

ESSENTIALS *of*
ANATOMY &
PHYSIOLOGY



MARTINI
♦
BARTHOLOMEW

Essentials of Anatomy & Physiology

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

with

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Art coordinator and illustrator

Claire W. Garrison, R.N.
Illustrator

Kathleen Welch, M.D.
Clinical consultant

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Biomedical Photographer



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

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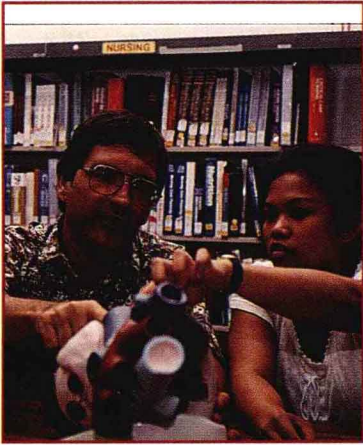
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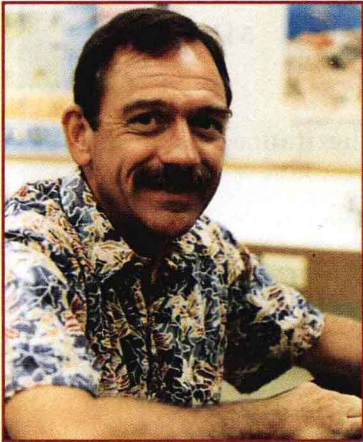
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Frederic H. Martini received his Ph.D. from Cornell University in Comparative and Functional Anatomy. He has broad interests in vertebrate biology, with special expertise in anatomy, physiology, histology, and embryology. Dr. Martini's publications include journal articles, technical reports, magazine articles, and a book for naturalists on the biology and geology of tropical islands. Working with Professor Michael J. Timmons, he has coauthored an undergraduate textbook, *Human Anatomy* (Prentice Hall, 1995).

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 teaches part-time in the winters, and devotes most of his attention to developing new approaches to A&P education. His primary interest is in the use of appropriate technologies in creating an integrated learning system. Dr. Martini is a member of the Human Anatomy and Physiology Society, the National Association of Biology Teachers, the American Society of Zoologists, 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 two and a half decades he 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 school west of the Rockies. Mr. Bartholomew has written journal articles, a weekly newspaper column, and

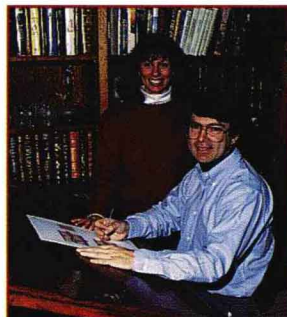
many magazine articles. He is a member of the Human Anatomy and Physiology Society, the National Association of Biology Teachers, and the American Association for the Advancement of Science.



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 as a Clinical Assistant Professor in the Department of Family 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.

Preface

Pick up a newspaper, turn on the television, or view the latest movie thriller and you will find that the human body is in the spotlight. Wonder drugs and deadly new diseases; sports records and sports injuries; crash diets and artificial sweeteners; cholesterol reduction and calcium supplements; brain structure and human behavior; a vanishing ozone layer and rising health care costs—these are just a few of the topics that are concerned with some aspect of human anatomy or physiology.

The increase in available, useful information concerning the structure and function of the body has the potential to affect every aspect of our lives. There have never been greater opportunities for employment in applied health-related fields, from nursing to sports training, from dietetics to occupational safety. At the same time, however, this information explosion has the potential to overwhelm and frustrate new students of anatomy and physiology. A common student response to this avalanche of information is, “There is no way I can understand this because I don’t have the time to learn all those terms!”

No textbook can give a student more time. A carefully crafted text can, however, help students make better use of their time. To succeed in this course, students must do more than develop a large technical vocabulary and retain a large volume of detailed information. They must relate what they learn in various chapters and understand how a small, localized change in structure or function can affect the entire body. In other words, anatomy and physiology students must develop their capacity for critical thinking, abstraction, and concept integration. These skills are important for everyone, not only for those pursuing careers in the health sciences.

Recent educational research has demonstrated that memorization of information does not by itself improve critical thinking skills unless the individual learns the material in a logical framework that stresses concept organization. Unfortunately, introductory students are often unprepared for this type of course, primarily because secondary school courses often stress rote memorization and recital of discrete blocks of information. This text has evolved to help students make the transition from one learning style to another, while making the process as easy and enjoyable as possible.

This textbook introduces the basic concepts and principles important to an understanding of the human body. It has two primary goals:

1. Building a foundation of essential knowledge (What structure is that? How does it work? What happens when it doesn’t work?) that will support further courses dealing with specific topics in human anatomy or physiology.

2. Providing a framework for applying, interpreting, and applying related information obtained outside of the classroom.

Our aim has been to present information simply and clearly, with suitable emphasis on the concrete, applied aspects of each topic. Those pursuing careers in the medical or allied health sciences will acquire the background needed to organize and integrate additional information. For those seeking careers outside the biomedical fields, the perception that anatomical and physiological processes are understandable, relevant, and logical should remain intact and valuable long after the origin and insertion of the *latissimus dorsi* muscle have been forgotten.

THEMES

The cornerstone of any introductory anatomy and physiology course is the concept that the human body functions as an integrated unit. That integration exists at all structural levels, from cell to cell, tissue to tissue, organ to organ, and system to system. Homeostasis is maintained through interactions that occur on each of these levels, as well as between levels. When homeostasis breaks down, symptoms of disease appear. The basic concepts of structure and function and homeostasis are introduced early in the text and reinforced in all subsequent chapters.


GENERAL FEATURES OF ESSENTIALS OF ANATOMY & PHYSIOLOGY

Essentials of Anatomy & Physiology is intended to inform, develop, and stimulate a continuum of student populations; from those considering or planning careers in health, to those interested in understanding their own body and the basics of health.

Given that not all students comprehend and internalize information in the same way, the pedagogical structure of each chapter now offers more help to the diverse types of students who take this course. Every element from the chapter-opening vignette to the Three Level Review System that ties together the end-of-chapter material, as well as several key ancillaries to the text, are indicative of a sensitivity to the ways students learn and retain information

Emphasis on Concepts

- **Chapter Opening:** Each of the twenty-one chapters in *Essentials of Anatomy & Physiology* opens with a photograph and a narrative that briefly highlights the relationship between the image and the material covered in that particular chapter. This feature is designed to stimulate interest, generate questions, and establish lines of thought that will propel the reader into the chapter with anticipation instead of anxiety.

- **Learning Objectives:** The chapter opener also contains a manageable list of learning objectives. These objectives focus attention on the key concepts presented in the chapter text. Mastering these objectives will provide students with a foundation to build upon, and presenting them at the outset provides a preview of the key concepts that will be developed. To help students find pertinent information when reviewing chapter material, the learning objectives have been integrated with the chapter outline.
- **The Use of Analogies:** Whenever possible, basic physiological principles are related to familiar physical principles or events in everyday life. This helps to create a mental picture that enhances comprehension.
- **An Emphasis on Applied Topics:** The running text often makes reference to concrete, real-life examples that drive home the impact of relatively abstract material. Our text also contains boxed discussions dealing with clinical and applied topics.
- **Boxed Material:** The text includes several different types of boxed discussions. These boxes, located after or immediately adjacent to the relevant narrative, provide useful insights into the relevance or application of important concepts. Because the material is both boxed and categorized by topic, it can be read, if assigned, or ignored without disturbing the flow of essential information in the running text. Although few instructors assign all of the material presented, these discussions, together with the supplemental material in the Applications Manual, address the major clinical conditions and problems affecting each system. This information represents a useful reference for information about personal or family health concerns. With this in mind, care has been taken to ensure that the information contained is current, concise, and accurate.
- **A Discussion of the Effects of Aging on Each System:** These discussions place the physiological changes associated with aging into the context of normal anatomy and physiology. An understanding of the aging process is becoming increasingly important because the proportion of the population over age sixty-five is increasing dramatically.
- **Concept Checkpoints:** Two to four questions are placed near the end of each major section in a chapter. These questions are intended to provide a quick means of checking reading comprehension and improving the ability to integrate the information contained in blocks of text material. For easy reference, the answers are located in the Appendix.
- **Cross-referencing:** A concept link icon () and page reference will be found wherever the development of a new concept builds on material presented earlier in the text.

Outstanding Illustrations

- **Integrated and Comprehensive Illustrations:** The art program and the text evolved together, and the layout helps the reader correlate the information provided by the text and the illustrations.
- **Use of Figures Showing the Relationships between Macroscopic and Microscopic Structure:** Introductory students are most familiar (and most comfortable) with the higher levels of organization, those of the individual or organ system. They are much less familiar with, and considerably more apprehensive of, events at the molecular or cellular level. *Essentials of Anatomy & Physiology* includes keystone figures that bridge the gap between the familiar, macroscopic world and the unfamiliar world of cells and tissues.
- **Use of Concept Maps and Flow Charts:** The illustration program for *Essentials of Anatomy & Physiology* provides visual summaries of organizational and functional relationships within and between vital systems.
- **Systems Integrators:** These figures, found near the ends of chapters dealing with specific systems, reinforce the concept that the body functions as an integrated unit rather than as a set of relatively isolated, independent systems.
- **Figure Dots:** Figure callouts in the text are followed by a red dot (●) that refers the reader to the red dots that precede the Figure captions. The dots in the text provide convenient placemarks for the reader, facilitating the return to the narrative after referencing the appropriate figure.


These features have been specifically designed to address the problems students encounter with this material. The extensive use of concept maps and flow charts provides a visual overview that should assist visual learners in mastering difficult material and relationships. The macro- to micro- figures bring the microscopic world into perspective and make structural and functional relationships easier to understand. Cross-referencing of text and figures, coupled with special system-integration figures, helps students develop an integrated perspective on the functioning of the body.

Vocabulary Development Aids

- **Vocabulary Development and Key Words:** An alphabetical list of relevant prefixes, suffixes, combining forms, and word roots is provided near the beginning of each chapter. Within the chapter text, the related key terms are presented in boldface, along with pronunciation guides and the associated word roots.
- **Additional Vocabulary Development.** Several chapters contain tables that summarize informa-

tion concerning the proper use of terms dealing with anatomical orientation, directional terms, and descriptive terms used when dealing with the skeletal or muscular systems.

Appropriate Clinical Coverage

- **Clinical Discussions:** Boxed Clinical Discussions (CDs) contain clinical material relevant to the preceding text. Each CD focuses attention on one or more disorders that demonstrate the consequences of homeostatic imbalances. The discussion is directly tied to the normal physiological or anatomical material in the adjacent text. The number of CDs varies from chapter to chapter.
- **Clinical Notes:** These notes are isolated from the running text. They contain extended discussions of major clinical disorders, diagnostic procedures, medical topics related to athletic activities, and issues that make headlines or stimulate controversy.
- **Focus Boxes:** These boxes integrate text and art to provide a visual summary of important information.
- **Applications Manual References:** The text contains references to (1) extended discussions of applied topics and (2) supplementary photographs that are contained in the *Applications Manual for Essentials of Anatomy & Physiology*. The linkage is indicated by an icon () with the title of the relevant discussion shown in blue.

Extensive Chapter Review Material

- **Chapter Review:** Each chapter ends with an extensive Chapter Review comprising features that work together to help students study, review, apply, and integrate new material into the general framework of the course. Each module contains the following elements:
- **Key Terms Review:** The most important key terms in the chapter are listed in this section, along with the relevant page numbers in case a quick review is needed.
- **Study Outline:** The Study Outline at the end of each chapter reviews the major concepts and topics in summary fashion. Relevant page numbers are indicated for major headings, and related key terms are boldfaced. For ease of reference, the related figure and table numbers are indicated as appropriate.
- **Review Questions:** The review questions are organized around a **Three Level Review System** that affords each student the opportunity to review material in increasing levels of difficulty.

Level One tests the understanding and recall of basic concepts and related terminology.

Level Two encourages students to combine, integrate, and relate the basic concepts mastered in level one.

Level Three promotes critical thinking skills at a point where such skills are most effectively developed—after mastering level one and level two material.

THE APPLICATIONS MANUAL

The *Applications Manual for Essentials of Anatomy & Physiology* is organized into units, each dealing with a different series of applied topics. Sections within those units are cross-referenced to relevant passages in the text, with page numbers indicated. The units address the following topics:

- *A Foundation for Anatomy and Physiology* provides hints on how to best learn the special language of anatomy and physiology, and introduces the methods by which we understand the human body.
- *An Introduction to Diagnostics* introduces the basic principles involved in the clinical detection and identification of disease states.
- *Applied Research Topics* considers principles of chemistry and molecular biology that are important to understanding, diagnosing, or treating homeostatic disorders.
- The *Body Systems* unit contains sections dealing with each of the eleven physiological systems. Each section ends with a series of critical thinking questions, and clinical problems follow groups of systems, such as muscular/skeletal or nervous/endocrine.
- The *Surface Anatomy Cadaver Atlas* contains twenty-four full-color pages of Ralph Hutchings photographs that supplement the images and line art in the text.

OTHER USEFUL FEATURES

- **Endpapers:** The front endpapers contain the most important foreign word roots, prefixes, suffixes, and combining forms encountered in the text. The back endpapers contain a list of common abbreviations and an overview of the contents of the Applications Manual.
- **Appendices:** The appendices contain material that most students and instructors will use at some time in the course.

Appendix I contains the answers to the concept checkpoints organized by chapter and page number. These answers let students monitor their progress and their abilities to deal with the various types of questions encountered in each chapter.

Appendix II provides a review of the important systems of weights and measures used in the text. Students are usually advised to review this material while completing the introductory chapter, to avoid confusion and distress later in the text.

Appendix III contains reference tables that report normal physiological values for body fluids.

- **Glossary:** The glossary provides pronunciations and definitions of important terms.

SUPPLEMENTS

Like the textbook itself, the ancillary package has been carefully crafted to meet the needs of the instructor and the student.

For the Instructor

Our new **CD-ROM Image Bank** for anatomy and physiology is a multimedia tool that enables you to easily create customized presentations in the classroom. The Image Bank contains images from the text as well as additional photographs, animations, and video. Included on the Image Bank is **Multimedia Presentation Manager 2.0**, a navigation software package that allows you to perform keyword searches, read and customize notes for each image, organize items in any order, incorporate outside lecture resources, and print a list of all resources chosen with accompanying notes.

A set of 276 full-color **Transparency Acetates**, which includes key illustrations from the main text, will also be available to adopters.

The **Instructor's Resource Guide** is a unique supplement designed to be useful for both the new instructor, as well as one who has taught Anatomy & Physiology for several years. It's your source for lively, unique analogies and teaching tips as well as suggestions from other instructors across the country.

For those wanting more exploration on their own, the **Anatomy & Physiology Home Page** is the place to go. This Web site features an interactive Study Guide and links to "hot" A&P sites on the Internet for students; and for instructors, there will be tips on how to teach A&P using the Web.

The **Test Item File** offers over 3000 questions and parallels the three-level learning system of the text. In addition, 200 pieces of unlabeled text art is included to create labeling exercises for exams.

The **Prentice Hall Custom Test** is an easily accessible software version of the above Test Item File and is designed to operate on all platforms—DOS, Windows, and Macintosh. It offers full mouse support, complete question editing capabilities, random test generation, graphics and printing capabilities.

The **Prentice Hall Laserdisc for Anatomy and Physiology** and its **Bar Code Manual** encourage instructors to bring a wealth of images into the classroom and the lab. The disc features text art, quiz frames (text figures with labels removed), histology slides, 300 cadaver images, pictures of common lab models and equipment and a complete set of cat dissection photographs. The video portion of the disc has high-quality, three-dimensional physiology animations and

footage demonstrating lab experiments that are inaccessible to many faculty members (i.e. those utilizing computer analysis, animal specimens, and human body fluids). The disc can also be accessed using the Prentice Hall Multimedia Presentation Manager for Anatomy and Physiology, software that allows instructors to organize visual presentations and create custom overlays for images that accompany lectures. The Presentation Manager has its own User's Guide.

For the Student

An **Applications Manual** comes packaged with each new copy of the textbook. This unique supplement provides students with access to interesting and relevant clinical and diagnostic information. Critical thinking questions and clinical problems offer students the opportunity to think analytically. Historical background and information on recent research give them a frame of reference for the study of anatomy and physiology. Two atlases, one of color cadaver photographs and one of surface anatomy, are included as additional image resources.

Life on the Internet: Biology—A Student's Guide is an exciting supplement that brings students up to speed on what the Internet is and how to navigate it. This dynamic supplement offers many helpful hints and suggestions for exploring biology resources available on the Internet. This handy guide can be used as an introduction to the Internet for students who have no previous experience on the World Wide Web or as a source of reference for students with more experience.

The **Study Guide** is an excellent companion to the text and includes a number of labeling exercises and Concept Maps.

The **Laboratory Text and Study Guide** (by Michael Wood) combines student-referenced laboratory activities, study questions, and a comprehensive art program to create a unique one-stop student study aid.

For students seeking the opportunity to see the dynamics of the most difficult physiological processes, the **Anatomy and Physiology Video Tutor** has it all—even if students don't have access to a computer. This 75-minute video focuses on the concepts that instructors across the country have consistently identified 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-referenced study booklet promote repeated concept review.

The *New York Times* **"Themes of the Times"** Program is sponsored jointly by Prentice Hall and the *New York Times* and is designed to enhance student access to current, relevant information. Articles are selected by the text authors and compiled into a free supplement that helps students make the connection between the classroom and the outside world

THE DEVELOPMENT PROCESS

We undertook this project to respond to the concerns and suggestions of anatomy and physiology instructors seeking a text suitable for a one-semester course.

Essentials of Anatomy & Physiology and the associated supplements addresses important educational problems, such as the wide diversity of students' learning types, backgrounds, degrees of preparation, and intellectual abilities, as well as limited instructional time and resources. As a result, it differs in many ways from other essentials of anatomy and physiology texts. The design and implementation of the features unique to our text reflect the combined efforts of the authors, aided by the collective wisdom of many other instructors who were kind enough to assist us.

ACKNOWLEDGMENTS

This textbook represents a group effort, rather than being the product of any single individual. Foremost on the list stand the faculty and reviewers whose advice, comments, and collective wisdom helped to shape the text into its final form. 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 would like to express our sincere thanks and best wishes.

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

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Our gratitude is also extended to the many faculty and students at campuses across the country (and out of the country) whose suggestions and comments stimulated the decision to develop *Essentials of Anatomy and Physiology*.

A text has two components: narrative and visual. In preparing the narrative, we were ably assisted by two development editors. Susan Zorn reviewed an early draft, while Laura Edwards, Development Editor at Prentice Hall, handled the later drafts and assisted us throughout the production process. Laura 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 *Applications 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 aiding the students to understand essential material. The art program was primarily directed by Bill Ober, M.D. and Claire Garrison, R.N. Many of these figures include color photographs or micrographs collected from a variety of sources. Much of the work in tracking down these materials was performed by Stuart Kenter, whose efforts are greatly appreciated. Many of the light micrographs prepared by the senior author used commercially available slides obtained with the assistance of Carolina Biological Supply and Wards Scientific. The cadaver images and organ photos were provided in large part by Ralph Hutchings, whose artistic abilities and fine eye for detail are both envied and appreciated.

The authors wish to express their appreciation to the editors and support staff at Prentice Hall who made the entire project possible and who kept the text, art, and production programs on schedule and in relative harmony. Special thanks are due to Ray Mullaney, Editor in Chief, College Book Editorial Development, who gave Laura Edwards extra support and latitude; to Tim Bozik, Editorial Director for Engineering, Science, and Mathematics, for his support of the project; to David K. Brake, Executive Editor for Biology, for being the

driving force and project coordinator; and to Joanne Jimenez and Karen Malley, Production Editors, for somehow managing to keep people, text, and art moving in the proper directions at the appropriate times. We would also like to thank David Riccardi, Assistant Vice President of Production and Manufacturing, and the pagemaking wizards led by John J. Jordan.

Any errors or oversights within this text are strictly those of the authors, and not the reviewers, artists, or editors. In an effort to improve future editions, we would ask that readers with pertinent information, suggestions, or comments concerning the organization or content of this textbook send their remarks to us care of David Brake, Executive Editor for Biology, Prentice Hall, Inc., 1208 East Broadway, Suite 200, Tempe, AZ 85282. You may also reach us directly, via email, through martini@maui.net. Any and all comments and suggestions will be deeply appreciated and carefully considered in the preparation of the second edition.

TO THE STUDENT

This text was designed to help you master the terminology and basic concepts of human anatomy and physiology. It should also make it possible for you to begin applying what you learn to every-day problems and situations. These aims have helped to shape every aspect of the book.

We have no doubt that you will find the study of anatomy and physiology to be one of the most interesting, challenging, and satisfying of all your educational experiences. Because the subject is so broad, extra care has been taken to give you every possible assistance in organizing new information. Many learning aids are built into the format of the text to make your study of this material easier and more rewarding. This book is meant to be a “machine for learning,” one that can help you to focus your efforts and get the most from the time and energy you invest. We encourage you to examine the following overview carefully and to consult your instructor if you have further questions about how to use this textbook.

Best wishes!



Frederic H. Martini
Haiku, Hawaii



Edwin F. Bartholomew
Makawao, Hawaii

Emphasizing Concepts

16

THE RESPIRATORY SYSTEM



This is one way to go nowhere fast—pedaling on a treadmill. All the effort, however, is hardly wasted. The rather awkward-looking array of hoses and wires attached to this rider is designed to monitor respiratory and cardiovascular performance during exercise. Similar equipment can be used in a clinical setting to assess respiratory function in resting or active individuals.

Chapter Outline and Objectives

Introduction, p. 408

Functions of the Respiratory System, p. 408

1 Describe the primary functions of the respiratory system.

Organization of the Respiratory System, p. 408

The Respiratory Tract, p. 408
The Nose, p. 408
The Pharynx, p. 409
The Larynx, p. 410
The Trachea, p. 412
The Bronchi, p. 413
Bronchioles, p. 413
Alveolar Ducts and Alveoli, p. 414
The Respiratory Membrane, p. 414
The Lungs, p. 416
The Pleural Cavities, p. 416
Respiratory Changes at Birth, p. 416

2 Explain how the delicate respiratory exchange surfaces are protected from pathogens, debris, and other hazards.

3 Relate respiratory functions to the structural specializations of the tissues and organs in the system.

Respiratory Physiology, p. 417

Pulmonary Ventilation, p. 417

Gas Exchange at the Respiratory Membrane, p. 421

Gas Pickup and Delivery, p. 423

4 Describe the physical principles governing the movement of air into the lungs and the diffusion of gases into and out of the blood.

5 Describe the chemical principles governing the exchange of gases.

6 Describe how respiratory gases are transported in the blood.

Control of Respiration, p. 425

The Respiratory Reflex, p. 425

Control by Higher Brain Centers, p. 425

7 Describe the rate of respiration.

8 Identify the factors that affect the rate of respiration.

Aging and the Respiratory System, p. 425

9 Describe the effects of aging on the respiratory system.

Interactions with Other Systems, p. 425

10 Describe the interactions between the respiratory system and other body systems.

11 Describe the interactions between the respiratory system and the cardiovascular system.

12 Describe the interactions between the respiratory system and the nervous system.

13 Describe the interactions between the respiratory system and the endocrine system.

14 Describe the interactions between the respiratory system and the immune system.

15 Describe the interactions between the respiratory system and the musculoskeletal system.

16 Describe the interactions between the respiratory system and the integumentary system.

17 Describe the interactions between the respiratory system and the reproductive system.

18 Describe the interactions between the respiratory system and the urinary system.

19 Describe the interactions between the respiratory system and the digestive system.

20 Describe the interactions between the respiratory system and the circulatory system.

21 Describe the interactions between the respiratory system and the lymphatic system.

22 Describe the interactions between the respiratory system and the nervous system.

23 Describe the interactions between the respiratory system and the endocrine system.

24 Describe the interactions between the respiratory system and the immune system.

25 Describe the interactions between the respiratory system and the musculoskeletal system.

26 Describe the interactions between the respiratory system and the integumentary system.

27 Describe the interactions between the respiratory system and the reproductive system.

28 Describe the interactions between the respiratory system and the urinary system.

29 Describe the interactions between the respiratory system and the digestive system.

30 Describe the interactions between the respiratory system and the circulatory system.

31 Describe the interactions between the respiratory system and the lymphatic system.

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34 Describe the interactions between the respiratory system and the immune system.

35 Describe the interactions between the respiratory system and the musculoskeletal system.

36 Describe the interactions between the respiratory system and the integumentary system.

37 Describe the interactions between the respiratory system and the reproductive system.

38 Describe the interactions between the respiratory system and the urinary system.

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46 Describe the interactions between the respiratory system and the integumentary system.

47 Describe the interactions between the respiratory system and the reproductive system.

48 Describe the interactions between the respiratory system and the urinary system.

49 Describe the interactions between the respiratory system and the digestive system.

50 Describe the interactions between the respiratory system and the circulatory system.

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.

Concept Links

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

408 Chapter 16 The Respiratory System

alveolus, a hollow cavity; *alveolus*, *alveolar duct*
ateles, imperfect; *atelectasis*
cricoid, ring-shaped; *cricoid cartilage*

Vocabulary Development

ektasis, expansion; *atelectasis*
-ia, condition; *pneumonia*
kentesis, puncture; *thoracentesis*
or, mouth; *oropharynx*
pneuma, air; *pneumothorax*

pneumon, lung; *pneumonia*
stoma, mouth; *tracheostomy*
thorac-, chest; *thoracentesis*
thyroid, shield-shaped; *thyroid cartilage*

The Respiratory Tract

The **respiratory tract** consists of the airways that carry air to and from the exchange surfaces of the lungs. The respiratory tract can be divided into a **conducting portion** and a **respiratory portion**. The conducting portion begins at the entrance to the nasal cavity and continues through the pharynx, larynx, trachea, bronchi, and the larger bronchioles. The respiratory portion includes the smallest and most delicate bronchioles and the alveoli that are the site of gas exchange.

In addition to delivering air to the lungs, the conducting passageways filter, warm, and humidify the air, thereby protecting the alveoli from debris, pathogens, and environmental extremes. By the time the air reaches the alveoli, most foreign particles and pathogens have been removed, and the humidity and temperature are within acceptable limits.

The Nose

Air normally enters the respiratory system via the paired **external nares** (nostrils) that communicate with the **nasal cavity**. The **vestibule** (VES-ti-bul) is the portion of the nasal cavity contained within the flexible tissues of the external nose. Here coarse hairs guard the nasal cavity from large airborne particles such as sand, dust, and insects.

The maxillary, nasal, frontal, ethmoid, and sphenoid bones form the lateral and superior walls of the nasal cavity. The **nasal septum** divides the nasal cavity into left and right sides. The bony posterior septum includes portions of the vomer and the ethmoid bone. A bony **hard palate**, formed by the palatine and maxillary bones, separates the oral and nasal cavities. A fleshy **soft palate** extends behind the hard palate, marking the boundary line between the superior **nasopharynx** (nā-zō-FAR-inks) and the rest of the pharynx. The nasal cavity opens into the nasopharynx at the **internal nares** (NĀ-rēz).

Superior, middle, and inferior nasal conchae project toward the nasal septum from the lateral walls of the nasal cavity (Figure 16-2*). To pass from the vestibule to the internal nares, air tends to flow between adjacent conchae. As the air eddies and swirls, like water flowing over rapids, small airborne particles come in contact with the mucus that coats the lining of the nasal cavity. In addition to promoting fil-

Vocabulary Aids:

Vocabulary Development

This box follows the chapter opener and lists the important word parts that form the basis of the vocabulary in the chapter.

Key Terms

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

FUNCTIONS OF THE RESPIRATORY SYSTEM

The respiratory system performs the following range of functions. It (1) moves air to and from the gas-exchange surfaces where diffusion can occur between air and circulating blood, (2) provides nonspecific defenses against pathogenic invasion, (3) permits vocal communication, and (4) helps control body fluid pH.

ORGANIZATION OF THE RESPIRATORY SYSTEM

The **respiratory system** consists of the nose, nasal cavity, and sinuses; the **pharynx** (throat); the **larynx** (voice box); the **trachea** (windpipe); and the **bronchi** and **bronchioles** (conducting passageways) and **alveoli** (exchange surfaces) of the lungs (Figure 16-1*).

Visualizing Structure & Function

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.

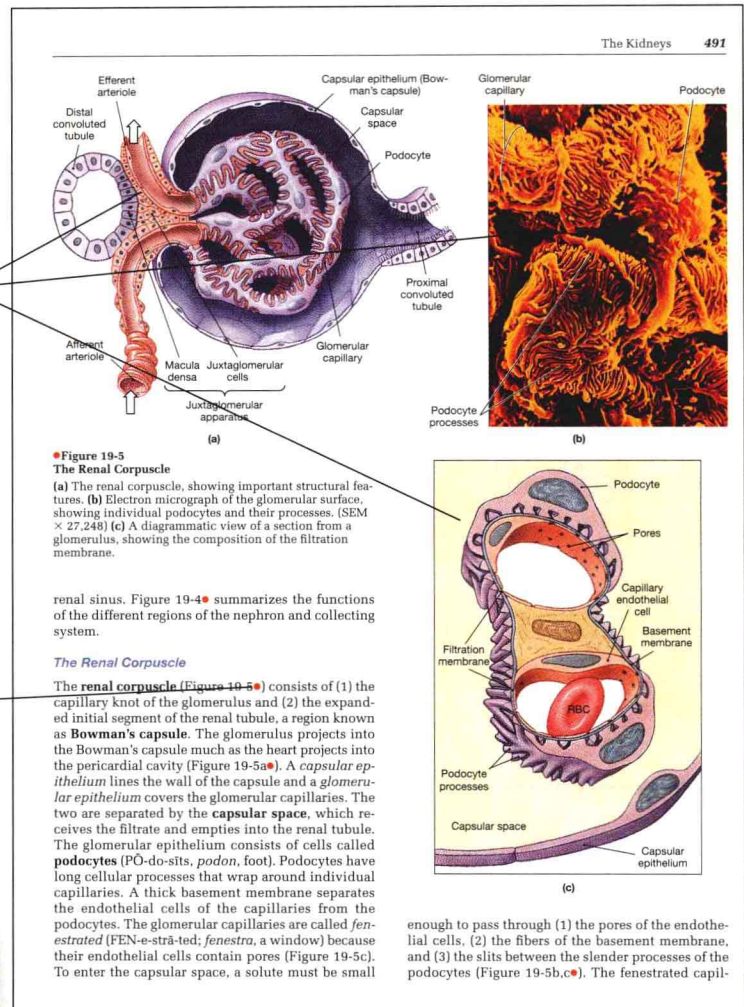
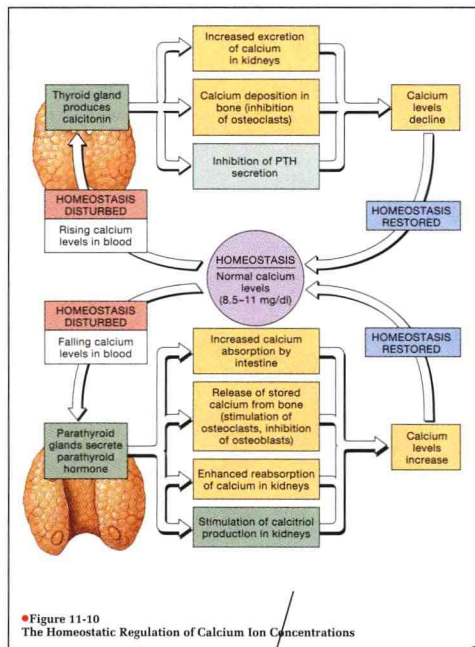


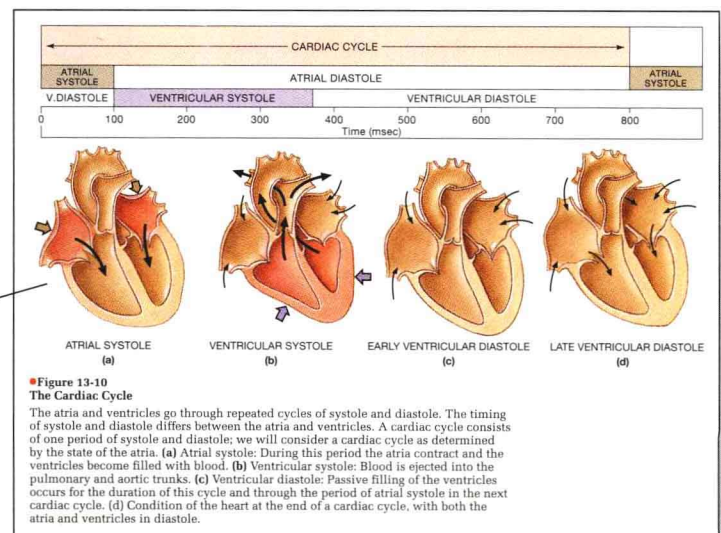
Figure Reference Locators

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

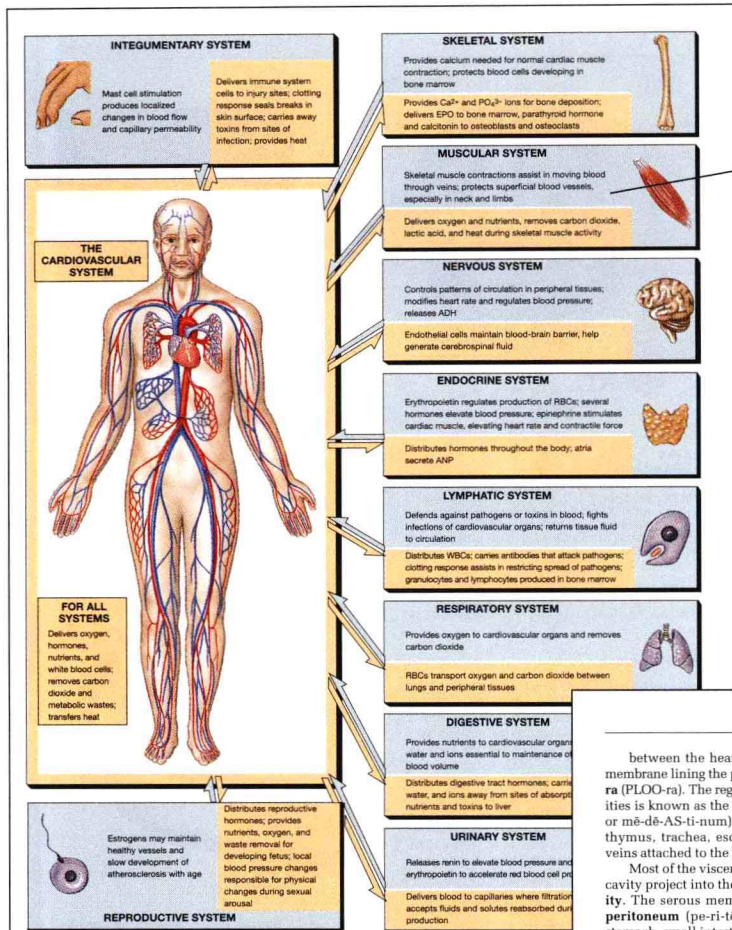


Conceptual Diagrams Show Physiology

Physiological processes are easier to understand with flowcharts and diagrams that link structure and function.



Integrating Concepts



•Figure 14-23
Functional Relationships between the Cardiovascular System and Other Systems

System Integrators

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

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. Answers are provided in Appendix 1.

The Language of Anatomy 21

between the heart and pericardium. The serous membrane lining the pleural cavities is called the **pleura** (PLOOR-ah). The region between the two pleural cavities is known as the **mediastinum** (mê-dê-as-tî-num or mê-dê-AS-tî-num). The mediastinum contains the thymus, trachea, esophagus, the large arteries and veins attached to the heart, and the pericardial cavity.

Most of the visceral organs in the abdominopelvic cavity project into the **peritoneal** (per-i-tô-NE-ah) cavity. The serous membrane lining this cavity is the **peritoneum** (pe-ri-tô-NE-um). Organs such as the stomach, small intestine, and portions of the large intestine are suspended within the peritoneal cavity by double sheets of peritoneum, called **mesenteries** (MES-en-ter-ēs). Mesenteries provide support and stability while permitting limited movement.

This chapter provided an overview of the locations and functions of the major components of each organ system. It also introduced the anatomical vocabulary needed to follow more detailed anatomical descriptions in later chapters. Modern methods of visualizing anatomical structures in living individuals are summarized on pp. 00–00. Many of the figures in later chapters contain images produced by the procedures outlined in that section.

- ✓ What type of section would separate the two eyes?
- ✓ If a surgeon makes an incision just inferior to the diaphragm, what body cavity will be opened?

FOCUS Sectional Anatomy and Clinical Technology

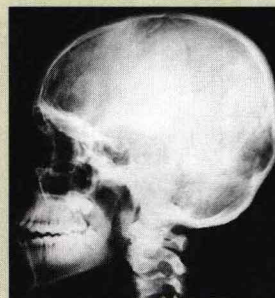
The term **radiological procedures** includes not only those scanning techniques that involve radioisotopes but also methods that employ radiation sources outside the body. Physicians who specialize in the performance and

analysis of these procedures are called **radiologists**. Radiological procedures can provide detailed information about internal systems. Figures 1-11 and 1-12 compare the views provided by several different techniques.

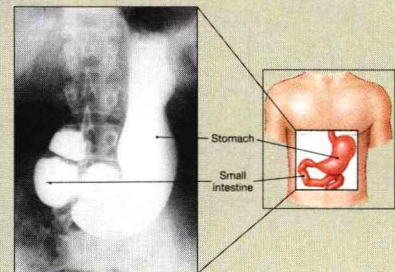
These figures include examples of X-rays, CT scans, MRI scans, and ultrasound images. Other examples of clinical technology will be found in later chapters.

Focus Boxes

These essays provide illustrated summaries of important processes or clinical conditions. Topics in the text include visual accommodation problems (p. 264), urine formation (p. 498), and bone fractures (p. 117).



(a)



(b)

•Figure 1-11
X-rays.

(a) An X-ray of the skull, taken from the left side. X-rays are a form of high-energy radiation that can penetrate living tissues. In the most familiar procedure, a beam of X-rays travels through the body and strikes a photographic plate. All of the projected X-rays do not arrive at the film; some are absorbed or deflected as they pass through the body. The resistance to X-ray penetration is called **radiodensity**. In the human body, the order of increasing radiodensity is as follows: air, fat, liver, blood, muscle, bone. The result is an image with radiodense tissues, such as bone, appearing in white, and less dense tissues in shades of gray to black. The picture is a two-dimensional image of a three-dimensional object; in this image it is difficult to decide whether a particular feature is on the left side (toward the viewer) or on the right side (away from the viewer). (b) A barium-contrast X-ray of the upper digestive tract. Barium is very dense, and the contours of the gastric and intestinal lining can be seen outlined against the white of the barium solution.

Relating Clinical Examples



Clinical Note

Checking the Pulse and Blood Pressure

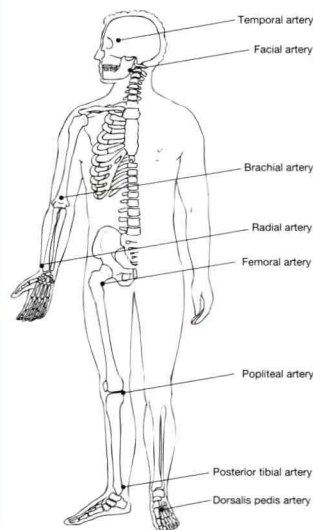
The pulse can be felt within any of the large or medium-sized arteries. The usual procedure involves squeezing an artery with the fingertips against a relatively solid mass, preferably a bone. When the vessel is compressed, the pulse is felt as a pressure against the fingertips.

Figure 14-5a indicates the locations used to check the pulse. The inside of the wrist is often used because the radial artery can easily be pressed against the distal portion of the radius. Other accessible arteries include the temporal, facial, carotid, brachial, femoral, popliteal, and posterior tibial arteries. Firm pressure exerted at one of these arteries near the base of a limb can reduce or eliminate arterial bleeding distal to the site; the locations are called **pressure points**.

Blood pressure is determined with a **sphygmomanometer** (sfig-mō-mā-NOM-e-ter; sphygmos, pulse +

manometer, device for measuring pressure), as shown in Figure 14-5b. An inflatable cuff is placed around the arm in such a position that its inflation squeezes the brachial artery. A stethoscope is placed over the artery distal to the cuff, and the cuff is then inflated. A tube connects the cuff to a glass chamber containing liquid mercury, and as the pressure in the cuff rises it pushes the mercury up into a vertical column. A scale along the column permits one to determine the cuff pressure in millimeters of mercury (mm Hg). Inflation continues until cuff pressure is roughly 30 mm Hg above the pressure sufficient to completely collapse the brachial artery, stop the flow of blood, and eliminate the sound of the pulse.

The investigator then slowly lets the air out of the cuff. When the pressure in the cuff falls below systolic pressure, blood can again enter the artery. At first, blood enters only at peak systolic pressures, and the stethoscope picks up the sound of blood pulsing through the artery. As the pressure falls further, the sound changes because the vessel is remaining open for longer and longer periods. When the cuff pressure falls below diastolic pressure, blood flow becomes continuous and the sound of the pulse becomes muffled or disappears completely. Thus the pressure at which the pulse appears corresponds to the peak systolic pressure; when the pulse fades, the pressure has reached diastolic levels. The distinctive sounds heard during this test are called **sounds of Korotkoff** (sometimes spelled *Korotkov* or *Korotkow*). When the blood pressure is recorded, systolic and diastolic pressures are usually separated by a slashmark, as in "120/80" ("one twenty over eighty") or "110/75." A reading of 120/80 would give a pulse pressure of 40 (mm Hg).



• **Figure 14-5**
Checking the Pulse and Blood Pressure
(a) Pressure points used to check the presence strength of the pulse. (b) Use of a sphygmomanometer to check arterial blood pressure.

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 or AIDS, in addition to other subjects of special interest, such as clinical procedures.

Clinical Discussions

Important clinical topics presented in context are set off by an icon, title, and vertical color bar. 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.

phocytes are actively dividing. Lymphoid nodules are found beneath the epithelia lining the respiratory, digestive, and urinary tracts. Large nodules in the walls of the pharynx are called **tonsils**. There are usually five tonsils: a single **pharyngeal tonsil**, or **adenoids**, a pair of **palatine tonsils**, and a pair of **lingual tonsils**.

The lymphocytes in a lymphoid nodule are not always able to destroy bacterial or viral invaders, and if pathogens become established in a lymphoid nodule, an infection develops. Two examples are probably familiar to you: **tonsillitis**, an infection of one of the tonsils (usually the pharyngeal tonsil), and **appendicitis**, an infection of lymphoid nodules in the appendix, an organ of the digestive tract. **Infected Lymphoid Nodules**

Lymphoid Organs

Lymphoid organs have a stable internal structure and are separated from surrounding tissues by a fibrous capsule. Important lymphoid organs include the **lymph nodes**, the **thymus**, and the **spleen**.

Lymph Nodes

Lymph nodes are small, oval lymphoid organs ranging in diameter from 1 to 25 mm. They are covered by a dense, fibrous capsule (Figure 15-5). One set of lymphatics delivers lymph to a lymph node, and another

other carries the lymph onward, toward the venous system. The lymph node functions like a kitchen water filter: It filters and purifies the lymph before it reaches the venous system. As lymph flows through a lymph node, at least 99 percent of the antigens present in the arriving lymph will be removed. As the antigens are detected and removed, T cells and B cells are stimulated, and an immune response initiated. Lymph nodes are located in regions where they can detect and eliminate harmful "intruders" before they reach vital organs of the body (Figure 15-1, p. 384).

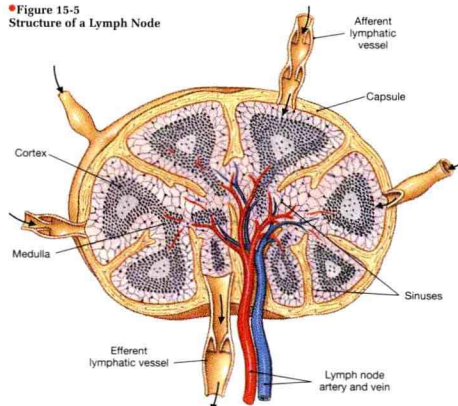


SWOLLEN GLANDS

Lymph nodes are often called **lymph glands**, and "swollen glands" usually accompany tissue inflammation or infection. Chronic or excessive enlargement of lymph nodes, a sign called **lymphadenopathy** (lim-fad-e-NOP-a-the), may occur in response to bacterial or viral infections, endocrine disorders, or cancer.

Since the lymphatic capillaries offer little resistance to the passage of cancer cells, cancer cells often spread along the lymphatics and become trapped in the lymph nodes. Thus an analysis of swollen lymph nodes can provide information on the distribution and nature of the cancer cells, aiding in the selection of appropriate therapies. **Lymphomas**, an important group of lymphatic system cancers, are discussed in the *Applications Manual*. **Lymphomas**

• **Figure 15-5**
Structure of a Lymph Node



The Thymus

The **thymus**, site of T cell maturation, lies behind the sternum (Figure 15-6). The thymus reaches its greatest size (relative to body size) in the first year or two after birth and its maximum absolute size during puberty, when it weighs between 30 and 40 g (1.06 to 1.41 oz.). Thereafter the thymus gradually decreases in size.

The thymus has two lobes, each divided into **lobules** by fibrous partitions, or **septa** (sep-tum, a wall). Each lobule consists of a densely packed outer **cortex** and a paler central **medulla**. Lymphocytes in the cortex are dividing, and as the T cells mature they migrate into the medulla, eventually entering one of the blood vessels in that region. Other cells within the lobules produce the thymic hormones collectively known as **thymosins**.

Application Manual References

Many clinical topics introduced in the narrative or in Clinical Notes and Discussions are expanded upon in the *Applications Manual* that accompanies each copy of the text. The *Applications Manual* also contains detailed coverage of relevant clinical topics that are not discussed in the text. References to the *Applications Manual* are identified in the text by the **AM** icon, followed by the title of the relevant discussion in blue.

Reviewing the Concepts

Chapter Review

KEY TERMS

anatomical position, p. 15
anatomy, p. 2
diaphragm, p. 19
frontal plane, p. 17

homeostasis, p. 12
negative feedback, p. 12
peritoneum, p. 21
physiology, p. 2

positive feedback, p. 14
sagittal plane, p. 17
transverse plane, p. 17
viscera, p. 19

SUMMARY OUTLINE

INTRODUCTION p. 2

1. **Biology** is the study of life; one of its goals is to discover the unity and patterns that underlie the diversity of living organisms.

2. All living things from single **cells** to large multicellular organisms, perform the same basic functions: they respond to changes in their environment (i.e., they show adaptability to their environment); they grow and reproduce to create future generations; they are capable of producing movement; and they absorb materials from the environment. Organisms absorb and consume oxygen during respiration, and they discharge waste products during excretion. Digestion occurs in specialized areas of the body to break down complex foods. The circulation forms an internal transportation system between areas of the body.

THE SCIENCES OF ANATOMY AND PHYSIOLOGY p. 2

Anatomical Perspectives p. 3

1. **Anatomy** is the study of internal and external structure and the physical relationships between body parts. **Physiology** is the study of how living organisms perform vital functions. All specific functions are performed by specific structures.

2. The boundaries of **microscopic anatomy** are established by the equipment used. **Cytology** analyzes the internal structure of individual cells. **Histology** examines **tissues** (groups of cells that have specific functional roles). Tissues combine to form **organs**, anatomical units with multiple functions.

3. **Gross (macroscopic) anatomy** considers features visible without a microscope. It includes **surface anatomy** (general form and superficial markings); **regional anatomy** (superficial and internal features in a specific area of the body); and **systemic anatomy** (structure of major organ systems).

Physiology p. 3

4. Human physiology is the study of the functions of the human body. It is based on **cell physiology**, the study of the functions of living cells. **Special physiology** studies the physiology of specific organs. **System physiology** considers all aspects of the function of specific organ systems. **Pathological physiology** studies the effects of diseases on organ or system functions.

LEVELS OF ORGANIZATION p. 4

1. Anatomical structures and physiological mechanisms are arranged in a series of interacting levels of organization. (Figure 1-1)

AN INTRODUCTION TO ORGAN SYSTEMS p. 4

1. The major organs of the human body are arranged into 11 organ systems. The organ systems of the human

body are the **integumentary, skeletal, muscular, nervous, endocrine, cardiovascular, lymphatic, respiratory, digestive, urinary, and reproductive systems**. (Figures 1-2, 1-3)

HOMEOSTASIS AND SYSTEM INTEGRATION p. 12

1. **Homeostasis** is the tendency for physiological systems to stabilize internal conditions; through **homeostatic regulation** these systems adjust to preserve homeostasis.

Homeostatic Regulation p. 12

2. Homeostatic regulation usually involves a **receptor** sensitive to a particular stimulus and an **effector** whose activity affects the same stimulus.

3. **Negative feedback** is a **corrective** mechanism involving an action that directly opposes a variation from normal limits. (Figure 1-4)

4. In **positive feedback** the initial stimulus produces a response that reinforces the stimulus. (Figure 1-5)

Homeostasis And Disease p. 14

5. Symptoms of **disease** appear when failure of homeostatic regulation causes organ systems to malfunction.

THE LANGUAGE OF ANATOMY p. 15

Superficial Anatomy p. 15

1. Standard anatomical illustrations show the body in the **anatomical position**. If the figure is shown lying down, it can be either **supine** (face up) or **prone** (face down). (Figure 1-6; Table 1-1)

2. **Abdominopelvic quadrants** and **abdominopelvic regions** represent two different approaches to describing anatomical regions of the body. (Figure 1-7)

3. The use of special direction when describing anatomical Table 1-2)

Sectional Anatomy p. 16

4. The three **sectional plane, sagittal plane, and transverse plane** show the relationships between the parts of the body. (Figure 1-9; Table 1-3)

5. **Body cavities** protect delicate organs and changes in the size and shape of **body cavity** contains the **cranial cavity** and **spinal cavity** (surround **ventral body cavity** surrounds the **dorsal body cavity**, digestive, urinary, and reproductive organs). (Figure 1-10a)

6. During development the **ventral body cavity** into the **superior peritoneal cavities**. By birth, the

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.

ATP (adenosine triphosphate). When energy is available, cells make ATP by adding a phosphate group to ADP. When energy is needed, ATP is broken down to ADP and phosphate. (Figure 2-17)

CHEMICALS AND LIVING CELLS p. 42

14. Biochemical building blocks form functional units called **cells**. (Figure 2-18; Table 2-7)

CHAPTER 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. atomic number
2. covalent bond
3. ionic bond
4. catabolism
5. anabolism
6. exchange reaction
7. reversible reaction
8. acid
9. enzyme
10. buffer
11. organic compounds
12. inorganic compounds
13. In atoms, protons and neutrons are found:
(a) only in the nucleus
(b) outside the nucleus
(c) inside and outside the nucleus
(d) in the electron cloud
14. The number and arrangement of electrons in an atom's outer electron shell determines its:
(a) atomic weight (b) atomic number
(c) electrical properties (d) chemical properties
15. The bond between sodium and chlorine in the compound sodium chloride (NaCl) is:

Column B

- a. synthesis
- b. catalyst
- c. sharing of electrons
- d. $A + B \rightleftharpoons AB$
- e. stabilize pH
- f. number of protons
- g. decomposition
- h. carbohydrates, lipids, proteins
- i. loss or gain of electrons
- j. water, salts
- k. H^+ donor
- l. $AB + CD \rightarrow AD + CB$
- (a) an ionic bond
(b) a single covalent bond
(c) a nonpolar covalent bond
(d) a double covalent bond
16. What is the role of enzymes in chemical reactions?
17. List six elements found in abundance in the body.
18. What four major classes of organic compounds are found in the body?
19. List seven major functions performed by proteins.

LEVEL 2 Reviewing Concepts

20. Oxygen has 8 protons, 8 neutrons, and 8 electrons. What is the molecular weight of O_2 ?
(a) 8 (b) 16
(c) 24 (d) 32
21. Of the following selections, the one that contains only **inorganic** compounds is:
(a) water, electrolytes, oxygen, carbon dioxide
(b) oxygen, carbon dioxide, water, sugars
(c) water, electrolytes, salts, nucleic acids
(d) carbohydrates, lipids, proteins, vitamins
22. Glucose and fructose are examples of:
(a) monosaccharides (simple sugars)

- (b) isotopes
(c) lipids
(d) a, b, and c are all correct
23. Explain the differences among (1) nonpolar covalent bonds, (2) polar covalent bonds, and (3) ionic bonds.
24. Why does pure water have a neutral pH?
25. A biologist analyzes a sample that contains an organic molecule and finds the following constituents: carbon, hydrogen, oxygen, nitrogen, and phosphorus. On the basis of this information, is the molecule a carbohydrate, a lipid, a protein, or a nucleic acid?

LEVEL 3 Critical Thinking and Clinical Applications

26. The element sulfur has an atomic number of 16 and an atomic weight of 32. How many neutrons are in the nucleus of a sulfur atom? Assuming that sulfur forms covalent bonds with hydrogen, how many hydrogen atoms could bond to one sulfur atom?
27. An important buffer system in the human body involves carbon dioxide (CO_2) and bicarbonate ion (HCO_3^-) as shown below:
$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

If a person becomes excited and exhales large amounts of CO_2 , how will his body's pH be affected?

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.

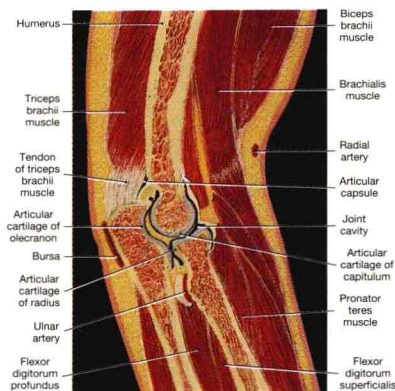
Level 2 questions help you check your grasp of concepts and your ability to integrate ideas presented in different parts of the chapter.

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

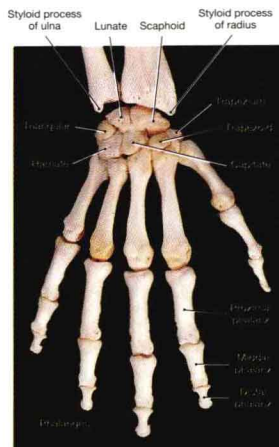
The Applications Manual

The unique student *Applications Manual* that accompanies each copy of this text provides a wealth of supplemental material to enrich your students' learning experience. Although all essential principles of anatomy and physiology are covered in the text, the *Applications Manual* allows students to explore many clinical and diagnostic topics in greater depth.

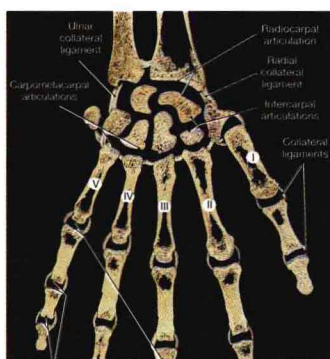
- The introductory sections of the *Applications Manual* include an explanation of the scientific methods and discussions of the applications of chemistry and cell biology to the diagnosis and treatment of disease.
- The Body Systems section parallels the text system by system. Included are more detailed discussions of many clinical topics introduced in the text, as well as discussions of additional diseases, syndromes, and diagnostic techniques not covered in the text.



5.4 Elbow joint, coronal section



5.5a Bones of the right wrist and hand,
posterior view



5.5b Joints of the right wrist and hand, sectional view

C-12



5.5c Muscles, tendons, and ligaments of the right wrist and hand, anterior view

- Cross-referencing integrates the text and *Applications Manual*, making it easy to move back and forth between related material in the two books.

- A full-color Cadaver Atlas of dissection photographs allows students to visualize the internal structure of all major body regions and organs. A selection of surface anatomy photographs of live models is included for comparison with the dissection views.

- Critical Thinking Questions at the end of each system help students sharpen their ability to think analytically.

Body Systems: Clinical and Applied Topics

natic injuries, such as fractures or dislocations and infections also affect the cartilages, and ligaments associated with the bones. A somewhat different array of conditions affect soft tissues of the bone marrow. Areas of marrow contain the stem cells for red blood cells, white blood cells, and platelets. The marrow becomes abnormal in diseases of the bone marrow that are characterized by blood cell overproduction (e.g., leukemia, polycythemia, p. 96, 91) or underproduction (several anemias, p. 92, 95).

restrict movement, often form at the interphalangeal joints of the fingers in arthritis.

5. **Abnormal posture:** Bone disorders that affect the spinal column can result in abnormal posture. This is most apparent when the condition alters the normal spinal curvature. Examples include *kyphosis*, *lordosis*, and *scoliosis* (p. 51). A condition involving an intervertebral joint, such as a herniated disc, will also produce abnormal posture and movement.

~~SYMPTOMS OF BONE AND DISORDERS~~

A symptom of a skeletal system disorder is bone pain and joint pain are common symptoms associated with many bone disorders. As the presence of pain does not provide much in identifying a specific bone or joint disorder, aching bone or joint pain may be tolerated, and a person often will not seek medical assistance until the condition is relatively advanced. For a symptom that may require immediate attention is a *pathologic fracture*. Pathologic fractures result of weakening of the skeleton by disease processes, such as *osteosarcoma* (a bone cancer). Fractures may be caused by physical stresses generated by normal bones.

EXAMINATION OF THE SKELETAL SYSTEM

The bones of the skeleton cannot be seen without relatively sophisticated equipment. However, there are a number of physical signs that can assist in the diagnosis of a bone or joint disorder. Important factors noted in the physical examination include

1. **Limitation of movement or stiffness:** Many joint disorders, such as the various forms of arthritis, will restrict movement or produce stiffness at one or more joints.
2. **The distribution of joint involvement and inflammation:** In a *monoarthritic* condition, only one joint is affected. In a *polyarthritic* condition, several joints are affected simultaneously.
3. **Sounds associated with joint movement:** Bony crepitation (CREP-i-tas) is a crackling or grating sound generated during movement of an abnormal joint. The sound may result from the movement and collision of bone fragments following an articular fracture or from friction and abrasion at an arthritic joint.
4. **The presence of abnormal bone deposits:** Thickened, raised areas of bone develop around fracture sites during the repair process. Abnormal bone deposits may also develop around the joints in the fingers. These deposits are called *nodules* or *nodes*. When palpated, nodules are solid and painless. Nodules, which can

Inherited Abnormalities in Skeletal Development

that result in

There are several inherited conditions that result in abnormal bone formation. Three examples are *osteogenesis imperfecta*, *Marfan's syndrome*, and *achondroplasia*.

Osteogenesis imperfecta (im-per-FEK-ta) is an inherited condition, appearing in 1 individual in about 20,000, that affects the organization of collagen fibers. Osteoblast function is impaired, growth is abnormal, and the bones are very fragile, leading to progressive skeletal deformation and repeated fractures. Fibroblast activity is also affected, and the ligaments and tendons are very "loose," permitting excessive movement at the joints.

Marfan's syndrome is also linked to defective connective tissue structure. Extremely long and slender limbs, the most obvious physical indication of this disorder, result from excessive cartilage formation at the epiphyseal plates. (Marfan's syndrome is discussed further on p. 103.)

Achondroplasia (a-kon-dro-PLÄ-sē-a) is another condition resulting from abnormal epiphyseal activity. In this case the epiphyseal plates grow unusually slowly, and the individual develops short, stocky limbs. Although there are other skeletal abnormalities, the trunk is normal in size, and sexual and mental development remain unaffected. The adult will be an *achondroplastic dwarf*.

In **osteomalacia** (os-tê-ô-ma-LĀ-shē-ah; *malakia*, softness) the size of the skeletal elements remains the same, but their mineral content decreases, softening the bones. In this condition the osteoblasts are working hard, but the matrix isn't accumulating enough calcium salts. This can occur in adults or children whose diet contains inadequate levels of calcium or vitamin D₃.

† Hyperostosis and Acromegaly

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The excessive formation of bone is termed **hyperostosis** (hi-per-os-Tō-sis). In **osteopetrosis** (os-tē-o-pe-TRō-sis; petros, stone) the total mass of the skeleton gradually increases because of a decrease in osteoclast activity. Remodeling stops, and the shapes of the bones gradually change. Osteopetrosis in children produces a variety of skeletal deformities. The primary cause for this relatively rare condition is unknown.

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