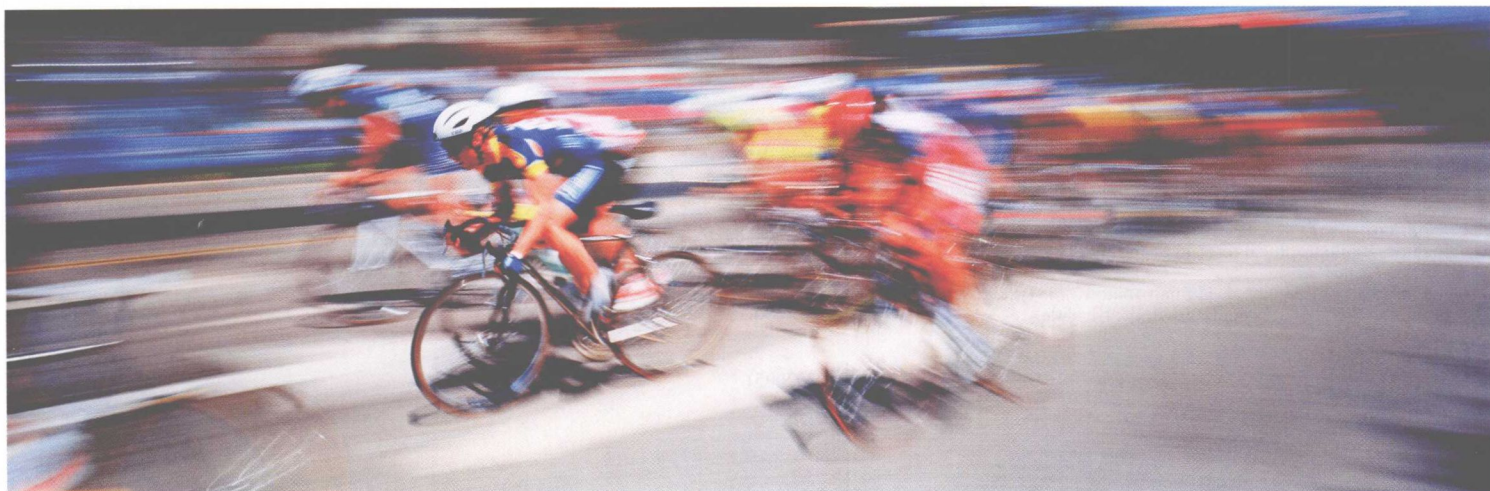


Martini / Bartholomew



Essentials of
Anatomy & Physiology

THIRD EDITION



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Anatomy & Physiology

THIRD EDITION

Frederic H. Martini, Ph.D.
Edwin F. Bartholomew, M.S.

with

William C. Ober, M.D.

Art Coordinator and Illustrator

Claire W. Garrison, R.N.

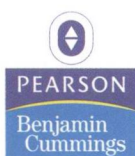
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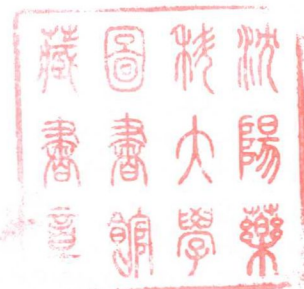
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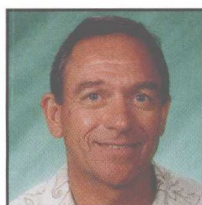
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Frederic H. Martini received his Ph.D. from Cornell University in comparative and functional anatomy. He has broad interests in vertebrate biology, with special expertise in anatomy, physiology, histology, and embryology. Dr. Martini's publications include journal articles, technical reports, magazine articles, and a book for naturalists on the biology and geology of tropical islands. He is the author of *Fundamentals of Anatomy and Physiology* (5e, Prentice Hall, 2001) and the coauthor of three other undergraduate texts on anatomy or anatomy and physiology.

Dr. Martini has been involved in teaching undergraduate courses in anatomy and physiology (comparative and/or human) since 1970. During the 1980s, he spent his winters teaching courses, including human anatomy and physiology, at Maui Community College and his summers teaching an upper-level field course in vertebrate biology and evolution for Cornell University at the Shoals Marine Laboratory (SML). Dr. Martini now devotes most of his attention to developing new approaches to A&P education, especially the use of appropriate technologies. He is a member of the Human Anatomy and Physiology Society, the American Association of Anatomists, the American Physiological Society, the National Association of Biology Teachers, the Society for Integrative and Comparative Biology, the Society for College Science Teachers, the Western Society of Naturalists, and the National Association of Underwater Instructors.



Edwin F. Bartholomew received his undergraduate degree from Bowling Green State University in Ohio and his M.S. from the University of Hawaii. His interests range widely, from human anatomy and physiology to the marine environment and the "backyard" aquaculture of escargots and ornamental fish. During the last three decades, Mr. Bartholomew has taught human anatomy and physiology at both the secondary and undergraduate levels. In addition, he has taught a wide variety of other science courses (from botany to zoology) at Maui Community College. He is presently teaching at historic Lahainaluna High School, the oldest high school west of the Rockies. He has written journal articles, a weekly newspaper column, and many magazine articles. Working with Dr. Martini, he coauthored *Structure and Function of the Human Body* (Prentice Hall, 1999) and *The Human Body in Health and Disease* (Prentice Hall, 2000). Mr. Bartholomew is a member of the Human Anatomy and Physiology Society, the National Association of Biology Teachers, the National Science Teachers Association, and the American Association for the Advancement of Science.



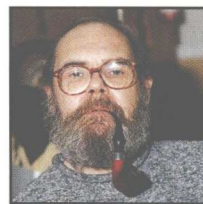
Dr. Kathleen Welch (clinical consultant) received her M.D. from the University of Washington in Seattle and did her residency at the University of North Carolina in Chapel Hill. For two years she served as Director of Maternal and Child Health at the LBJ Tropical Medical Center in American Samoa and subsequently was a member of the Department of Family Practice at the Kaiser Permanente Clinic in Lahaina, Hawaii. She has been in private practice since 1987. Dr. Welch is a Fellow of the American Academy of Family Practice. She is also a member of the Hawaii Medical Association and the Human Anatomy and Physiology Society.



Dr. William C. Ober (art coordinator and illustrator) received his undergraduate degree from Washington and Lee University and his M.D. from the University of Virginia in Charlottesville. While in medical school, he also studied in the Department of Art as Applied to Medicine at Johns Hopkins University. After graduation Dr. Ober completed a residency in family practice and is currently on the faculty of the University of Virginia in the Department of Sports Medicine. He is also part of the Core Faculty at Shoals Marine Laboratory, where he teaches biological illustration in the summer program. Dr. Ober now devotes his full attention to medical and scientific illustration.

Claire W. Garrison, R.N. (illustrator) practiced pediatric and obstetric nursing for nearly 20 years before turning to medical illustration as a full-time career. Following a five-year apprenticeship, she has worked as Dr. Ober's associate since 1986. Ms. Garrison is also a Core Faculty member at Shoals.

Texts illustrated by Dr. Ober and Ms. Garrison have received national recognition and awards from the Association of Medical Illustrators (Award of Excellence), American Institute of Graphics Arts (Certificate of Excellence), Chicago Book Clinic (Award for Art and Design), Printing Industries of America (Award of Excellence), and Bookbuilders West. They are also recipients of the Art Directors Award.



Ralph T. Hutchings is a biomedical photographer who was associated with the Anatomy Department of the Royal College of Surgeons for 20 years. An engineer by training, Mr. Hutchings has focused for years on photographing the structure of the human body. The result has been a series of color atlases, including the *Color Atlas of Human Anatomy*, *The Color Atlas of Surface Anatomy*, and *The Human Skeleton* (all published by Mosby-Yearbook Publishing, St. Louis, Missouri, USA). Mr. Hutchings makes his home in North London, where he tries to balance the demands of his photographic assignments with his hobbies of early motor cars and airplanes.

Dedication

*To Kitty, P. K. , Ivy, and Kate:
We couldn't have done this without you.
Thank you for your encouragement, patience,
and understanding.*

Preface

THIS TEXTBOOK IS DESIGNED as an introduction to the specialized terms, basic concepts, and principles important to an understanding of the human body. It has two primary goals:

1. **Building a foundation of essential knowledge in human anatomy and physiology.** Constructing this knowledge requires answers to questions such as: What structure is that? How does it work? What happens when it does not work?
2. **Providing a framework for interpreting and applying information that can be used in problem-solving.** This framework is based on the fact that certain themes and patterns appear again and again in the study of anatomy and physiology. These themes and patterns provide the hooks on which to organize and hang the information you will find in the text. Problems that require interpreting and applying information include such general questions as: How does a change in one body system affect the others? How does aging affect body systems?

The landscape of the new millennium in which we now live and work is dynamic, not static. There is a continuing explosion in what we know, how we know what we know, and how we share what we know. Our knowledge base in anatomy and physiology has expanded tremendously. For example, we know much more than ever about the specific roles molecules play in many normal physiological processes and in diseases; we can manipulate the DNA within cells and even clone identical animals; and, an initial survey of the human genome has been completed. These gains in knowledge have led to new methods and procedures to combat disease, reduce suffering, and promote good health. New methods of accessing and sharing information have linked health professionals around the world. Technology has become a means for acquiring and distributing information, and medical professionals have learned to use new technologies to increase their effectiveness as well as to improve the quality of medical care.

Modern technology has enhanced our ability to find specific information. As a result, it has affected how each of us deals with information in general. In many cases, knowing where to look for information is preferable to trying to memorize specific facts. That is certainly the trend in the training of medical and allied health professionals today. Students begin by mastering the terminology and memorizing a substantial core of basic concepts. In the process, they are also given (1) a “mental framework” for organizing new information, (2) the ability to access additional information when needed, by referring to relevant print or electronic data sources, and (3) an understanding of how to apply their knowledge to solve particular problems. The same skills are equally important to people in other career paths. To be effective in almost any job today, you must know how to access and absorb new information, to use (or learn to use) available technology, and to solve problems.

Essentials of Anatomy and Physiology third edition, has been carefully designed to place information in a meaningful context and to help students develop their problem-solving skills. Any one deciding

to embark on a career in a medical or allied health field must master the same skills that are needed to succeed in this course. Developing a large technical vocabulary and retaining a large volume of detailed information is not enough. A person must learn how to learn—how to organize new information, how to connect it to what is already known, and then how to apply it as needed. The electronic additions to this edition, including the enclosed CD-ROM and the Companion Website, make it easy for students and instructors to use current technology to access and manage information.

The focus of this text and learning system has been to simplify the processes of teaching and learning anatomy and physiology. Much as we would like to, we cannot create materials that will give any of us more time. But a carefully designed text and supplements package can help both instructors and students make better use of the time they do have. The User’s Guide that begins on p. xix outlines our specific teaching framework and shows the many learning aids that are built into this text. These features were developed through feedback from students and instructors on campuses across the United States, Canada, Australia, New Zealand, and Europe. Many students, in person or by phone or e-mail, have told us that this system really works for them when other presentation styles have not.

WHAT’S DIFFERENT ABOUT THE THIRD EDITION?

Each new edition requires some revising and updating. Our first step in planning for the third edition involved integrating the feedback from dozens of reviewers with our own experiences in the classroom. We were then able to identify key areas where students were having trouble following the narrative or grasping important concepts. We then worked with the illustration team to revise the art program while we revised the narrative and the teaching and learning system.

A detailed comparison with the second edition will show significant changes:

- New art design and corresponding revisions in tables and figures.
- The total number of chapters has been reduced from 21 to 20. Previously, the nervous system was split into two chapters; but now full coverage is provided in a single chapter.
- Many sections have been revised to focus more closely on the needs of students pursuing careers in allied health in one-semester courses.
- In a number of chapters, including those on the chemical level of organization (2), the skeletal system (6), and the urinary system (18), new illustrations have been added to simplify complex topics. The overall illustration count has been increased by about 7 percent.
- Each of the organ system chapters (i.e., Chapters 5–8 and 10–20) contains new Concept Check questions concerning how the system under consideration interacts with other selected body systems. The questions are keyed to the system integrator figures and are intended to reinforce the concept that the body functions as a unit.

- More clinical information has been added in the form of a list of Relevant Clinical Terms.
- New Concept Check questions have been added to reinforce understanding of the Aging and Systems Integration sections in each body system chapter. As in the second edition, the answers to all Concept Check questions are given at the end of each chapter.
- New Web Explorations. The MediaLab at the end of 11 chapters encourages students to investigate a text topic further on the Web.
- Each new copy of the textbook contains an EAP Interactive Student CD-ROM. It contains visual tools to help understand anatomy and physiology; dissectable 3-D animations, tutorials, interactive clinical case studies; and an audio glossary.
- Each new copy of the textbook includes a copy of the Applications Manual (AM).

INTEGRATED SUPPLEMENTS

For the Instructor

- **300 Full Color Transparencies** Key illustrations, including artwork, scans, and cadaver photographs, make up this outstanding transparency set. Artwork, labels, and leaders are enlarged for easier visibility and a special production technique is used to saturate all colors making them crisp, vivid, and clear.
- **Instructor's Resource Guide** This guide makes it easy to see content at a glance in detailed lecture outlines for each chapter. It also provides unique analogies and useful teaching techniques that will engage students by promoting lively classroom discussion and by infusing lectures with interesting and appropriate clinical notes. Tips from other instructors across the country are also included.
- **Instructor's Media Portfolio** All of the artwork, scans, and photographs can be easily accessed from our Instructor's Media Portfolio. In addition, this fantastic resource provides instructors with both labeled and unlabeled art, images with lecture outlines in PowerPoint, and all of the animations from the student CD-ROM. This easy-to-use tool enables you to build multimedia lectures using PowerPoint.
- **Test Item File and Prentice Hall Custom Text Software** Access a complete testing package with more than 3000 questions. The testing package parallels the three-level learning system used in the textbook and also includes over 200 pieces of unlabeled text art to allow instructors to create labeling exercises for exams.
- **Prentice Hall Laserdisc for Anatomy and Physiology and Bar Code Manual** This laserdisc uses videodisc technology to feature high-quality animations based on art from the text.

For the Student

- **Student Tutor CD-ROM** This interactive CD-ROM offers a wealth of supplemental content and learning exercises to complement the material presented in the text and helps reinforce the concepts students learned in class. Interactive tutorials use text graphics, animations, and audio to help students visualize difficult concepts and encourage self-assessment and promote retention with several types of innovative quizzes. Animations provide step-by-step

views of physiological processes, while 3-D visualizations allow you to explore, rotate, and dissect lifelike three-dimensional models of the human body. Case studies expressly written to complement material in this third edition of the text help students integrate knowledge and practice their analytical and diagnostic skills in real-world situations.

- **WebCT** provides you with high-quality, class-tested material pre-programmed and fully functional in the WebCT environment. Whether used as an online supplement to either a campus-based or a distance-learning course, our preassembled course content gives you a tremendous head start in developing your own online courses.
- **Instructors 1st** For qualified adopters, Prentice Hall is proud to introduce Instructors 1st—the first integrated service committed to meeting your customization, support, and training needs for your course.
- **Companion Website for Essentials of Anatomy and Physiology** An exciting new edition of Prentice Hall's Companion Website has been developed specifically for students using the third edition of Essentials of Anatomy and Physiology. In addition to multiple-choice, essay, and short-answer questions, this site's self-grading quizzes offer exercises in labeling and concept mapping for each chapter. Numerous interesting, related Websites are referenced and annotated in the Destinations sections, and our NetSearch offers a convenient gateway to hundreds of other sites of interest.
- **Study Guide** Designed to help students master the topics and concepts covered in the textbook, the study guide includes a variety of review questions, including labeling, concept mapping, and crossword puzzles, that promote an understanding of body systems. It is keyed to each chapter's learning objectives and parallels the three-level learning system in the textbook.
- **Applications Manual** This supplement provides students with access to interesting and relevant clinical and diagnostic information. It includes introductory sections about the scientific method and the applications of chemistry and cell biology to clinical work, sections about each body system that parallel the textbook organization and provide more detailed clinical information, a full-color Surface Anatomy and Cadaver Atlas, and Critical-Thinking Questions for each body system. The Applications Manual is fully cross-referenced to the textbook to promote the integration of this material into the course.
- **Student Notetaking Guide** This unique supplement features selected key art from the text in full four-color on the left-hand side of the page with the entire right side left blank for notes. Instead of scrambling to quickly sketch the images depicted on the transparencies, students can spend the time actually listening to the lecture and jotting down the critical notes right beside the artwork.
- **Anatomy and Physiology Video Tutor** This highly praised, 75-minute videotape focuses on the concepts that both instructors and students consistently identify as the most challenging. Physiological processes are demonstrated through the use of top-quality three-dimensional animations and video footage. On-camera narration and the accompanying frame-references study booklet allow for repeated concept review.

- **New York Times “Themes of the Times” Program** Prentice Hall’s unique alliance with *The New York Times* enhances your access to current, relevant information and applications. Articles are selected by the text authors and are compiled into a free supplement that helps instructors make the connection between the classroom and the outside world.
- **Life on the Internet—A Student’s Guide** This hands-on supplement brings students up to speed on what the Internet is and how to navigate it.

Products for the Laboratory

- **Laboratory Manual for Anatomy and Physiology** by Roberta Meehan
- **Instructor’s Manual to accompany the Laboratory Manual**, by Roberta Meehan
- **Anatomy and Physiology Laboratory Manual** by Michael Wood
- **Instructor’s Manual to Accompany Anatomy and Physiology Laboratory Manual** by Michael Wood

ACKNOWLEDGMENTS

Every textbook represents a group effort. Foremost on the list are the faculty and reviewers whose advice, comments, and collective wisdom helped shape this edition. Their interest in the subject, their concern for the accuracy and method of presentation, and their experience with students of widely varying abilities and backgrounds made the review process an educational experience. To these individuals, who carefully recorded their comments, opinions, and sources, we express our sincere thanks and best wishes. We would also like to acknowledge the many users, survey respondents, and focus group members whose advice, comments, and collective wisdom helped shape this text into its final form. Their passion for the subject, their concern for accuracy and method of presentation, and their experience with students of widely varying abilities and backgrounds have made the review process much more fruitful.

The following individuals devoted large amounts of time reviewing drafts of *Essentials of Anatomy and Physiology*:

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Professor Jeffrey Kiggins, *Blue Ridge Community College*
 Dr. Jennifer Lundmark, *California State University at Sacramento*
 Professor Bert Atsma, *Union County College*
 Dr. Ann Wright, *Canisius College*
 Professor Luanne Clark, *Lansing Community College*
 Dr. Louis Miller, *University of Wisconsin-Stout*
 Dr. George Spiegel, Jr., *Mid Plains Community College*
 Dr. Barbara Christie-Pope, *Cornell College*

Technical Reviewers

We would also like to thank,
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Reviewers for the Second Edition

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Technical Reviewers

Brent DeMars, *Lakeland Community College*
 Kathleen Flickinger, *Iowa State University*

Our gratitude is also extended to the many faculty and students at campuses across the United States (and out of the country) who made suggestions and comments that helped us improve this edition of *Essentials of Anatomy and Physiology*.

A textbook has two components: narrative and visual. In preparing the narrative, we were ably assisted by Ray Mullaney, Vice President/Editor in Chief of Development, who played a vital role in shaping this text by helping us keep the text organization, general tone, and level of presentation consistent throughout. The accuracy, currency, and clarity of the clinical material in the text and in the Application Manual reflect the detailed clinical reviews performed by Kathleen Welch, M.D.

Virtually without exception, reviewers stressed the importance of accurate, integrated, and visually attractive illustrations in helping students understand essential material. The creative talents brought to this project by our artist team, William Ober, M.D., and Claire Garrison, R.N., are inspiring and very much appreciated. Bill and Claire worked intimately and tirelessly with us, imparting a unity of vision to the book as a whole while making it both clear and beautiful. Their superb art program is greatly enhanced by the incomparable bone and cadaver photographs of Ralph T. Hutchings, formerly of The College of Surgeons of England, and co-author of the best-selling *McMinns Color Atlas of Human Anatomy*.

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We would like to thank Mike Banino, media consultant, and Sharon Simpson who worked closely with the talented team at VPG on the Student Tutor CD-ROM. Crissy Dudonis also displayed her creative talents to create the outstanding website that accompanies this text. We greatly appreciate their contributions. Kate Flickinger played an instrumental role assisting with media products and writing the MediaLabs that appear in the text. Mike was joined by a committed media production group led by Nicole Bush (Assistant Managing

Editor, Media), whose eye for detail and skill with project management are both envied and appreciated.

We are grateful to Paul Corey, President of the Engineering, Science, and Mathematics Division of Prentice Hall, and Sheri Snively, Vice President/Editor in Chief of Life and Geosciences, for their continued enthusiastic support of this project, as well as for our other books at Prentice Hall. We would also like to acknowledge the contributions of Marty McDonald, Senior Marketing Manager, and Jennifer Welchans, Executive Marketing Manager, who keep their fingers on the pulse of the market and help us meet the needs of our users. Above all, thanks to our editor, Halee Dinsey, for her patience in nurturing this project, her tireless efforts to coordinate the various components of the package, and her work on the media supplements and Interactive CD-ROM.

Finally, we would like to thank our families for their love and support during the revision process.

No two people could expect to produce a flawless textbook of this scope and complexity. Any errors or oversights are strictly our own rather than those of the reviewers, artists, or editors. In an effort to improve future editions, we ask that readers with pertinent information, suggestions, or comments concerning the organization or content of this textbook send their remarks to us directly, by email, or care of Halee Dinsey, Senior Editor, Applied Biology, Prentice Hall, One Lake Street, Upper Saddle River, NJ, 07458. Any and all comments and suggestions will be deeply appreciated and carefully considered in the preparation of the next edition.



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Chapter Outline and Objectives Each chapter opens with an outline that gives you an overview of the concepts. Integrated objectives help you structure your reading and keep your attention focused on the key points.

5

The Integumentary System

CHAPTER OUTLINE AND OBJECTIVES

Introduction	110
Integumentary Structure and Function	110
The Epidermis, p. 111	
The Dermis, p. 114	
The Subcutaneous Layer, p. 114	
Accessory Structures, p. 114	
Describe the general functions of the integumentary system.	
Describe the main structural features of the epidermis, and explain their functional significance.	
Explain what accounts for individual and racial differences in skin, such as skin color.	
Describe how the integumentary system helps regulate body temperature.	
Discuss the effects of ultraviolet radiation on the skin and the role played by melanocytes.	
Discuss the functions of the skin's accessory structures.	
Describe the mechanisms that produce hair and that determine hair texture and color.	
Local Control of Homeostasis	118
Injury and Repair, p. 118	
Explain how the skin responds to injury and repairs itself.	
Aging and the Integumentary System	120
Summarize the effects of the aging process on the skin.	
Integration with Other Systems	120

Vocabulary Development

cornu	horn; stratum corneum
cutis	skin; cutaneous
derma	skin; dermis
epi-	above or over; epidermis
facere	to make; cornified
germinare	to start growing; stratum germinatum
keros	horn; keratin
kyanos	blue; cyanosis
luna	moon; lunula
melas	black; melanin
onyx	nail; onychium
papilla	a nipple-shaped mound; dermal papillae

THE BOogie BOARD SURFER "shredding" the wave is probably too busy to consider what contributions and sacrifices are normally made by her skin. This remarkable structure absorbs ultraviolet radiation, prevents dehydration, preserves normal body temperature, and tolerates chafing and abrasion. Although few people think of it in these terms, the skin is actually an organ—the largest organ of the body. In this chapter we will examine its varied functions.

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The Peripheral Nervous System • The Autonomic Nervous System • Aging and the Nervous System • Interplay with Other Systems • Chapter Review

nervous system (CNS), consisting of the brain and the spinal cord, integrates and coordinates sensory data and motor commands. The CNS is also the seat of higher functions, such as intelligence, memory, and emotion. All communication between the CNS and the rest of the body occurs over the **peripheral nervous system (PNS)**. The peripheral nervous system includes all the neural tissue *outside* the CNS. Its **afferent division** (*af-*, to + *ferre*, to carry) brings sensory information to the CNS, and its **efferent division** (*ef-*, from) carries motor commands to muscles and glands. Within the efferent division, the **somatic nervous system (SNS)** provides control over skeletal muscle contractions, and the **autonomic nervous system (ANS)**, or **visceral motor system**, provides automatic involuntary regulation of smooth muscle, cardiac muscle, and glandular secretions. The ANS includes a **sympathetic division** and a **parasympathetic division**, which commonly have opposite effects. For example, activity of the sympathetic division accelerates the heart rate whereas the parasympathetic division slows the heart rate.

Cellular Organization in Neural Tissue

The nervous system includes all the neural tissue in the body. Neural tissue, introduced in Chapter 4, consists of two kinds

of cells, **neurons** and **neuroglia**. **Neurons** (*neuro-*, nerve) are the basic units of the nervous system. All neural functions involve the communication of neurons with one another and with other cells. The **neuroglia** (*neuro-*, nerve; *-glia*, glue) regulate the environment around the neurons, provide a supporting framework for neural tissue, and act as phagocytes. Although they are much smaller cells, neuroglia, also called **glial cells**, far outnumber neurons. Unlike most neurons, most glial cells retain the ability to divide.

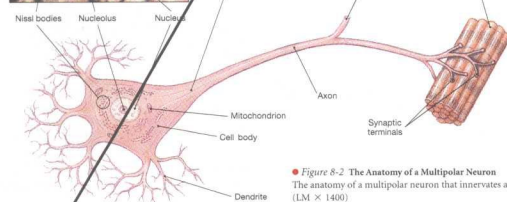
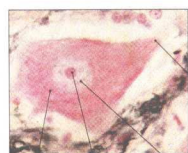
NEURONS

The General Structure of Neurons

A "model" neuron has (1) a cell body; (2) several branching, sensitive **dendrites**, which receive incoming signals; and (3) an elongate **axon**, which carries outgoing signals toward (4) one or more **synaptic terminals** (Figure 8-2a). At each synaptic terminal, the neuron communicates with another cell. (Because the synaptic terminals between neurons are rounded, they are also called **synaptic knobs**.) Neurons can have a variety of shapes. Figure 8-2b shows a **multipolar neuron**, the most common type of neuron in the CNS.

The cell body of a typical neuron contains a large, round nucleus with a prominent nucleolus. There are usually no centrioles, organelles that in other cells form the spindle fibers that move chromosomes during cell division. Most neurons lose their centrioles during differentiation and become incapable of undergoing mitosis. As a result, most neurons lost to injury or disease cannot be replaced.

The cell body also contains the organelles that provide energy and synthesize organic compounds. The numerous mitochondria, free and fixed ribosomes, and membranes of



• Figure 8-2 The Anatomy of a Multipolar Neuron
The anatomy of a multipolar neuron that innervates a skeletal muscle. (LM $\times 1400$)

Key Terms The most important new terms are highlighted in bold type and often include the pronunciation. Key terms are also listed at the end of the chapter for easy review.

Concept Links The chain-link icon provides a quick visual signal that new material being presented is related to or builds on earlier discussions.

Vocabulary Development This section lists the important word roots that form the basis of the vocabulary in the chapter.

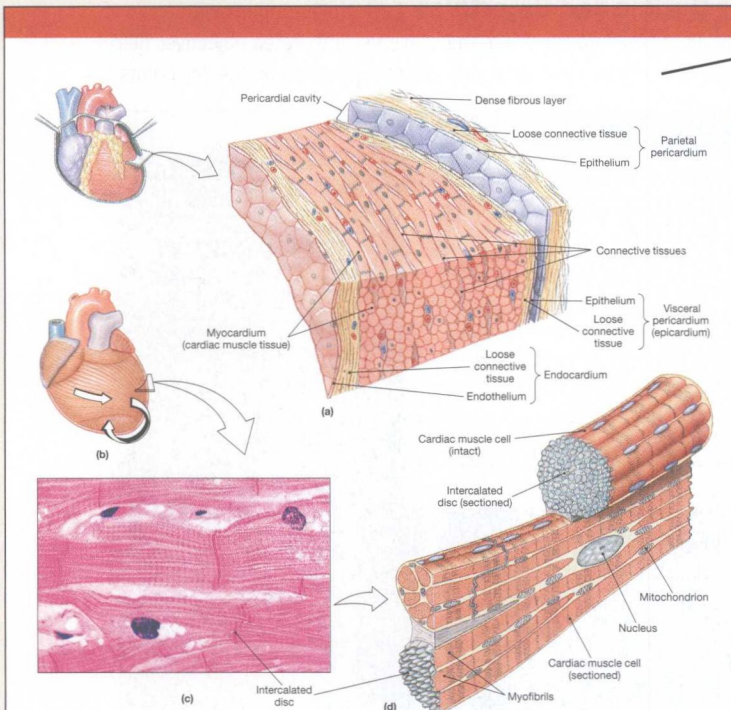
Figure Reference Locators Red dots serve as place markers, making it easy to return to your spot in the narrative after you've studied an illustration.

CHAPTER REVIEW

Key Terms

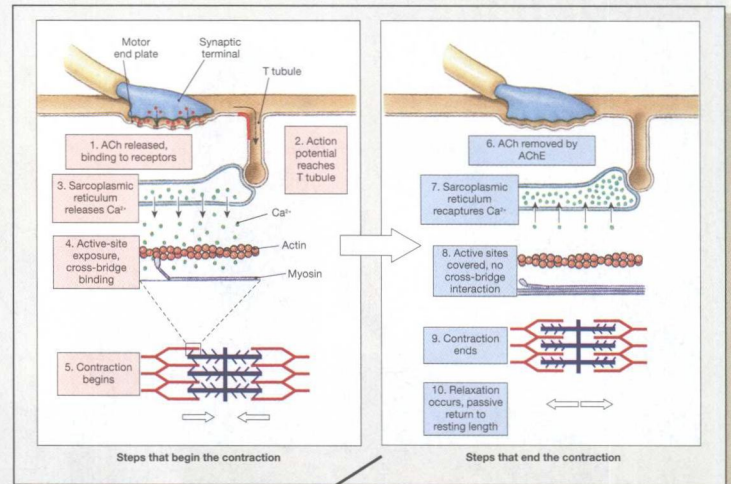
action potential	233	diencephalon	243	midbrain	
autonomic nervous system (ANS)	227	dual innervation	267	myelin	
axon	227	ganglion/ganglia	240	nerve plexus	
cerebellum	243	hypothalamus	243	neuroglia	
cerebrospinal fluid	230	limbic system	251	neurotransmitter	
cerebrum	243	medulla oblongata	243	parasympathetic division	
cranial nerves	231	membrane potential	232	polysynaptic	
		meninges	238	postganglionic	

Visualizing Structure & Function



● Figure 12-4 The Heart Wall
(a) A diagrammatic section through the heart wall, showing the relative positions of the epicardium, myocardium, and endocardium.
(b) Cardiac muscle tissue forms concentric layers that wrap around the atria and spiral within the walls of the ventricles.
(c, d) Sectional and diagrammatic views of cardiac muscle tissue. Cardiac muscle cells are smaller than skeletal muscle fibers and have a single, central nucleus, branching interconnections between cells, and intercalated discs. (LM × 575)

Outstanding Anatomy Art and Photos To understand physiology, you must be able to visualize structures in the human body. Macro-to-micro drawings, coupled with histology or electron micrographs, make the details of anatomy easy to understand.



Conceptual Diagrams Show Physiology Physiological processes are easier to understand with flowcharts and diagrams that link structure and function.

Concept Check Questions These questions, located at the ends of major sections in the narrative, will help you assess your understanding of the basic concepts addressed in the previous pages.

CONCEPT CHECK QUESTIONS

Answers on page 222

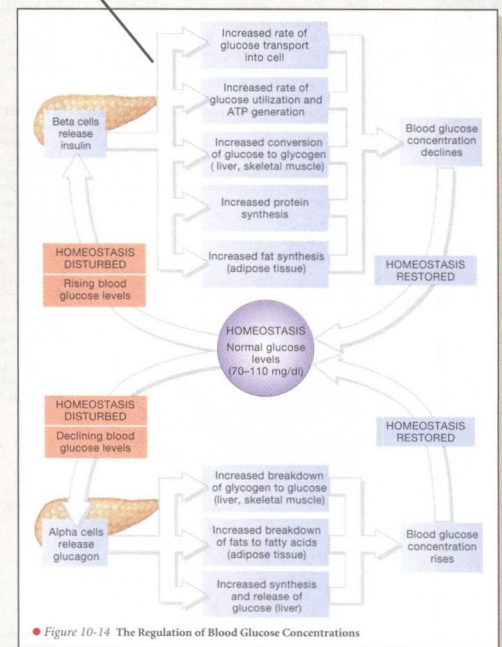
1. How would severing the tendon attached to a muscle affect the ability of the muscle to move a body part?
2. Why does skeletal muscle appear striated when viewed through a microscope?
3. Where would you expect the greatest concentration of calcium ions in resting skeletal muscle to be?

Answers to Concept Check Questions

Page 182

1. Since tendons attach muscles to bones, severing the tendon would disconnect the muscle from the bone. When the muscle contracted, nothing would happen.
2. Skeletal muscle appears striated when viewed under the microscope because this muscle is composed of the myofilaments actin and myosin, which have an arrangement that produces a banded appearance in the muscle.
3. You would expect to find the greatest concentration of calcium ions in the cisternae of the sarcoplasmic reticulum of the muscle.

Page 184



● Figure 10-14 The Regulation of Blood Glucose Concentrations

Answers to Concept Check Questions

The answers to concept check questions are provided at the end of each chapter.

Relating Clinical Examples



CLINICAL NOTE Abnormal Hemoglobin

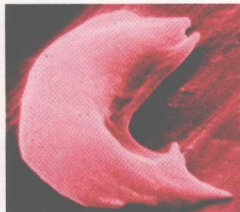
Several inherited disorders are characterized by the production of abnormal hemoglobin. Two of the best known are *thalassemia* and *sickle-cell anemia* (SCA).

The various forms of *thalassemia* (thal-ah-SĒ-mĕ-uh) result from an inability to produce adequate amounts of the globular protein components of hemoglobin. As a result, the rate of RBC production is slowed, and the mature RBCs are fragile and short-lived. The scarcity of healthy RBCs reduces the oxygen-carrying capacity of the blood and leads to problems in growth and development. Individuals with severe thalassemia must undergo frequent *transfusions*—the administration of blood components—to maintain adequate numbers of RBCs in the blood.

Sickle-cell anemia (SCA) results from a mutation affecting the amino acid sequence of one pair of the globular proteins of the hemoglobin molecule. When blood contains an abundance of oxygen, the hemoglobin molecules and the RBCs that carry them appear normal (Figure 11-3a). But when the defective hemoglobin gives up enough of its stored oxygen, the adjacent hemoglobin molecules interact, and the cells change shape, becoming stiff and markedly curved (Figure 11-3b). This “sickling” does not affect the oxygen-carrying capabilities of the RBCs, but it makes them more fragile and easily damaged. Moreover, when an RBC that has folded to squeeze into a narrow capillary delivers its oxygen to the surrounding tissue, the cell can become stuck as sickling occurs. This blocks blood flow and nearby tissues become oxygen-starved.



(a) Normal RBC



(b) Sickled RBC

● **Figure 11-3 Sickling in Red Blood Cells** (a) When fully oxygenated, the individual with the sickling trait appears as normal RBCs. (b) When deoxygenated, the RBCs change shape, becoming more rigid and sharp (SEM × 5200)

Clinical Note Clinical or health-related topics of particular importance are presented in boxes set off from the main text. These essays cover major diseases, such as lung cancer and AIDS, in addition to other subjects of special interest, such as clinical procedures.



STRESS AND THE IMMUNE RESPONSE

Interleukin-1 is one of the first cytokines produced as part of the immune response. In addition to promoting inflammation, it also stimulates production of adrenocorticotropic hormone (ACTH) by the anterior pituitary gland. This, in turn, leads to the secretion of glucocorticoids by the adrenal cortex. p. 327 The anti-inflammatory effects of the glucocorticoids may help control the intensity of the immune response. However, the long-term secretion of glucocorticoids, as in chronic stress, can inhibit the immune response and lower resistance to disease. p. 334 Glucocorticoids depress inflammation, inhibit phagocytes, and reduce interleukin production. The mechanisms involved are still under investigation. It is well known, however, that immune system depression due to chronic stress represents a serious threat to health.

Clinical Discussions Important clinical topics presented in context are set off by an icon and title. These topics have been selected not only for their medical importance, but also to show how an understanding of abnormal conditions can shed light on normal functions, and vice versa.

Focus Boxes These essays provide illustrated summaries of important processes or clinical conditions. Topics in the text include visual accommodation problems (p. 293), urine formation (p. 559), and bone fractures (p. 135).



FOCUS

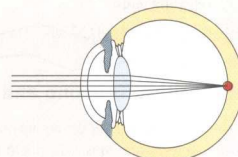
Accommodation Problems

In the normal eye, when the ciliary muscles are relaxed and the lens is flattened, a distant image will be focused on the retinal surface (Figure 9-16a). However, irregularities in the shape of the lens or cornea can affect the clarity of the visual image. This condition, called *astigmatism*, can usually be corrected by glasses or special contact lenses.

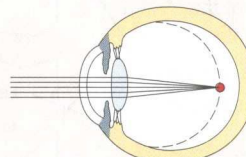
Figure 9-16 diagrams two other common problems with the accommodation mechanism.

If the eyeball is too deep, the image of a distant object will form in front of the retina, and the retinal picture will be blurry and out of focus (Figure 9-16b). Vision at close range will be normal, because the lens will be able to round up as needed to focus the image on the retina. As a result, such individuals are said to be “nearsighted.” Their condition is more formally termed *myopia* (*myein*, to shut + *ops*, eye). Myopia can be corrected by placing a diverging lens in front of the eye (Figure 9-16c).

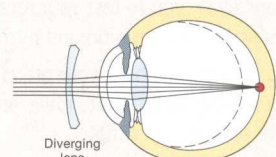
If the eyeball is too shallow, *hyperopia* results (Figure 9-16d). The ciliary muscles must contract to focus even a distant object on the retina, and at close range the lens cannot provide enough refraction. These individuals are said to be “farsighted” because they can see distant objects most clearly. Older individuals become farsighted as their lenses lose elasticity; this form of hyperopia is called *presbyopia* (*presbys*, old man). Hyperopia can be treated by placing a converging lens in front of the eye (Figure 9-16e).



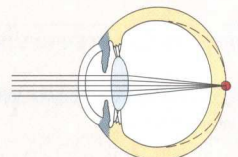
(a) Emmetropia



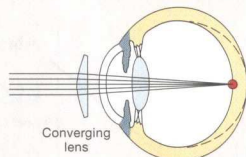
(b) Myopia



(c) Myopia (corrected)



(d) Hyperopia



(e) Hyperopia (corrected)

● **Figure 9-16 Visual Abnormalities** (a) In normal vision, the lens focuses the visual image on the retina. One common problem of accommodation involves (b) an inability to lengthen the focal distance enough to focus the image of a distant object on the retina—myopia. (c) A diverging lens is used to correct myopia. (d) Another accommodation problem is an inability to shorten the focal distance adequately for near objects—hyperopia. (e) A converging lens is used to correct hyperopia.

Related Clinical Terms

ankylosis (ang-ki-LŌ-sis): An abnormal fusion between articulating bones in response to trauma and friction within a joint.

arthritis (ar-THRĪ-tis): Rheumatic diseases that affect synovial joints. Arthritis always involves damage to the articular cartilages, but the specific cause can vary. The diseases of arthritis are usually classified as either *degenerative* or *inflammatory*.

arthroscopic surgery: The surgical modification of a joint by using an *arthroscope* (a fiberoptic instrument used to view the inside of joint cavities).

bursitis: An inflammation of a bursa, causing pain whenever the associated tendon or ligament moves.

carpal tunnel syndrome: An inflammation of the tissues at the anterior wrist, causing compression of the median nerve.

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Related Clinical Terms New to the third edition is a list of relevant clinical terms at the end of each chapter.

Reviewing the Concepts

18 THE URINARY SYSTEM

The Organization of the Urinary System • The Kidneys • Basic Principles of Urine Production • Urine Transport, Storage, and Elimination

CHAPTER REVIEW

Key Terms

acidosis	569	filtrate	550	loop of Henle	550	ureters	562
aldosterone	558	glomerular filtration rate	556	micturition	563	urinary bladder	563
alkalosis	569	glomerulus	550	nephron	550	urine	555
angiotensin II	560	juxtaglomerular apparatus	553	peritubular capillaries	554		
buffer system	570	kidney	548	renin	560		

Summary Outline

INTRODUCTION548

1. The functions of the **urinary system** include (1) eliminating organic waste products, (2) regulating plasma concentrations of ions, (3) regulating blood volume and pressure by adjusting the volume of water lost and releasing hormones, (4) stabilizing blood pH, and (5) conserving nutrients.

THE ORGANIZATION OF THE URINARY SYSTEM548

1. The urinary system includes the kidneys, the ureters, the urinary bladder, and the urethra. The kidneys produce urine (a fluid containing water, ions, and soluble compounds); during urination urine is forced out of the body. (Figure 18-1)

THE KIDNEYS548

1. The left kidney extends superiorly slightly more than the right kidney. Both lie in a **retroperitoneal** position. (Figure 18-2)

Superficial and Sectional Anatomy549

2. A fibrous renal capsule surrounds each kidney. The **hilus** provides entry for the **renal artery** and exit for the **renal vein** and **ureter**.
3. The ureter is connected to the **renal pelvis**. This chamber branches into two **major calyces**, each connected to four or five **minor calyces**, which enclose the **renal papillae**. Urine production begins in **nephrons**. (Figure 18-3)

The Nephron550

4. The nephron (the basic functional unit in the kidney) includes the **renal corpuscle** and a **renal tubule**, which empties into the **collecting system** through a **collecting duct**. From the renal corpuscle, the filtrate travels through the **proximal convoluted tubule**, the **loop of Henle**, and the **distal convoluted tubule**. (Figures 18-3c, 18-4)
5. Nephrons are responsible for the (1) production of **filtrate**, (2) reabsorption of nutrients, and (3) reabsorption of water and ions.
6. The renal tubule begins at the **renal corpuscle**. It includes a knot of intertwined capillaries called the **glomerulus** surrounded by the **Bowman's capsule**. Blood arrives from the **afferent arteriole** and departs in the **efferent arteriole**. (Figure 18-5)
7. At the glomerulus, **podocytes** cover the basement membrane of the capillaries that project into the **capsular space**. The processes of the podocytes are separated by narrow slits. (Figure 18-5)
8. The **proximal convoluted tubule (PCT)** actively reabsorbs nutrients, plasma proteins, and electrolytes from the filtrate. They are then released into the surrounding interstitial fluid. (Figure 18-4)
9. The **loop of Henle** includes a **descending limb** and an **ascending limb**. The ascending limb is impermeable to water and solutes; the descending limb is permeable to water. (Figure 18-4)

10. The ascending limb delivers fluid to the **distal convoluted tubule (DCT)**, which actively secretes ions and reabsorbs sodium ions from the urine. The **juxtaglomerular apparatus**, which releases **renin** and **erythropoietin**, is located at the start of the DCT. (Figure 18-5a)

11. The **collecting ducts** receive urine from nephrons and merge into a **papillary duct** that delivers urine to a minor calyx. The collecting system makes final adjustments to the urine by reabsorbing water or reabsorbing or secreting various ions.

The Blood Supply to the Kidneys553

12. The blood vessels of the kidneys include the **interlobar**, **arcuate**, and **interlobular arteries**, and the **interlobar**, **arcuate**, and **interlobular veins**. Blood travels from the **peritubular capillaries** and the **capillaries of the vasa recta** and **tial fluid** that surrounds the ne

BASIC PRINCIPLES OF URINE

1. The primary purpose in **urine** is the **elimination** of dissolved solutes, primarily **urea**, **creatinine**, and **uric acid**.
2. Urine formation involves **filtration** (Tables 18-1, 18-2)

Filtration at the Glomerulus

3. Glomerular filtration occurs in the **glomerulus**, where blood is filtered through the **glomerular capillaries**. The amount of filtrate produced in the glomerulus is called the **glomerular filtration rate (GFR)**, which alters the **filtration** (blood) pressure and kidney function.
4. Dropping filtration pressures **releases renin**. Renin release **lowers blood pressure**.

Reabsorption and Secretion Along the Renal Tubule

5. The cells of the **PCT** normally **reabsorb** the filtrate produced in the glomerulus, and **secrete** various substances.
6. Water and ions are **reabsorbed**. The **ascending limb** reabsorbs **water** and **ions**, which encourages the **osmotic flow**.

Key Terms Important terms introduced in the chapter are listed here with a page reference for quick review in context with the relevant material.

Summary Outline This outline provides a detailed summary of all the sections in the chapter—including page references and all corresponding figure and table numbers.

Review Questions

Level 1: Reviewing Facts and Terms

Match each item in column A with the most closely related item in column B. Use letters for answers in the spaces provided.

COLUMN A

1. urination
2. renal capsule
3. hilus
4. medulla
5. nephrons
6. renal corpuscle
7. external urethral sphincter
8. internal urethral sphincter
9. aldosterone
10. podocytes
11. efferent arteriole
12. afferent arteriole
13. vasa recta

COLUMN B

- a. site of urine production
- b. capillaries around loop of Henle
- c. causes sensation of thirst
- d. accelerated sodium reabsorption
- e. voluntary control
- f. glomerular epithelium
- g. fibrous covering
- h. blood leaves glomerulus
- i. dominant cation in ICF
- j. renal pyramids
- k. blood to glomerulus
- l. interstitial fluid
- m. contains glomerulus

Level 2: Reviewing Concepts

30. The urinary system regulates blood volume and pressure by:
 - (a) adjusting the volume of water lost in the urine
 - (b) releasing erythropoietin
 - (c) releasing renin
 - (d) a, b, and c are correct

33. When pure water is consumed:
 - (a) the ECF becomes hypertonic with respect to the ICF
 - (b) the ECF becomes hypotonic with respect to the ICF
 - (c) the ICF becomes hypotonic with respect to the ECF
 - (d) water moves from the ICF into the ECF

34. Increasing or decreasing the amount of water consumed affects the osmolarity of the ECF.

Level 3: Critical Thinking and Clinical Applications

40. Long-haul trailer truck drivers are on the road for long periods of time between restroom stops. Why might that lead to kidney problems?
41. For the past week, Susan has felt a burning sensation in the urethral area when she urinates. She checks her temperature and finds that

- she has a low-grade fever. What would you expect to find in her urine?
42. Mannitol is a sugar that is filtered but not reabsorbed. What effect would drinking a solution of mannitol have on the volume of urine produced?

ANSWERS TO CHAPTER REVIEW QUESTIONS

CHAPTER 1

Level 1: Reviewing Facts and Terms

1. g 2. d 3. a 4. j 5. b 6. l 7. n 8. f 9. h 10. e 11. c 12. o 13. k 14. i 15. m 16. c 17. d 18. b 19. c 20. c 21. b

Level 2: Reviewing Concepts

22. responsiveness, adaptability, growth, reproduction, movement, metabolism, absorption, respiration, excretion
23. molecules-cell-tissues-organs-organ systems—organisms
24. Homeostatic regulation refers to adjustments in physiological systems that are responsible for the preservation of homeostasis.
25. In negative feedback, a variation outside normal ranges triggers an au-

follows: 2 in the first level, 8 in the second level, and 6 in the third level. To achieve a full 8 electrons in the third level, the sulfur atom could accept 2 electrons in an ionic bond or share 2 electrons in a covalent bond. Since hydrogen atoms can share 1 electron in a covalent bond, the sulfur atom would form 2 covalent bonds, 1 with each of 2 hydrogen atoms.

27. If a person exhales large amounts of carbon dioxide, the equilibrium will shift to the left and the level of hydrogen ion in the blood will decrease. A decrease in the amount of hydrogen ion will cause the pH to rise.

CHAPTER 3

Level 1: Reviewing Facts and Terms

1. e 2. d 3. h 4. a 5. f 6. b 7. g 8. c 9. m 10. k 11. a

Review Questions Questions are organized in a three-tiered system to help you build your knowledge:

Level 1 questions allow you to test your recall of the chapter's basic information and terminology.

Level 2 questions help you check your grasp of concepts and your ability to integrate ideas presented in different parts of the chapter.

Level 3 questions let you develop your powers of reasoning and analysis by applying chapter material to plausible real-world and clinical situations.

Answers to Chapter Review Questions

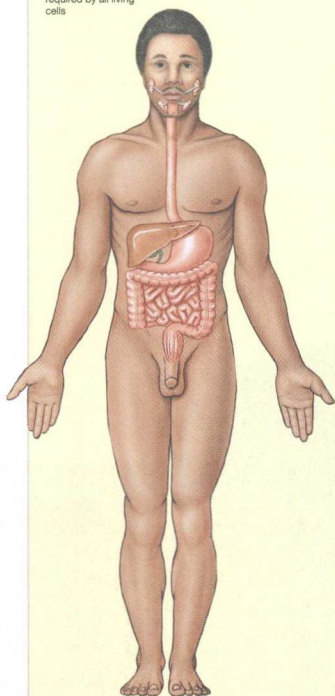
For easy reference, the chapter review questions are answered in Appendix I, p. A-1.

Integrating Concepts

The Large Intestine • Digestion and Absorption • Aging and the Digestive System • Integration with Other Systems • Chapter Review

The Digestive System

For All Systems
Absorbs organic substrates, vitamins, ions, and water required by all living cells



The Integumentary System

- Provides vitamin D₃ needed for the absorption of calcium and phosphorus
- Provides lipids for storage by adipocytes in subcutaneous layer

The Skeletal System

- Skull, ribs, vertebrae, and pelvic girdle support and protect parts of digestive tract; teeth important in mechanical processing of food
- Absorbs calcium and phosphate ions for incorporation into bone matrix; provides lipids for storage in yellow marrow

The Muscular System

- Protects and supports digestive organs in abdominal cavity; controls entrances and exits to digestive tract
- Liver regulates blood glucose and fatty acid levels; metabolizes lactic acid from active muscles

The Nervous System

- ANS regulates movement and secretion; reflexes coordinate passage of materials along tract; control over skeletal muscles regulates ingestion and defecation; hypothalamic centers control hunger, satiety and feeding behaviors
- Provides substrates essential for neurotransmitter synthesis

The Endocrine System

- Epinephrine and norepinephrine stimulate constriction of sphincters and depress digestive activity; hormones coordinate activity along tract
- Provides nutrients and substrates to endocrine cells; endocrine cells of pancreas secrete insulin and glucagon; liver produces angiotensinogen

The Cardiovascular System

- Distributes hormones of the digestive tract; carries nutrients, water, and ions from sites of absorption; delivers nutrients and toxins to liver
- Absorbs fluid to maintain normal blood volume; absorbs vitamin K; liver excretes heme (as bilirubin); synthesizes coagulation proteins

The Lymphatic System

- Tonsils and other lymphoid nodules along digestive tract defend against infection and toxins absorbed from the tract; lymphatic vessels carry absorbed lipids to venous system
- Secretions of digestive tract (acids and enzymes) provide defense against pathogens

The Respiratory System

- Increased thoracic and abdominal pressure to assist in defecation
- Pressure of digestive organs against the diaphragm limit inhalation

The Urinary System

- Excretes toxins absorbed by the digestive tract; excretes bilirubin produced by liver
- Absorbs water needed to excrete waste products; provides water needed to maintain normal body fluid volume

The Reproductive System

- Provides additional nutrients required to support and (in pregnant women) embryonic and fetal development

● Figure 16-19 Functional Relationships Between the Digestive System and Other Systems

Systems Integrators Found at the end of each body system chapter, systems integrators show how one particular system interacts with each of the body's other systems.

20 DEVELOPMENT AND INHERITANCE

Also Overview of Topics in Development • Fertilization • The First Trimester • The Second and Third Trimesters • Labor and Delivery

EXPLORE MediaLab

EXPLORATION #1

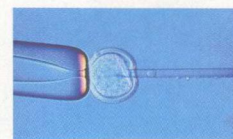
Estimated time for completion: 10 minutes

PRENATAL DEVELOPMENT is an amazing series of events. A quick look at Table 20-2 reveals how much is occurring at the cellular, tissue, and organ level during this 36-week period. With so much biochemical and cellular activity, you would be correct in thinking that this is also a very sensitive period for the developing individual. Many seemingly innocuous compounds, referred to as teratogens, can have devastating effects on the regulated pattern of development. Alcohol is one of the most common and well-understood teratogens. Alcohol restricts blood flow to the placenta, depriving the developing cells of the fetus of much-needed oxygen. It also crosses the placenta, damaging fetal cells. With chronic exposure, the fetus may develop Fetal Alcohol Syndrome (FAS), Alcohol-Related Neurodevelopmental Disorder (ARND), and Alcohol-Related Birth Defects (ARBD). These three syndromes describe differing degrees of facial abnormalities, growth deficiencies, and central nervous system dysfunction. Prepare a chart of prenatal development similar to Table 20-2. On your chart, indicate when excessive alcohol intake might cause each of these effects. What other detrimental effects would you expect to see? You should be able to list at least one effect for each system. To complete your chart, go to Chapter 20 at the Companion Web site, visit the MediaLab section, and click on the key word "FAS." The information compiled by the ADA, Division of Alcohol and Drug Abuse, will help you add to your chart.



Drinking for two. This beer affects not only the mother's body systems but also the fetus that she is carrying.

642



A donor nucleus being injected into a sheep egg for cloning.

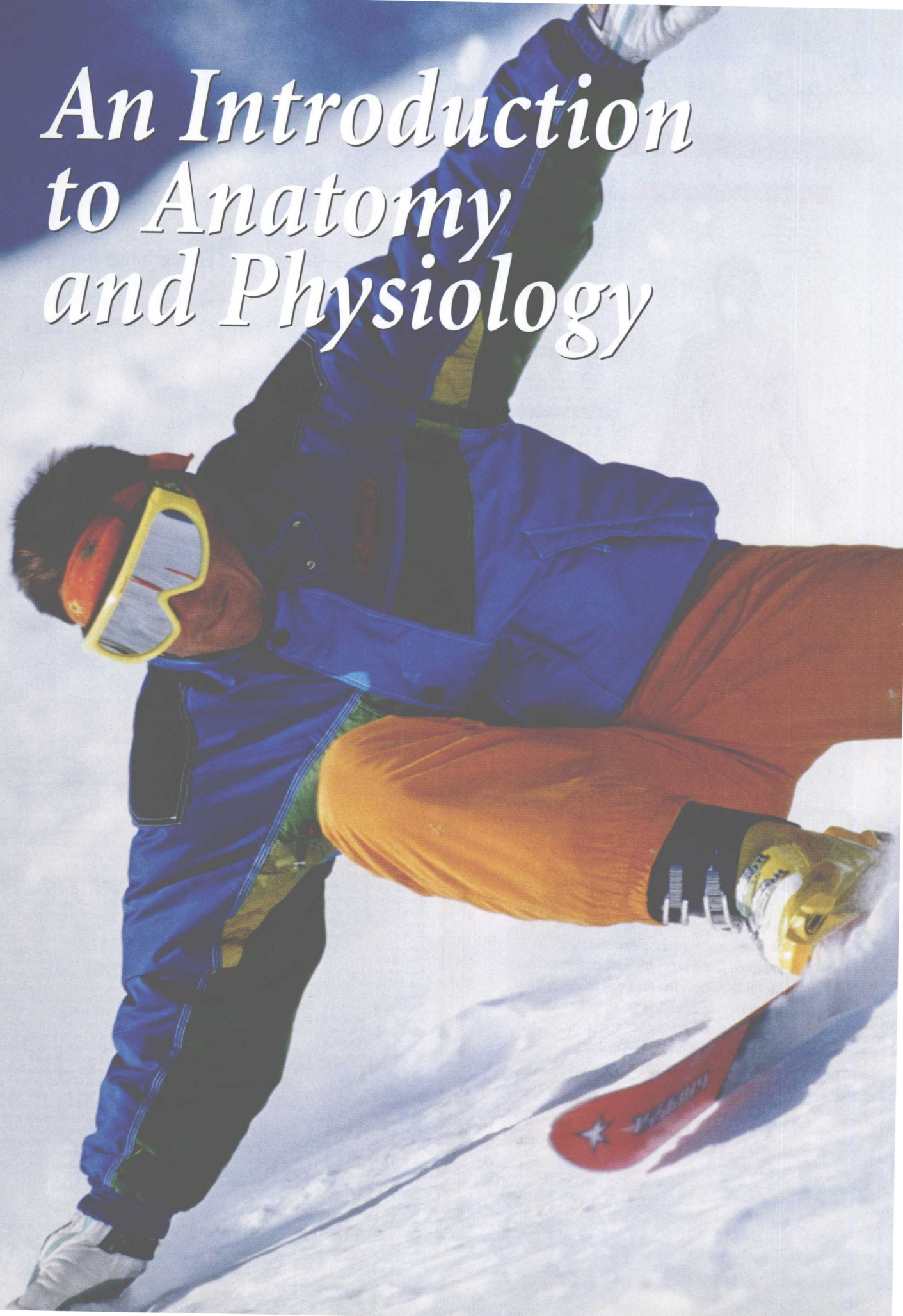
EXPLORATION #2

Estimated time for completion: 10 minutes

WITH THE SUCCESSES of the Human Genome Project (see p. 635), the news is full of debates on the issue of human cloning. Two types of cloning are currently being pursued in research laboratories: reproductive cloning and therapeutic cloning. Reproductive cloning, the goal of which is to create a genetically identical copy of an organism, has been successfully performed on a variety of animals, including mice, sheep, and cows. Although reproductive cloning has not yet been attempted on humans, advancements in this technique are occurring rapidly. We may soon have the ability to create genetically identical copies of humans. Therapeutic cloning of human cells has already been successful. The goal of therapeutic cloning is not to create a new individual, but rather to create a viable embryo from which stem cells can be harvested. Figure 20-40 depicts the stage of development at which these cells are removed. Harvesting stem cells destroys the embryo, but provides a population of potentially therapeutically useful tissue cells. A good pictorial explanation of this procedure is provided by Science magazine at <http://www.sciam.com/explorations/2001/112401ezell/how.html>. As these cloning regimes become mainstream, we are faced with the ethics of using them. What are your thoughts on these issues? Should scientists be able to continue addressing the reproductive cloning of humans? Why or why not? Is therapeutic cloning a medical breakthrough or a moral issue in that viable embryos are destroyed? After preparing a short position paper on this topic, go to Chapter 20 at the Companion Web site, visit the MediaLab section, and click on the key word "cloning." Read through a NOVA staff writer's interview of Dr. Don Wolf, Director of the Andrology/Embryology Laboratory at Oregon Health and Sciences University in Portland. Do you agree with Dr. Wolf's views? Strengthen your position paper with quotes and information from this article.

MediaLab New to this edition are the MediaLabs that appear at the end of eleven chapters. These exercises provide an opportunity to explore interesting and thought-provoking situations by supplementing the information presented in the text with additional materials found on the World Wide Web. The theme of the MediaLabs is integration—how the body's systems interact and work together. Many of the exercises deal with the clinical implications of these interactions, focusing on how a problem in one system can affect other systems, and ultimately the whole body.

An Introduction to Anatomy and Physiology



Brief Contents

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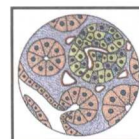


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