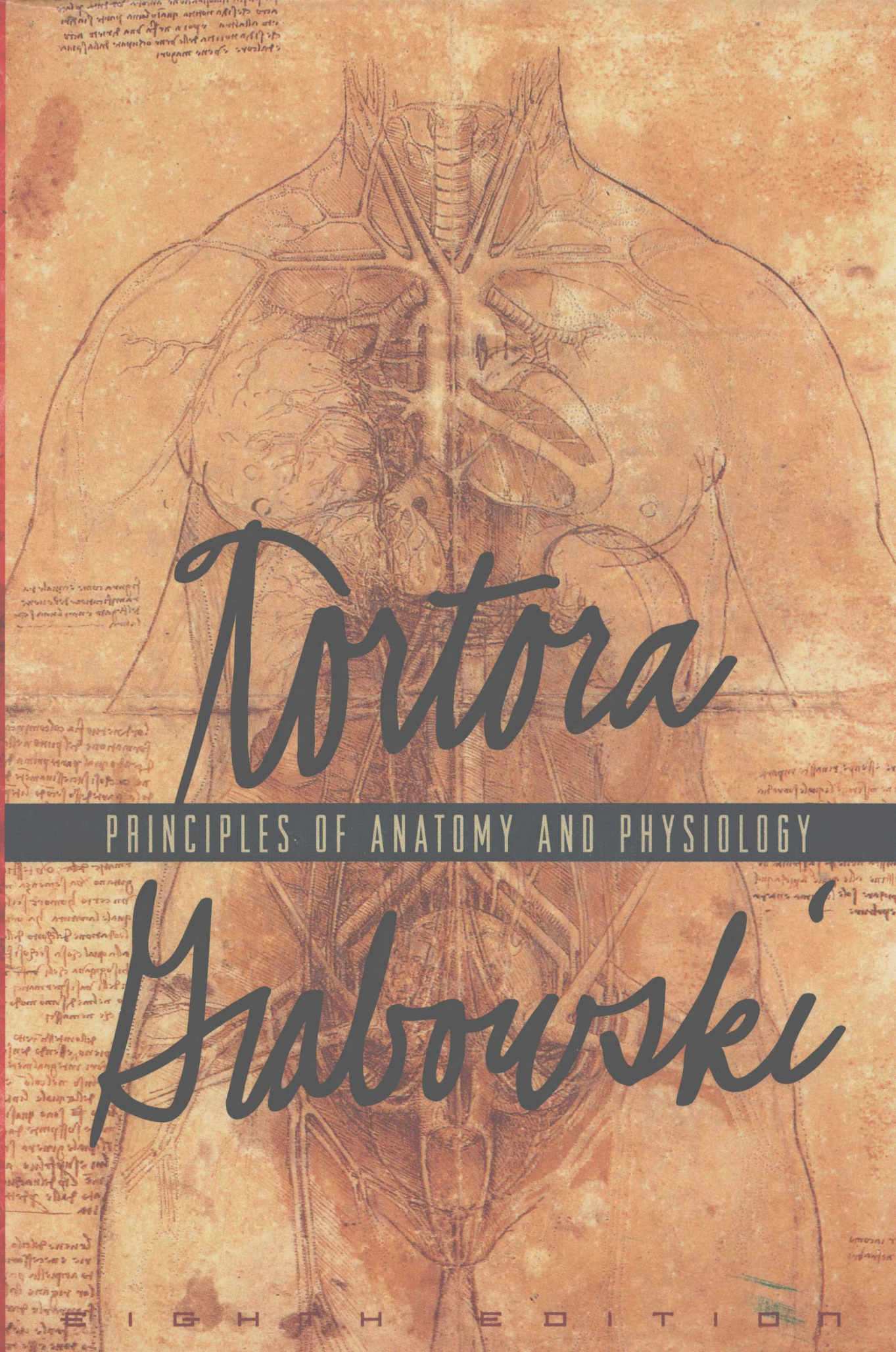


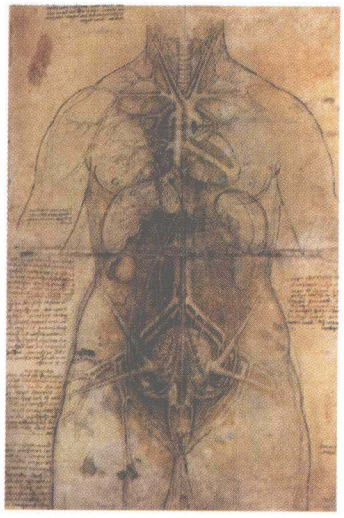
Tortora

PRINCIPLES OF ANATOMY AND PHYSIOLOGY

Grabowski

EIGHTH EDITION

EIGHTH EDITION



PRINCIPLES OF ANATOMY AND PHYSIOLOGY

Gerard J. Tortora
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PURDUE UNIVERSITY

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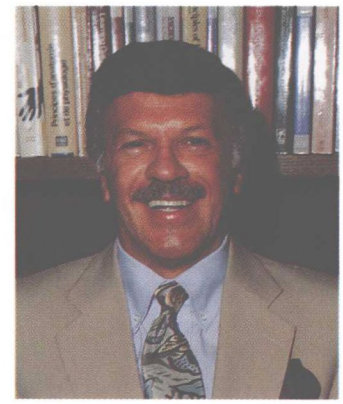
PRINCIPLES OF ANATOMY AND PHYSIOLOGY

ABOUT THE AUTHORS

Gerard J. Tortora



Jerry Tortora is a professor of biology and teaches human anatomy and physiology and microbiology at Bergen Community College in Paramus, New Jersey. He is the Biology Coordinator and has just completed 33 years as a teacher, the past 27 at Bergen CC. He received his B.S. in biology from Fairleigh Dickinson University in 1962 and his M.A. in biology from Montclair State College in 1965. He has also taken graduate courses in education and science at Columbia University and Rutgers University. He belongs to numerous biology organizations, such as the Human Anatomy and Physiology Society (HAPS), the American Association for the Advancement of Science (AAAS), the American Association of Microbiology (ASM), and the Metropolitan Association of College and University Biologists (MACUB). Jerry is the author of a number of best-selling anatomy and physiology, anatomy, and microbiology textbooks and several laboratory manuals.

Sandra Reynolds Grabowski

Sandy Grabowski is an instructor in the Department of Biological Sciences at Purdue University in West Lafayette, Indiana. Since 1977 she has taught human anatomy and physiology to students in a wide range of academic programs. In 1992 students selected her as one of the top 10 teachers in the School of Science at Purdue. Sandy received her B.S. in biology and Ph.D. in neurophysiology from Purdue. She is an active member of the Human Anatomy and Physiology Society (HAPS), served as editor of *HAPS News* from 1990 through 1992, and was elected to serve a three-year term as President-Elect, President, and Past-President from 1992 to 1995. In addition, she is a member of the American Association for the Advancement of Science (AAAS), the Association for Women in Science (AWIS), the National Science Teachers Association (NSTA), the Society for College Science Teachers (SCST), and the Association of Biology Laboratory Educators (ABLE).

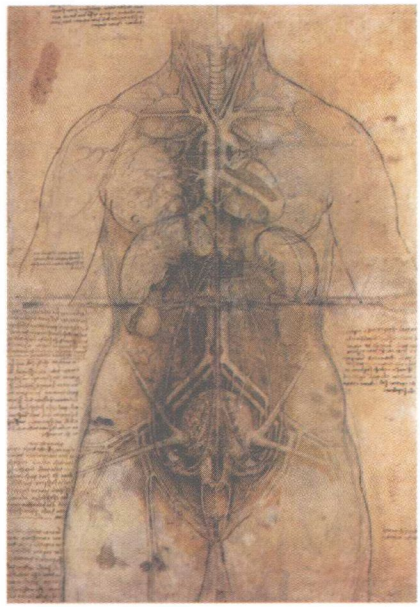
To Lynne Marie, Gerard Joseph, Jr., Kenneth Stephen, Christopher Andrew, and Anthony Gerard, who make it all worthwhile.

G.J.T.

To my husband Zbig, for his steadfast and loving support.

S.R.G.

ABOUT THE COVER



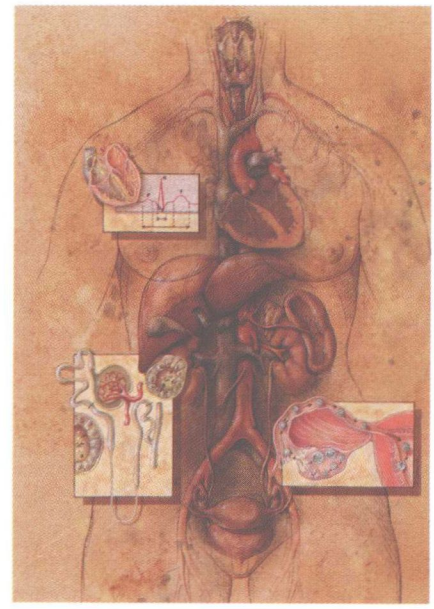
At first glance the elegant illustrations that grace the front and back cover of the eighth edition of Principles of Anatomy and Physiology *appear to be from the same era. Yet nearly 500 years of learning about human anatomy and physiology separate these drawings.*

The front cover is Leonardo da Vinci's so-called Great Lady Anatomy, *drawn about 1508. Although more widely known today for about a dozen paintings, including* Mona Lisa *and* The Last Supper, *Leonardo left a legacy of nearly a thousand biological sketches. Like many other sketches,* Great Lady Anatomy *shows marginal notes in which Leonardo, using his unique mirror-image script, included speculations about some aspects of biological function.*

Unfortunately, what this masterpiece achieves in artistic beauty, it fails to provide in anatomical and physiological accuracy. The trachea bifurcates into equally inclined primary bronchi, the liver is misshapen and confined to the right side, the heart has only two chambers, the aortic branches and iliac vessels are misrepresented, and the apparently pregnant uterus sprouts horn-like structures.

These inaccuracies are rather surprising in light of Leonardo's claim to have dissected ten cadavers. Most likely, he had access only to portions of cadavers over many years. Leonardo may have never even dissected a female; indeed, the figure outline of Great Lady Anatomy *looks masculine. Leonardo was also influenced by his extensive animal dissections. His representation of the uterus and the aortic arch is consistent with their appearance in other mammals. But perhaps the greatest impediment to accuracy was the adherence of Leonardo and others of his time to the philosophy of Galen, a second-century physician, whose writings engendered 1300 years of scientific dogma.*

On the back cover is a composition by Kevin Somerville, a well-known contemporary medical illustrator who also has created dozens of the drawings in Principles of Anatomy and Physiology, *Eighth Edition. This image is anatomically correct and integrates form and function in a superimposed fashion. Somerville attractively blends an aged appearance with modern-day science, serving as a tribute to generations of artists who have striven for accurate, beautiful portrayals of human anatomy and physiology.*



Kevin Petti
Associate Professor
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PREFACE

Principles of Anatomy and Physiology is designed for an introductory course in anatomy and physiology and assumes no prior knowledge of the human body by the student. It is geared to students preparing for careers in health-related professions, such as nursing, occupational therapy, physical therapy, medical technology, medicine, and dentistry. Because of its scope, the text is also useful for students in the biological sciences, science technology, science education, and physical education programs.

This eighth edition of *Principles of Anatomy and Physiology* builds on the phenomenal and unprecedented success of the past seven editions. Previous editions have been so successful because of clear and concise readability, outstanding art programs, the introduction of so many unique and innovative pedagogical aids, and the refinement of tried and tested learning devices. In the eighth edition the themes and organization, the features just mentioned, and the accuracy of previous editions, upon which anatomy and physiology instructors and students have depended for over twenty years, have been retained. The text has been completely revised, however, and includes many new and revised figures, up-to-date physiology, some new and innovative learning devices, and interesting, new clinical applications.

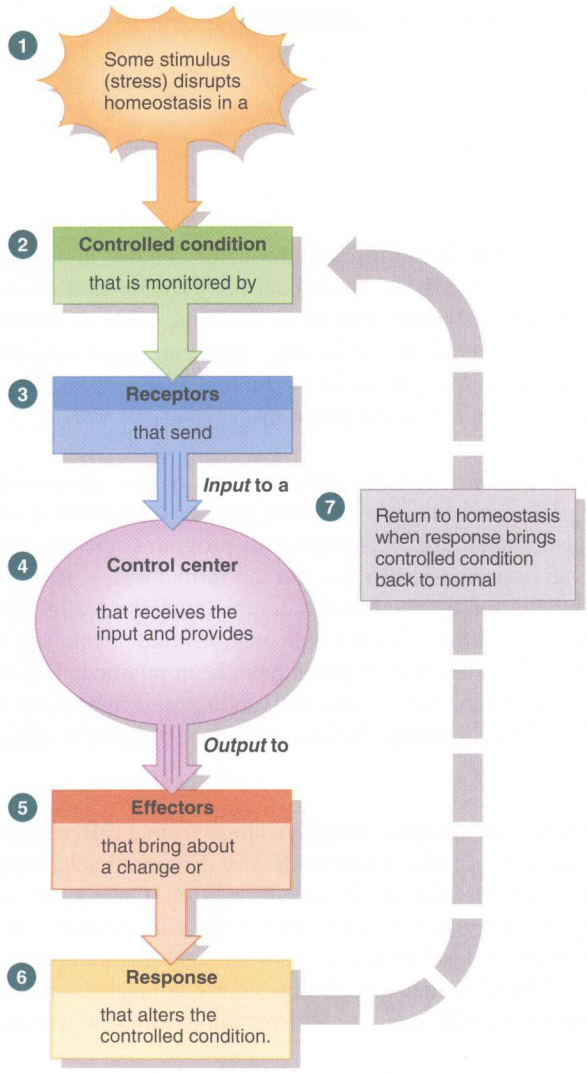
Each instructor approaches the teaching of anatomy and physiology from a different perspective and background. The advantage of two authors with very different backgrounds working together proved practical and beneficial in the seventh edition. Once again, our collaboration has resulted in a text that presents a body of knowledge filtered and refined both by an anatomist and a physiologist. Thus the balance between anatomy and physiology continues to be fine-tuned. In addition, we have emphasized correlations between normal physiology and pathophysiology, normal anatomy and pathology, and homeostasis and homeostatic imbalances.

THEMES AND ORGANIZATION

Homeostasis and Homeostatic Imbalances

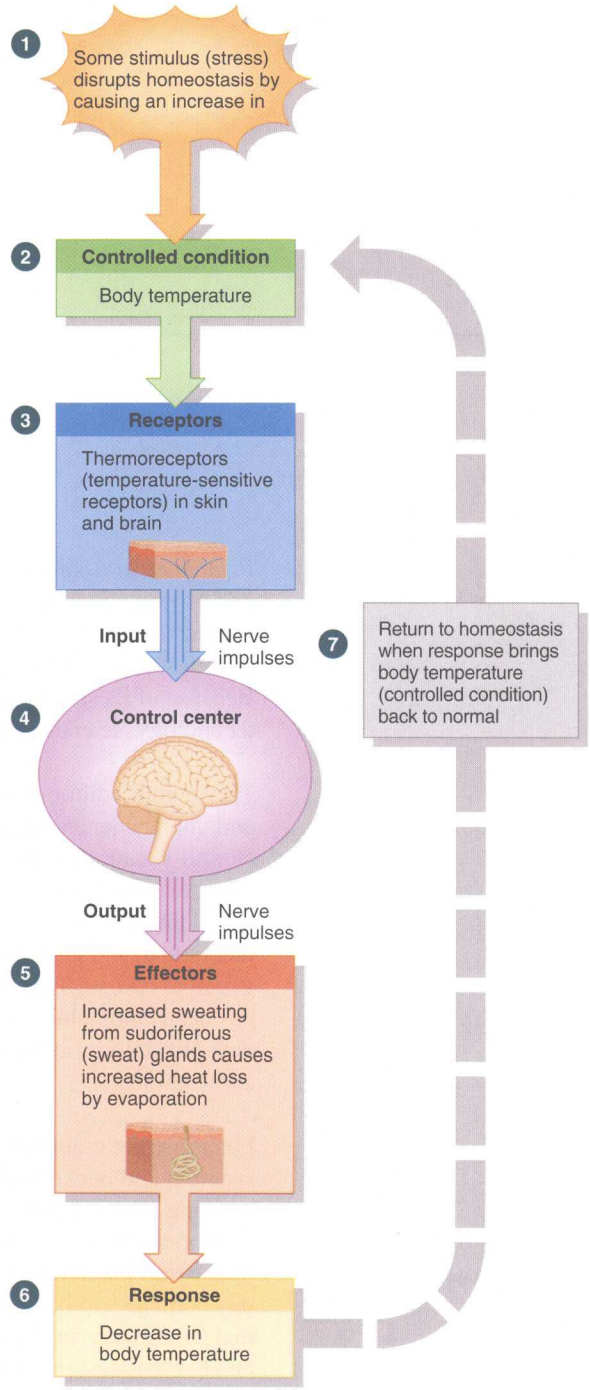
As in the past, the eighth edition has two underlying themes: homeostasis and homeostatic imbalances. **Homeostasis**, the condition in which the body's internal environment remains within certain physiological limits, is immediately introduced in Chapter 1 and continued throughout the book. The ***negative feedback illustrations***, so well received in the last edition, have been modified and enhanced where appropriate. These diagrams help make potentially confusing concepts much easier to understand. They are used whenever applicable to help students grasp the dynamic counterbalancing act that systems must perform to maintain normal anatomy and physiology.

Figure 1.3 Components of a feedback system (loop).



Q What are two differences between negative and positive feedback systems?

Figure 5.7 Thermoregulation: homeostasis of body temperature by the skin.

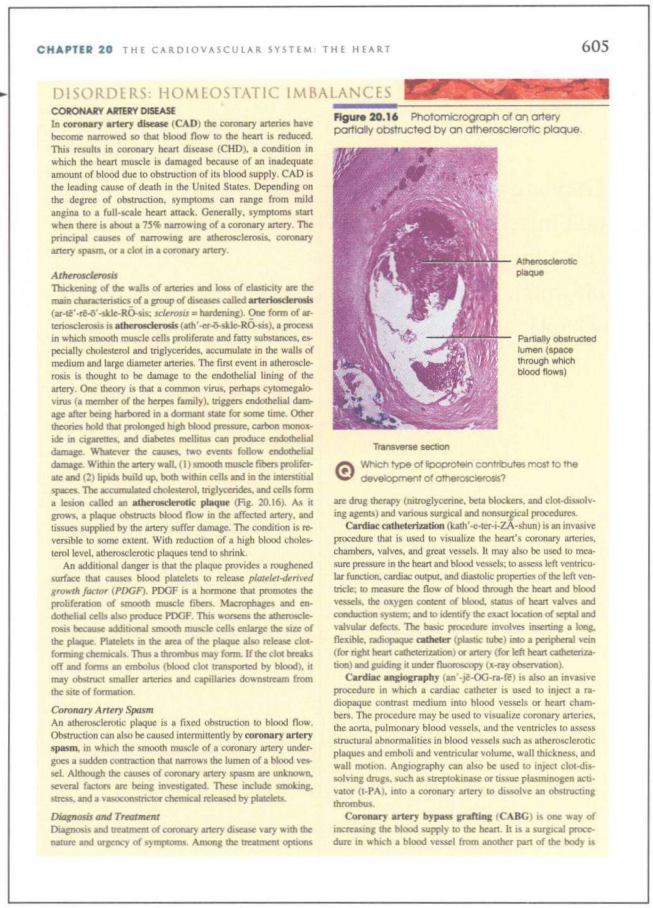


Q Why is this a negative (rather than a positive) feedback cycle?

Homeostatic Imbalances, the other theme of the textbook, represent disruptions in homeostasis that could result in illness or even death. Once students have been introduced to normal anatomy and physiology, they are provided with examples of homeostatic imbalances through clinical applications and disorders. These discussions further illustrate the relevance of normal mechanisms.

Clinical applications are in-text discussions that apply knowledge of normal body processes to clinical situations. These discussions are now readily identifiable by the use of a stethoscope icon.

Disorders: Homeostatic Imbalances at the end of most chapters provide additional explanations of important medical problems. These include answers to many of the questions that students ask about medical conditions and diseases.



CHAPTER 20 THE CARDIOVASCULAR SYSTEM: THE HEART 605

DISORDERS: HOMEOSTATIC IMBALANCES

CORONARY ARTERY DISEASE

In **coronary artery disease** (**CAD**) the coronary arteries have become narrowed so that blood flow to the heart is reduced. This results in coronary heart disease (CHD), a condition in which the heart muscle is damaged because of an inadequate amount of blood due to obstruction of its blood supply. CAD is the leading cause of death in the United States. Depending on the degree of obstruction, symptoms can range from mild angina to a full-scale heart attack. Generally, symptoms start when there is about a 75% narrowing of a coronary artery. The principal causes of narrowing are atherosclerosis, coronary artery spasm, or a clot in a coronary artery.

Atherosclerosis

Thickening of the walls of arteries and loss of elasticity are the main characteristics of a group of diseases called **arteriosclerosis** (ar-tē'-rē-ō'-skle-RŌ-sis; *sclerosis* = hardening). One form of arteriosclerosis is **atherosclerosis** (ath'-er-ō-skle-RŌ-sis), a process in which smooth muscle cells proliferate and fatty substances, especially cholesterol and triglycerides, accumulate in the walls of medium and large diameter arteries. The first event in atherosclerosis is thought to be damage to the endothelial lining of the artery. One theory is that a common virus, perhaps cytomegalovirus (a member of the herpes family), triggers endothelial damage after being harbored in a dormant state for some time. Other theories hold that prolonged high blood pressure, carbon monoxide in cigarettes, and diabetes mellitus can produce endothelial damage. Whatever the causes, two events follow endothelial damage. Within the artery wall, (1) smooth muscle fibers proliferate and (2) lipids build up, both within cells and in the interstitial spaces. The accumulated cholesterol, triglycerides, and cells form a lesion called an **atherosclerotic plaque** (Fig. 20.16). As it grows, a plaque obstructs blood flow in the affected artery, and tissues supplied by the artery suffer damage. The condition is reversible to some extent. With reduction of a high blood cholesterol level, atherosclerotic plaques tend to shrink.

An additional danger is that the plaque provides a roughened surface that causes blood platelets to release *platelet-derived growth factor* (*PDGF*). PDGF is a hormone that promotes the proliferation of smooth muscle fibers. Macrophages and endothelial cells also produce PDGF. This worsens the atherosclerosis because additional smooth muscle cells enlarge the size of the plaque. Platelets in the area of the plaque also release clot-forming chemicals. Thus a thrombus may form. If the clot breaks off and forms an embolus (blood clot transported by blood), it may obstruct smaller arteries and capillaries downstream from the site of formation.

Coronary Artery Spasm

An atherosclerotic plaque is a fixed obstruction to blood flow. Obstruction can also be caused intermittently by **coronary artery spasm**, in which the smooth muscle of a coronary artery undergoes a sudden contraction that narrows the lumen of a blood vessel. Although the causes of coronary artery spasm are unknown, several factors are being investigated. These include smoking, stress, and a vasoconstrictor chemical released by platelets.

Diagnosis and Treatment

Diagnosis and treatment of coronary artery disease vary with the nature and urgency of symptoms. Among the treatment options are drug therapy (nitroglycerine, beta blockers, and clot-dissolving agents) and various surgical and nonsurgical procedures.

Figure 20.16 Photomicrograph of an artery partially obstructed by an atherosclerotic plaque.

Transverse section

Which type of lipoprotein contributes most to the development of atherosclerosis?

Cardiac catheterization (kath'-e-ter-i-ZĀ-shun) is an invasive procedure that is used to visualize the heart's coronary arteries, chambers, valves, and great vessels. It may also be used to measure pressure in the heart and blood vessels; to assess left ventricular function, cardiac output, and diastolic properties of the left ventricle; to measure the flow of blood through the heart and blood vessels, the oxygen content of blood, status of heart valves and conduction system; and to identify the exact location of septal and valvular defects. The basic procedure involves inserting a long, flexible, radiopaque **catheter** (plastic tube) into a peripheral vein (for right heart catheterization) or artery (for left heart catheterization) and guiding it under fluoroscopy (x-ray observation).

Cardiac angiography (an'-jē-OG-ra-fē) is also an invasive procedure in which a cardiac catheter is used to inject a radiopaque contrast medium into blood vessels or heart chambers. The procedure may be used to visualize coronary arteries, the aorta, pulmonary blood vessels, and the ventricles to assess structural abnormalities in blood vessels such as atherosclerotic plaques and emboli and ventricular volume, wall thickness, and wall motion. Angiography can also be used to inject clot-dissolving drugs, such as streptokinase or tissue plasminogen activator (t-PA), into a coronary artery to dissolve an obstructing thrombus.

Coronary artery bypass grafting (**CABG**) is one way of increasing the blood supply to the heart. It is a surgical procedure in which a blood vessel from another part of the body is

TREATING SPORTS INJURIES

Most sports injuries should be treated initially with **RICE** therapy, which stands for **R**est, **I**ce, **C**ompression, and **E**levation. Immediately apply ice and rest and elevate the injured part. Then apply an elastic bandage, if possible, to compress the injured tissue. Continue using RICE for 2–3 days, and resist the temptation to apply heat, which may worsen the swelling. Follow-up treatment may include alternating moist heat and ice massage to enhance blood flow in the injured area. Sometimes, nonsteroidal anti-inflammatory drugs (NSAIDs), such as aspirin or ibuprofen, or local injections of corticosteroids, such as cortisone, are needed. During the recovery period, it is important to keep active with an alternate fitness program. And careful exercise is needed to rehabilitate the injured area itself. ■

Organization

The book follows the same unit and topic sequence as its seven earlier editions. It is divided into five principal areas of concentration. Unit 1, "Organization of the Human Body," provides an understanding of the structural and functional levels of the body, from molecules to organ systems. Unit 2, "Principles of Support and Movement," analyzes the anatomy and physiology of the skeletal system, articulations, and the muscular system. Unit 3, "Control Systems of the Human Body," emphasizes the importance of neural communication in the immediate maintenance of homeostasis, the role of sensory receptors in providing information about the internal and external environment, and the significance of hormones in maintaining long-term homeostasis. Unit 4, "Maintenance of the Human Body," explains how body systems function to maintain homeostasis on a day-to-day basis through the processes of circulation, respiration, digestion, cellular metabolism, urinary functions, and buffer systems. Unit 5, "Continuity," covers the anatomy and physiology of the reproductive systems, development, and the basic concepts of genetics and inheritance.

THE ILLUSTRATION PROGRAM

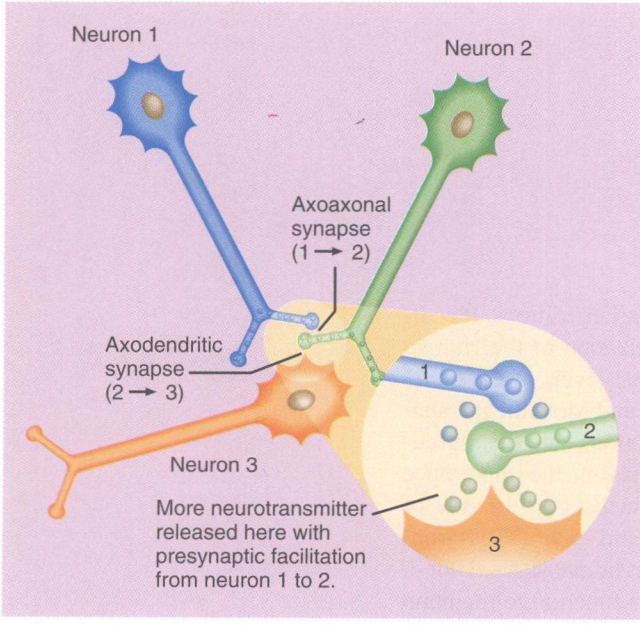
The illustration program is one of the signature features of *Principles of Anatomy and Physiology*. Once again, it has been reviewed and refined to continue the standard of excellence expected. To emphasize structural and functional relations, colors are used in a consistent and meaningful manner throughout the text. For example, sensory structures, sensory neurons, and sensory regions of the brain are shades of blue ■, whereas motor structures are light red ■. Membrane phospholipids are gray ■ and orange ■, the cytosol is sand ■, and extracellular fluid is blue ■. Negative and positive feedback loops also use color cues to aid students in understanding and recognizing the concept. Stimulus and response are both orange ■ since they both alter the controlled condition. The controlled condition itself is green ■, the receptor is blue ■, the control center is purple ■, and the effector is red ■. Such color cues provide additional help for students who are trying to learn complex anatomical and physiological concepts.

Successful Illustration Features Maintained and Enhanced

Questions with figures are questions that accompany most figures. They are designed to help students interpret the figures and correlate them with the textual material. This very well-received feature has been refined and expanded in the eighth edition. Many of these questions require students to synthesize verbal and visual information, think critically, or draw conclusions. Answers are given at the end of each chapter.

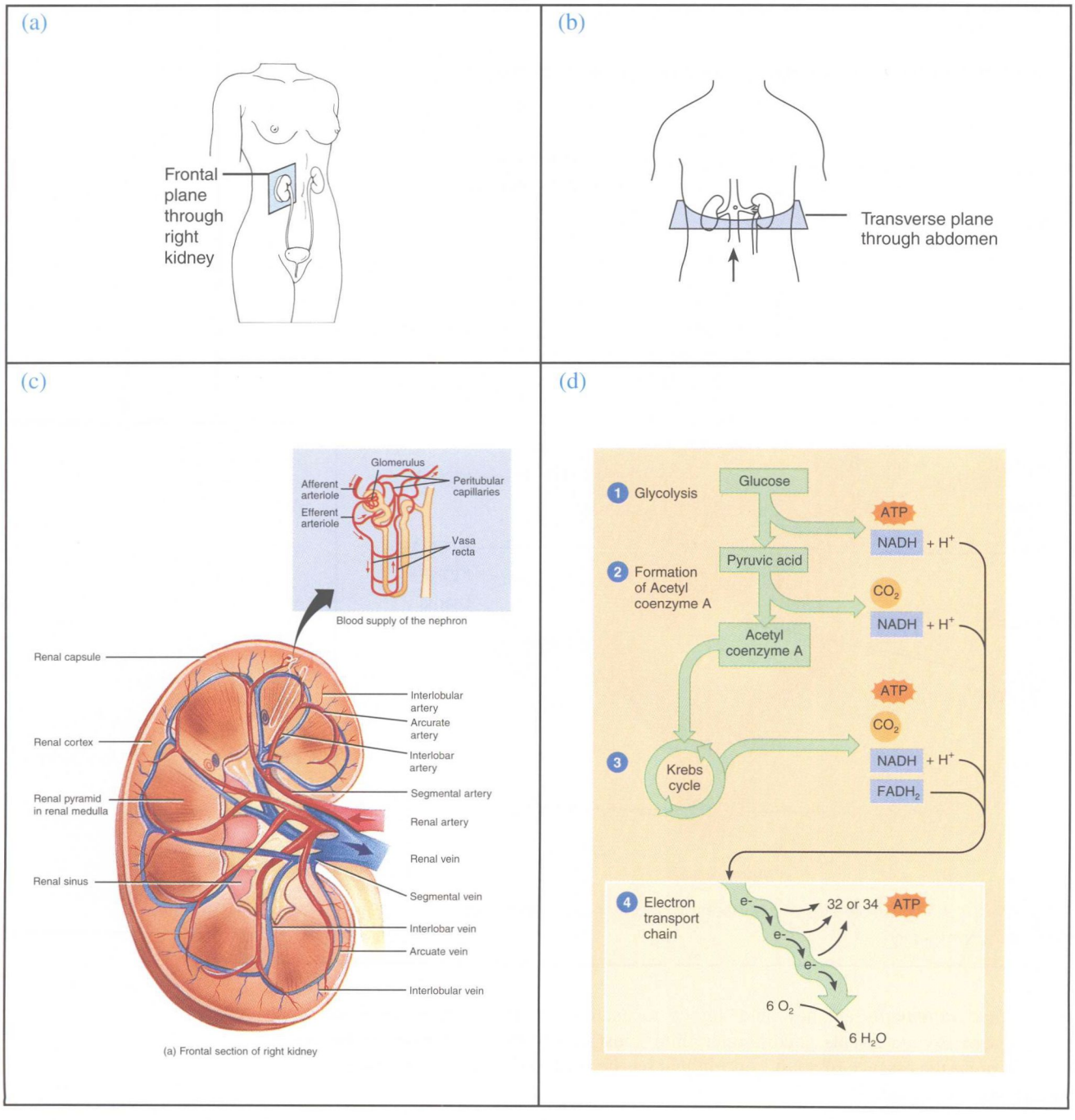
Figure 12.15 Presynaptic facilitation and inhibition. An excitatory or inhibitory neurotransmitter released by neuron 1 can facilitate or inhibit release of neurotransmitter by neuron 2 at its synapse with neuron 3.

Presynaptic facilitation increases the amount of neurotransmitter released whereas presynaptic inhibition decreases it.



Suppose that neuron 2 transmits pain information. Will more or less pain be felt if neuron 1 provides presynaptic inhibition?

Orientation insets, introduced in the last edition, have been greatly expanded and modified in the eighth edition. In one type of inset, not only are planes used to indicate where certain sections are made, but the planes are now labeled so that the reader can more easily relate the planes to the sections that result when a part of the body is cut (a). Other insets contain a directional arrow to indicate the direction from which the body is viewed (superior, inferior, posterior, anterior, and so on) (b). Still other insets have arrows leading from or to them to direct attention to enlarged and detailed parts of illustrations (c). Added to Chapter 25 are new orientation diagrams for metabolic reactions, which are miniature versions of larger illustrations with a selected part highlighted (d). These are designed to help students relate the various steps of a process, such as the electron transport chain, to the overall process, in this case cellular respiration.



New Illustration Features

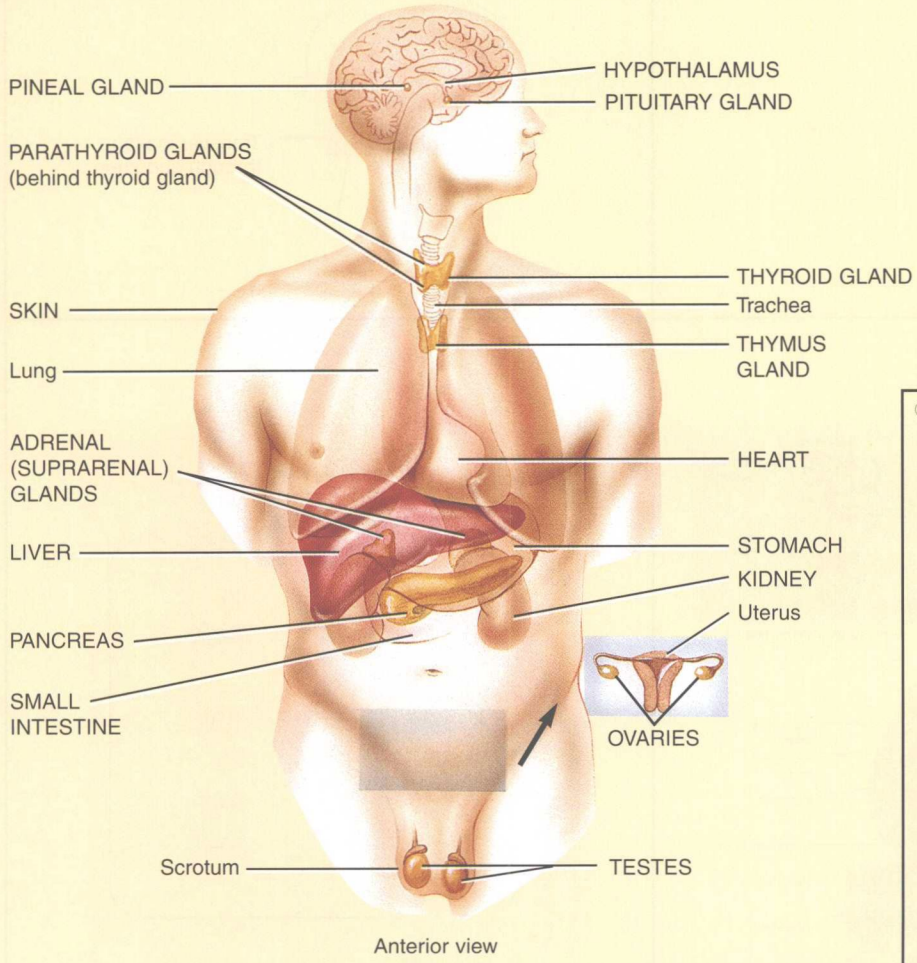
New cadaver photographs have replaced most of the older ones for this edition and several additional photos have been added. The dissections were prepared under the supervision of Mark Nielsen of the University of Utah and photographed by Borge Andersen specifically for use in this textbook.

New illustrations have been added throughout the book to amplify both anatomical and physiological concepts. Many illustrations have been revised for better clarity. These additions and enhancements are in keeping with the standard of excellence that *Principles of Anatomy and Physiology* always strives to exceed.

Overview of Functions is a unique new feature that juxtaposes the anatomical components and a brief functional overview for each body system. These function boxes accompany the first figure of most chapters, as well as selected other figures. They permit students to visually integrate the anatomy and physiology of a body system at the outset.

Figure 18.1 Location of many endocrine glands, other organs that contain endocrine tissue, and associated structures.

Endocrine glands secrete hormones that diffuse into the blood for transport to target tissues.



OVERVIEW OF HORMONE FUNCTIONS

1. Regulate the chemical composition and volume of the internal environment (extracellular fluid).
2. Help regulate metabolism and energy balance.
3. Help regulate contraction of smooth and cardiac muscle fibers and secretion by glands.
4. Help maintain homeostasis despite disruptions such as infection, trauma, emotional stress, dehydration, starvation, hemorrhage, and temperature extremes.
5. Regulate certain activities of the immune system.
6. Play a role in the smooth, sequential integration of growth and development.
7. Contribute to the basic processes of reproduction, including gamete (oocyte and sperm) production, fertilization, nourishment of the embryo and fetus, delivery, and nourishment of the newborn.

What is the basic difference between an endocrine gland and an exocrine gland?

Key Concept Statements are new and unique to anatomy and physiology textbooks. They are concise statements incorporated into most illustrations, symbolized by a , that capture the essence of a key concept that has been stated in the text and then amplified in the illustration.

Flow charts included in some figures permit students to concentrate on the movement of a substance from one area to another while still visualizing the anatomical components at the same time.

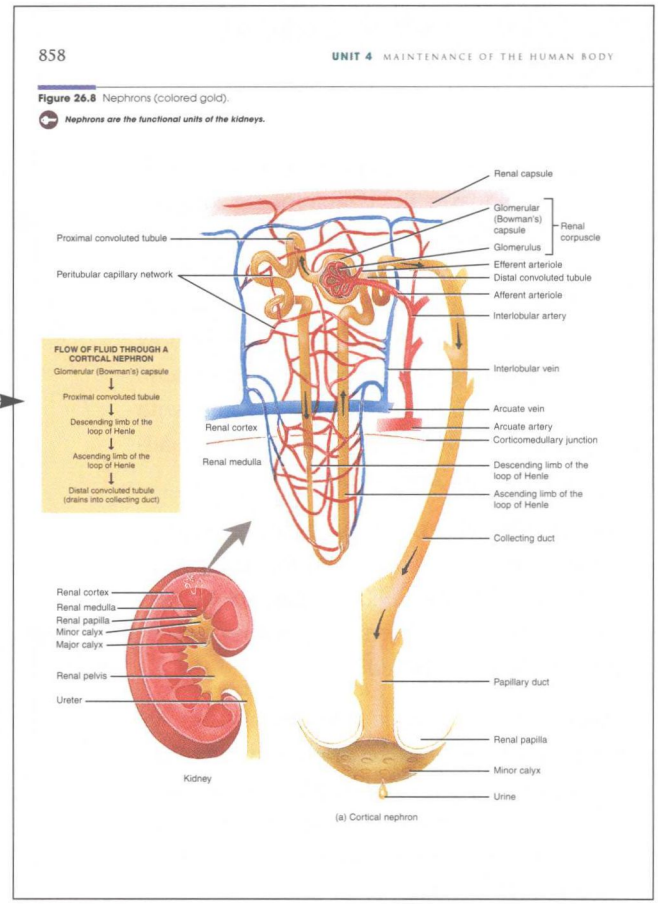

858 UNIT 4 MAINTENANCE OF THE HUMAN BODY

Figure 26.8 Nephrons (colored gold).

Nephrons are the functional units of the kidneys.

Renal capsule
Glomerular (Bowman's) capsule
Renal corpuscle
Glomerulus
Proximal convoluted tubule
Peritubular capillary network
Efferent arteriole
Distal convoluted tubule
Afferent arteriole
Interlobular artery
Interlobular vein
Arcuate vein
Arcuate artery
Corticomedullary junction
Renal cortex
Renal medulla
Descending limb of the loop of Henle
Ascending limb of the loop of Henle
Collecting duct
Papillary duct
Renal papilla
Minor calyx
Urine

FLOW OF FLUID THROUGH A CORTICAL NEPHRON
Glomerular (Bowman's) capsule
↓
Proximal convoluted tubule
↓
Descending limb of the loop of Henle
↓
Ascending limb of the loop of Henle
↓
Distal convoluted tubule (drains into collecting duct)

Renal cortex
Renal medulla
Renal papilla
Minor calyx
Major calyx
Renal pelvis
Ureter
Kidney

(a) Cortical nephron

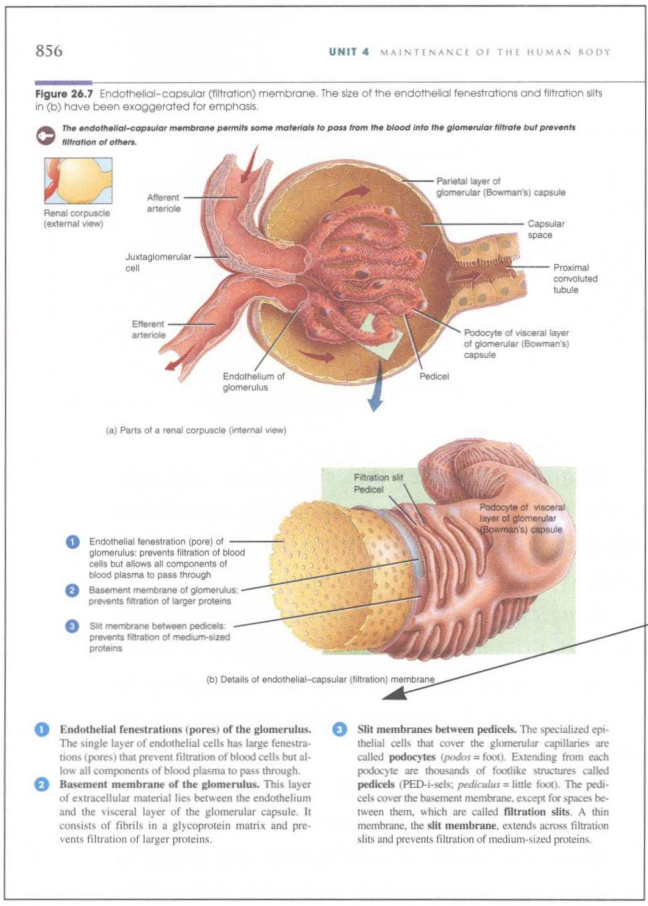

856 UNIT 4 MAINTENANCE OF THE HUMAN BODY

Figure 26.7 Endothelial–capsular (filtration) membrane. The size of the endothelial fenestrations and filtration slits in (b) have been exaggerated for emphasis.

The endothelial–capsular membrane permits some materials to pass from the blood into the glomerular filtrate but prevents filtration of others.

Renal corpuscle (external view)
Afferent arteriole
Parietal layer of glomerular (Bowman's) capsule
Capsular space
Juxtaglomerular cell
Proximal convoluted tubule
Efferent arteriole
Podocyte of visceral layer of glomerular (Bowman's) capsule
Endothelium of glomerulus
Pedicel

(a) Parts of a renal corpuscle (internal view)

Filtration slit
Pedicel
Podocyte of visceral layer of glomerular (Bowman's) capsule
1 Endothelial fenestration (pore) of glomerulus: prevents filtration of blood cells but allows all components of blood plasma to pass through
2 Basement membrane of glomerulus: prevents filtration of larger proteins
3 Slit membrane between pedicels: prevents filtration of medium-sized proteins

(b) Details of endothelial–capsular (filtration) membrane

1 **Endothelial fenestrations (pores) of the glomerulus.** The single layer of endothelial cells has large fenestrations (pores) that prevent filtration of blood cells but allow all components of blood plasma to pass through.

2 **Basement membrane of the glomerulus.** This layer of extracellular material lies between the endothelium and the visceral layer of the glomerular capsule. It consists of fibrils in a glycoprotein matrix and prevents filtration of larger proteins.

3 **Slit membranes between pedicels.** The specialized epithelial cells that cover the glomerular capillaries are called **podocytes** (*podos* = foot). Extending from each podocyte are thousands of footlike structures called **pedicels** (PED-i-sels; *pediculus* = little foot). The pedicels cover the basement membrane, except for spaces between them, which are called **filtration slits**. A thin membrane, the **slit membrane**, extends across filtration slits and prevents filtration of medium-sized proteins.

Correlating sequential processes in text and art is achieved through the use of numbered lists in the text that correspond to numbered segments in the accompanying art. This is done extensively throughout the book and permits the reader to connect the text description with the illustration under consideration more easily.

NEW ICONS ARE USED THROUGHOUT THE BOOK.

Key concept statements are identified by a key

Clinical applications by a stethoscope

Questions with figures by a circle with a Q

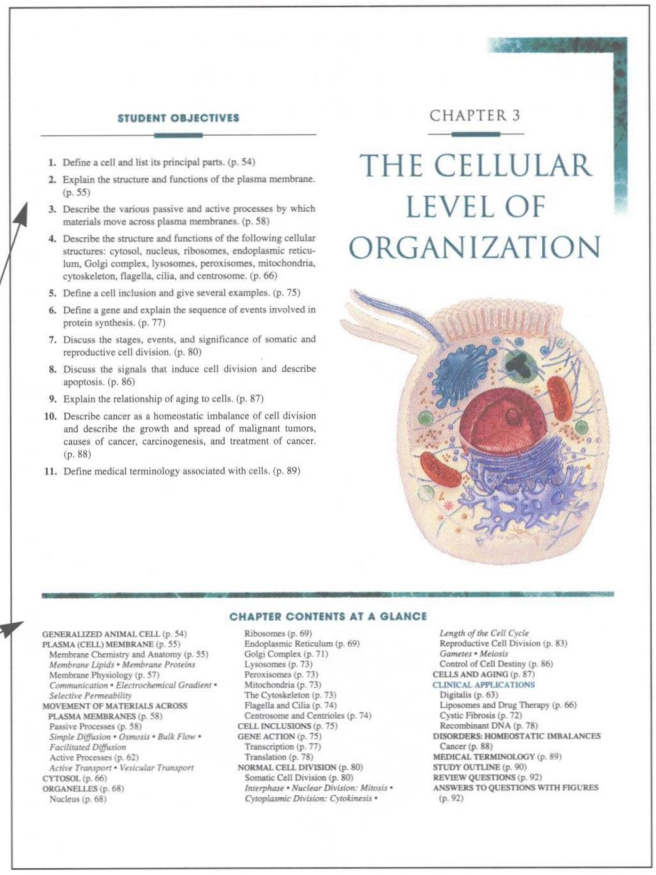
Developmental anatomy descriptions by a fetus

EXCEPTIONAL PEDAGOGICAL STRUCTURE

The highly praised pedagogical features, introduced in this text over the course of its editions, continue to be refined and molded based on feedback from students who rely on their effectiveness. Each feature described below has been considered for its individual value as well as for how it works as a part of the entire pedagogical system. The variety of features ensures that students with differing learning styles have help in understanding and studying important concepts.

Student Objectives, on the opening page of each chapter, is a list of outcomes that can be expected after reading and understanding the chapter comments. These have been *page referenced* for the first time in the eighth edition.

Chapter Contents at a Glance, also on the opening page of each chapter, is an outline of the topics covered and chapter organization. Readers who wish to find a specific section or clinical application will appreciate the addition of page numbers, also new to this edition.



STUDENT OBJECTIVES

1. Define a cell and list its principal parts. (p. 54)
2. Explain the structure and functions of the plasma membrane. (p. 55)
3. Describe the various passive and active processes by which materials move across plasma membranes. (p. 58)
4. Describe the structure and functions of the following cellular structures: cytosol, nucleus, ribosomes, endoplasmic reticulum, Golgi complex, lysosomes, peroxisomes, mitochondria, cytoskeleton, flagella, cilia, and centrosome. (p. 66)
5. Define a cell inclusion and give several examples. (p. 75)
6. Define a gene and explain the sequence of events involved in protein synthesis. (p. 77)
7. Discuss the stages, events, and significance of somatic and reproductive cell division. (p. 80)
8. Discuss the signals that induce cell division and describe apoptosis. (p. 86)
9. Explain the relationship of aging to cells. (p. 87)
10. Describe cancer as a homeostatic imbalance of cell division and describe the growth and spread of malignant tumors, causes of cancer, carcinogenesis, and treatment of cancer. (p. 88)
11. Define medical terminology associated with cells. (p. 89)

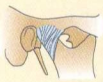
CHAPTER 3

THE CELLULAR LEVEL OF ORGANIZATION

CHAPTER CONTENTS AT A GLANCE

GENERALIZED ANIMAL CELL (p. 54)
PLASMA (CELL) MEMBRANE (p. 55)
Membrane Chemistry and Anatomy (p. 55)
Membrane Lipids • Membrane Proteins
Membrane Physiology (p. 57)
Communication • Electrochemical Gradient • Selective Permeability
MOVEMENT OF MATERIALS ACROSS PLASMA MEMBRANES (p. 58)
Passive Processes (p. 58)
Simple Diffusion • Osmosis • Bulk Flow • Facilitated Diffusion
Active Processes (p. 62)
Active Transport • Vesicular Transport
CYTOSOL (p. 66)
ORGANELLES (p. 68)
Nucleus (p. 68)
Ribosomes (p. 69)
Endoplasmic Reticulum (p. 69)
Golgi Complex (p. 71)
Lysosomes (p. 73)
Peroxisomes (p. 73)
Mitochondria (p. 73)
The Cytoskeleton (p. 73)
Flagella and Cilia (p. 74)
Centrosome and Centrioles (p. 74)
CELL INCLUSIONS (p. 75)
GENE ACTION (p. 75)
Transcription (p. 77)
Translation (p. 78)
NORMAL CELL DIVISION (p. 80)
Somatic Cell Division (p. 80)
Interphase • Nuclear Division: Mitosis • Cytoplasmic Division: Cytokinesis • Length of the Cell Cycle
Reproductive Cell Division (p. 83)
Gametes • Meiosis
Control of Cell Destiny (p. 86)
CELLS AND AGING (p. 87)
CLINICAL APPLICATIONS
Digitalis (p. 63)
Liposomes and Drug Therapy (p. 66)
Cystic Fibrosis (p. 72)
Recombinant DNA (p. 78)
DISORDERS: HOMEOSTATIC IMBALANCES
Cancer (p. 88)
MEDICAL TERMINOLOGY (p. 89)
STUDY OUTLINE (p. 90)
REVIEW QUESTIONS (p. 92)
ANSWERS TO QUESTIONS WITH FIGURES (p. 92)

EXHIBIT 9.3 REPRESENTATIVE JOINTS ACCORDING TO ARTICULAR COMPONENTS, CLASSIFICATION, AND MOVEMENTS

Joint	Articular Component	Structural Classification	Functional Classification	Movements
Temporo-mandibular joint (TMJ) 	Joint formed by condylar process of the mandible and mandibular fossa and articular tubercle of temporal bone. The TMJ is the only movable joint between skull bones; all other skull joints are sutures and therefore immovable.	Synovial: combined hinge (ginglymus) and gliding (arthrodial) type.	Diarthrosis.	Only the mandible moves since the maxilla is firmly anchored to other bones by sutures. Accordingly, the mandible may function in depression (jaw opening), elevation (jaw closing), protraction, retraction, lateral displacement, and slight rotation.
Atlanto-occipital joints 	Joints formed by the superior articular facets of the atlas and the occipital condyles of the occipital bone.	Synovial: condyloid (ellipsoidal) type.	Diarthrosis.	Flexion (forward bending of head), extension (backward bending of head), and slight lateral tilting of head to either side.
Intervertebral joints 	Joints formed between (1) vertebral bodies and between (2) vertebral arches.	Joints between vertebral bodies—cartilaginous (fibrocartilage), symphysis type. Joints between vertebral arches—synovial, gliding (arthrodial) type.	Amphiarthrosis (symphysis) between vertebral bodies. Diarthrosis between vertebral arches.	Flexion (bending the backbone forward), extension (bending the backbone backward), lateral flexion (bending the backbone to either side), and rotation.
Lumbosacral joint 	Joint formed by the body of the fifth lumbar vertebra and the superior articular facet of the first sacral vertebra of the sacrum.	Joint between the fifth lumbar vertebra and the first sacral vertebra—cartilaginous (fibrocartilage), symphysis type. Joint between the articular processes—synovial joint, gliding (arthrodial) type.	Amphiarthrosis (symphysis) between fifth lumbar vertebra and first sacral vertebra. Diarthrosis between articular processes.	Similar to those of intervertebral joints.
Shoulder (glenohumeral) joint 	Joint formed by the head of the humerus and the glenoid cavity of the scapula.	Synovial joint, ball-and-socket (spheroid) type.	Diarthrosis.	Flexion (humerus drawn forward), extension (humerus drawn backward), abduction (humerus drawn away from midline), adduction (humerus drawn toward midline), medial rotation, lateral rotation, and circumduction.

Exhibits are tables that summarize concepts or take material out of the narrative to consolidate information for review. Illustrations have been added to many more Exhibits in this edition.

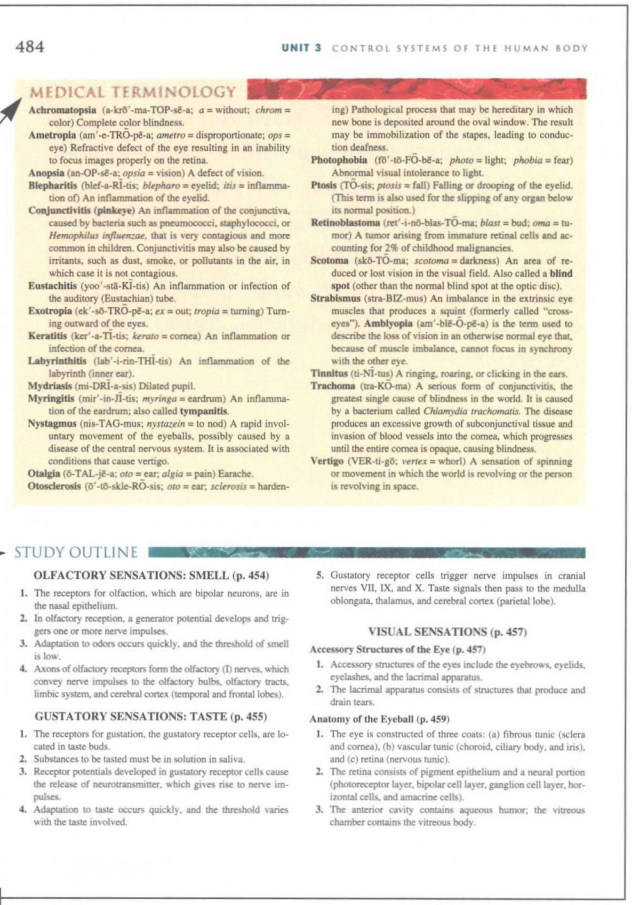
Language aids are provided to help students with the difficult task of learning a new vocabulary at the same time that they are attempting to master the topical coverage. Three types of aid are presented:

- ***Phonetic pronunciations***, presented in an easily remembered format (see Glossary page G-1), allow the reader to confidently and correctly pronounce terms that may be new. Pronunciations appear in parentheses immediately after introduction of a new term. This feature has been expanded considerably in the eighth edition.
- ***Word roots*** are derivations designed to provide an understanding of the meaning of new terms. They also appear in parentheses when a term is introduced. More than 200 new word roots were added for this edition.
- ***Singular and plural forms*** of a term are given when the term is first introduced unless the plural is formed merely by adding an "s" or "es."

Cross-References are references that guide the reader to previously studied concepts for reinforcement or to new material for a more complete discussion of the topic at hand. These references help students more thoroughly grasp the interrelatedness of the body's systems.

Medical Terminology, located at the end of most chapters, is a listing of relevant new terms, together with phonetic pronunciations, that helps students build a medical vocabulary.

Study Outlines are a concise summary of important topics covered in each chapter. Page numbers permit easy reference to text pages for amplification of details.



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MEDICAL TERMINOLOGY

Achromatopsia (a-krō′-ma-TOP-sē-a; *a* = without; *chrom* = color) Complete color blindness.
Ametropia (am′-e-TRŌ-pē-a; *ametro* = disproportionate; *ops* = eye) Refractive defect of the eye resulting in an inability to focus images properly on the retina.
Anopsia (an-OP-sē-a; *opsia* = vision) A defect of vision.
Blepharitis (blef-a-RĪ-tis; *blepharo* = eyelid; *itis* = inflammation of) An inflammation of the eyelid.
Conjunctivitis (pinkeye) An inflammation of the conjunctiva, caused by bacteria such as pneumococci, staphylococci, or *Hemophilus influenzae*, that is very contagious and more common in children. Conjunctivitis may also be caused by irritants, such as dust, smoke, or pollutants in the air, in which case it is not contagious.
Eustachitis (yoo′-stā-KĪ-tis) An inflammation or infection of the auditory (Eustachian) tube.
Exotropia (ek′-sō-TRŌ-pē-a; *ex* = out; *tropia* = turning) Turning outward of the eyes.
Keratitis (ker′-a-TĪ-tis; *kerato* = cornea) An inflammation or infection of the cornea.
Labyrinthitis (lab′-i-rin-THĪ-tis) An inflammation of the labyrinth (inner ear).
Mydriasis (mi-DRĪ-a-sis) Dilated pupil.
Myringitis (mir′-in-JĪ-tis; *myringa* = eardrum) An inflammation of the eardrum; also called **tympanitis**.
Nystagmus (nis-TAG-mus; *nystazein* = to nod) A rapid involuntary movement of the eyeballs, possibly caused by a disease of the central nervous system. It is associated with conditions that cause vertigo.
Otalgia (ō-TAL-jē-a; *oto* = ear; *algia* = pain) Earache.
Otosclerosis (ō′-tō-skle-RŌ-sis; *oto* = ear; *sclerosis* = hardening) Pathological process that may be hereditary in which new bone is deposited around the oval window. The result may be immobilization of the stapes, leading to conduction deafness.
Photophobia (fō′-tō-FŌ-bē-a; *photo* = light; *phobia* = fear) Abnormal visual intolerance to light.
Ptosis (TŌ-sis; *ptosis* = fall) Falling or drooping of the eyelid. (This term is also used for the slipping of any organ below its normal position.)
Retinoblastoma (ret′-i-nō-blas-TŌ-ma; *blast* = bud; *oma* = tumor) A tumor arising from immature retinal cells and accounting for 2% of childhood malignancies.
Scotoma (skō-TŌ-ma; *scotoma* = darkness) An area of reduced or lost vision in the visual field. Also called a **blind spot** (other than the normal blind spot at the optic disc).
Strabismus (stra-BIZ-mus) An imbalance in the extrinsic eye muscles that produces a squint (formerly called "cross-eyes"). **Amblyopia** (am′-blē-Ō-pē-a) is the term used to describe the loss of vision in an otherwise normal eye that, because of muscle imbalance, cannot focus in synchrony with the other eye.
Tinnitus (ti-NĪ-tus) A ringing, roaring, or clicking in the ears.
Trachoma (tra-KŌ-ma) A serious form of conjunctivitis, the greatest single cause of blindness in the world. It is caused by a bacterium called *Chlamydia trachomatis*. The disease produces an excessive growth of subconjunctival tissue and invasion of blood vessels into the cornea, which progresses until the entire cornea is opaque, causing blindness.
Vertigo (VER-ti-gō; *vertex* = whorl) A sensation of spinning or movement in which the world is revolving or the person is revolving in space.

STUDY OUTLINE

OLFACTORY SENSATIONS: SMELL (p. 454)

1. The receptors for olfaction, which are bipolar neurons, are in the nasal epithelium.
2. In olfactory reception, a generator potential develops and triggers one or more nerve impulses.
3. Adaptation to odors occurs quickly, and the threshold of smell is low.
4. Axons of olfactory receptors form the olfactory (I) nerves, which convey nerve impulses to the olfactory bulbs, olfactory tracts, limbic system, and cerebral cortex (temporal and frontal lobes).

GUSTATORY SENSATIONS: TASTE (p. 455)

1. The receptors for gustation, the gustatory receptor cells, are located in taste buds.
2. Substances to be tasted must be in solution in saliva.
3. Receptor potentials developed in gustatory receptor cells cause the release of neurotransmitter, which gives rise to nerve impulses.
4. Adaptation to taste occurs quickly, and the threshold varies with the taste involved.
5. Gustatory receptor cells trigger nerve impulses in cranial nerves VII, IX, and X. Taste signals then pass to the medulla oblongata, thalamus, and cerebral cortex (parietal lobe).

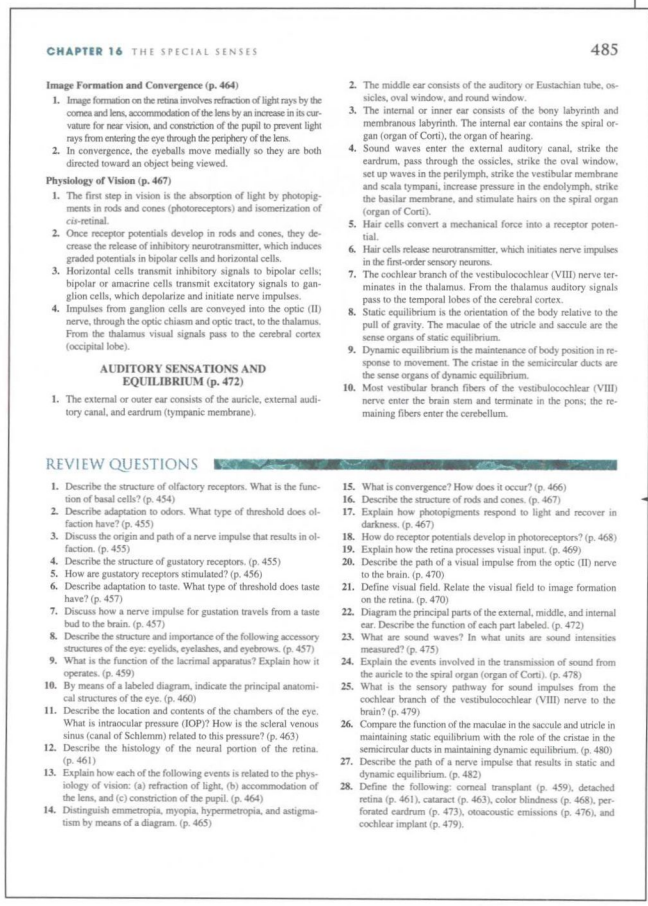
VISUAL SENSATIONS (p. 457)

Accessory Structures of the Eye (p. 457)

1. Accessory structures of the eyes include the eyebrows, eyelids, eyelashes, and the lacrimal apparatus.
2. The lacrimal apparatus consists of structures that produce and drain tears.

Anatomy of the Eyeball (p. 459)

1. The eye is constructed of three coats: (a) fibrous tunic (sclera and cornea), (b) vascular tunic (choroid, ciliary body, and iris), and (c) retina (nervous tunic).
2. The retina consists of pigment epithelium and a neural portion (photoreceptor layer, bipolar cell layer, ganglion cell layer, horizontal cells, and amacrine cells).
3. The anterior cavity contains aqueous humor; the vitreous chamber contains the vitreous body.



CHAPTER 16 THE SPECIAL SENSES 485

Image Formation and Convergence (p. 464)

1. Image formation on the retina involves refraction of light rays by the cornea and lens, accommodation of the lens by an increase in its curvature for near vision, and constriction of the pupil to prevent light rays from entering the eye through the periphery of the lens.
2. In convergence, the eyeballs move medially so they are both directed toward an object being viewed.

Physiology of Vision (p. 467)

1. The first step in vision is the absorption of light by photopigments in rods and cones (photoreceptors) and isomerization of *cis*-retinal.
2. Once receptor potentials develop in rods and cones, they decrease the release of inhibitory neurotransmitter, which induces graded potentials in bipolar cells and horizontal cells.
3. Horizontal cells transmit inhibitory signals to bipolar cells; bipolar or amacrine cells transmit excitatory signals to ganglion cells, which depolarize and initiate nerve impulses.
4. Impulses from ganglion cells are conveyed into the optic (II) nerve, through the optic chiasm and optic tract, to the thalamus. From the thalamus visual signals pass to the cerebral cortex (occipital lobe).

AUDITORY SENSATIONS AND EQUILIBRIUM (p. 472)

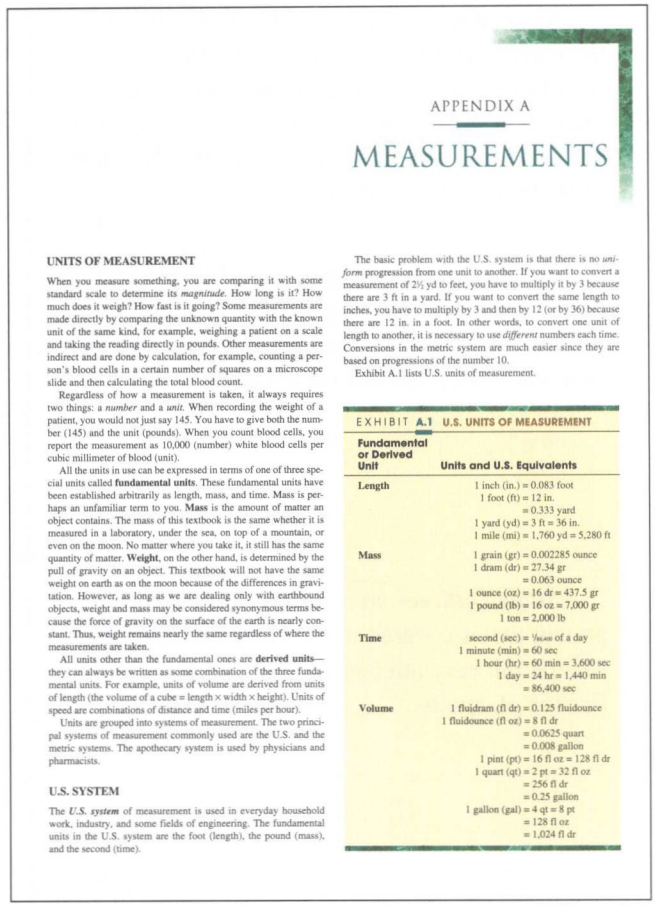
1. The external or outer ear consists of the auricle, external auditory canal, and eardrum (tympanic membrane).
2. The middle ear consists of the auditory or Eustachian tube, ossicles, oval window, and round window.
3. The internal or inner ear consists of the bony labyrinth and membranous labyrinth. The internal ear contains the spiral organ (organ of Corti), the organ of hearing.
4. Sound waves enter the external auditory canal, strike the eardrum, pass through the ossicles, strike the oval window, set up waves in the perilymph, strike the vestibular membrane and scala tympani, increase pressure in the endolymph, strike the basilar membrane, and stimulate hairs on the spiral organ (organ of Corti).
5. Hair cells convert a mechanical force into a receptor potential.
6. Hair cells release neurotransmitter, which initiates nerve impulses in the first-order sensory neurons.
7. The cochlear branch of the vestibulocochlear (VIII) nerve terminates in the thalamus. From the thalamus auditory signals pass to the temporal lobes of the cerebral cortex.
8. Static equilibrium is the orientation of the body relative to the pull of gravity. The maculae of the utricle and saccule are the sense organs of static equilibrium.
9. Dynamic equilibrium is the maintenance of body position in response to movement. The cristae in the semicircular ducts are the sense organs of dynamic equilibrium.
10. Most vestibular branch fibers of the vestibulocochlear (VIII) nerve enter the brain stem and terminate in the pons; the remaining fibers enter the cerebellum.

REVIEW QUESTIONS

1. Describe the structure of olfactory receptors. What is the function of basal cells? (p. 454)
2. Describe adaptation to odors. What type of threshold does olfaction have? (p. 455)
3. Discuss the origin and path of a nerve impulse that results in olfaction. (p. 455)
4. Describe the structure of gustatory receptors. (p. 455)
5. How are gustatory receptors stimulated? (p. 456)
6. Describe adaptation to taste. What type of threshold does taste have? (p. 457)
7. Discuss how a nerve impulse for gustation travels from a taste bud to the brain. (p. 457)
8. Describe the structure and importance of the following accessory structures of the eye: eyelids, eyelashes, and eyebrows. (p. 457)
9. What is the function of the lacrimal apparatus? Explain how it operates. (p. 459)
10. By means of a labeled diagram, indicate the principal anatomical structures of the eye. (p. 460)
11. Describe the location and contents of the chambers of the eye. What is intraocular pressure (IOP)? How is the scleral venous sinus (canal of Schlemm) related to this pressure? (p. 463)
12. Describe the histology of the neural portion of the retina. (p. 461)
13. Explain how each of the following events is related to the physiology of vision: (a) refraction of light, (b) accommodation of the lens, and (c) constriction of the pupil. (p. 464)
14. Distinguish emmetropia, myopia, hypermetropia, and astigmatism by means of a diagram. (p. 465)
15. What is convergence? How does it occur? (p. 466)
16. Describe the structure of rods and cones. (p. 467)
17. Explain how photopigments respond to light and recover in darkness. (p. 467)
18. How do receptor potentials develop in photoreceptors? (p. 468)
19. Explain how the retina processes visual input. (p. 469)
20. Describe the path of a visual impulse from the optic (II) nerve to the brain. (p. 470)
21. Define visual field. Relate the visual field to image formation on the retina. (p. 470)
22. Diagram the principal parts of the external, middle, and internal ear. Describe the function of each part labeled. (p. 472)
23. What are sound waves? In what units are sound intensities measured? (p. 475)
24. Explain the events involved in the transmission of sound from the auricle to the spiral organ (organ of Corti). (p. 478)
25. What is the sensory pathway for sound impulses from the cochlear branch of the vestibulocochlear (VIII) nerve to the brain? (p. 479)
26. Compare the function of the maculae in the saccule and utricle in maintaining static equilibrium with the role of the cristae in the semicircular ducts in maintaining dynamic equilibrium. (p. 480)
27. Describe the path of a nerve impulse that results in static and dynamic equilibrium. (p. 482)
28. Define the following: corneal transplant (p. 459), detached retina (p. 461), cataract (p. 463), color blindness (p. 468), perforated eardrum (p. 473), otoacoustic emissions (p. 476), and cochlear implant (p. 479).

Review Questions are questions designed to help students achieve the learning objectives stated at the beginning of the chapter. Page numbers guide students to the appropriate pages for confirming answers.

Appendices are the sources of various types of information. *Appendix A: Measurements* summarizes U.S., metric, and apothecary units of length, mass, volume, and time. *Appendix B: Normal Values for Selected Blood and Urine Tests* contains a listing of reference values, given in both conventional U.S. units and S.I. units, for the principal constituents of these fluids. *Appendix C: Periodic Table* is included for easy reference. In addition, the end papers of the book include lists of *Symbols and Medical Abbreviations*, *Eponyms Used in the Text*, and *Selected Terms Used in Writing Prescriptions.*



APPENDIX A

MEASUREMENTS

UNITS OF MEASUREMENT

When you measure something, you are comparing it with some standard scale to determine its *magnitude*. How long is it? How much does it weigh? How fast is it going? Some measurements are made directly by comparing the unknown quantity with the known unit of the same kind, for example, weighing a patient on a scale and taking the reading directly in pounds. Other measurements are indirect and are done by calculation, for example, counting a person's blood cells in a certain number of squares on a microscope slide and then calculating the total blood count.

Regardless of how a measurement is taken, it always requires two things: a *number* and a *unit*. When recording the weight of a patient, you would not just say 145. You have to give both the number (145) and the unit (pounds). When you count blood cells, you report the measurement as 10,000 (number) white blood cells per cubic millimeter of blood (unit).

All the units in use can be expressed in terms of one of three special units called **fundamental units**. These fundamental units have been established arbitrarily as length, mass, and time. Mass is perhaps an unfamiliar term to you. **Mass** is the amount of matter an object contains. The mass of this textbook is the same whether it is measured in a laboratory, under the sea, on top of a mountain, or even on the moon. No matter where you take it, it still has the same quantity of matter. **Weight**, on the other hand, is determined by the pull of gravity on an object. This textbook will not have the same weight on earth as on the moon because of the differences in gravitation. However, as long as we are dealing only with earthbound objects, weight and mass may be considered synonymous terms because the force of gravity on the surface of the earth is nearly constant. Thus, weight remains nearly the same regardless of where the measurements are taken.

All units other than the fundamental ones are **derived units**—they can always be written as some combination of the three fundamental units. For example, units of volume are derived from units of length (the volume of a cube = length × width × height). Units of speed are combinations of distance and time (miles per hour).

Units are grouped into systems of measurement. The two principal systems of measurement commonly used are the U.S. and the metric systems. The apothecary system is used by physicians and pharmacists.

U.S. SYSTEM

The ***U.S. system*** of measurement is used in everyday household work, industry, and some fields of engineering. The fundamental units in the U.S. system are the foot (length), the pound (mass), and the second (time).

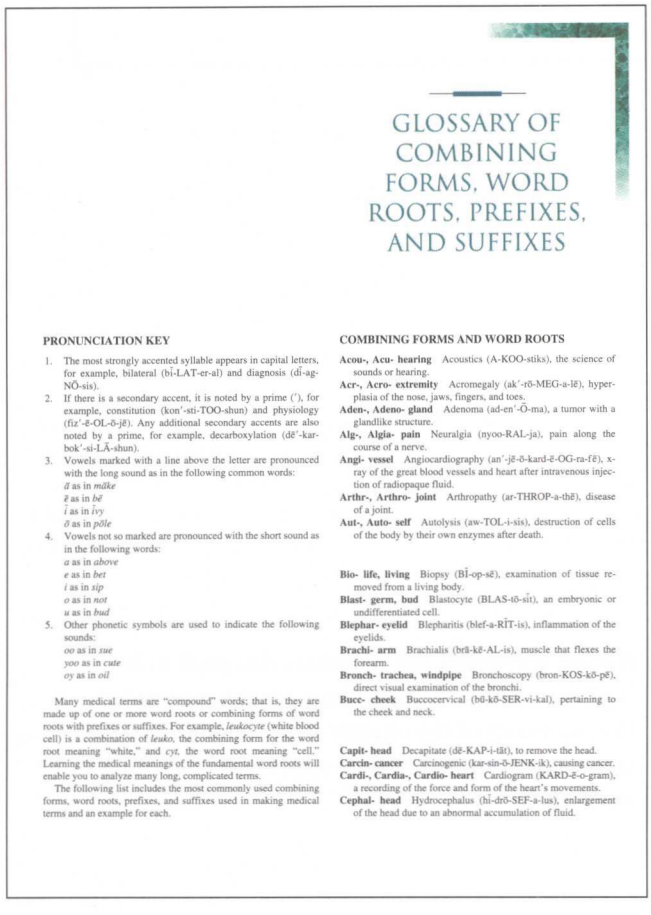
The basic problem with the U.S. system is that there is no *uniform* progression from one unit to another. If you want to convert a measurement of 2½ yd to feet, you have to multiply it by 3 because there are 3 ft in a yard. If you want to convert the same length to inches, you have to multiply by 3 and then by 12 (or by 36) because there are 12 in. in a foot. In other words, to convert one unit of length to another, it is necessary to use *different* numbers each time. Conversions in the metric system are much easier since they are based on progressions of the number 10.

Exhibit A.1 lists U.S. units of measurement.

EXHIBIT A.1 U.S. UNITS OF MEASUREMENT

Fundamental or Derived Unit	Units and U.S. Equivalents
Length	1 inch (in.) = 0.083 foot 1 foot (ft) = 12 in. = 0.333 yard 1 yard (yd) = 3 ft = 36 in. 1 mile (mi) = 1,760 yd = 5,280 ft
Mass	1 grain (gr) = 0.002285 ounce 1 dram (dr) = 27.34 gr = 0.063 ounce 1 ounce (oz) = 16 dr = 437.5 gr 1 pound (lb) = 16 oz = 7,000 gr 1 ton = 2,000 lb
Time	second (sec) = $\frac{1}{86,400}$ of a day 1 minute (min) = 60 sec 1 hour (hr) = 60 min = 3,600 sec 1 day = 24 hr = 1,440 min = 86,400 sec
Volume	1 fluidram (fl dr) = 0.125 fluidounce 1 fluidounce (fl oz) = 8 fl dr = 0.0625 quart = 0.008 gallon 1 pint (pt) = 16 fl oz = 128 fl dr 1 quart (qt) = 2 pt = 32 fl oz = 256 fl dr = 0.25 gallon 1 gallon (gal) = 4 qt = 8 pt = 128 fl oz = 1,024 fl dr

Glossaries appear at the end of the book. One glossary presents combining forms, word roots, prefixes, and suffixes. The other is a comprehensive glossary containing definitions and pronunciations.



GLOSSARY OF COMBINING FORMS, WORD ROOTS, PREFIXES, AND SUFFIXES

PRONUNCIATION KEY

1. The most strongly accented syllable appears in capital letters, for example, bilateral (bī-LAT-er-al) and diagnosis (dī-ag-NŌ-sis).
2. If there is a secondary accent, it is noted by a prime ('), for example, constitution (kon'-sti-TOO-shun) and physiology (fiz'-ē-OL-ō-jē). Any additional secondary accents are also noted by a prime, for example, decarboxylation (dē'-kar-bok'-si-LĀ-shun).
3. Vowels marked with a line above the letter are pronounced with the long sound as in the following common words:
   ā as in *māke*
   ē as in *bē*
   ī as in *ivy*
   ō as in *pōle*
4. Vowels not so marked are pronounced with the short sound as in the following words:
   a as in *above*
   e as in *bet*
   i as in *sip*
   o as in *not*
   u as in *bud*
5. Other phonetic symbols are used to indicate the following sounds:
   oo as in *sue*
   yoo as in *cute*
   oy as in *oil*

Many medical terms are "compound" words; that is, they are made up of one or more word roots or combining forms of word roots with prefixes or suffixes. For example, *leukocyte* (white blood cell) is a combination of *leuko,* the combining form for the word root meaning "white," and *cyt,* the word root meaning "cell." Learning the medical meanings of the fundamental word roots will enable you to analyze many long, complicated terms.

The following list includes the most commonly used combining forms, word roots, prefixes, and suffixes used in making medical terms and an example for each.

COMBINING FORMS AND WORD ROOTS

Acou-, Acu- hearing Acoustics (A-KOO-stiks), the science of sounds or hearing.
Acr-, Acro- extremity Acromegaly (ak'-rō-MEG-a-lē), hyperplasia of the nose, jaws, fingers, and toes.
Aden-, Adeno- gland Adenoma (ad-en'-Ō-ma), a tumor with a glandlike structure.
Alg-, Algia- pain Neuralgia (nyoo-RAL-ja), pain along the course of a nerve.
Angi- vessel Angiocardiography (an'-jē-ō-kard-ē-OG-ra-fē), x-ray of the great blood vessels and heart after intravenous injection of radiopaque fluid.
Arthr-, Arthro- joint Arthropathy (ar-THROP-a-thē), disease of a joint.
Aut-, Auto- self Autolysis (aw-TOL-i-sis), destruction of cells of the body by their own enzymes after death.

Bio- life, living Biopsy (BĪ-op-sē), examination of tissue removed from a living body.
Blast- germ, bud Blastocyte (BLAS-tō-sīt), an embryonic or undifferentiated cell.
Blephar- eyelid Blepharitis (blef-a-RĪT-is), inflammation of the eyelids.
Brachi- arm Brachialis (brā-kē-AL-is), muscle that flexes the forearm.
Bronch- trachea, windpipe Bronchoscopy (bron-KOS-kō-pē), direct visual examination of the bronchi.
Bucc- cheek Buccocervical (bū-kō-SER-vi-kal), pertaining to the cheek and neck.

Capit- head Decapitate (dē-KAP-i-tāt), to remove the head.
Carcin- cancer Carcinogenic (kar-sin-ō-JENK-ik), causing cancer.
Cardi-, Cardia-, Cardio- heart Cardiogram (KARD-ē-o-gram), a recording of the force and form of the heart's movements.
Cephal- head Hydrocephalus (hī-drō-SEF-a-lus), enlargement of the head due to an abnormal accumulation of fluid.