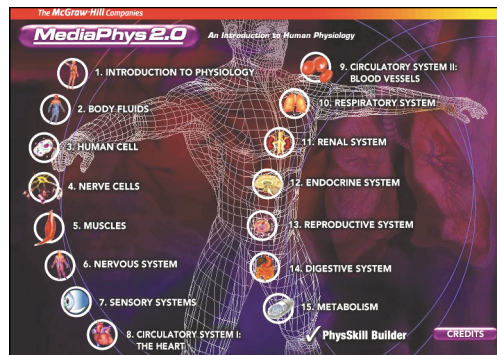
anatomy and physiology course. Definitions are provided in both English and Spanish. A phonetic guide to pronunciation follows each word in the glossary.



***A Visual Guide for Anatomy and Physiology***, 0-07-286378-1, is a visual atlas containing key gross anatomy illustrations that have been enlarged in size to make it easier for students to learn anatomy.

**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. *Hole's Human Anatomy & Physiology* Online Learning Center is available within all of these platforms.

## For the Student



### MediaPhys 2.0 CD-ROM

This interactive tool offers detailed explanations, high quality illustrations and animations to provide students with a thorough introduction to the world of physiology—giving them a virtual tour of physiological processes. MediaPhys is filled with interactive activities and quizzes to help reinforce physiology concepts that are often difficult to understand.

### Online Learning Center (<http://www.mhhe.com/shier10>)

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

- **Live News Feeds**

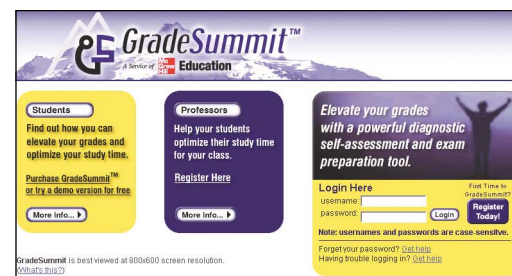
The OLC offers course specific real-time news articles to help students stay current with the latest topics in anatomy and physiology.

- **Tutorial Service**

This free “homework hotline” offers students the opportunity to discuss text questions with our A&P consultant.

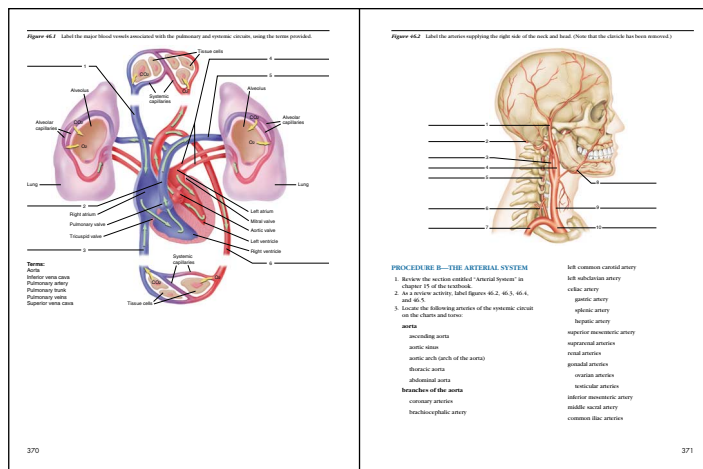
- **GetBody Smart.com** is an online examination of human anatomy and physiology.

- **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.

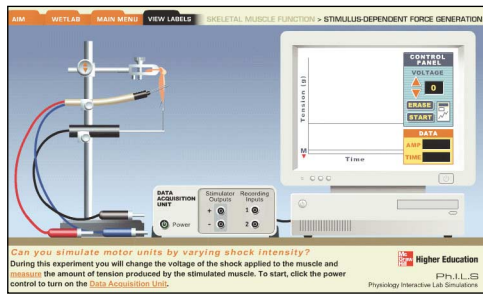


### GradeSummit ([www.gradesummit.com](http://www.gradesummit.com))

This Internet-based self-assessment service provides students and instructors with diagnostic information about subject strengths and weaknesses. This detailed feedback and direction enables learners and teachers to focus study time on areas where it will be most effective. GradeSummit also enables instructors to measure their students’ progress and assess that progress relative to others in their classes and worldwide.



The **Laboratory Manual for Hole's Human Anatomy & Physiology**, Tenth Edition, 0-07-243891-6, by Terry R. Martin, Kishwaukee College  
This lab manual is designed to accompany the tenth edition of *Hole's Human Anatomy and Physiology*.



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

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.

### Student Study Guide, 0-07-243893-2, by Nancy A.

Sickles Corbett contains chapter overviews, chapter objectives, focus questions, mastery tests, study activities, and mastery test answers.

### Anatomy and Physiology Laboratory Manual—Fetal Pig,

Second Edition, 0-07-243814-2, 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.



### 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.

### 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.

### 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.

## Acknowledgments

Any textbook is the result of hard work by a large team. Although we directed the revision, many “behind-the-scenes” people at McGraw-Hill were indispensable to the project. We would like to thank our editorial team of Michael Lange, Marty Lange, Kris Tibbetts, Michelle Watnick, and Pat Hesse; our production team, which included Jayne Klein, Sandy Ludovissy, Wayne Harms, John Leland, Sandy Schnee, Barb Block; Joanne Bales, art director, Precision Graphics; and most of all, John Hole, for giving us the opportunity and freedom to continue his classic work. We also thank our wonderfully patient families for their support.

David Shier

Jackie Butler

Ricki Lewis

## Reviewers

We would like to acknowledge the valuable contributions of all professors and their students who have provided detailed recommendations for improving chapter content and illustrations throughout the revision process for each edition. Hundreds of professors from the U.S., Canada, and Europe have played a vital role in building a solid foundation for *Hole's Human Anatomy & Physiology*.

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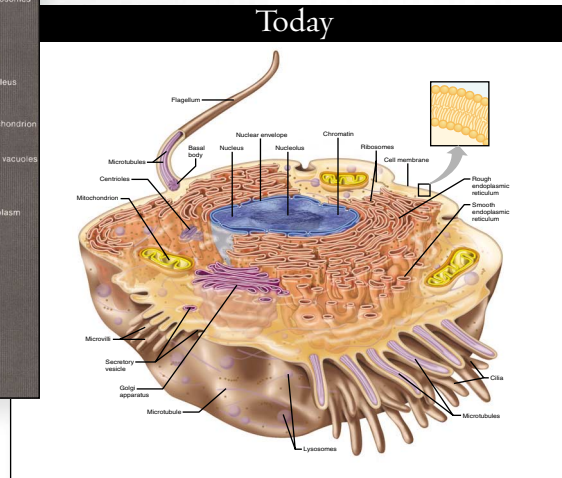
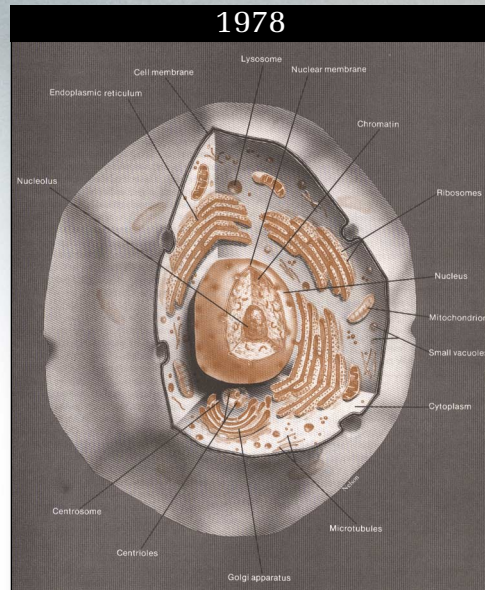
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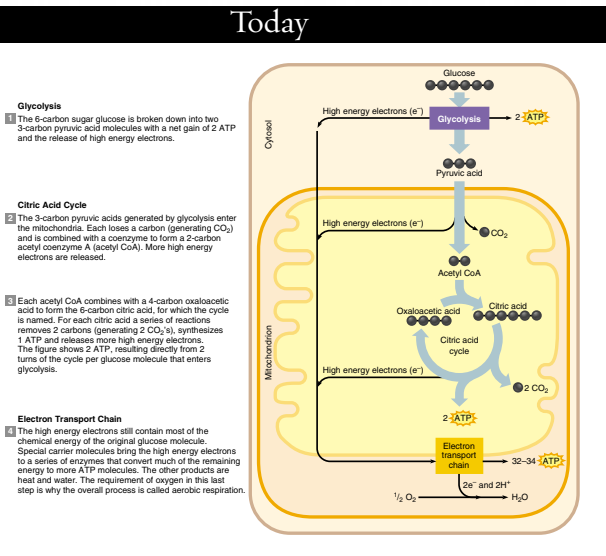
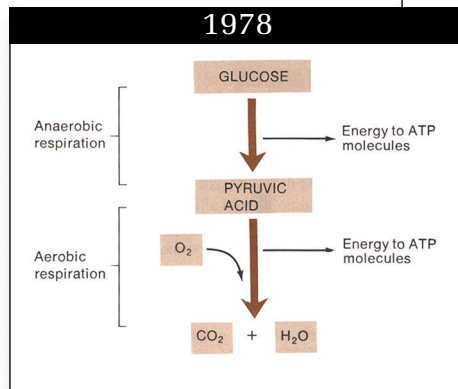
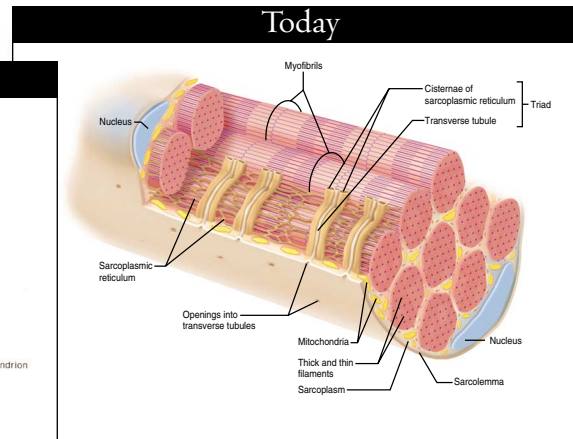
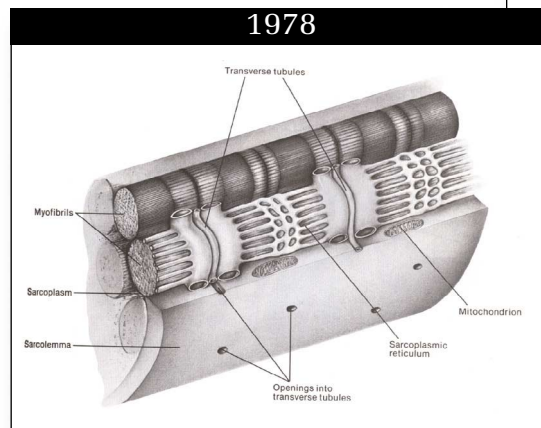
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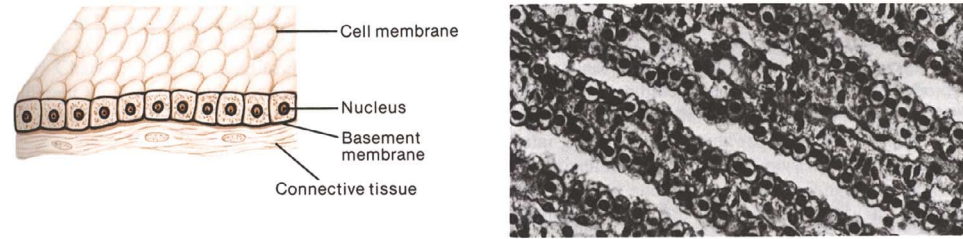
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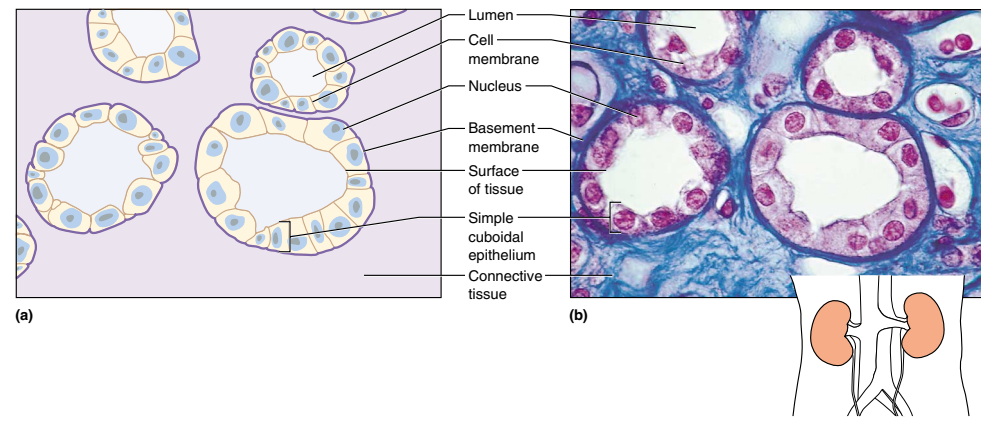
# ART PROGRAM

Correlation of  
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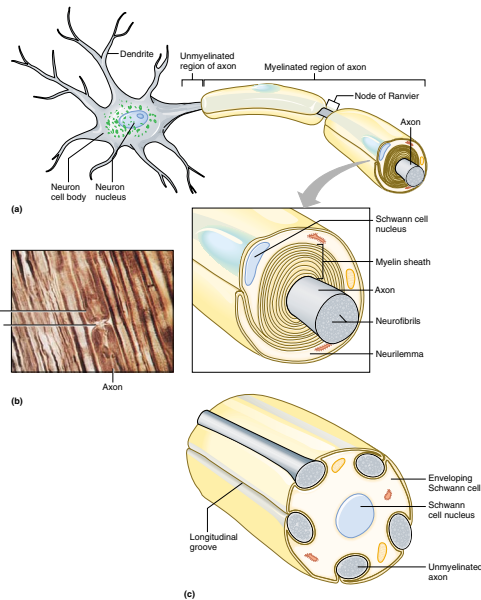
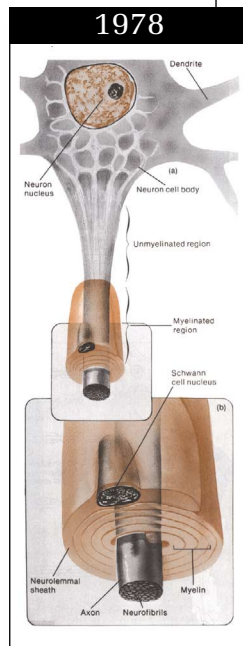
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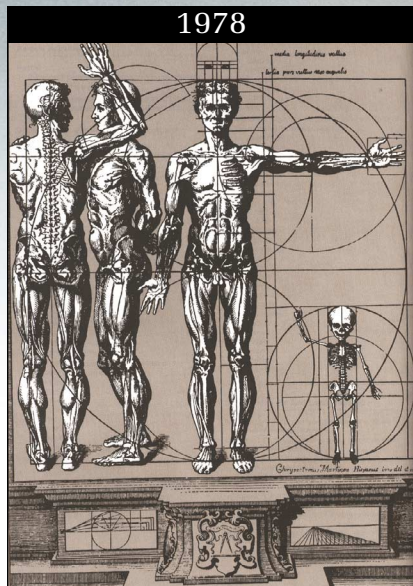
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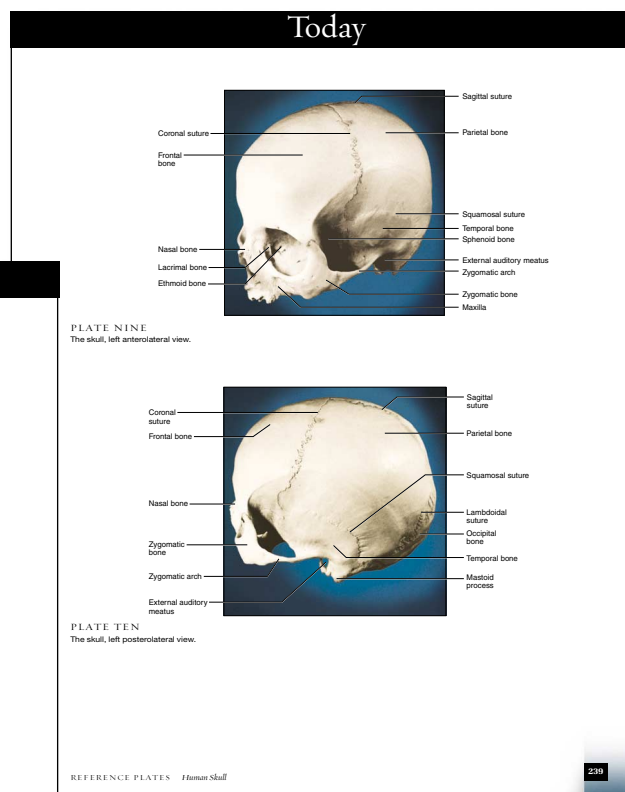
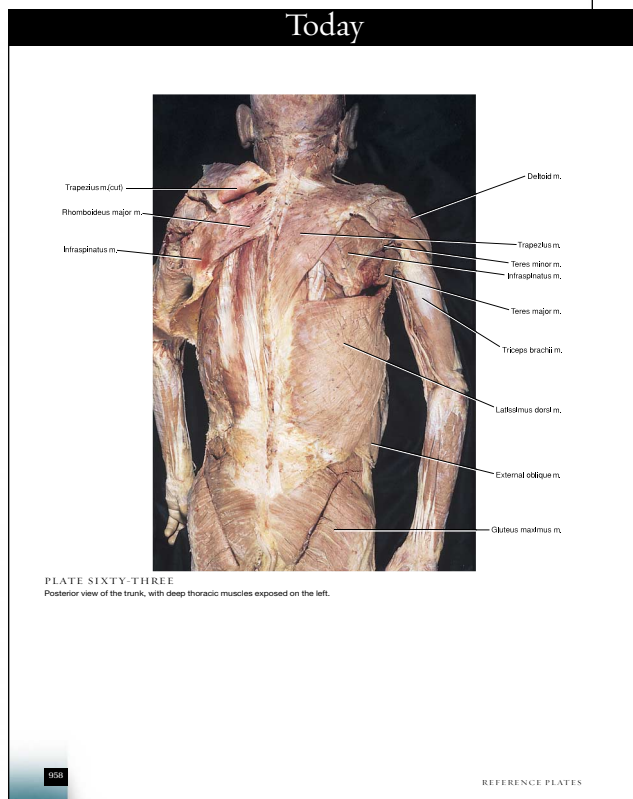
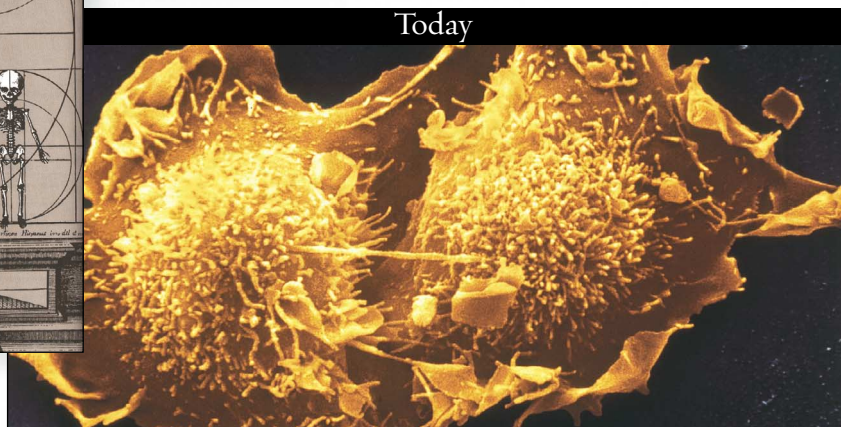


Macroscopic to  
Microscopic Presentation  
makes the connection between gross  
anatomy and microscopic anatomy.



Dynamic Chapter Opener Photos

give students a closer look inside the wonders of the human body through the technology of scanning electron micrographs, endoscopic photography, and immunofluorescent light micrographs.



Reference Plates

of the human skull and the human cadaver have been added over the years to give students an additional reference in the study of body structure.

# CLINICAL CONNECTIONS

Textbooks provide a foundation of facts, viewpoints, and overviews. They sequence information and facts to understand issues and create a context for comparing and understanding other sources.

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

In 1978, John Hole integrated short, boxed readings within the text to help students apply the ideas presented in the narrative to clinical situations. Today, because the author team recognizes the vital role clinical connections play in bridging the gap between facts and real life, they have integrated several engaging formats.

**C**ells aggregate to form tissues, and tissues interact to form organs. Dissecting a complex organ to observe how tissues comprise it is a commonly performed exercise; attempting to build an organ from its component cells and tissues is much more challenging.

The field of tissue engineering uses cells, synthetic materials, or combinations of them to fashion human body parts. Consider the task facing Nicolas L'Heureux, who recreated a small-diameter human blood vessel when a graduate student. Such a vessel has three layers: an innermost layer of like endothelial cells that secrete anti-clotting agents, a middle layer of smooth muscle and elastic connective tissue, and an outer layer of fibroblasts and the collagen protein they secrete.

Previous attempts at producing a small blood vessel combined natural and synthetic ingredients in various ways, with mixed results. The goal is to keep the inner lining smooth enough to prevent blood clots from forming, but construct outer layers that are strong enough to keep the vessel open under the pressure of circulating blood. The trick, L'Heureux found, was to let the cells do the work—with a little help.

L'Heureux and his co-workers grew fibroblasts and smooth muscle cells in sheets. They then rolled the sheets around tubes through which nutrients circulated in, and cellular wastes circulated out. Then the researchers seeded endothelial cells onto the inner surface, where the cells laid a smooth inner lining. By allowing the fibroblasts to secrete the collagen, rather than supplying the protein directly, the vessels formed in a more natural way and persisted. Blood vessels engineered in this way may eventually be used to treat patients who need vascular grafts in their legs or new vessels.

In all complex organisms, cells are organized into layers or groups called **tissues**. Although the cells of different tissues vary in size, shape, arrangement, and function, those within a tissue are quite similar.

**RECONNECT TO CHAPTER 3. INTERCELLULAR JUNCTIONS, PAGE 67.**

Usually, tissue cells are separated by nonliving, intercellular materials that the cells produce. These intercellular materials vary in composition from one tissue to another and may be solid or liquid. For example, a solid (mineral) separates bone cells, whereas a liquid (plasma) separates blood cells.

The tissues of the human body include four major types: **epithelial, connective, muscle, and nervous**. Each type of tissue has specialized functions. Table 5.1 compares the four major tissue types.

One of the ways that cancer cells spread is by secreting a substance that dissolves basement membranes. This enables cancer cells to invade adjacent tissue layers. Cancer cells also produce fewer adhesion proteins, or none at all, which allows them to invade surrounding tissue.

Epithelial tissue is anchored to connective tissue by a thin layer called the **basement membrane**.

Type	Function	Location
Epithelial	Protection, secretion, absorption, excretion	Cover body surface, cover and line internal organs, compose glands
Connective	Bind, support, protect, fill spaces, store fat, produce blood cells	Widely distributed throughout the body
Muscle	Movement	Attached to bones, in the walls of hollow internal organs, heart
Nervous	Transmit impulses for coordination, regulation, integration, and sensory reception	Brain, spinal cord, nerves

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## Chapter Opening Vignettes

introduce each topic. Taken from headlines and scientific journal reports, they extend the students' view of the chapter content.

## Boxed Information

continues to connect chapter ideas to clinical situations, discusses changes in organ structure and function, and introduces new medical technology or experiments.

## From Science to Technology

previews the technological applications of knowledge in anatomy and physiology that students are likely to encounter in the future and explains how and why the technology was developed.

## 5.1

### FROM SCIENCE TO TECHNOLOGY

#### TISSUE ENGINEERING

If an automobile or appliance part is damaged or malfunctions, replacing it is fairly simple. Not so for the human body. To replace a human body part, biomedical engineers must first learn how to replicate the combination of cells, biochemicals, and intercellular materials that comprise tissues and organs. Then physicians must dampen the immune response sufficiently for the body to accept the replacement. A solution to the challenge of replacing body parts is **tissue engineering**, which combines synthetic materials with cells.

The basic recipe for a bioengineered tissue is to place cells in or on a scaffolding sculpted from a synthetic material that is accepted in the body. The cells secrete substances as they normally would, or they may be genetically altered to overproduce

their natural secreted products or supply entirely different ones with therapeutic benefit, such as growth factors that might make the implant more acceptable to the body.

#### New Skin and More

Burn patients can sometimes be helped by a bioengineered skin consisting of the patient's epidermal cells placed in sheets over dermal cells grown in culture. A nylon mesh framework supports both layers. This semisynthetic skin may also be useful for patients who have lost a great deal of skin in surgery to remove tattoos, cancers, or moles. Bioengineered skin is also used for *in vitro* toxicity testing. In many laboratories, it has replaced live animals in testing cosmetic ingredients. A replacement cartilage similar to the skin recipe, consisting of

chondrocytes in collagen, may help replace joints destroyed by arthritis.

A scaled-down version of an engineered tissue, called a cell implant, offers a new route to drug delivery, placing cells that naturally manufacture vital substances precisely where a patient needs them. The cells are packaged so that they secrete without altering the immune system. The cells of the implant are surrounded with a polymer membrane with holes small enough to allow nutrients in and the therapeutic biochemicals out, while excluding the larger molecules that trigger immune rejection.

Prime candidates for cell implants are pancreatic beta cells, which would secrete insulin to aid people with diabetes mellitus. Brain implants would secrete dopamine, providing the biochemical that is deficient in people who have Parkinson disease. ■

stratified squamous epithelium lines the oral cavity, pseudostratified columnar epithelium lines part of the nasal cavity, and simple columnar epithelium lines the small intestine. Goblet cells within a mucous membrane secrete **mucus**.

The **cutaneous (ku-'tu-'fo-us) membrane** is an organ of the integumentary organ system and is more commonly called **skin**. It is described in detail in the next chapter.

1 Name the four types of membranes, and explain how they differ.

#### CHAPTER SUMMARY

##### Introduction (page 132)

Cells are organized in layers or groups to form tissues. Intercellular materials, varying from solid to liquid, separate cells. The four major types of human tissue are epithelial tissues, connective tissues, muscle tissues, and nervous tissues.

##### Epithelial Tissues (page 133)

- General characteristics
  - Epithelial tissue covers all free body surfaces and is the major tissue of glands.
  - A basement membrane anchors epithelium to connective tissue. Epithelial tissue lacks blood vessels, contains little intercellular material, and is continuously replaced.
  - If functions in protection, secretion, absorption, and excretion.
- Simple squamous epithelium
  - This tissue consists of a single layer of thin, flattened cells through which substances pass easily.

- If functions in the exchange of gases in the lungs and lines blood vessels, lymph vessels, and membranes within the thorax and abdomen.
- Simple cuboidal epithelium
  - This tissue consists of a single layer of cube-shaped cells.
  - It carries on secretion and absorption in the kidneys and various glands.
- Simple columnar epithelium
  - This tissue is composed of elongated cells whose nuclei are near the basement membrane.
  - It lines the uterus and digestive tract, where it functions in protection, secretion, and absorption.
  - Absorbing cells often possess microvilli.
  - This tissue usually contains goblet cells that secrete mucus.
- Pseudostratified columnar epithelium
  - This tissue appears stratified because the nuclei are at two or more levels.

## 11.5

## CLINICAL APPLICATION

## PARKINSON DISEASE

Actor Michael J. Fox was only 29 years old when he consulted a physician about a mysterious twitch in a finger. Fox, veteran of two hit television comedies and a long list of films, was shocked to receive a diagnosis of Parkinson disease, a condition that usually begins much later in life. He was one of the ten percent of the millions of people with Parkinson disease worldwide to experience symptoms before age forty.

Fox kept his diagnosis to himself, but by the late 1990s, his co-workers began to notice symptoms that emerged when medication wore off—rigidity, a shuffling and off-balance gait, and poor small motor control. It was difficult to ignore Fox's expressionless, mask-like face, a characteristic of Parkinson disease called hypomimia. Most frustrating to Fox was his worsening ability to communicate. His voice became so weakened that it took a huge effort to speak, a symptom called hypophonia. When he could speak, he found that even though his brain could string thoughts into coherent sentences, the muscles of his jaw, lips, and tongue could not utter them. Oddest of all was micrographia, the tendency of his handwriting to become extremely small.

Parkinson disease also causes the sensation of not being able to stay in one spot.

By 1998, chased by relentless tabloid reporters eager to expose his illness, Fox publicly disclosed his condition. He continued to act on his television program Spin City, but in 2000, he quit, and began the Michael J. Fox Foundation for Parkinson's Research, which provides rapid funding for research into curing the disease. Today he continues to testify before Congress about the potential benefits of stem cell research and therapy, which he calls "the gateway" to curing Parkinson and other neurodegenerative disorders.

In Parkinson disease, neurons in the basal nuclei that synthesize the neurotransmitter dopamine degenerate. The resulting deficiency of dopamine in the striatum causes the motor symptoms. In some patients, non-motor symptoms develop too, including depression, dementia, constipation, incontinence, sleep problems, and orthostatic hypotension (dizziness upon standing).

No treatments can cure or slow the course of Parkinson disease, but replacing or enhancing utilization of dopamine can temporarily alleviate symptoms. The stan-

dard treatment for many years has been levodopa, which is a precursor to dopamine that can cross the blood-brain barrier. Once in the brain, levodopa is converted to dopamine. Fox takes levodopa so that he can do interviews without jumping around constantly. The medication allows him to live normally for short periods—riding bikes with his wife, or fishing with his son. But always, too soon, he begins to feel the tell-tale twitches, rigidity, and vibrations, and knows that the symptoms have returned.

Drug treatment for Parkinson disease is temporary, and becomes less effective over time. The brain becomes dependent on the external supply of dopamine and decreases its own production further, so that eventually higher doses of levodopa are needed to achieve the effect. Unfortunately, taking too much levodopa leads to another condition, called tardive dyskinesia, that produces uncontrollable facial tics and spastic extensions of the limbs. Tardive dyskinesia may result from effects of excess dopamine in areas other than those affected in Parkinson disease.

Surgery can alleviate Parkinson's

It surrounds the third ventricle and is largely composed of gray matter. Within the diencephalon, a dense mass, called the **thalamus** (thal'ah-mus), bulges into the third ventricle from each side. Another region of the diencephalon that includes many nuclei is the **hypothalamus** (hi'po-thal'ah-mus). It lies below the thalamic nuclei and forms the lower walls and floor of the third ventricle (see reference plates 49 and 53).

Other parts of the diencephalon include (1) the **optic tracts** and the **optic chiasma** that is formed by the optic nerve fibers crossing over; (2) the **infundibulum**, a conical process behind the optic chiasma to which the pituitary gland is attached; (3) the **posterior pituitary gland**, which hangs from the floor of the hypothalamus; (4) the **mammillary** (mam'til'er'e) **bodies**, which are two rounded structures behind the infundibulum; and (5) the **pineal gland**, which forms as a cone-shaped evagination from the roof of the diencephalon (see chapter 13, p. 000).

The thalamus impulses ascend to the cerebral cortex (except those that descend to the thalamus).

The thalamus by synchronizing activity on the nucleus (LGN) action potential have observed a rise—that is, it rises only if the stimulus is strong enough to trigger an action potential.

life, bone matrix is removed faster than it is laid down. By age thirty-five, all of us start to lose bone mass.

Trabecular bone, due to its spongy, less compact nature, shows the changes of aging first, as they thin, increasing in porosity and weakening the overall structure. The vertebrae consist mostly of trabecular bone. It is also found in the upper part of the femur, whereas the shaft is more compact bone. The fact that trabecular bone weakens sooner than compact bone destabilizes the femur, which is why it is a commonly broken bone among the elderly.

Compact bone loss begins at around age forty and continues at about half the rate of loss of trabecular bone. As remodeling continues throughout life, older osteons disappear as new ones are built next to them. With age, the osteons may coalesce, further weakening the overall structures as gaps form.

Bone loss is slow and steady in men, but in women, it is clearly linked to changing hormone levels. In the first decade following menopause, 15 to 20% of trabecular bone is lost, which is two to three times the rate of loss in men and premenopausal women. During the same time, compact bone loss is 10 to 15%, which is three to four times the rate of loss in men and premenopausal women. By about age seventy, both sexes are losing bone at about the same rate. By very old age, a woman may have only half the trabecular and compact bone mass as she did in her twenties, whereas a very elderly man may have one-third less bone mass.

Falls among the elderly are common and have many causes (see table 7.13). The most common fractures, after vertebral compression and hip fracture, are of the wrist, leg, and pelvis. Aging-related increased risk of fracture usually begins at about age fifty. Because healing is slowed, pain from a broken bone may persist for months. Preserving skeletal health may involve avoiding falls, taking calcium supplements, getting enough vitamin D, avoiding carbonated beverages (phosphates deplete bone), and getting regular exercise.

- Why is bone lost faster, with aging, than bone replacement?
- In which bones do fractures most commonly occur in the elderly?

**TABLE 7.13** Reasons for Falls Among the Elderly

Overall frailty
Decreased muscle strength
Decreased coordination
Side effects of medication
Slowed reaction time due to stiffening joints
Poor vision and/or hearing
Disease (cancer, infection, arthritis)

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## Clinical Applications

encourage students to explore information on related pathology, historical insights, and clinical examples that they are likely to encounter in their careers.

## Clinical Terms Related to the Skeletal System

**achondroplasia** (a-kon'dro-pla'ze-ah) Inherited condition that retards formation of cartilaginous bone. The result is a type of dwarfism.

**acromegaly** (ak'tro-meg'ah-le) Abnormal enlargement of facial features, hands, and feet in adults as a result of overproduction of growth hormone.

**Colles fracture** (kol'sez-frak'tiir) Fracture at the distal end of the radius that displaces the smaller fragment posteriorly.

**epiphysiolysis** (ep'i-fiz'i-ol'i'tis) Separation or loosening of the epiphysis from the diaphysis of a bone.

**laminectomy** (lan'm-ank-to-me) Surgical removal of the posterior arch of a vertebra, usually to relieve symptoms of a ruptured intervertebral disc.

**lumbago** (lum-ba'go) Dull ache in the lumbar region of the back.

**orthopedics** (or'tho-pe'diks) Medical specialty that prevents, diagnoses, and treats diseases and abnormalities of the skeletal and muscular systems.

**ostealgia** (os'te-al'jeh-ah) Pain in a bone.

**osteotomy** (os'te-to-me) Surgical removal of a bone.

**osteitis** (os'te-i'tis) Inflammation of bone tissue.

**osteochondritis** (os'te-o-kon-dri'tis) Inflammation of bone and cartilage tissues.

**osteogenesis** (os'te-o-je-n'e-sis) Bone development.

**osteogenesis imperfecta** (os'te-o-je-n'e-sis im-per-fek'ta) Inherited condition of deformed and abnormally brittle bones.

**osteoma** (os'te-o'mah) Tumor composed of bone tissue.

**osteomalacia** (os'te-o-mah-la'she-ah) Softening of adult bone due to a disorder in calcium and phosphorus metabolism, usually caused by vitamin D deficiency.

**osteomyelitis** (os'te-o-mi-'l'i-tis) Bone inflammation caused by the body's reaction to bacterial or fungal infection.

**osteonecrosis** (os'te-o-ne-kro'sis) Death of bone tissue. This condition most commonly occurs in the femur head in elderly persons and may be due to obstructed arteries supplying the bone.

**osteopathology** (os'te-o-pah-thol'o-je) Study of bone diseases.

**osteopenia** (os'te-o-pe-ni-ah) Decrease in bone mass due to reduction in rate of bone tissue formation.

**osteoporosis** (os'te-o-po-ro'sis) Decreased bone mineral content.

**osteotomy** (os'te-o'to-me) Cutting a bone.

## UNIT TWO

primarily long, slender, bones of the lower limbs.

An infant with two casts on her feet is probably being treated for clubfoot, a very common birth defect in which the foot twists out of its normal position, turning in, out, up, down, or some combination of these directions. Clubfoot probably results from arrested development during fetal existence, but the precise cause is not known. Clubfoot can almost always be corrected with special shoes, or surgery, followed by several months in casts to hold the feet in the correct position.

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

## Life-Span Changes

Aging-associated changes in the skeletal system are apparent at the cellular and whole-body levels. Most obvious is the incremental decrease in height that begins at about age thirty, with a loss of about 1/16 of an inch a year. In the later years, compression fractures in the vertebrae may contribute significantly to loss of height (fig. 7.57). Overall, as calcium levels fall and bone material gradually vanishes, the skeleton loses strength, and the

## Clinical Terms

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

Pelvic Girdle and Lower Limbs	
	<b>Special Features</b>
leg with the other coxal bone with the sacrum posteriorly in hip and knee	Ilium, iliac crest, anterior superior iliac spine, ischium, ischial tuberosity, ischial spine, obturator foramen, acetabulum, pubis
of knee	Head, fovea capitis, neck, greater trochanter, lesser trochanter, linea aspera, lateral condyle, medial condyle, gluteal tuberosity, intercondylar fossa
leg, between knee and ankle	A flat, saucer-shaped bone located within a tendon
leg, between knee and ankle	Medial condyle, lateral condyle, tibial tuberosity, anterior crest, medial malleolus, intercondylar eminence
	Head, lateral malleolus
	Freely movable talus that articulates with leg bones; calcaneus that forms the base of the heel; five other tarsal bones bound firmly together
	One in line with each toe, arranged and bound by ligaments to form arches
	Three in each toe, two in great toe

by three phalanges—a phalanx—except the middle one, which has two



**FIGURE 7.57**  
The bones change to different degrees and at different rates over a lifetime.

bones become brittle and increasingly prone to fracture. However, the continued ability of fractures to heal reveals that the bone tissue is still alive and functional.

Components of the skeletal system and individual bones change to different degrees and at different rates over a lifetime. Gradually, osteoclasts come to outnumber osteoblasts, which means that bone is eaten away in the remodeling process at a faster rate than it is replaced—resulting in more spaces in bones. The bone thins, its strength waning. Bone matrix changes, with the ratio of mineral to protein increasing, making bones more brittle and prone to fracture. Beginning in the third decade of

## Life-Span Changes

There is no escaping the fact that aging is a part of life. Because our organs and organ systems are interrelated, aging-related changes in one influence the functioning of others. These readings chart the changes specific to particular organ systems.

# LEARNING SYSTEM

This text evolved because John W. Hole, Jr. had the desire and vision to provide the best possible anatomy and physiology text for his students. The pedagogical elements created were the key to engaging students and involving them actively in the learning process. With each edition, the current authors continue to include, expand, and improve upon the learning system features that define this text.

## Understanding Words

includes *root words, stems, prefixes, and suffixes* revealing word meanings and origins. Knowing the roots from these lists help students remember scientific word meanings and understand new terms.

## Chapter Objectives

provide a glimpse ahead to important sections of the narrative. They indicate what the student should be able to do after mastering the chapter content.

### CHAPTER 7

## Skeletal System

**UNDERSTANDING WORDS**

**ax,** axis: axial skeleton—upright portion of the skeleton that supports the head, neck, and trunk.

**-blast,** blast: a growing organism in early stages; osteoblast—cell that will form bone tissue.

**canal,** channel: canaliculus—tubular passage.

**carp,** wrist: carpal—wrist bones.

**-clast,** break: osteoclast—cell that breaks down bone tissue.

**clav,** bar: clavicle—bone that articulates with the sternum and scapula.

**candy,** knob, knoblike: condyle—rounded, bony process.

**corac,** a crow's beak: coracoid process—hooklike process of the scapula.

**cribr,** sieve: cribriform plate—portion of the ethmoid bone with many small openings.

**crest,** crest: crista galli—bony ridge that projects upward into the cranial cavity.

**fav,** pit: fovea capitis—pit in the head of a femur.

**glen,** joint socket: glenoid cavity—depression in the scapula that articulates with the head of a humerus.

**inter,** among: intervertebral disc—structure located between adjacent vertebrae.

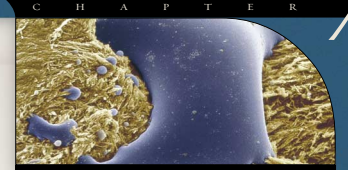
**intra,** inside: intramembranous bone—bone that forms within sheetlike masses of connective tissue.

**lamell,** thin plate: lamella—thin bony plate.

**meat,** passage: auditory meatus—canal of the temporal bone that leads inward to parts of the ear.

**odont,** tooth: odontoid process—toothlike process of the second cervical vertebra.

**poie,** make, produce: hematopoiesis—process by which blood cells are formed.



An osteoclast (blue) is a type of bone cell that removes old bone tissue, thereby playing a vital role in the remodeling of this tissue. Colored scanning electron micrograph (SEM).

**CHAPTER OBJECTIVES**

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

1. Classify bones according to their shapes and name an example from each group.
2. Describe the general structure of a bone and list the functions of its parts.
3. Distinguish between intramembranous and endochondral bones and explain how such bones grow and develop.
4. Describe the effects of sunlight, nutrition, hormonal secretions, and exercise on bone development.
5. Discuss the major functions of bones.
6. Distinguish between the axial and appendicular skeletons and name the major parts of each.
7. 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.
8. Describe life-span changes in the skeletal system.

## Key Terms and Pronunciations

anchor the students' understanding of anatomy and physiology. The bold face terms found throughout the narrative are key to building a solid science vocabulary.

### Microscopic Structure

Recall from chapter 5 (p. 148) that bone cells called **osteocytes** (os'tee-oh-sit) are located in tiny, bony chambers called **lacunae**, which form concentric circles around central canals (Haversian canals). Osteocytes transport nutrients and wastes to and from nearby cells by means of cellular processes passing through canaliculi. The intercellular material of bone tissue is largely collagen and inorganic salts. Collagen gives bone its strength and resilience, and inorganic salts make it hard and resistant to bending.

### Compact Bone

In compact bone, the osteocytes and layers of intercellular material concentrically cluster around a central canal form a cylinder-shaped unit called an **osteon** (os'tee-on), sometimes called an Haversian system (fig. 7.4). Many of these units cemented together form the substance of compact bone (fig. 7.5). The orientation of the osteons resists compressive forces.

Each central canal contains blood vessels and nerve fibers surrounded by loose connective tissue. Blood in these vessels nourishes bone cells associated with the central canal via gap junctions between osteocytes.

Central canals pervade bone tissue longitudinally. Transverse **perforating canals** (Volkmann's canals) interconnect them. These canals contain larger blood vessels and nerves that allow the smaller blood vessels and nerve cell processes in the osteonic canals to communicate with the surface of the bone and the medullary cavity (see fig. 7.4).

### Spongy Bone

Spongy bone is also composed of osteocytes and intercellular material, but the bone cells do not aggregate around central canals. Instead, the cells lie within the trabeculae and get nutrients from substances diffusing into the canaliculi that lead to the surface of these thin, bony plates.

Severe bone pain is a symptom of sickle cell disease, which is inherited. Under low oxygen conditions, abnormal hemoglobin (an oxygen-carrying protein) bends the red blood cells that contain it into a sickle shape, which obstructs circulation. X rays can reveal blocked arterial blood flow in bones of sickle cell disease patients.

1. Explain how bones are classified.
2. List five major parts of a long bone.
3. How do compact and spongy bone differ in structure?
4. Describe the microscopic structure of compact bone.

## 6.3

### CLINICAL APPLICATION

#### ACNE

Many young people are all too familiar with **acne vulgaris**, a disorder of the **sebaceous glands**. Excess sebum and squamous epithelial cells clog the glands, producing blackheads and whiteheads (comedones). The blackness is not dirt but results from the accumulated cells blocking light. In addition, the clogged sebaceous gland provides an attractive environment for anaerobic bacteria that signals the immune system to trigger inflammation. The inflamed, raised area is a **pimple** (pustule).

**A Hormonal Problem**  
Acne is the most common skin disease, affecting 80% of people at some time between the ages of eleven and thirty. It is largely hormonally induced. Just before puberty, the adrenal glands increase production of androgens, which stimulate increased secretion of sebum. At puberty, sebum production surges again. Acne usually develops because the sebaceous glands are extra responsive to androgens, but in some cases, androgens may be produced in excess.

Acne can cause skin blemishes far more serious than the perfect models in acne medication ads depict (fig. 62). Scarring from acne can lead to emotional problems. Fortunately, several highly effective treatments are available.

**What to Do—And Not Do**  
Acne is not caused by underactivity or eating too much chocolate or greasy food. Although cleansing products containing soaps, detergents, or astringents can remove surface sebum, they do not stop the flow of oil that contributes to acne. Abrasive products are actually harmful because they irritate the skin and increase inflammation.

Several acne treatments are available, but most take weeks to months to work. Women with acne are sometimes prescribed birth control pills because the estrogens counter androgen excess. Other drugs with estrogenic effects are available in Europe but not in the United States or Canada. Isotretinoin is a derivative of vitamin A that helps nearly all people achieve relief or even permanent cures, but it has several side effects and causes birth defects. Systemic antibiotics can treat acne by clearing bacteria from sebaceous glands. Topical treatments include tretinoin (another vitamin A derivative), salicylic acid (an aspirin solution), and benzoyl peroxide. Treatment for severe acne requires a doctor's care. Drug combinations are tailored to the severity of the condition (table 6A).



**FIGURE 6D**  
Acne is a common skin condition usually associated with a surge of androgen activity—not eating chocolate, as was once believed.

**TABLE 6A** Acne Treatments (By Increasing Severity)

Condition	Treatment
Noninflammatory comedonal acne (blackheads and whiteheads)	Topical tretinoin or salicylic acid
Peppery inflammatory acne	Topical antibiotic
Widespread blackheads and pustules	Topical tretinoin and systemic antibiotic
Severe cysts	Systemic isotretinoin
Explosive acne (scarred lesions, fever, joint pain)	Systemic corticosteroids

### Regulation of Body Temperature

The regulation of body temperature is vitally important because even slight shifts can disrupt the rates of metabolic reactions. Normally, the temperature of deeper body parts remains close to a set point of 37°C (98.6°F). The maintenance of a stable temperature requires that the amount of heat the body loses be balanced by the amount it produces. The skin plays a key role in the homeostatic mechanism that regulates body temperature.

RECONNECT WITH  
CHAPTER 1.  
HOMEOSTASIS. PAGE 10.

#### Heat Production and Loss

Heat is a product of cellular metabolism; thus, the more active cells of the body are the major heat producers. These cells include skeletal and cardiac muscle cells and the cells of certain glands, such as the liver.

When body temperature rises above the set point, nerve impulses stimulate structures in the skin and other

## Tables

are designed to organize and summarize sections of the narrative and to present pertinent data.

## Reconnect Icon

prompts the student to review key concepts found in previous chapters that will promote their understanding of new information.

## Review Questions

occur at the ends of major sections within each chapter. They challenge students to test their mastery of the concepts before moving on to additional topics.

## InnerConnections

conceptually link the highlighted body system to every other system. These graphic representations review chapter concepts, make connections, and stress the “big picture” in learning and applying the concepts and facts of anatomy and physiology.

**INNER CONNECTIONS**  
SKELETAL SYSTEM

**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 penis helps support the uterus during pregnancy. Bone may provide a source of calcium during lactation.

**SKELETAL SYSTEM**  
Bones, cartilages, and ligaments also play a role in calcium balance.

CHAPTER SEVEN Skeletal System

## Chapter Summary

provides an outline for the students to use during review of the major ideas presented in the chapter and as a tool in organizing their thoughts.

**CHAPTER SUMMARY**

**Introduction (page 182)**  
Individual bones are the organs of the skeletal system. A bone contains very active tissues.

**Bone Structure (page 182)**  
Bone structure reflects its function.

- Bone classification  
Bones are grouped according to their shapes—long, short, flat, irregular, or round (sesamoid).
- Parts of a long bone
  - Epiphyses at each end are covered with articular cartilage and articulate with other bones.
  - The shaft of a bone is called the diaphysis.
  - Except for the articular cartilage, a bone is covered by a periosteum.
  - Compact bone has a continuous matrix with no gaps.
  - Spongy bone has irregular interconnecting spaces between bony plates.
  - Both compact and spongy bone are strong and resist bending.
  - The diaphysis contains a medullary cavity filled with marrow.
- Microscopic structure
  - Compact bone contains osteons connected together.
  - Central canals contain blood vessels that nourish the cells of osteons.
  - Perforating canals connect central canals transversely and communicate with the bone's surface and the medullary cavity.
  - Diffusion from the surface of thin bony plates nourishes cells of spongy bones.

**Bone Development and Growth (page 182)**

- Intramembranous bones
  - Certain flat bones of the skull are intramembranous bones.
  - They develop from layers of connective tissue.
  - Osteoblasts within the membranous layers fuse.
  - Mature bone cells are called osteocytes.
  - Primitive connective tissue gives rise to the periosteum.
- Endochondral bones
  - Most of the bones of the skeleton are endochondral.
  - They develop as hyaline cartilage that is laid by bone tissue.
  - Primary ossification centers appear in the whorled secondary ossification centers at epiphyses.
  - An epiphyseal plate remains between the secondary ossification centers.
- Growth at the epiphyseal plate
  - An epiphyseal plate consists of layers of cells: young dividing cells, older enlarging dying cells.
  - The epiphyseal plates are responsible for long bones continue to lengthen until the plates are ossified.

**Bone Function (page 193)**

- Support and protection
  - Bones shape and form body structures.
  - Bones support and protect softer, underlying tissues.
- Body movement
  - Bones and muscles function together as levers.
  - A lever consists of a red, a pivot (fulcrum), a resistance, and a force that applies energy.
  - Parts of a first-class lever are arranged resistance-pivot-force; of a second-class lever, resistance-force-pivot; of a third-class lever, resistance-force-pivot.

### REVIEW EXERCISES

- Part A**
- List four groups of bones based upon their shapes, and name an example from each group.
  - Sketch a typical long bone, and label its epiphyses, diaphysis, medullary cavity, periosteum, and articular cartilages.
  - Distinguish between spongy and compact bone.
  - Explain how central canals and perforating canals are related.
  - Explain how the development of intramembranous bone differs from that of endochondral bone.
  - Distinguish between osteoblasts and osteocytes.
  - Explain the function of an epiphyseal plate.
  - Explain how a bone grows in thickness.
  - Define osteoclast.
  - Explain how osteoclasts and osteoblasts regulate bone mass.
  - Describe the effects of vitamin deficiencies on bone development.
  - Explain the causes of pituitary dwarfism and gigantism.
  - Describe the effects of thyroid and sex hormones on bone development.
  - Explain the effects of exercise on bone structure.
  - Provide several examples to illustrate how bones support and protect body parts.
  - Describe a lever, and explain how its parts may be arranged to form first-, second-, and third-class levers.
  - Explain how upper limb movements function as levers.
  - Describe the functions of red and yellow bone marrow.
  - Explain the mechanism that regulates the concentration of blood calcium ions.
  - List three substances that may be abnormally stored in bone.
  - Distinguish between the axial and appendicular skeletons.
  - Name the bones of the cranium and the facial skeleton.
  - Explain the importance of fontanelles.
  - Describe a typical vertebra.

### WEB CONNECTIONS

Visit the Student Edition of the Online Learning Center at [www.mhhe.com/shier10](http://www.mhhe.com/shier10) for answers to chapter questions, additional quizzes, interactive learning exercises, and other study tools.

- Part B**
- Match the parts listed in column I with the bones listed in column II.
- |  |  |
|--|--|
| <p><b>I</b></p> <ol style="list-style-type: none"> <li>Coronoid process</li> <li>Cribriform plate</li> <li>Foramen magnum</li> <li>Mastoid process</li> <li>Palatine process</li> <li>Sella turcica</li> <li>Supraorbital notch</li> <li>Temporal process</li> <li>Acromion process</li> <li>Deltoid tuberosity</li> <li>Greater trochanter</li> <li>Lateral malleolus</li> <li>Medial malleolus</li> <li>Olecranon process</li> <li>Radial tuberosity</li> <li>Xiphoid process</li> </ol> | <p><b>II</b></p> <ol style="list-style-type: none"> <li>Ethmoid bone</li> <li>Frontal bone</li> <li>Mandible</li> <li>Maxillary bone</li> <li>Occipital bone</li> <li>Temporal bone</li> <li>Sphenoid bone</li> <li>Zygomatic bone</li> <li>Femur</li> <li>Fibula</li> <li>Humerus</li> <li>Radius</li> <li>Scapula</li> <li>Sternum</li> <li>Tibia</li> <li>Ulna</li> </ol> |
|--|--|

## Review Exercises

check the students' understanding of the major ideas presented in the chapter.

### Lower Limb (page 227)

- of the lower limb provide the frameworks of the thigh, ankle, and foot.
- Femur**
- The femur extends from the hip to the knee.
  - It has a head, fovea capitis, neck, greater trochanter, lesser trochanter, linea aspera, lateral condyle, and medial condyle.
- Patella**
- The patella is a flat, round, or sesamoid bone in the tendon that passes anteriorly over the knee.
  - It controls the angle of this tendon and functions in lever actions associated with lower limb movements.
- Tibia**
- The tibia is located on the medial side of the leg.
  - It has medial and lateral condyles, tibial tuberosity, anterior crest, and medial malleolus.
  - It articulates with the talus of the ankle.
- Fibula**
- The fibula is located on the lateral side of the tibia.
  - It has a head and lateral malleolus that articulates with the ankle but does not bear body weight.
- Ankle and foot**
- The ankle and foot consists of the tarsus, metatarsus, and five toes.
  - It includes the talus that helps form the ankle, six other tarsals, five metatarsals, and fourteen phalanges.

### Life-Span Changes (page 231)

- Aging associated changes in the skeleton are apparent at the cellular and whole-body levels.
- Incremental decrease in height begins at about age thirty.
  - Gradually, bone loss exceeds bone replacement.
  - In the first decade following menopause, bone loss occurs more rapidly in women than in men or premenopausal women. By age seventy, both sexes are losing bone at about the same rate.
  - Aging increases risk of bone fractures.

### CRITICAL THINKING QUESTIONS

- What steps do you think should be taken to reduce the chances of bones accumulating abnormal metabolic elements such as lead, radium, and strontium?
- Why do you think incomplete, longitudinal fractures of bone shafts (greenstick fractures) are more common in children than in adults?
- When a child's bone is fractured, growth may be stimulated at the epiphyseal plate. What problems might the extra growth cause in an upper or lower limb before the growth of the other limb compensates for the difference in length?
- Why do elderly persons often develop bowed backs and appear shorter than they were in earlier years?
- How might the condition of an infant's fontanelles be used to evaluate skeletal development? How might the fontanelles be used to estimate intracranial pressure?

### QUESTIONS

- Why are women more likely than men to develop osteoporosis? What steps can reduce the risk of developing this condition?
- How does the structure of a bone make it strong yet lightweight?
- 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 10% less than those of the other two skeletons. The skeletons with the lower bone mass also have broader front pelvic bones. Within the two groups defined by bone mass, smaller skeletons have bones with evidence of epiphyseal plates, but larger bones have only a thin line where the epiphyseal plates should be. Give the age group and gender of the individuals in this find.

## Web Connections

direct students to the Online Learning Center at [www.mhhe.com/shier10](http://www.mhhe.com/shier10) where they will find answers to chapter questions, additional quizzes, interactive learning exercises, and other study tools.

## Critical Thinking Questions

apply main concepts of the chapter to clinical or research situations and take the student beyond memorization to the utilization of knowledge.