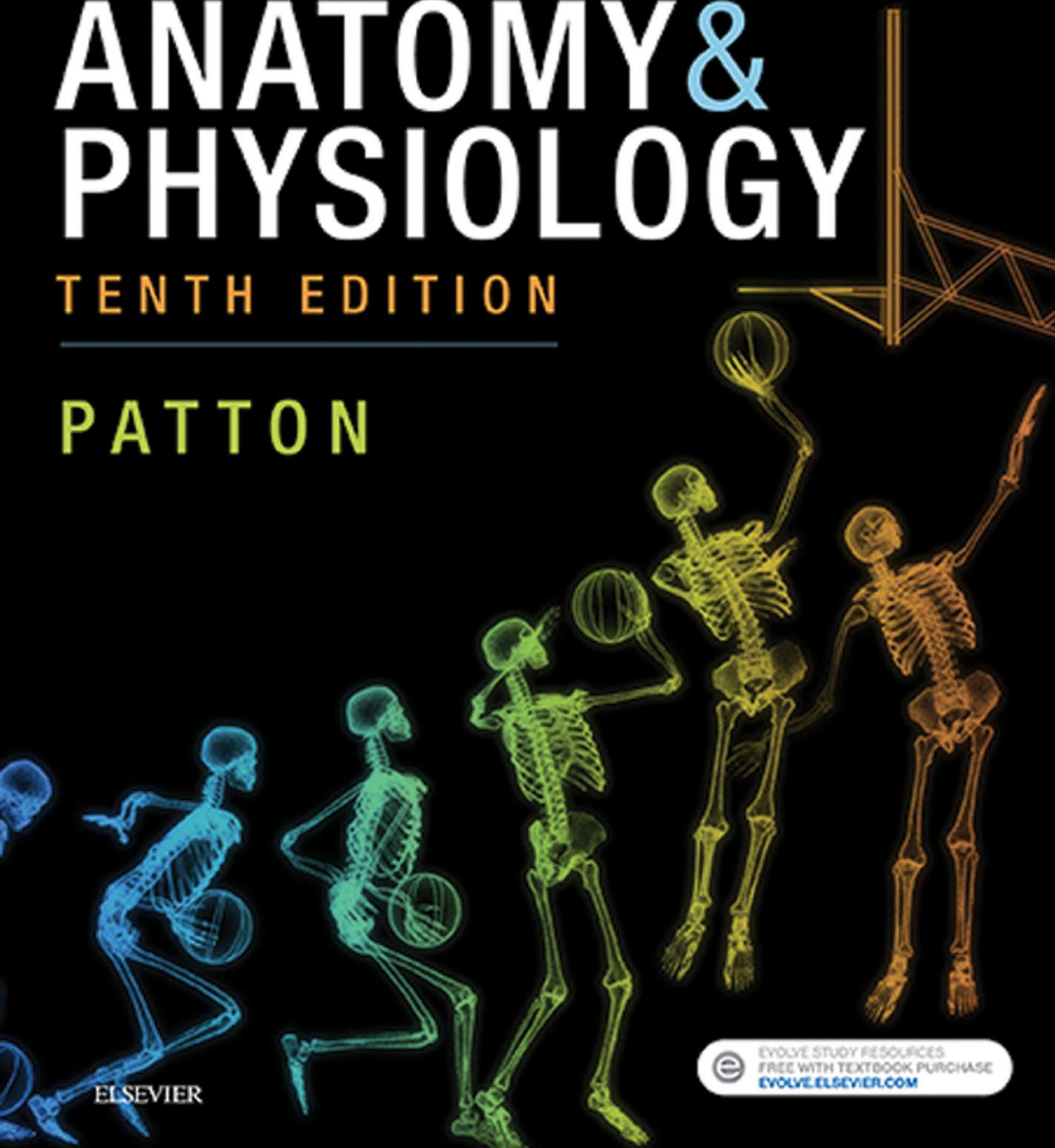
ANATOMY & PHYSIOLOGY

TENTH EDITION

PATTON



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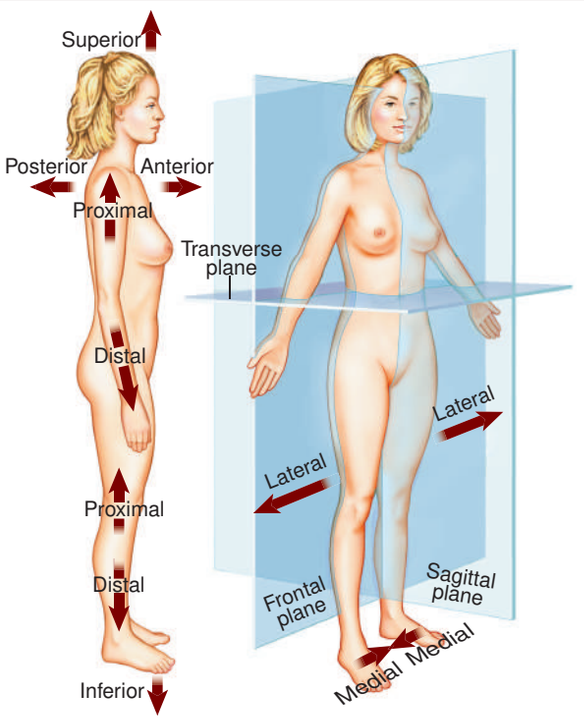
Anatomical Directions

DIRECTIONAL TERM	DEFINITION	EXAMPLE OF USAGE
Left	To the left of body (not *your* left, the subject's)	The stomach is to the *left* of the liver.
Right	To the right of the body or structure being studied	The *right* kidney is damaged.
Lateral	Toward the side; away from the midsagittal plane	The eyes are *lateral* to the nose.
Medial	Toward the midsagittal plane; away from the side	The eyes are *medial* to the ears.
Anterior	Toward the front of the body	The breastbone (sternum) is *anterior* to the heart.
Posterior	Toward the back (rear) of the body	The heart is *posterior* to the breastbone (sternum).
Superior	Toward the top of the body	The shoulders are *superior* to the hips.
Inferior	Toward the bottom of the body	The stomach is *inferior* to the heart.
Dorsal	Along (or toward) the vertebral surface of the body	Her scar is along the *dorsal* surface.
Ventral	Along (toward) the belly surface of the body	The navel is on the *ventral* surface.
Caudad (caudal)	Toward the tail (used for 4-legged animals)	The neck is *caudad* to the skull.
Cephalad	Toward the head (used for 4-legged animals)	The neck is *cephalad* to the tail.
Proximal	Toward the trunk (describes relative position in a limb or other appendage)	The joint is *proximal* to the toenail.
Distal	Away from the trunk or point of attachment	The hand is *distal* to the elbow.
Visceral	Toward an internal organ; away from the outer wall (describes positions inside a body cavity)	This organ is covered with the *visceral* layer of the membrane.
Parietal	Toward the wall; away from the internal structures	The abdominal cavity is lined with the *parietal* peritoneal membrane.
Deep	Toward the inside of a part; away from the surface	The thigh muscles are *deep* to the skin.
Superficial	Toward the surface of a part; away from the inside	The skin is a *superficial* organ.
Medullary	Refers to an inner region, or medulla	The *medullary* portion contains nerve tissue.
Cortical	Refers to an outer region, or cortex	The *cortical* area produces hormones.
Ipsilateral	On the same side of the body as	The left knee is *ipsilateral* to the left ankle.
Contralateral	On the opposite side of the body	The left knee is *contralateral* to the right knee.



To make the reading of anatomical figures a little easier, an anatomical compass is used throughout this book. On many figures, you will notice a small compass rosette similar to those on geographical maps. Rather than being labeled *N*, *S*, *E*, and *W*, the anatomical rosette is labeled with abbreviated anatomical directions.

A = Anterior	**P** (opposite A) = Posterior
D = Distal	**P** (opposite D) = Proximal
I = Inferior	**S** = Superior
L (opposite M) = Lateral	**M** = Medial
L (opposite R) = Left	**R** = Right

F. Netter M.D.

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Brief Contents

ON THE COVER

The brightly colored skeletons on the cover may at a glance appear to be medical images. However, they are artist's renderings of what the human skeleton looks like as a person plays basketball. The human skeleton in action represents several important aspects of what you will learn by studying this book. First, the images get us thinking about what is going on inside our bodies as we do ordinary things—as we live our lives. The fact that the cover shows a *sequence* of images reminds us that even simple processes are made up of many individual steps. We can also clearly see that *form fits function*, that the elements of the skeleton fit together and move in a way that allows certain kinds of actions. These and many other general concepts in understanding human structure and function are revealed throughout the chapters of this new edition of *Anatomy & Physiology*.

ANATOMY & PHYSIOLOGY

TENTH EDITION

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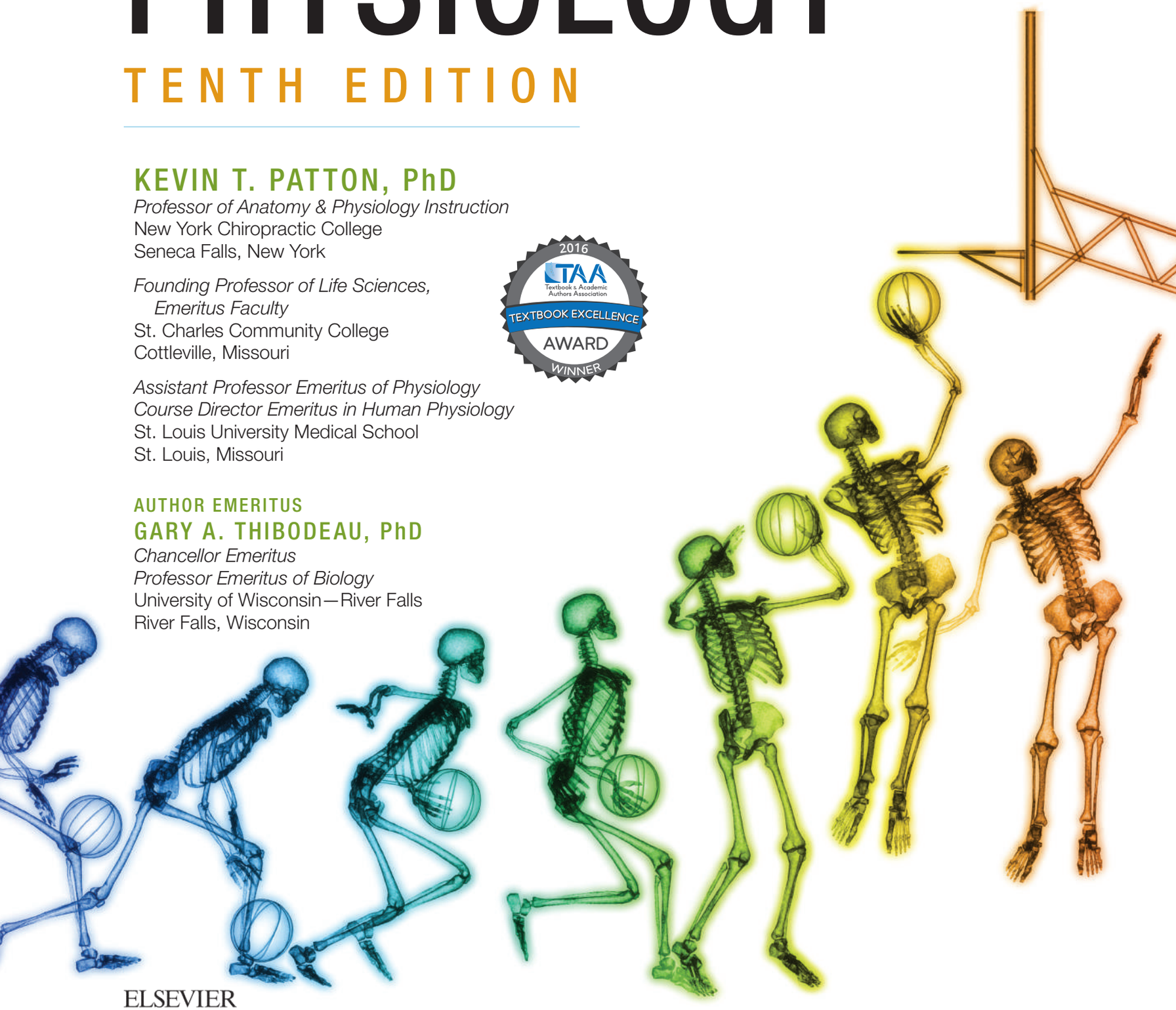

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About the Author

Kevin T. Patton has taught anatomy and physiology (A&P) to high school, community college, and university students from various backgrounds for more than 3 decades. Kevin found that the work that led him to a PhD in vertebrate anatomy and physiology instilled in him an appreciation for the "Big Picture" of human structure and function. This experience has helped him produce a text that will be easier to understand for all students. He has earned several citations for teaching A&P, including the Missouri Governor's Award for Excellence in Teaching.

"One thing I've learned," says Kevin, "is that most of us learn scientific concepts more easily when we can see what's going on." His talent for using imagery to teach is evident throughout this edition, with its extensive array of visual resources. Kevin's strong interest in applying the principles of learning science to effectively teaching A&P is also evident in the instructional design of this textbook, which earned the 2016 Textbook Excellence Award from the Textbook & Academic Authors Association (TAA).

Kevin's work in promoting excellence in teaching A&P has led him to take an active role in the Human Anatomy and Physiology Society (HAPS), where he is a President Emeritus. He was the founding director of the HAPS Institute (HAPS-I) and was awarded the HAPS President's Medal for outstanding contributions in promoting the mission of excellence in A&P teaching and learning.

Kevin also teaches graduate courses to prospective and current A&P professors. He has served as a mentor to A&P professors across the continent and produces online resources for A&P students and teachers, including *theAPstudent.org* and *theAPprofessor.org*. His blog *PattonAP.org* provides insights and teaching notes for faculty using this textbook.

To my family and friends, who never let me forget the joys of discovery, adventure, and good humor.

To the many teachers who taught me more by who they were than by what they said.

To my students who help me keep the thrill of learning fresh and exciting.

Kevin T. Patton

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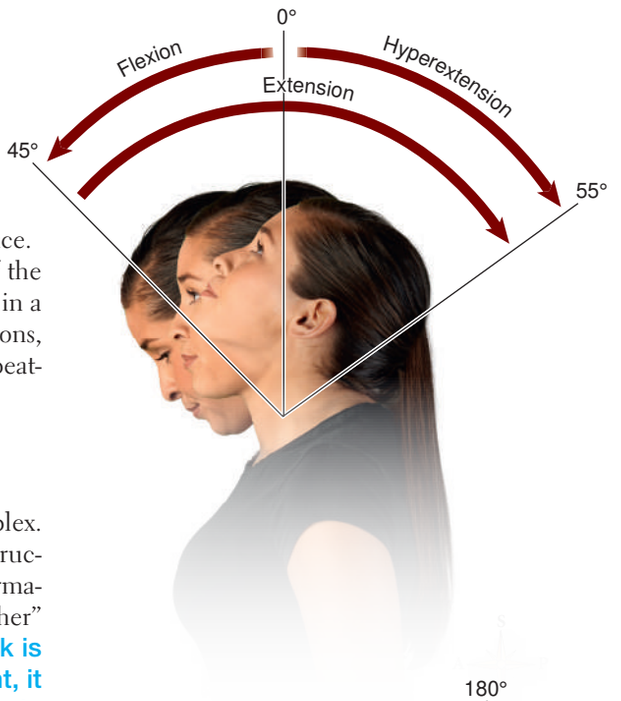
Preface

This textbook relates the story of the human body's structure and function. More than a simple collection of facts, it is both a teaching tool and a learning tool. It was written to help students unify information, stimulate critical thinking, and acquire a taste for knowledge about the wonders of the human body. The story related in this textbook will help students avoid becoming lost in a maze of facts while navigating a complex learning environment. It will encourage them to explore, to question, and to look for relationships, not only between related facts in a single discipline, but also between fields of academic inquiry and personal experience.



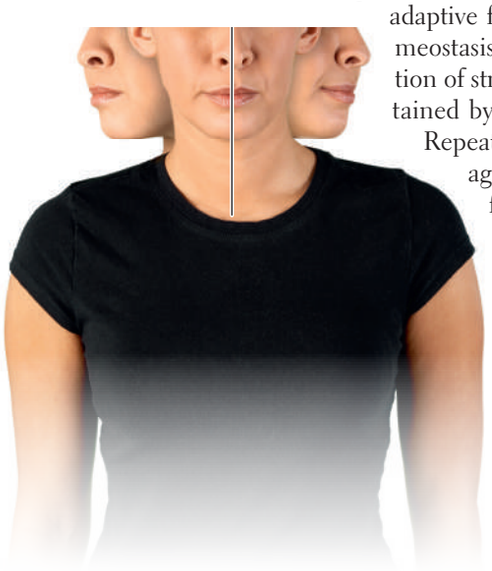
This new edition of the text has been carefully revised to better tell the story of the human body. Essential, accurate, and current information continues to be presented in a comfortable storytelling style. Emphasis is placed on concepts rather than descriptions, and the "connectedness" of the human body—in which *structure fits function*—is repeatedly reinforced by unifying themes.

UNIFYING THEMES

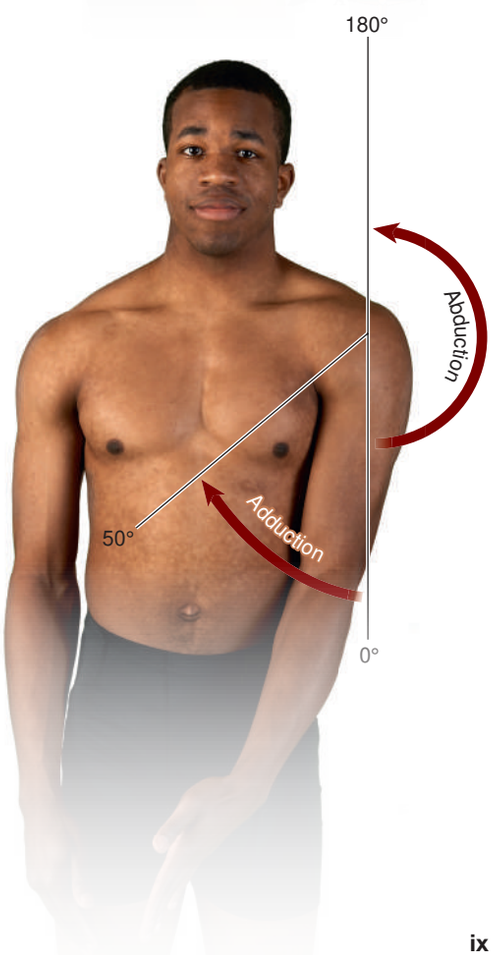
Anatomy and physiology encompasses a body of knowledge that is large and complex. Students are faced with the need to know and understand a multitude of individual structures and functions that constitute a bewildering array of seemingly disjointed information. Ultimately, the student of anatomy and physiology must be able to "pull together" this information to view the body as a whole—to see the "Big Picture." **If a textbook is to be successful as a teaching tool in such a complex learning environment, it must help unify information, stimulate critical thinking, and motivate students to master a new vocabulary.**

To accomplish this synthesis of information, unifying themes are required to tell the story of the human body effectively. In addition, a mechanism to position and implement these themes must be an integral part of each chapter. Prior to Unit 1 is "Seeing the Big Picture," an overview that encourages students to place individual structures or functions into an integrated framework. Then, a special "The Big Picture" section wraps up the story of each chapter so that its significance in the overall function of the body can easily be seen.

Anatomy & Physiology is dominated by two major unifying themes: (1) **structure fits function** and (2) **homeostasis**. The student is shown, as the story unfolds, how organized anatomical structures of a particular size, shape, form, or placement serve unique adaptive functions. The integrating principle of homeostasis is used to show how the "normal" interaction of structure and function is achieved and maintained by counterbalancing forces within the body.



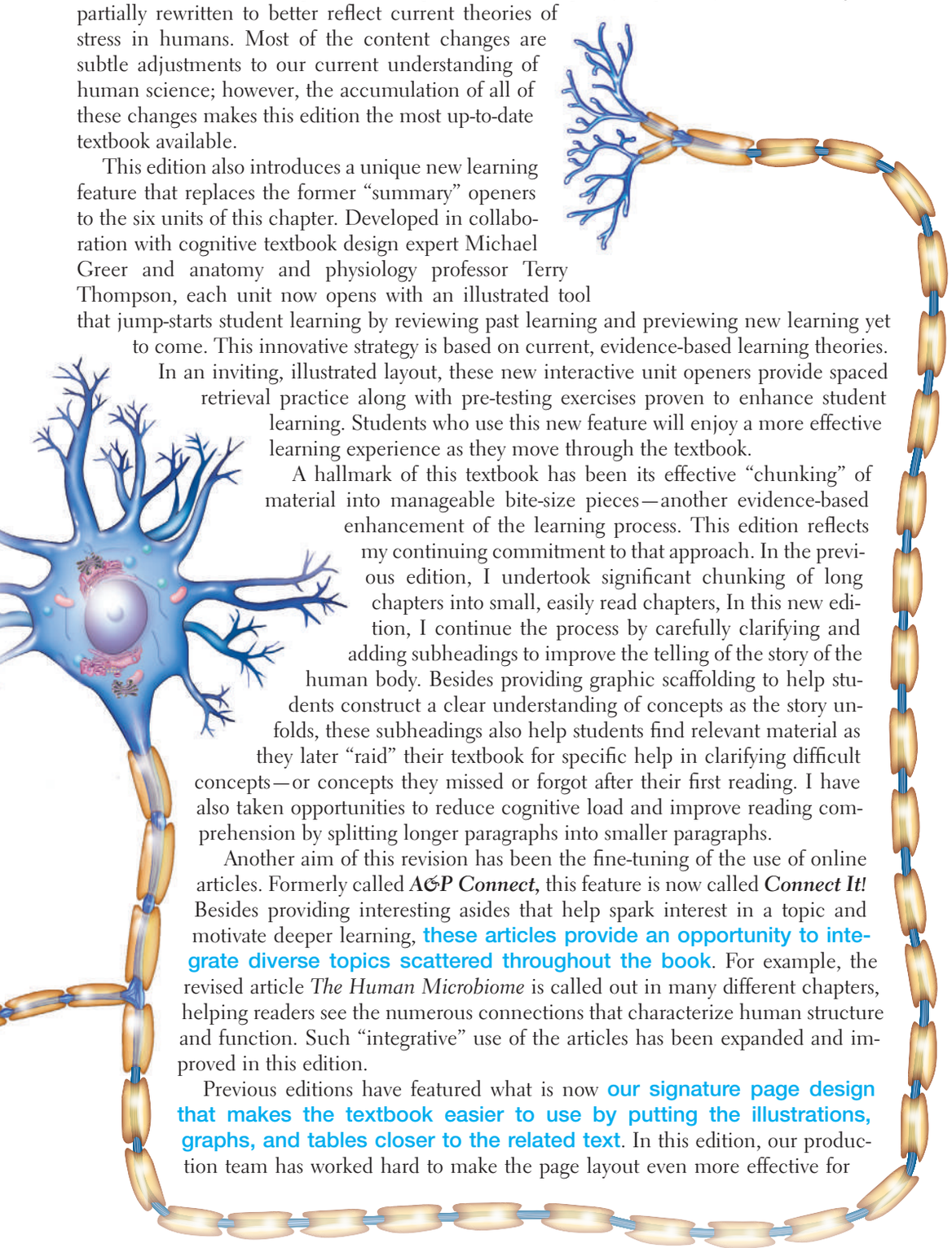
Repeated emphasis of these principles encourages students to integrate otherwise isolated factual information into a cohesive and understandable whole. "The Big Picture" summarizes the larger interaction between structures and functions of the different body systems. As a result, **the story of anatomy and physiology emerges as a living and dynamic topic of personal interest and importance to students.**



AIMS OF THE REVISION

As in past editions, my revision efforts focused on identifying the need for new or revised information and for additional visual presentations that clarify important, yet sometimes difficult, content areas.

In this tenth edition, I have included information on new concepts and new perspectives in many areas of anatomy and physiology. Some of the terminology has been updated to reflect the most current usage in the scientific community. The discussion of osmosis in Chapter 4 and several other chapters has been clarified to reflect the latest scientific understanding while still retaining an "entry level" treatment of this important concept. The stress chapter (Chapter 34) has been reorganized and partially rewritten to better reflect current theories of stress in humans. Most of the content changes are subtle adjustments to our current understanding of human science; however, the accumulation of all of these changes makes this edition the most up-to-date textbook available.



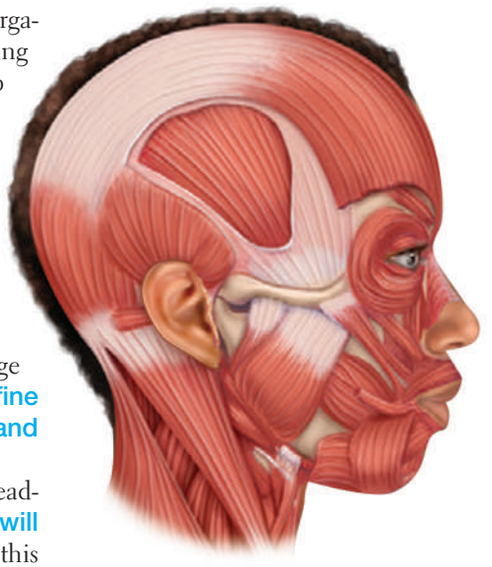
This edition also introduces a unique new learning feature that replaces the former "summary" openers to the six units of this chapter. Developed in collaboration with cognitive textbook design expert Michael Greer and anatomy and physiology professor Terry Thompson, each unit now opens with an illustrated tool that jump-starts student learning by reviewing past learning and previewing new learning yet to come. This innovative strategy is based on current, evidence-based learning theories. In an inviting, illustrated layout, these new interactive unit openers provide spaced retrieval practice along with pre-testing exercises proven to enhance student learning. Students who use this new feature will enjoy a more effective learning experience as they move through the textbook.

A hallmark of this textbook has been its effective "chunking" of material into manageable bite-size pieces—another evidence-based enhancement of the learning process. This edition reflects my continuing commitment to that approach. In the previous edition, I undertook significant chunking of long chapters into small, easily read chapters, In this new edition, I continue the process by carefully clarifying and adding subheadings to improve the telling of the story of the human body. Besides providing graphic scaffolding to help students construct a clear understanding of concepts as the story unfolds, these subheadings also help students find relevant material as they later "raid" their textbook for specific help in clarifying difficult concepts—or concepts they missed or forgot after their first reading. I have also taken opportunities to reduce cognitive load and improve reading comprehension by splitting longer paragraphs into smaller paragraphs.

Another aim of this revision has been the fine-tuning of the use of online articles. Formerly called ***A&P Connect,*** this feature is now called ***Connect It!*** Besides providing interesting asides that help spark interest in a topic and motivate deeper learning, **these articles provide an opportunity to integrate diverse topics scattered throughout the book**. For example, the revised article *The Human Microbiome* is called out in many different chapters, helping readers see the numerous connections that characterize human structure and function. Such "integrative" use of the articles has been expanded and improved in this edition.

Previous editions have featured what is now **our signature page design that makes the textbook easier to use by putting the illustrations, graphs, and tables closer to the related text**. In this edition, our production team has worked hard to make the page layout even more effective for

telling the story of the human body. The extensive set of summary tables helps students visually organize important concepts and complements the improved design to provide a multisensory learning tool. The art program has been enhanced by moving descriptions of "steps" from the legend into the diagram itself, thus reducing cognitive load and improving comprehension.



The efforts in **representing diversity of the human form** continue in this edition by adding a new set of muscle illustrations featuring a female subject. Our artists have also replaced many illustrations throughout the book with art representing a more diverse set of human traits.

Several new illustrations also maintain the use of a consistent ***Color Key*** (found on the Evolve website at *evolve.elsevier.com/Patton/AP/*) for certain cell parts, tissue types, and biomolecules to help make learning easier for beginning students.

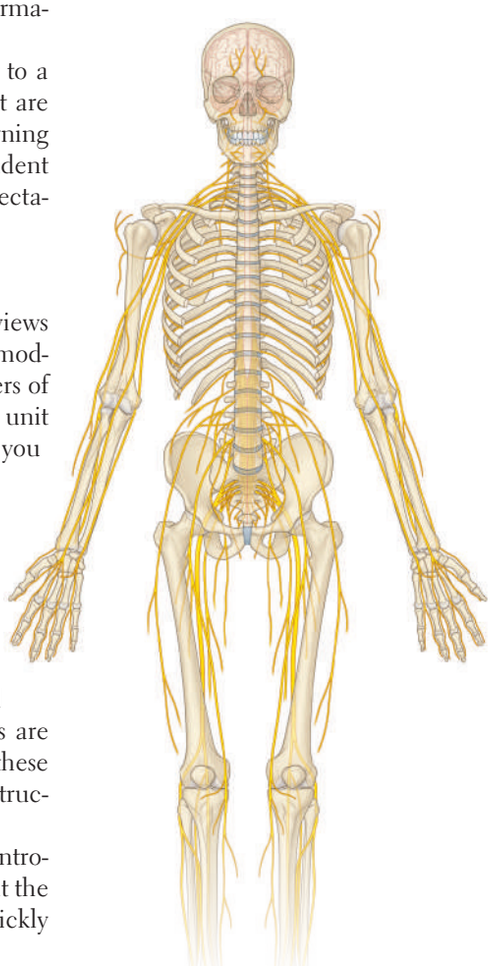
In this edition, I continue my effort to make this text accessible to students whose first language is not English. After consulting with ESL specialists and ESL learners, **I have continued to refine chapter word lists and improve readability to make the concepts of human structure and function more understandable for all students.**

As a teacher of anatomy and physiology, I know that to be effective a text must be clear and readable, and it must challenge and excite the student. **This text remains one that students will read—one designed to help the teacher teach and the student learn.** To accomplish this end, I facilitated the comprehension of difficult material for students with thorough, consistent, and nonintimidating explanations that are free of unnecessary terminology and extraneous information. This easy access to complex ideas remains the single most striking hallmark of this textbook.

■ LEARNING AIDS

Anatomy & Physiology is a student-oriented text. Written in a readable style that tells a coherent story, the text is designed with many different pedagogical aids to motivate and maintain interest. The special features and learning aids listed below are intended to facilitate learning and retention of information in the most effective and efficient manner.

No textbook can replace the direction and stimulation provided by an enthusiastic teacher to a curious and involved student. However, a full complement of innovative pedagogical aids that are carefully planned and implemented can contribute a great deal to the success of a text as a learning tool. An excellent textbook can and should be enjoyable to read and should be helpful to both student and teacher. I hope you agree that the learning aids in *Anatomy & Physiology* meet the high expectations I have set.



Interactive Unit Introductions

Each of the six major units of the text begins with a brief, interactive learning opportunity that reviews past learning and "primes the pump" for new learning in the chapters that lay ahead. Based on modern learning science, using this strategy will enhance your understanding as you read the chapters of each unit. This is followed by a clear overview of the story told in the chapters of the unit. Each unit has a color-coded tab at the outside edge of every page to help you quickly find the information you need.

Chapter Learning Aids

Study Hints *give specific suggestions for using many of the learning aids found in each chapter.* Because many readers have never learned the special skills needed to make effective use of the pedagogical resources found in science textbooks, helpful tips are embedded within each Chapter Outline, Language of Science & Medicine list, Case Study, Chapter Summary, Review Questions set, and Critical Thinking section. Answers for the Quick Check and Case Study questions are available for students on the Evolve website (*evolve.elsevier.com/Patton/AP/*), and answers for these plus the Review and Critical Thinking Exercises are available for instructors in the TEACH Instructor's Resource.

The **Chapter Outline** *summarizes the contents of a chapter at a glance.* An overview outline introduces each chapter and enables the student to preview the content and direction of the chapter at the major concept level before beginning a detailed reading. Page references enable students to quickly locate topics in the chapter.

Language of Science *introduces you to new scientific terms in the chapter.* A comprehensive list of new terms is presented at the beginning of the chapter. Each term in the list has an easy-to-use pronunciation guide to help the learner easily "own" the word by being able to say it. Literal translations of each term's word parts are included to help students learn how to deduce the meaning of new terms on their own. The listed terms are defined in the text body, where they appear in boldface type, and are also in the Glossary at the back of the book. The boldface type feature enables students to scan the text for new words before beginning their first detailed reading of the material, so they may read without having to disrupt the flow to grapple with new words or phrases. The Language of Science word list includes terms related to the essential anatomy and physiology presented in the chapter. Another word list near the end of the chapter, a feature described as the Language of Medicine, is an inventory of all of the new clinical terms introduced in the chapter.

LANGUAGE OF SCIENCE

isometric contraction
(aye-soh-MET-rik kon-TRAK-shun)
[*iso-* **equal,** *-metr-* **measure,**
-ic **relating to,** *con-* **together,**
-tract- **drag or draw,** *-tion* **process**]

isotonic contraction
(aye-soh-TON-ik kon-TRAK-shun)
[*iso-* **equal,** *ton-* **stretch or tension,**
-ic **relating to,** *con-* **together,**
-tract- **drag or draw,** *-tion* **process**]

lactate (LAK-tayt)
[*lact-* **milk,** *-ate* **salt of an acid**]

Color-coded illustrations *help beginning students appreciate the "Big Picture" of human structure and function.* A special feature of the illustrations in this text is the careful and consistent use of color to identify important structures and substances that recur throughout the book. Consistent use of a color key helps beginning students appreciate the "Big Picture" of human structure and function each time they see a familiar structure in a new illustration. For an explanation of the color scheme, see the Color Key on the Evolve website (*evolve.elsevier.com/Patton/AP/*).

Directional rosettes *help students learn the orientation of anatomical structures.* Where appropriate, small orientation diagrams and directional rosettes are included as part of an illustration to help students locate a structure with reference to the body as a whole or orient a small structure in a larger view.

Quick Check questions *test your knowledge of material you've just read.* Short objective-type questions are located immediately following major topic discussions throughout the body of the text. These questions cover important information presented in the preceding section. Students unable to answer the questions should reread that section before proceeding. This feature therefore enhances reading comprehension. Quick Check items are numbered by chapter, and a numerical listing of their answers can be found on the Evolve website (*evolve.elsevier.com/Patton/AP/*).

Quick CHECK

1. List the major subdivisions of the human nervous system.
2. What two organs make up the central nervous system?
3. Contrast the somatic nervous system with the autonomic nervous system.

Connect It! features *call the reader's attention to online articles that illustrate, clarify, and apply concepts encountered in the text.* Embedded within the text narrative, these boxes connect you with interesting, brief online articles that stimulate thinking, satisfy your curiosity, and help you apply important concepts. Connect It! articles also help you understand connections among structures and functions throughout the body, integrating concepts into a "Big Picture" of human function. They are often illustrated with micrographs, medical images, and medical illustrations.

CONNECT IT!

Tiny, barrel-shaped organelles called *vaults* may also assist with transport of molecules to and from the nucleus. To learn more about these little transport shuttles, check out ***Vaults*** online at **Connect It!**

Cycle of Life *describes major changes that occur over a person's lifetime.* In many body systems, changes in structure and function are frequently related to a person's age or state of development. In appropriate chapters of the text, these changes are highlighted in this special section.

The Big Picture *explains the interactions of the system discussed in a particular chapter with the body as a whole.* This helps students relate information about body structures or functions that are discussed in the chapter to the body as a whole. The Big Picture feature helps you improve critical thinking by focusing on how structures and functions relate to one another on a bodywide basis.

Mechanisms of Disease *helps you understand the basic principles of human structure and function by showing what happens when things go wrong.* Examples of pathology, or disease, are included in many chapters of the book to stimulate student interest and to help students understand that the disease process is a disruption in homeostasis, a breakdown of normal integration of form and function. The intent of the Mechanisms of Disease section is to reinforce understanding of the normal structures and mechanisms of the body while highlighting the general causes of disorders for a particular body system. These sections are heavily illustrated with diagrams and medical photographs that bring pathology concepts to life.

Language of Medicine *introduces you to new clinical terms in the chapter.* A brief list of clinical terms is presented near the end of each chapter. As in the Language of Science list at the beginning of the chapter, each term has a phonetic pronunciation guide and translations of word parts. The listed terms are defined in the text body, where they appear in boldface type.

A **Case Study** *challenges you with "real-life" clinical or other practical situations so you can creatively apply what you have learned.* Case studies precede the chapter summaries. The case study consists of a description of a real-life situation and a series of questions that require the student to use critical thinking skills to determine the answers.

The **Chapter Summary** *outlines essential information in a way that helps you organize your study.* Detailed end-of-chapter summaries provide excellent guides for students as they review the text materials before examinations. Many students also find the summaries to be useful as a chapter preview in conjunction with the chapter outline.

Audio Chapter Summaries *allow you to listen and learn wherever you may be.* These summaries are available in MP3 format for download at the Evolve website (*evolve.elsevier.com/Patton/AP/*).

Review Questions *help you determine whether you have mastered the important concepts of each chapter.* Review questions at the end of each chapter give students practice in using a narrative format to discuss the concepts presented in the chapter.

Critical Thinking Questions *actively engage and challenge you to evaluate and synthesize the chapter content.* Critical thinking questions require students to use their higher level reasoning skills and demonstrate their understanding of, not just their repetition of, complex concepts.

Boxed Sidebars

As always, I made every effort to update factual information and incorporate the most current anatomy and physiology research findings in this edition. Although there continues to be an incredible explosion of knowledge in the life sciences, not all new information is appropriate for inclusion in a fundamental-level textbook. Therefore I was selective in choosing new clinical, pathological, and special-interest material to include in this edition. This text remains focused on normal anatomy and physiology. The addition of new boxed content is intended to stimulate student interest and provide examples that reinforce the immediate personal relevance of anatomy and physiology as important disciplines for study.

General Interest Boxes *provide an expanded explanation of specific chapter content.* Many chapters contain boxed essays, occasionally clinical in nature, that expand on or relate to material covered in the text. Examples of subjects include the Brainbow visualization of neural networks and the enteric nervous system.

Health Matters *presents current information on diseases, disorders, clinical applications, and other health issues related to normal structure and function.* In some instances, examples of structural anomalies or pathophysiology are presented. Information of this type is often useful in helping students understand the mechanisms involved in maintaining the "normal" interaction of structure and function.

Diagnostic Study *keeps you abreast of developments in diagnosing diseases and disorders.* These boxes deal with specific diagnostic tests used in clinical medicine or research. Lumbar puncture, angiography, and antenatal diagnosis and treatment are examples.

FYI *gives you more in-depth information on interesting topics mentioned in the text.* Topics of current interest, such as new advances in anatomy and physiology research, are covered in these "for your information" boxes.

Sports and Fitness *highlights sports-related topics.* Exercise physiology, sports injury, and physical education applications are highlighted in these boxes.

Career Choices *highlights individuals in health-related careers.* A Career Choices box appears at the end of each unit. These boxes feature health professionals describing a few of the diverse opportunities currently available in health-related occupations. They also demonstrate the importance of how an understanding of anatomy and physiology will be useful to students in their futures.

Glossary

A comprehensive glossary of terms is located at the end of the text. An expanded list of accurate, concise definitions and phonetic pronunciation guides is provided, along with word parts and their literal translations. An audio glossary is also available on the expanded Evolve website (*evolve.elsevier.com/Patton/AP/*) with definitions and audio pronunciations for most of the key terms in the text.

career choices | Adult Nurse Practitioner

While going through nursing school, I had the opportunity to shadow during an open-heart surgery. The quadruple-bypass procedure took 11 hours, but I never moved from my spot beside the anesthesiologist. I was in awe watching the patient's heart pumping blood through its chambers. My fascination with the cardiac system blossomed in that moment when the heart came back to life and started functioning after a successful bypass.

More than 20 years later, I still recall that amazing sight. I use *A&P* every day in my role as an adult nurse practitioner in a cardiology practice. I see patients with a variety of cardiovascular diseases, and educating patients on their conditions is key to my practice. I strive to explain complex cardiac anatomy and physiology to my patients in simple terms so that they can understand their disease and treatment plans. I illustrate this complicated system by dividing cardiology into three categories: electrical, "plumbing," and function. Electrical problems involve the intrinsic conduction system of the heart, including dysrhythmias. Plumbing problems relate to the coronary arteries that supply the blood flow to the heart muscle, including all the blockage problems of that system. The entire function of the heart is to pump blood through the pulmonary and systemic circulation. Any disease affecting muscle function can cause problems such as cardiomyopathies, congestive heart failure, and valve disease. By educating my patients on the anatomy and physiology of a healthy heart, I can explain cardiovascular disease treatments aimed at improving their health. •

Dena Kruse, APRN, MSN, ANP-BC

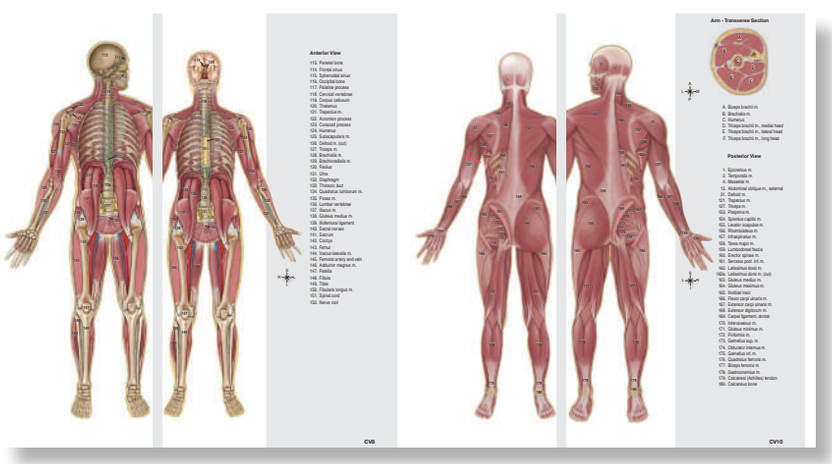
LEARNING SUPPLEMENTS FOR STUDENTS

Brief Atlas and Quick Guide

This comprehensive supplement is packaged with every new copy of this edition of *Anatomy & Physiology*. One section features a full-color ***Brief Atlas of Human Anatomy*** containing cadaver dissections, osteology, organ casts, histology specimens, and surface anatomy photographs. This helpful supplement serves as a handy reference for students as they study the human body in class and in the laboratory—and even later on in clinical and career contexts. Also included is the ***Quick Guide to the Language of Science & Medicine***, which provides the foundation for learning the terminology of anatomy and physiology. This quick guide features basic principles of terminology and lists of common roots, prefixes, suffixes, acronyms, Roman numerals, and the Greek alphabet.

Clear View of the Human Body

This edition again features a student favorite—a full-color, semitransparent model of the body called the ***Clear View of the Human Body.*** Found following p. 378, this feature permits the virtual dissection of male and female human bodies along several different planes of the body. Developed by Kevin Patton and Paul Krieger, this tool helps learners assimilate their knowledge of the complex structure of the human body. It also provides a unique learning resource that helps students visualize human anatomy in the manner of today's clinical body imaging technology.



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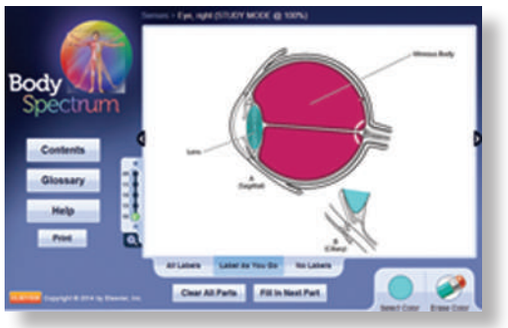
This new edition of *Anatomy & Physiology* is supported by an expanded multimedia Evolve website, featuring:

- Audio Summaries for each chapter available for streaming or download in convenient MP3 form.
- Answers to all of the Quick Check and Case Study questions found in the textbook.
- Quick access to all Connect It! articles cited in the textbook.
- An interactive audio glossary with definitions and pronunciations for more than 1000 key terms from the textbook.
- The Body Spectrum Electronic Anatomy Coloring Book, which offers dozens of anatomy illustrations that can be colored online or printed out and colored by hand.

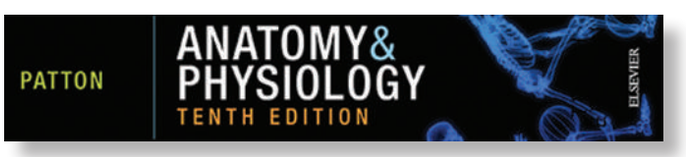


- More than 500 Student Post-Test questions that allow you to get instant feedback on what you've learned in each chapter.
- State-of-the-art 3-D animations, which show and describe physiological processes by body system.

You can visit the Evolve site by pointing your browser to *evolve.elsevier.com/Patton/AP/*.

Anatomy and Physiology Online

This 24-module online course brings anatomy and physiology to life and helps you understand the most important concepts presented in the book. Free to students who purchase a new textbook, this online course includes instructionally sound learning modules with animations, interactive exercises, and assessments.



Survival Guide for Anatomy & Physiology

The ***Survival Guide for Anatomy & Physiology (2nd edition)***, written by Kevin Patton, is an easy-to-read and easy-to-understand brief handbook to help you achieve success in your anatomy and physiology course. Read with greater comprehension using the 12 survival skills, study more effectively, prepare for tests and quizzes, and tap into all of the information resources at your disposal. The included *Maps, Charts, & Shortcuts* section is filled with illustrations, tables, analogies, and diagrams that convey all of the important facts and concepts students need to know to succeed in an anatomy and physiology course.

Anatomy & Physiology Laboratory Manual

The ***Anatomy & Physiology Laboratory Manual***, authored by Kevin Patton with new contributions from Frank Bell, continues to be an invaluable resource for students. This extensively illustrated, full-color manual features an extensively revised illustration program that includes many new dissection photographs. This popular lab

manual contains 55 well-integrated exercises that provide hands-on learning experience to help students acquire a thorough understanding of the human body.

Exercises in cat and pig anatomy, along with cow and sheep organs, are included to allow the flexible use of dissection specimens. Other features are boxed hints on handling specimens and managing laboratory activities, safety tips, coloring exercises, and summaries of landmark features used to distinguish microscopic specimens. Each exercise concludes with a lab report that may also serve as a homework assignment or self-test.

The lab manual includes *eLabs for Anatomy & Physiology*, an online lab program designed to complement traditional lab exercises. The lab exercises, based on both anatomy and physiology, are separated into modules. The labs are designed so that students can easily navigate between activities, allowing them the freedom to focus on the areas in which they need the most help.

TEACHING SUPPLEMENTS FOR INSTRUCTORS

Instructor Resources on Evolve

The TEACH *Instructor's Resource* was written and developed specifically for this new edition of *Anatomy & Physiology*. Available on Evolve, it provides critical thinking questions, learning objectives and activities, teaching tips for the text, synopses of difficult concepts, and clinical applications exercises. To make lecture preparations a little easier, the TEACH Instructor's Resource also includes lesson plans that allow you to hit the ground running.

The Evolve website for instructors also includes:

- ExamView Test Bank with more than 7000 multiple choice, true/false, and challenge questions (which you can also import into your Classroom Performance System to quickly assess student comprehension and monitor your classroom's response)
- A downloadable Image Collection featuring hundreds of full-color illustrations and photographs, with labels and lead lines that you can turn off and on
- A detailed Update Guide, listing all significant revisions in this edition
- PowerPoint Audience Response Q&A and much more!

Instructor's Guide for the Laboratory Manual

The *Instructor's Guide* for the ***A&P Laboratory Manual*** on Evolve offers detailed information to help the instructor prepare for the laboratory exercises. Alternate activities, substitutions, student handouts, and other resources help instructors tailor the use of the ***A&P Laboratory Manual*** to their own course. Answers for all questions on the lab reports in the ***A&P Laboratory Manual*** are also provided, either to check student work or to provide for students who use lab reports as self-tests.

Acknowledgments

Over the years, many people have contributed to the development and success of *Anatomy & Physiology*. I extend my thanks and deep appreciation to all of the students and classroom instructors who have provided me with helpful suggestions. I also thank the many contributors and reviewers who have, over the last several editions, provided me with extraordinary insights and useful features that I have added to this textbook.

Paul Krieger helped design the *Clear View of the Human Body*, for which I am grateful. Thanks to Betsy Brantley, who contributed many of the case studies found in this edition. Thanks also to those who provided their insights in the Career Choices boxes. Dan Matusiak and Linda Swisher have contributed in many ways to the last few editions.

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To those at Elsevier who put their best efforts into producing this edition, I am indebted. This new edition, and its comprehensive library of ancillary resources, would not have been possible without the efforts of Kellie White, Executive Content Strategist; Melissa Rawe, Content Development Specialist; and Laura Goodrich, Senior Content Development Specialist. Their expertise, support, and hard work have been vital to the success of this revision. Further, where the rubber meets the road, I am fortunate to have a wonderful team of professionals working together to keep it all on track and moving along: Julie Eddy, Publishing Services Manager; and Clay Broeker, Project Manager. I am also grateful to our friends at Graphic World, who helped us improve and execute the integrated design, layout, and art program.

Finally, I want to recognize and thank my longtime writing partner Gary A. Thibodeau. For the many years we have worked together, Gary has been an insightful collaborator, a generous mentor, and a supportive friend. Although he has retired from coauthoring, I'm grateful for his continuing role as advisor for successive editions of this book.

Kevin T. Patton

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17-4, A: Courtesy Dr. J.H. Venable, Department of Anatomy, Colorado State University, Fort Collins, CO. **17-4, B,** Courtesy Dr. H.E. Huxley. **17-6:** From Leeson CR, Leeson T, Paparo A: *Text/atlas of histology*, St. Louis, 1988, Saunders. **17-7, A:** Courtesy of Don Fawcett, Harvard Medical School, Boston, MA. In Pollard TD: Earnshaw W: *Cell biology*, ed 2, St. Louis, 2007, Saunders. **17-10, 17-11, 17-15:** From Lodish H: *Molecular cell biology*, ed 4, New York, 2000, WH Freeman. **17-12, B:** Courtesy H.E. Huxley, Brandeis University, Waltham, MA. **17-18, B:** Courtesy Dr. Paul C. Letourneau, Department of Anatomy, Medical School, University of Minnesota, MN. **17-22:** Adapted from Pollard T, Earnshaw W: *Cell biology*, ed 2, Philadelphia, 2008, Saunders. **17-30 (photos):** Courtesy Dr. Frederic S. Fay, Department of Physiology, University of Massachusetts, Worcester, MA. **17-32 (photo):** Courtesy Kellie White. **Box 17-6, A:** From Kumar V, Abbas A, Fausto N: *Robbins and Cotran pathologic basis of disease*, ed 7, Philadelphia, 2005, Saunders. **Box 17-7 (photo):** From Fritz S: *Mosby's fundamentals of therapeutic massage*, ed 5, St. Louis, 2013, Mosby. **Career Choices box:** Courtesy of Linda Carlson.

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18-1: From Patton KT, Thibodeau G: *Human body in health & disease*, ed 6, St. Louis, 2014, Mosby. **18-13:** Redrawn from FitzGerald MJT, Gruener G, Mtui E: *Clinical neuroanatomy and neuroscience*, ed 6, Edinburgh, 2011, Saunders. **18-14:** From Feldman M, Friedman L, Brandt L: *Sleisenger & Fordtran's gastrointestinal and liver disease*, ed 8, Philadelphia, 2006, Saunders. **Box 18-1, A:** Courtesy Marie Simar Couldwell, MD, and Maiken Nedergaard.

Chapter 19

Box 19-1 (photo): From Christensen GJ: *A consumer's guide to dentistry*, ed 2, St. Louis, 2002, Mosby. **Box 19-2:** Copyright Kevin Patton, Lion Den Inc., Weldon Spring, MO. **Box 19-3 (photo):** Courtesy Tamily Weissman, Jean Livet, and Jeff Lichtman, Harvard University.

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20-2, B, 20-10, C, Box 20-3: From Abrahams P, Marks S, Hutchings R: *McMinn's color atlas of human anatomy*, ed 5, Philadelphia, 2003, Mosby. **20-5, C, Table 20-3:** Redrawn from FitzGerald MJT, Gruener G, Mtui E: *Clinical neuroanatomy and neuroscience*, ed 6, Philadelphia, 2011, Saunders. **20-7 (photo):** From Gosling J, Harris P, Whitmore I, Willan P: *Human anatomy*, ed 4, Philadelphia, 2002, Mosby. **20-9, B:** Courtesy Vidic B, Suarez FR: *Photographic atlas of the human body*, St. Louis, 1984, Mosby. **20-16, C:** From Gigandet X, et al: Estimating the confidence level of white matter connections obtained with MRI tractography, *PLoS ONE*, 3(12):e4006, 2008. **20-25:** Courtesy Walter Schreider, University of Pennsylvania. **20-26:** Courtesy D.N. Markand. **Box 20-1 (photos):** From Forbes CD, Jackson WD: *Color atlas and text of clinical medicine*, ed 3, London, 2003, Mosby. **Box 20-6 (photo):** From Chipps EM, Clanin NJ, Campbell VG: *Neurologic disorders*, St. Louis, 1992, Mosby-Year Book.

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21-1: From Drake RL, et al: *Gray's atlas of anatomy*, Philadelphia, 2008, Churchill Livingstone/Elsevier. **Box 21-3 (photo):** From Habif TP: *Clinical dermatology*, ed 2, St. Louis, 1990, Mosby. **Box 21-4:** From Perkin GD: *Mosby's color atlas and text of neurology*, London, 1998, Times Mirror International Publishers. **Box 21-5:** From Beare P, Myers J: *Adult health nursing*, ed 3, St. Louis, 1998, Mosby.

Chapter 22

Case Study box (photo): Courtesy Flickr, Photo Sharing.

Chapter 23

23-1: Adapted from Guyton A, Hall J: *Textbook of medical physiology*, ed 11, Philadelphia, 2006, Saunders. **23-3, A:** From Seidel HM, Ball JW, Dains JE, Benedict GW: *Mosby's guide to physical examination*, ed 6, St. Louis, 2006, Mosby. **23-3, B:** From Swartz MH: *Textbook of physical diagnosis*, ed 4, Philadelphia, 2002, Saunders. **23-4:** Adapted from Boron W, Boulpaep E: *Medical physiology*, updated version, Philadelphia, 2005, Saunders.

Chapter 24

24-3, D: Omikron/Photo Researchers. **24-5, B:** From Patton KT, Thibodeau G: *Human body in health & disease*, ed 7, St. Louis, 2018, Mosby. **24-8, B:** Adapted from Guyton A, Hall J: *Textbook of medical physiology*, ed 11, Philadelphia, 2006, Saunders. **24-11:** Copyright Kevin Patton, Lion Den Inc, Weldon Spring, MO. **24-13:** From Newell FW: *Ophthalmology: principles and concepts*, ed 7, St. Louis, 1992, Mosby. **24-18, C:** Courtesy Dr. Scott Mittman, Johns Hopkins Hospital, Baltimore, MD. **24-23:** From Seidel HM, Ball JW, Dains JE, Benedict GW: *Mosby's guide to physical examination*, ed 3, St. Louis, 2003, Mosby. **24-25:** Adapted from Boron W, Boulpaep E: *Medical physiology*, updated version, Philadelphia, 2005, Saunders. **24-27:** From Bingham BJG, Hawke M, Kwok P: *Atlas of clinical otolaryngology*, St. Louis, 1992, Mosby Year Book. **24-29, 24-30, A:** From Swartz MH: *Textbook of physical diagnosis*, ed 4, Philadelphia, 2002, Saunders. **Box 24-3 (figure):** From *Ishihara's tests for colour deficiency*, Tokyo, 1973, Kanehara Trading Co, Copyright Isshinkai Foundation.

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25-13: Adapted from Hinson J, Raven P: *The endocrine system*, Edinburgh, 2007, Churchill Livingstone.

Chapter 26

26-2: From Erlandsen SL, Magney J: *Color atlas of histology*, St. Louis, 1992, Mosby. **26-7:** Adapted from Boron W, Boulpaep E: *Medical physiology*, updated version, Philadelphia, 2005, Saunders. **26-9, B:** From Jacob S: *Atlas of human anatomy*, Edinburgh, 2002, Churchill Livingstone. **26-12, B:** From Abrahams P, Marks S,

Hutchings R: *McMinn's color atlas of human anatomy*, ed 3, Philadelphia, 2003, Mosby. **26-13:** Dennis Strete. **26-15:** From Gosling J, Harris P, Whitmore I, Willan P: *Human anatomy*, ed 4, Philadelphia, 2002, Mosby. **26-17:** From Kierszenbaum A: *Histology and cell biology*, Philadelphia, 2002, Mosby. **Box 26-4, A:** From Swartz MH: *Textbook of physical diagnosis*, ed 4, Philadelphia, 2002, Saunders. **Box 26-4, B:** From Goldman L, Schafer AI: *Goldman's Cecil medicine*, ed 24, vol. 2, Philadelphia, 2012, Saunders. **Box 26-6 (figures):** Courtesy Gower Medical Publishers. **Box 26-1 (photo A):** Courtesy Robert F. Gagel, MD and Ian McCutcheon, MD, University of Texas MD Anderson Cancer Center, Houston, TX. In Black JM, Hawks JH: *Medical-surgical nursing: clinical management for positive outcomes*, ed 8, St. Louis, 2009, Saunders. **Box 26-1 (photo B):** From Forbes CD, Jackson WF: *Color atlas and text of clinical medicine*, ed 3, London, 2003, Mosby, Elsevier Science Ltd. **Box 26-4, C, Box 26-6, C:** From Patton KT, Thibodeau G: *Human body in health & disease*, ed 7, St. Louis, 2018, Mosby. **Career Choices box:** Courtesy of Kim Musicante.

UNIT 4

Chapter 27

27-3, D: From Zakus SM: *Clinical procedures for medical assistants*, ed 3, St. Louis, 1995, Mosby. **27-4:** From Shiland BJ: *Mastering healthcare terminology*, ed 3, St. Louis, 2010, Mosby. **27-5:** From Patton KT, Thibodeau G: *Human body in health & disease*, ed 6, St. Louis, 2014, Mosby. **27-8 (inset):** From Carr J, Rodak B: *Clinical hematology atlas*, St. Louis, 1999, Elsevier. **27-11 (inset):** From Belcher AE: *Blood disorders*, St. Louis 1993, Mosby. **27-13, 27-14, 27-15, 27-16, 27-17:** Dennis Strete. **27-18:** From Turgeon M: *Linne & Ringsud's clinical laboratory science*, ed 5, St. Louis, 2007, Mosby. **27-19:** From Carr JH, Rodak BF: *Clinical hematology atlas*, ed 2, St. Louis, 2004, Elsevier. **27-20, B:** Copyright Dennis Kunkel Microscopy Inc. **27-23:** From Cotran R, Kumar V, Collins T: *Robbins pathologic basis of disease*, ed 6, Philadelphia, 1999, Saunders. **27-24, 27-25:** From Kumar V, Abbas A, Fausto N: *Robbins and Cotran pathologic basis of disease*, ed 7, Philadelphia, 2005, Saunders. **Table 27-2:** Adapted from Pagana KD, Pagana TJ: *Mosby's manual of diagnostic and laboratory tests*, ed 5, St. Louis, 2013, Mosby. **Case Study box:** From Stevens ML: *Fundamentals of clinical hematology*, Philadelphia, 1997, Saunders.

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28-1: Courtesy Patricia Kane, Indiana University Medical School. **28-9 (drawing):** From Wilson SF, Giddens JF: *Health assessment for nursing practice*, ed 2, St. Louis, 2001, Mosby. **28-9 (inset):** From Seidel HM, Ball JW, Dains JE, Benedict GW: *Mosby's guide to physical examination*, ed 6, St. Louis, 2006, Mosby. **28-13, A, 28-16, 28-21**: From Patton KT, Thibodeau G: *Human body in health & disease*, ed 7, St. Louis, 2018, Mosby. **28-17:** From Noble A, Johnson R, Thomas A, Bass P: *The cardiovascular system*, Edinburgh, 2005, Churchill Livingstone. **28-20:** From Kumar V, Abbas A, Fausto N: *Robbins and Cotran pathologic basis of disease*, ed 7, Philadelphia, 2005, Saunders. **28-24:** Courtesy Guzzetta CE, Dossey BM, *Cardiovascular nursing: bodymind tapestry*, St. Louis, 1984, CV Mosby. **28-25:** From Aehlert B: *ACLS quick review study cards*, ed 2, St. Louis, 2004, Mosby. **28-26:** From Cotran R, Kumar V, Collins T: *Robbins pathologic basis of disease*, ed 6, Philadelphia, 1999, Saunders. **Box 28-1:** From Goldman L, Ausiello D: *Cecil textbook of medicine*, ed 23, Philadelphia, 2008, Saunders. **Case Study box:** From Hicks GH: *Cardiopulmonary anatomy and physiology*, Philadelphia, 2000, Saunders.

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29-5: Adapted from McCance K, Huether S: *Pathophysiology*, ed 5, St. Louis, 2006, Mosby. **29-9, C, 29-11, A, C, 29-13, B, C:** From Abrahams P, Marks S, Hutchings R: *McMinn's color atlas of human anatomy*, ed 5, Philadelphia, 2003, Mosby. **29-24:** From Patton KT, Thibodeau G: *Human body in health & disease*, ed 7, St. Louis, 2018, Mosby. **29-26 (photo):** From Swartz MH: *Textbook of physical diagnosis*, ed 4, Philadelphia, 2002, Saunders. **29-29:** From Cotran R, Kumar V, Collins T: *Robbins pathologic basis of disease*, ed 6, Philadelphia, 1999, Saunders. **Box 29-1:** Courtesy Simon C, Janner M: *Color atlas of pediatric diseases with differential diagnosis*, ed 2, Hamilton, Ontario, 1990, BC Decker. **Case Study box:** Courtesy Dr. Daniel Simon and Mr. Paul Zambino

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30-1: From Harvey W: *The anatomical exercises*, London, 1995, Dover Publishing. **30-6:** From Rhoades R, Pflanzer R: *Human physiology*, ed 3, Philadelphia, 1995, Perennial. **30-9:** Adapted from Guyton A, Hall J: *Textbook of medical physiology*, ed 11, Philadelphia, 2006, Saunders. **30-11, 30-19, B:** Adapted from Boron W, Boulpaep E: *Medical physiology*, updated version, Philadelphia, 2005, Saunders. **30-19, A:** From Patton KT, Thibodeau G: *Human body in health & disease*, ed 7, St. Louis, 2018, Mosby. **30-25:** Adapted from Canobbio MM: *Cardiovascular disorders*, St. Louis, 1990, Mosby. **30-28:** Adapted from the National High Blood Pressure Education Program.

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31-2, 31-5,A: From Patton KT, Thibodeau G: *Human body in health & disease*, ed 7, St. Louis, 2018, Mosby. **31-5B:** Courtesy Ballinger P, Frank E: *Merrill's atlas of radiographic positions and radiologic procedures*, ed 10, vol 1, St. Louis, 2003, Mosby. **31-6:** Adapted from McCance K, Huether S: *Pathophysiology*, ed 4, St. Louis, 2002, Mosby. **31-7:** Adapted from Boron W, Boulpaep E: *Medical physiology*, updated version, Philadelphia, 2005, Saunders. **31-8, A:** Adapted from Mathers L, Chase R, Dolph J, Glasgow E: *CLASS clinical anatomy principles*, Philadelphia, 1996, Mosby. **31-8, B:** From Nielsen M: *Human anatomy lab manual and workbook*, ed 4, Dubuque, IA, 2002, Kendall/Hunt Publishing Company. **31-9, B, 31-17, B:** Dennis Strete. **31-14:** From National Institute of Allergy and Infectious Diseases, National Institutes of Health, Bethesda, MD. **31-15, 31-24:** From Seidel HM, Ball JW, Dains JE, Benedict GW: *Mosby's guide to physical examination*, ed 6, St. Louis, 2006, Mosby. **31-16, B:** Courtesy Dr. Edward L. Applebaum, Head, Department of Otolaryngology, University of Illinois Medical Center, Chicago. **31-18:** Adapted from Rhoades R, Pflanzer R: *Human physiology*, ed 3, Philadelphia, 1995, Perennial. **31-19:** Courtesy Vidic B, Suarez FR: *Photographic atlas of the human body*, St. Louis, 1984, Mosby. **31-21:** Courtesy Walter Tunnesen, MD, The American Board of Pediatrics, Chapel Hill, NC. **31-22:** From Goldstein B,

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32-1, 32-8, Box 32-1, B: From Abbas A, Lichtman A: *Cellular and molecular immunology*, ed 5, Philadelphia, 2003, Saunders. **32-4:** From Roitt IM, Brostoff, Male DK: *Immunology*, ed 3, St. Louis, 1993, Mosby. **32-6:** Adapted from McCance K, Huether, S: *Pathophysiology*, ed 5, St. Louis, 2006, Mosby. **32-10:** From McCance K, Huether S: *Pathophysiology: the biologic basis for disease in adults and children*, ed 7, St. Louis, 2014, Mosby. **Box 32-1, A:** From Copstead-Kirkhorn L, Banasik J: *Pathophysiology*, ed 2, St. Louis, 1999, Saunders.

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33-1: Copyright Dennis Kunkel Microscopy Inc. **33-3, 33-4, 33-5, 33-9, 33-14, 33-15, 33-16, 33-17, 33-18, 33-20, Box 32-1, B, Box 33-6:** From Abbas A, Lichtman A: *Cellular and molecular immunology*, ed 5, Philadelphia, 2003, Saunders. **33-13, 33-21:** From Copstead-Kirkhorn L, Banasik J: *Pathophysiology*, ed 2, St. Louis, 1999, Saunders. **Box 33-3:** From Stinchcombe JC, Griffiths GM: The role of the secretory immunological synapse in killing by CD8+ CTL, *Semin Immunol*, 15(6):301-305, 2003. **Box 33-5:** Adapted from McCance K, Huether S: *Pathophysiology*, ed 4, St. Louis, 2002, Elsevier. **Case Study box:** From Mason DJ, Leavitt J, Chaffee M: *Policy and politics in nursing and health care*, ed 5, St. Louis, 2007, Saunders.

Chapter 34

34-1, A: Julie Dermansky/Science Source. **34-1, B:** Ria Novosti/Science Source. **34-1, C:** Mauro Fermariello/Science Source. **34-1, D:** Global Warming Art. **34-1, E:** Stocktrek Images/Thinkstock. **34-6:** Adapted from McEwan BS, Gianaros PJ: Stress- and allostasis-induced brain plasticity, *Annu Rev Med* 62:5.1-5.15, 2011. **Career Choices box:** Courtesy of Dena Kruse.

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35-4: From Stevens A, Lowe J: *Human histology*, ed 3, Philadelphia, 2005, Mosby. **35-8, B. C:** From Cox JD: *Radiation oncology*, ed 9, St. Louis, 2010, Mosby. **35-9:** Adapted from Thompson JM, Wilson SF: *Health assessment for nursing practice*, St. Louis, 1996, Mosby. **35-13, B:** From Erlandsen SL, Magney J: *Color atlas of histology*, St. Louis, 1992, Mosby. **35-12:** From Hutchings RT, McMinn RM: *McMinn's color atlas of human anatomy*, ed 2, Chicago, 1988, Year Book Medical Publishers. **35-13, A:** From Patton KT, Thibodeau G: *Structure & function*, ed 15, St. Louis, 2015, Mosby. **35-14:** From Epstein O, Perkin GD, Cookson J, de Bono D: *Clinical examination*, ed 3, Philadelphia, 2003, Mosby. **35-15:** From Patton KT, Thibodeau G: *Human body in health & disease*, ed 7, St. Louis, 2018, Mosby. **35-16:** Courtesy Vidic B, Suarez RF: *Photographic atlas of the human body*, St. Louis, 1984, Mosby. **35-19:** From Zitelli B, Davis H: *Atlas of pediatric physical diagnosis*, ed 4, Philadelphia, 2002, Mosby. **35-20, 35-21:** From Kumar V, Abbas A, Fausto N: *Robbins and Cotran pathologic basis of disease*, ed 7, Philadelphia, 2005, Saunders. **Box 35-1:** From Patton KT, Thibodeau G: *Human body in health & disease*, ed 7, St. Louis, 2018, Mosby.

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36-6: From Drake R, Vogl AW, Mitchell A: *Gray's anatomy for students*, Philadelphia, 2005, Churchill Livingstone. **36-9, A, 36-16:** Adapted from Boron W, Boulpaep E: *Medical physiology*, updated version, Philadelphia, 2005, Saunders. **39-9, B:** Antonia Reeve/Science Source. **36-12, Box 36-2:** Adapted from Davies A, Moores C: *The respiratory system*, Edinburgh, 2004, Churchill Livingstone. **36-14:** From Patton KT, Thibodeau G: *Human body in health & disease*, ed 6, St. Louis, 2014, Mosby. **Box 36-6:** Copyright Kevin Patton, Lion Den Inc, Weldon Spring, MO. **Box 36-7:** Adapted from Guyton A, Hall J: *Textbook of medical physiology*, ed 11, Philadelphia, 2006, Saunders.

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37-4, 37-13: Adapted from Boron W, Boulpaep E: *Medical physiology*, updated version, Philadelphia, 2005, Saunders. **37-5:** From Rhoades R, Pflanzer R: *Human physiology*, ed 3, Philadelphia, 1995, Perennial. **37-6:** From Patton KT, Thibodeau G: *Human body in health & disease*, ed 6, St. Louis, 2014, Mosby.

Chapter 38

38-5, B: Copyright Kevin Patton, Lion Den Inc, Weldon Spring, MO. **38-5:** Dennis Strete. **38-6, B:** From Zitelli B, Davis H: *Atlas of pediatric physical diagnosis*, ed 3, Philadelphia, 1997, Mosby. **38-10 (inset):** From Weir J, Abrahams P: *Imaging atlas of the human anatomy*, ed 2, Philadelphia, 1997, Mosby. **38-11, 38-12, A, 38-16:** From Patton KT, Thibodeau G: *Human body in health & disease*, ed 7, St. Louis, 2018, Mosby. **38-12, B:** From Stevens A, Lowe J: *Human histology*, ed 3, Philadelphia, Mosby, 2005. **38-18, A:** From Wilson SF, Giddens JF: *Health assessment for nursing practice*, ed 2, St. Louis, 2001, Mosby. **38-18, B:** From Greig JD, Garden OJ: *Color atlas of surgical diagnosis*, London, 1996, Times Mirror International Publishers. **38-20, D:** Courtesy Kevin Patton, Weldon Spring, MO. **38-21, B, 38-22, Box 38-2:** From Daffner DH: *Clinical radiology: the essentials*, ed 3, Baltimore, 1992, Lippincott, Williams & Wilkins.

Chapter 39

39-2, B: From Abrahams P, Marks S, Hutchings R: *McMinn's color atlas of human anatomy*, ed 5, Philadelphia, 2003, Saunders. **39-4, B:** From Erlandsen SL, Magney J: *Color atlas of histology*, St. Louis, 1992, Mosby. **39-5:** SPL/Photo Researchers. **39-10, A:** Courtesy Baylor Regional Transplant Institute, Baylor University Medical Center, Dallas, TX. **39-14:** Courtesy Thompson JM, Wilson SF: *Health assessment for nursing practice*, St. Louis, 1996, Mosby. **39-20:** From Cotran R, Kumar V, Collins T: *Robbins pathologic basis of disease*, ed 6, Philadelphia, 1999, Saunders. **39-17:** From Doughty DB, Jackson D: *Gastrointestinal disorders*, St. Louis, 1993, Mosby.

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40-3, 40-5: From Patton KT, Thibodeau G: *Human body in health & disease*, ed 7, St. Louis, 2018, Mosby. **40-4, Box 40-1:** Adapted from Boron W, Boulpaep E: *Medical physiology*, updated version, Philadelphia, 2005, Saunders. **40-19, B:** Courtesy Dr. Andrew Evan, Indiana University. **Box 40-2, B:** Adapted from Smith M, Morton D: *The digestive system*, Edinburgh, 2001, Churchill Livingstone. **Box 40-4, B, C:** From Stevens A, Lowe J: *Human histology*, ed 3, Philadelphia, 2005, Mosby.

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41-1: From the United States Food and Drug Administration: *Food labeling guide*, College Park, MD, 2013, Office of Nutrition, Labeling, and Dietary Supplements, HFS-800. **41-2, A:** From the United States Department of Agriculture: *MyPlate 2013*, Retrieved from http://www.choosemyplate.gov/print-materials-ordering/graphic-resources.html. **41-2, B:** From Health Canada, 2016. *Eating well with Canada's food guide*. Reproduced with permission from the Minister of Health, 2017. **41-14, B:** Courtesy Brenda Russell, PhD, University of Illinois at Chicago. **41-18, B:** Adapted from Carroll R: *Elsevier's integrated physiology*, Philadelphia, 2007, Mosby. **41-20:** Adapted from *Report of the Expert Panel for Population Strategies for Blood Cholesterol Reduction*, Bethesda, MD, 1990, The National Cholesterol Education Program, National Heart Lung and Blood Institute, Public Health Service, US Department of Health and Human Services, NIH Publication No. 90-3046. **41-25, 41-26, 41-29, 41-32, Box 41-9, B:** Adapted from Mahan LK, Escott-Stump S: *Krause's food, nutrition and diet therapy*, ed 11, St. Louis, 2004, Saunders. **41-31:** Adapted from Guyton A, Hall J: *Textbook of medical physiology*, ed 11, Philadelphia, 2006, Saunders. **41-33:** From Zitelli B, Davis H: *Atlas of pediatric physical diagnosis*, ed 3, Philadelphia, 1997, Mosby. **Box 41-2:** Courtesy Bevelander G, Ramalay J: *Essentials of histology*, ed 8, St. Louis, 1979, Mosby. **Box 41-9, B:** Adapted from Mahan LK, Escott-Stump S: *Krause's food, nutrition and diet therapy*, ed 11, St. Louis, 2004, Saunders.

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42-1, A: Barbara Cousins. **42-1, B, 42-2, B:** From Abrahams P, Marks S, Hutchings R: *McMinn's color atlas of human anatomy*, ed 5, Philadelphia, 2003, Mosby. **42-2, A, 42-10:** Adapted from Brundage DJ: *Renal disorders*, Mosby's Clinical Nursing Series, St. Louis, 1992, Mosby. **42-3, B:** From Weir J, Abrahams P: *Imaging atlas of the human anatomy*, ed 2, Philadelphia, 1997, Mosby. **42-6:** From Heylings D, Spence R, Kelly B: *Integrated anatomy*, Edinburgh, 2007, Churchill Livingstone. **42-7:** From Telser A, Young J, Baldwin K: *Elsevier's integrated histology*, Philadelphia, 2008, Mosby. **42-11, 42-16:** From Stevens A, Lowe J: *Human histology*, ed 3, Philadelphia, 2005, Mosby. **42-8:** From Gosling J, Harris P, Whitmore I, Willan P: *Human anatomy*, ed 4, Philadelphia, 2002, Mosby. **42-9:** Adapted from Guyton A, Hall J: *Textbook of medical physiology*, ed 11, Philadelphia, 2006, Saunders. **42-14, 42-15, B:** From Boron W, Boulpaep E: *Medical physiology*, updated version, Philadelphia, 2005, Saunders. **42-18, Box 42-6:** From Patton KT, Thibodeau G: *Human body in health & disease*, ed 7, St. Louis, 2018, Mosby. **42-29:** From Kumar V, Abbas A, Fausto N: *Robbins and Cotran pathologic basis of disease*, ed 7, Philadelphia, 2005, Saunders. **Table 42-2:** From Bonewit-West K: *Clinical procedures for medical assistants*, ed 8, St. Louis, Saunders, 2011.

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43-7: Copyright Kevin Patton, Lion Den Inc, Weldon Spring, MO. **43-18:** Modified from Goldman L, Schafer AI: *Goldman's Cecil medicine*, ed 24, Philadelphia, 2012, Saunders. **43-11:** Courtesy Kellie White.

Chapter 44

Box 44-1: Courtesy Kevin Patton, Lion Den Inc, Weldon Spring, MO. **Career Choices box:** Courtesy of Norma Cooper.

UNIT 6

Chapter 45

45-3, A, 45-8, E: Lennart Nilsson. **45-4, 45-8, F:** From Stevens A, Lowe J: *Human histology*, ed 3, Philadelphia, 2005, Mosby. **45-5:** Courtesy Dr. Mark Ludvigson, US Army Medical Corps, St. Paul, MN. **45-9, 45-10, 45-13:** From Erlandsen SL, Magney J: *Color atlas of histology*, St. Louis, 1992, Mosby. **45-11:** Barbara Cousins. **45-12:** From Abrahams P, Marks S, Hutchings R: *McMinn's color atlas of human anatomy*, ed 5, Philadelphia, 2003, Mosby. **45-14, B:** Courtesy Vidic B, Suarez RF: *Photographic atlas of the human body*, St. Louis, 1984, Mosby. **45-15:** Adapted from Guyton A, Hall J: *Textbook of medical physiology*, ed 11, Philadelphia, 2006, Saunders. **45-16:** Adapted from Boron W, Boulpaep E: *Medical physiology*, updated version, Philadelphia, 2005, Saunders. **45-17, Box 45-1:** From Seidel HM, Ball JW, Dains JE, Benedict GW: *Mosby's guide to physical examination*, ed 6, St. Louis, 2006, Mosby.

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46-1, B: From Moses K, Nava P, Banks J, Petersen D: *Moses atlas of clinical gross anatomy*, Philadelphia, 2005, Mosby. **46-3, B, 46-6, 46-7:** From Gosling J, Harris P, Whitmore I, Willan P: *Human anatomy*, ed 4, Philadelphia, 2002, Mosby. **46-5, C:** From Familiari G, et al: Ultrastructural dynamics of human reproduction, from ovulation to fertilization and early embryo development, *Int Rev Cytol*, 249:53-141, 2006. **46-10:** From Stevens A, Lowe J: *Human histology*, ed 3, Philadelphia, Mosby, 2005. **46-11:** From McKee GT: *Cytopathology*, London, 1997, Mosby-Wolfe. **46-12:** Courtesy Dr. Richard Blandau, Department of Biological Structure, University of Washington School of Medicine, Seattle, WA, from his film *Ovulation and egg transport in mammals*, 1973. **46-18:** Adapted from Boron W, Boulpaep E: *Medical physiology*, updated version, Philadelphia, 2005, Saunders. **46-21, 46-23:** From Mettler F: *Essentials of radiology*, ed 2, Philadelphia, 2005, Saunders. **46-22, A:** From Abrahams P, Marks S, Hutchings R: *McMinn's color atlas of human anatomy*, ed 5, Philadelphia, 2003, Saunders. **46-22, B:** From Symonds EM, MacPherson MB: *Color atlas of obstetrics and gynecology*, London, 1994, Mosby Wolfe. **46-24:** From Kumar V, Abbas A, Fausto N: *Robbins and Cotran pathologic basis of disease*, ed 7, Philadelphia, 2005, Saunders. **46-25, B, C,** From Cotran R, Kumar V, Collins T: *Robbins pathologic basis of disease*, ed 6, Philadelphia, 1999, Saunders. **Box 46-6 (photo):** From Ferri FF: *Ferri's color atlas and text of clinical medicine*, Philadelphia, 2009, Saunders/Elsevier. **Box 46-7:** Michael Donne, Science Photo Library, Science Source.

Chapter 47

47-5 (photo), 47-13: Lennart Nilsson. **47-7:** Courtesy Lucinda L. Veeck, Jones Institute for Reproductive Medicine, Norfolk, VA. **47-11, B:** From Cotran R, Kumar V, Collins T: *Robbins pathologic basis of disease*, ed 6, Philadelphia, 1999, Saunders. **47-12, B:** Adapted from Hinson J, Raven P: *The endocrine system*, Edinburgh, 2007, Churchill Livingstone. **47-14:** From Moore KL, Persand TV: *The developing human*, ed 6, Philadelphia, 1998, Saunders. **46-17, 46-18, 47-25:** Adapted from Boron W, Boulpaep E: *Medical physiology*, updated version, Philadelphia, 2005, Saunders. **47-20:** From Patton KT, Thibodeau G: *Human body in health & disease*, ed 7, St. Louis, 2018, Mosby. **47-23:** From Hockenberry MJ, Wilson D: *Wong's essentials of pediatrics nursing*, ed 8, St. Louis, 2009, Mosby. **47-24, Box 47-2, B:** Copyright Kevin Patton, Lion Den Inc, Weldon Spring, MO. **47-26:** Adapted from Mahan LK, Escott-Stump S: *Krause's food, nutrition and diet therapy*, ed 12, St. Louis, 2007, Saunders. **47-27:** Adapted from McCance K, Huether S: *Pathophysiology*, ed 5, St. Louis, 2005, Mosby. **47-29, B:** Adapted from Ignatavicius D, Bayne MV: *Medical-surgical nursing: a nursing process approach*, Philadelphia, 1991, Saunders. **47-30:** From Andersen JL, Schjerling P, Saltin B: Muscle, genes, and athletic performance, *Sci Am*, 283(3):49-55, 2000. **47-31:** From Goldman L, Ausiello D, *Cecil textbook of medicine*, ed 23, Philadelphia, 2003, Saunders. **Box 47-3 (photo):** Courtesy of the Progeria Research Foundation. Peabody, MA, http://www.progeriaresearch.org. **Case Study box:** From Hagen-Ansert SL: *Textbook of diagnostic ultrasonography*, ed 6, vol 2, St. Louis, 2007, Mosby.

Chapter 48

48-1: Adapted from Boron W, Boulpaep E: *Medical physiology*, updated version, Philadelphia, 2005, Saunders. **48-2:** From Patton KT, Thibodeau G: *Human body in health & disease*, ed 7, St. Louis, 2018, Mosby. **48-5:** From Jorde L, Carey J, Bamshad M: *Medical genetics*, ed 3, Philadelphia, 2004, Saunders. **48-10:** From McCance K, Huether S: *Pathophysiology*, ed 4, St. Louis, 2002, Mosby. **48-13, B:** From Kumar V, Abbas A, Fausto N: *Robbins and Cotran pathologic basis of disease*, ed 7, Philadelphia, 2005, Saunders. **48-14, A:** Courtesy Lois McGavran, Denver Children's Hospital. **48-14, B:** From Zitelli: *Atlas of pediatric physical diagnosis*, ed 6, St. Louis, 2012, Mosby. **48-15, 48-16, B, 48-17, B:** Courtesy Nancy S. Wexler, PhD, Columbia University. **Career Choices box:** Courtesy of Andrea L. Mose.

the big picture | Seeing the BIG picture

Before reading this introduction, you probably spent a few minutes flipping through this book. Naturally, you are curious about your course in human anatomy and physiology, and you want to see what lies ahead. It is more than that. You are curious about the human body—about yourself, really. We all have that desire to learn more about how our bodies are put together and how all the parts work. Unlike many other people, though, you now have the opportunity to gain an understanding of the underlying scientific principles of human structure and function.

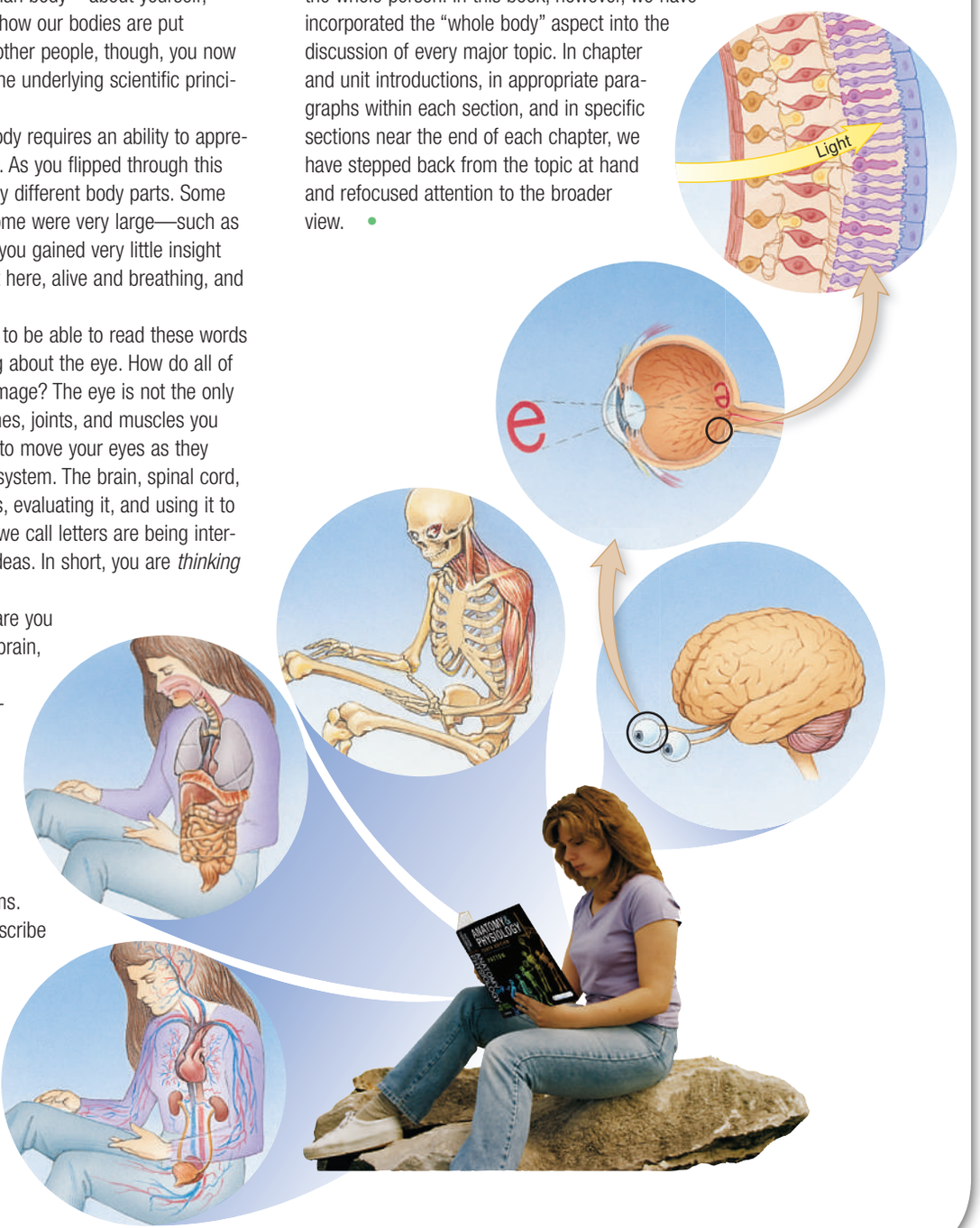
To truly understand the nature of the human body requires an ability to appreciate "the parts" and "the whole" at the same time. As you flipped through this book for the first time, you probably looked at many different body parts. Some were microscopic—such as muscle cells—and some were very large—such as arms and legs. In looking at these parts, however, you gained very little insight about how they worked together to allow you to sit here, alive and breathing, and read and comprehend these words.

Think about it for a moment. What does it take to be able to read these words and understand them? You might begin by thinking about the eye. How do all of its many intricate parts work together to form an image? The eye is not the only organ you are using right now. What about the bones, joints, and muscles you are using to hold the book, to turn the pages, and to move your eyes as they scan this paragraph? Let's not forget the nervous system. The brain, spinal cord, and nerves are receiving information from the eyes, evaluating it, and using it to coordinate the muscle movements. The squiggles we call letters are being interpreted near the top of the brain to form complex ideas. In short, you are *thinking* about what you are reading.

However, that does not cover everything. How are you getting the energy to operate your eyes, muscles, brain, and nerves? Energetic chemical reactions inside each cell of these organs require oxygen and nutrients captured by the lungs and digestive tract and delivered by the heart and blood vessels. These chemical reactions produce wastes that are handled by the liver, kidneys, and other organs. All of these functions must be coordinated, a feat accomplished by regulation of body organs by hormones, nerves, and other mechanisms.

Learning to name the various body parts, to describe their detailed structure, and to explain the mechanisms that produce their functions is an essential step that leads to the goal of understanding the human body. To actually reach that goal, however, you must be able to draw together isolated facts and concepts. In other words, understanding the nature of individual body parts becomes more meaningful when you understand how the parts work together in a living, whole person.

Many textbooks are written like reference books—dictionaries, for example. They provide detailed descriptions of the structure and function of individual body parts, often in logical groupings, while rarely stopping to step back and look at the whole person. In this book, however, we have incorporated the "whole body" aspect into the discussion of every major topic. In chapter and unit introductions, in appropriate paragraphs within each section, and in specific sections near the end of each chapter, we have stepped back from the topic at hand and refocused attention to the broader view. •

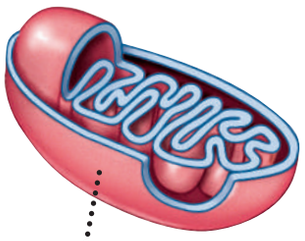


ANATOMY & PHYSIOLOGY

BEFORE YOU BEGIN . . .

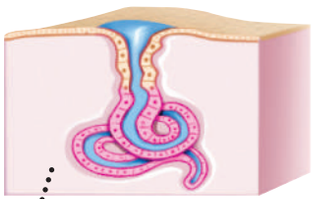
At the organelle level within the living skin cells, you probably think of the mitochondrion shown here as the "power plant" of the cell. In this unit you will learn more about the process of cellular respiration.

1. *What is the **molecule** produced by this cell part that transfers energy from nutrients to the chemical or metabolic processes of life?*
a) DNA b) RNA c) ATP



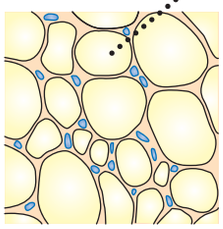
Sweat glands in our skin are epithelial tissue exocrine glands that secrete substances onto the surface of the skin. You know they help cool off your body when overheated, but they also secrete wastes in that fluid.

2. *What other **organ system** would also get rid of wastes as fluids?*



At the biochemical level, the subcutaneous layer under our skin has many fat cells. They provide insulation and energy reserves.

7. *An abundance of which of these four major groups of **organic substances** would be found in these cells?*
a) carbohydrates
b) lipids
c) proteins
d) nucleic acids



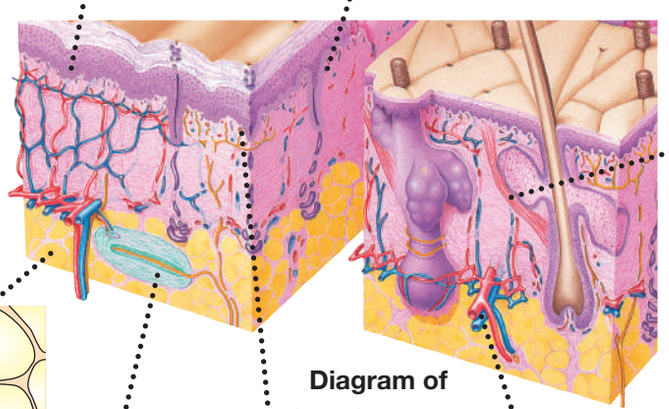
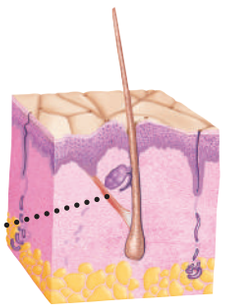
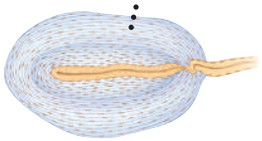


Diagram of Skin Structure



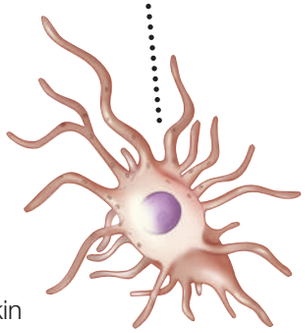
When you think about muscles in the human body, you probably focus on those that attach to and move the skeleton. However. there are several types of muscle tissue in humans. Shown here is smooth muscle that can make hair stand on end and form "goose bumps."

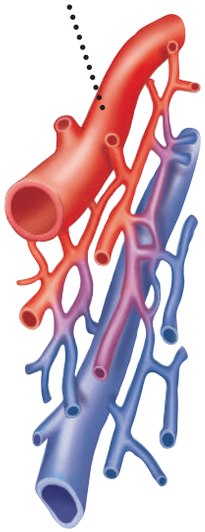
3. *Is contraction of this **tissue** controlled voluntarily or involuntarily?*



This receptor in the skin detects stimuli that make it possible for the body to respond to changes occurring in both the external and internal environments.

6. *This would be part of what **body system** responsible for communication, control, and integration?*





If you have ever cut yourself or become flushed when overheated, you know that our skin has a good blood supply. The larger vessels function for transport, but it is the small, microscopic vessels called capillaries that transfer nutrients and vital substances between blood and tissue cells.

4. *What are the two important **inorganic substances** exchanged at capillaries that are closely related to cellular respiration occurring in the mitochondrion shown above?*

Some specialized cells in the skin called melanocytes produce the pigment that gives our skin color. As you learn new terminology, such as the name of this cell, use clues in the name to help you remember its structure and function.

5. *What would you predict would be the name of the **pigment chemical** this cell produces?*
a) keratin b) elastin c) melanin

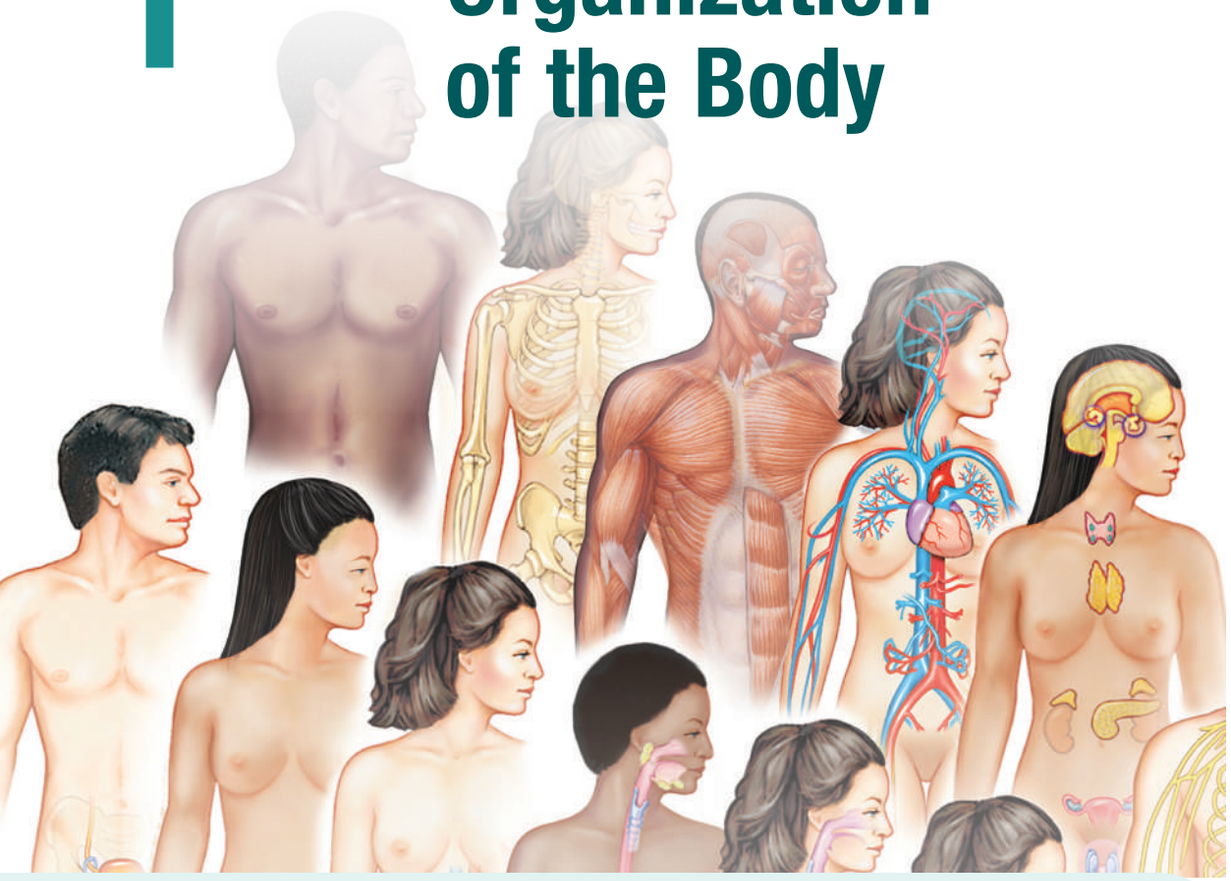
KEY: 1. c; 2. urinary system; 3. involuntary; 4. oxygen and carbon dioxide ; 5. c; 6. nervous system; 7. b

UNIT 1 The Body as a Whole

The nine chapters in Unit 1 "set the stage" for the study of human anatomy and physiology. They provide the unifying information required to understand the "connectedness" of human structure and function. You will explore different levels of organization from chemical to tissue level. The first organ you will study in the next unit will be the skin. Let's take a look ahead at its structure and function and figure out what you already know from your own experiences as a human or have learned before this at the foundational level. Watch for any ideas you have that are oversimplified so you can add to your knowledge or any misconceptions you can correct based on the scientific principles in this first unit. Try out these framework questions: ■

Hint **Why a set of hard questions before you even begin reading? The science of learning shows that *it will go easier* if you jump-start your brain with a few questions that get you thinking about concepts to be explored in this unit, *even if you have to guess!* Try answering (or guessing at) each item, moving clockwise around the facing page, then check your answer at the side of the page. It is okay if you do not answer them correctly; the goal here is simply to *get you thinking* before you read. Even though it seems odd, and maybe a bit discouraging the first time, it does work!** ■

1 Organization of the Body



CHAPTER OUTLINE

Hint *Scan this outline before you begin to read the chapter, as a preview of how the concepts are organized.*

LANGUAGE OF SCIENCE

Hint *Before reading the chapter, say each of these terms out loud. This will help you avoid stumbling over them as you read.*

abdominal (ab-DOM-ih-nal)
[*abdomin-* **belly,** *-al* **relating to**]

abdominopelvic cavity
(ab-DOM-ih-noh-PEL-vik KAV-ih-tee)
[*abdomin-* **belly,** *-pelv-* **basin,** *cav-* **hollow,** *-ity* **state**]

acromial (ah-KROH-mee-al)
[*acro-* **high,** *-omi-* **shoulder,** *-on* **thing**]

anatomical position
(an-ah-TOM-ih-kal poh-ZISH-un)
[*ana-* **apart,** *-tom-* **cut,** *-ical-* **relating to,** *posit-* **place,** *-tion* **state**]

anatomy (ah-NAT-oh-mee)
[*ana-* **apart,** *-tom-* **cut,** *-y* **action**]

antebrachial (an-tee-BRAY-kee-al)
[*ante-* **before,** *-brachi-* **arm,** *-al* **relating to**]

antecubital (an-tee-KYOO-bih-tal)
[*ante-* **before,** *-cubit-* **elbow,** *-al* **relating to**]

anterior (an-TEER-ee-or)
[*ante-* **front,** *-er-* **more,** *-or* **quality**]

apical (AY-pik-al)
[*apic-* **tip,** *-al* **relating to**]

appendicular (ah-pen-DIK-yoo-lar)
[*append-* **hang upon,** *-ic-* **relating to,** *-ul-* **little,** *-ar* **relating to**]

atom (AT-om)
[*atom* **indivisible**]

autopoiesis (aw-toe-poy-EE-sis)
[*auto-* **self,** *-poiesis* **making**]

axial (AK-see-al)
[*axi-* **axis,** *-al* **relating to**]

axillary (AK-sil-layr-ee)
[*axilla-* **wing,** *-ary* **relating to**]

basal (BAY-sal)
[*bas-* **base,** *-al* **relating to**]

bilateral symmetry
(bye-LAT-er-al SIM-e-tree)
[*bi-* **two,** *-later-* **side,** *-al* **relating to,** *sym-* **together,** *-metr-* **measure,** *-ry* **condition of**]

body plane (BOD-ee playn)

brachial (BRAY-kee-al)
[*brachi-* **arm,** *-al* **relating to**]

buccal (BUK-al)
[*bucca-* **cheek,** *-al* **relating to**]

cadaver (kah-DAV-er)
[*cadaver* **dead body**]

continued on p. 18

You have just begun the study of one of nature's most wondrous structures—the human body. **Anatomy** and **physiology** are branches of biology that are concerned with the form and functions of the body. Anatomy is the study of body structure, whereas physiology deals with body function. As you learn about the complex interdependence of structure and function in the human body, you become, in a very real sense, the subject of your own study.

Regardless of your field of study or your future career goals, acquiring and using information about your body structure and functions will enable you to live a more knowledgeable, involved, and healthy life in this science-conscious age. Your study of anatomy and physiology provides a unique and fascinating understanding of self, and this knowledge allows for more active and informed participation in your own personal health care decisions. If you are pursuing a health-, science-, or athletic-related career, your study of anatomy and physiology takes on added significance. It provides the necessary concepts you will need to understand your professional courses and succeed in clinical experiences. ■

■ SCIENCE AND SOCIETY

Before we get to the details, we should emphasize that everything you will read in this book is in the context of a broad field of inquiry called *science*. Science is a style of inquiry that attempts to understand nature in a rational, logical manner.

Scientific Method

Using detailed observations and vigorous tests, or **experiments,** scientists winnow out each element of an idea or **hypothesis** until a reasonable conclusion about its validity can be made. Rigorous experiments that eliminate any influences or biases not being directly tested are called *controlled experiments.*

If the results of observations and experiments are repeatable, they may verify a hypothesis and eventually lead to enough confidence in the concept to call it a **theory.** Theories in which scientists have an unusually high level of confidence are sometimes called **laws.** Experiments may disprove a hypothesis, a result that often leads to the formation of new hypotheses to be tested.

Figure 1-1 summarizes some of the basic concepts of how new scientific principles are developed. As you can see, science is a dynamic process of getting closer and closer to the truth about nature, including the nature of the human body. Science is definitely not a set of unchanging facts as many people in our culture often assume.

Cultural Context

We should point out the social and cultural context of the science presented in this book. Scientists drive the process of science, but our culture drives the kinds of questions we ask about nature and how we attempt to answer them. For example, cutting apart human **cadavers** (dead bodies) for the purpose of studying them has not always been an acceptable activity in all cultures. Today a debate faced by our culture concerns the acceptability of using live animals in scientific experiments. Because our culture does not condone most experiments involving living humans, we have until now often conducted testing on animals that are similar to humans. In fact, most of the theories presented in this book are based on animal experimentation, but cultural influences now are pulling scientists in other experimental directions they otherwise may not have taken.

Similarly, science affects culture. Recent advances in understanding human genes and technological advances in our ability to use so-called *stem cells* and other tissues from human embryos, human cadavers, and living donors to treat devastating diseases have sparked

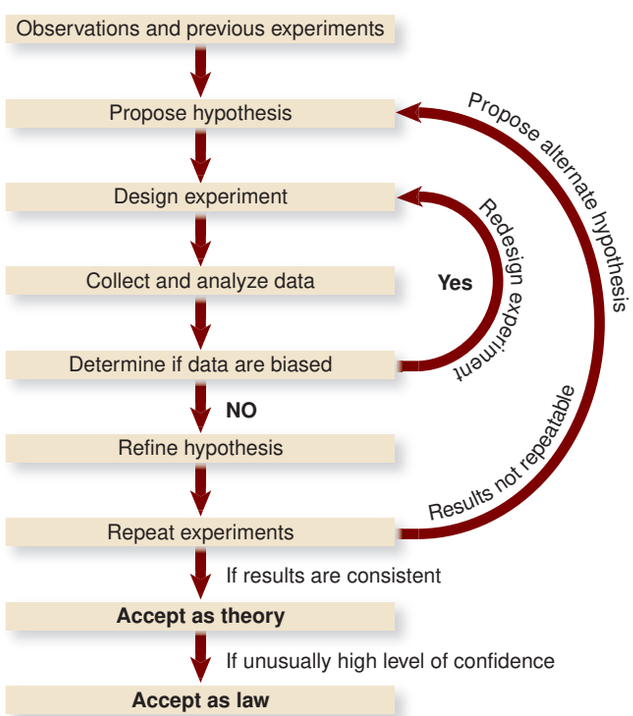


FIGURE 1-1 Scientific method. This flowchart summarizes the classic ideal of how new principles of science are developed. Initial observations or results from other experiments may lead to the formation of a new hypothesis. As more testing is performed to eliminate outside influences or biases and ensure consistent results, scientists begin to have more confidence in the principle and call it a *theory* or *law.*

new debates concerning how our culture defines what it means to be a human being.

As you study the concepts presented in this book, keep in mind that they are not set in stone. Science is a rapidly changing set of ideas and processes that not only is influenced by our cultural biases but also affects our cultural awareness of who we are.

CONNECT IT!

For a quick peek at the major scientific breakthroughs that have changed our lives—and serve as the core concepts of this book—check out ***The Nobel Legacy*** online at **Connect It!**

ANATOMY AND PHYSIOLOGY

Anatomy

Anatomy is often defined as study of the structure of an organism and the relationships of its parts. The word *anatomy* is derived from Greek word parts that mean "to cut apart." Students of anatomy still learn about the structure of the human body by literally cutting it apart. This process, called *dissection*, remains a principal technique used to isolate and study the structural components or parts of the human body.

Biology is defined as the scientific study of life. Both anatomy and physiology are subdivisions of this very broad area of inquiry. Each of these subdivisions can be further divided into smaller areas of study. For example, the term **gross anatomy** is used to describe the study of body parts visible to the naked eye. Before invention of the microscope, anatomists had to study human structure by relying only on the eye during dissection. These early anatomists could make only a gross, or whole, examination, as you can see in **Figure 1-2**. With the use of modern microscopes, many anatomists now specialize in **microscopic anatomy,** including the study of cells, called *cytology* (sye-TOL-oh-jee), and tissues, called *histology* (his-TOL-oh-jee).

Other branches of anatomy include the study of human growth and development *(developmental anatomy)* and the study of diseased body structures *(pathological anatomy)*. In the chapters that follow, you will study the body by systems—a process called *systemic anatomy*. Systems are groups of organs that have a common function, such as the bones in the skeletal system and the muscles in the muscular system.

FIGURE 1-2 Gross anatomy. This famous woodcut of a gross dissection appeared in the world's first modern anatomy textbook, *De Humani Corporis Fabrica (On the Structure of the Human Body),* in 1543. This woodcut features the book's author, Andreas Vesalius, who is considered to be the founder of modern anatomy. The body being dissected is called a *cadaver.*

Physiology

Physiology is the science that deals with the functions of the living organism and its parts. The term *physiology* is a combination of two Greek words (*physis*, "nature," and *logos*, "words or study"). Simply stated, it is the study of physiology that helps us understand how the body works. Physiologists attempt to discover and understand the intricate control systems that permit the body to operate and survive in changing and often hostile environments.

As a scientific discipline, physiology can be subdivided according to (1) the type of organism involved, such as human physiology or plant physiology; (2) the organizational level studied, such as molecular or cellular physiology; or (3) a specific or *systemic* function being studied, such as neurophysiology, respiratory physiology, or cardiovascular physiology.

In the chapters that follow, you will see again and again that anatomical parts have structures exactly suited to perform specific functions. Each has a particular size, shape, form, or position in the body related directly to its ability to perform a unique and specialized activity. This principle—that *structure fits function*—explains why studying anatomy and physiology together is the key to understanding the human body.

Quick CHECK

1. Describe how science develops new principles.
2. Define *anatomy* and *physiology.*
3. List the three ways in which physiology can be subdivided as a scientific discipline.
4. What name is used to describe the study of the body that focuses on groups of organs that have a common function?

LANGUAGE OF SCIENCE AND MEDICINE

You may have noticed by now that many scientific terms, such as *anatomy* and *physiology*, are made up of non-English word parts. Many such terms make up the core of the language used to communicate ideas in science and medicine. Learning in science thus begins with learning a new vocabulary, just as when you learn a new language to help you understand and communicate in a region of the world other than the one you call home.

To help you learn the vocabulary of anatomy and physiology, we have provided several helpful tools for you. Within each chapter, lists of new terms titled *Language of Science* and *Language of Medicine* give you each new key (boldface) term that you will be learning in that chapter. Each term in the list has a pronunciation guide and an explanation (or meaning) of each of the word parts that make up the term.

We have also included a separate compact reference called Quick Guide to the Language of Science and Medicine with this textbook. Take a moment now to locate it. After you have finished reading this chapter, quickly review the tips for learning scientific language. Then keep it nearby so that you will have a handy list of commonly used word parts at your fingertips.

You will see that most scientific terms are made up of word parts from Latin or Greek. Most Western scientists first began corresponding

with one another in these languages, because they were commonly the first written languages learned by educated people. Other languages such as German, French, and Japanese are also sources of some scientific word parts.

As with any language, scientific language changes constantly. This is useful because we often need to fine-tune our terminology to reflect changes in our understanding of science and to accommodate new discoveries. But it also sometimes leads to confusion.

In an attempt to clear up some of the confusion, the International Federation of Associations of Anatomists (IFAA) formed a worldwide committee to publish a list of "universal" or standard anatomical terminology. The list for *gross anatomy*, the structure we can see without magnification, was published in 1998 as *Terminologia Anatomica (TA)*. In 2008 *Terminologia Histologica (TH)* was published for *microscopic anatomy*—the study of body structure requiring significant magnification for the purpose of visualization.

Although there remain some alternate (and newer) terms used in anatomy, the lists are useful standard references. The lists show each term in Latin and English (based on the Latin form), along with a reference number. In this textbook we use the English terms from the published lists as our standard reference, but we do occasionally refer to the pure Latin form or an alternate term when appropriate for beginning students.

One of the basic principles of the standardized terminology is the avoidance of **eponyms,** or terms that are based on a person's name. Instead, a more descriptive Latin-based term is always preferred. Thus the term *eustachian tube* (tube connected to the middle ear, named after the famed Italian anatomist Eustachius) is now replaced with the more descriptive *auditory tube*. Likewise, the *islets of Langerhans* (in the pancreas) are now simply *pancreatic islets*.

In the rare cases where eponyms do appear in a standard list, we now avoid the possessive form. Thus *Bowman's capsule* (in kidney tissue) is now either *glomerular capsule* or *Bowman capsule*.

There are no such standard lists of physiological terms. However, many principles used in anatomical terminology are used in physiology. For example, most terms have an English spelling but are based on Latin or Greek word parts. And, as in anatomy, eponyms are less favored than descriptive terms.

A Quick Guide to the Language of Science and Medicine accompanies this book. It offers a handy summary of the basic principles of using your new "A&P language." The quick guide also lists common roots, prefixes, and suffixes—along with acronyms, abbreviations, Greek letters, Roman numerals, and much more.

This may all seem like a lot more than you want to know right now. However, if you focus on learning the new words as you begin each new topic, as though you are in a foreign land and need to pick up a few phrases to get by, you will find your study of anatomy and physiology easy and enjoyable.

CHARACTERISTICS OF LIFE

Anatomy and physiology are important disciplines in biology—the study of life. But what is life? What is the quality that distinguishes a vital and functional being from a dead body? We know that a living organism is endowed with certain characteristics not associated with inorganic matter. However, it is sometimes hard to find a single criterion to define life.

One could say that living organisms are self-organizing or self-maintaining and nonliving structures are not. This concept is called **autopoiesis,** which literally means "self-making." Another idea, called the *cell theory*, states that any independent structure made up of one or more microscopic units called *cells* is a living organism.

Instead of trying to find a single difference that separates living and nonliving things, scientists sometimes define life by listing what are often called *characteristics of life*. Lists of characteristics of life may differ from one physiologist to the next, depending on the type of organism being studied and the way in which life functions are grouped and defined. Attributes that characterize life in bacteria, plants, or animals may vary. Characteristics of life that are considered most important in humans are described in **Table 1-1**.

Each characteristic of life is related to the sum total of all the physical and chemical reactions occurring in the body. The term **metabolism** is used to describe these various processes. They include the steps involved in the breakdown of nutrient materials to produce energy and the transformation of one material into another. For example, if we eat and absorb more sugar than needed for the body's immediate energy requirements, it is converted into an alternate form, such as fat, that can be stored in the body.

Metabolic reactions are also required for making complex compounds out of simpler ones, as in tissue growth, wound repair, or manufacture of body secretions.

Each characteristic of life—its functional manifestation in the body, its integration with other body functions and structures, and its

TABLE 1-1 Characteristics of Human Life

CHARACTERISTIC	DESCRIPTION
Responsiveness	Ability of an organism to sense, monitor, and respond to changes in both its external and internal environments
Conductivity	Capacity of living cells to transmit a wave of electrical disturbance from one point to another within the body
Growth	Organized increase in the size and number of cells and therefore an increase in size of the individual or a particular organ or part
Respiration	Exchange of respiratory gases (oxygen and carbon dioxide) between an organism and its environment
Digestion	Process by which complex food products are broken down into simpler substances that can be absorbed and used by individual body cells
Absorption	Movement of molecules, such as respiratory gases or digested nutrients, through a membrane and into the body fluids for transport to cells for use
Secretion	Production and release of important substances, such as digestive juices and hormones, for diverse body functions
Excretion	Removal of waste products from the body
Circulation	Movement of body fluids containing many substances from one body area to another in a continuous, circular route through hollow vessels
Reproduction	Formation of new individual offspring

mechanism of control—is the subject of study in subsequent chapters of the text.

Quick CHECK

5. What is an *eponym*?
6. What single criterion might be used to define life?
7. Define the term *metabolism* as it applies to the characteristics of life.

LEVELS OF ORGANIZATION

Before you begin the study of the structure and function of the human body and its many parts, it is important to think about how the parts are organized and how they might logically fit together and function effectively. Because you already know that *structure fits function*, it should not surprise you that the highly complex and coordinated functions of the whole body can be understood by discovering the many basic processes that occur in the smaller parts, such as organs, tissues, and cells. These differing *levels of organization* that help us better understand the body are illustrated in **Figure 1-3**.

CHEMICAL LEVEL

Note that organization of the body begins at the chemical level (see **Figure 1-3**). There are more than 100 different chemical building blocks of nature called **atoms**—tiny spheres of matter so small they are invisible. Every material thing in our universe, including the human body, is composed of atoms.

Combinations of atoms form larger chemical groupings, called **molecules.** Molecules, in turn, often combine with other atoms and molecules to form larger and more complex chemicals, called **macromolecules.**

The unique and complex relationships that exist among atoms, molecules, and macromolecules in living material form a gel-like material made of fluids, particles, and membranes called *cytoplasm*—the essential material of human life. Unless proper relationships among chemical elements are maintained, death results. Maintaining the type of chemical organization in cytoplasm required for life requires the expenditure of energy. In Chapters 3 and 4, important information related to the chemistry of life is discussed in more detail.

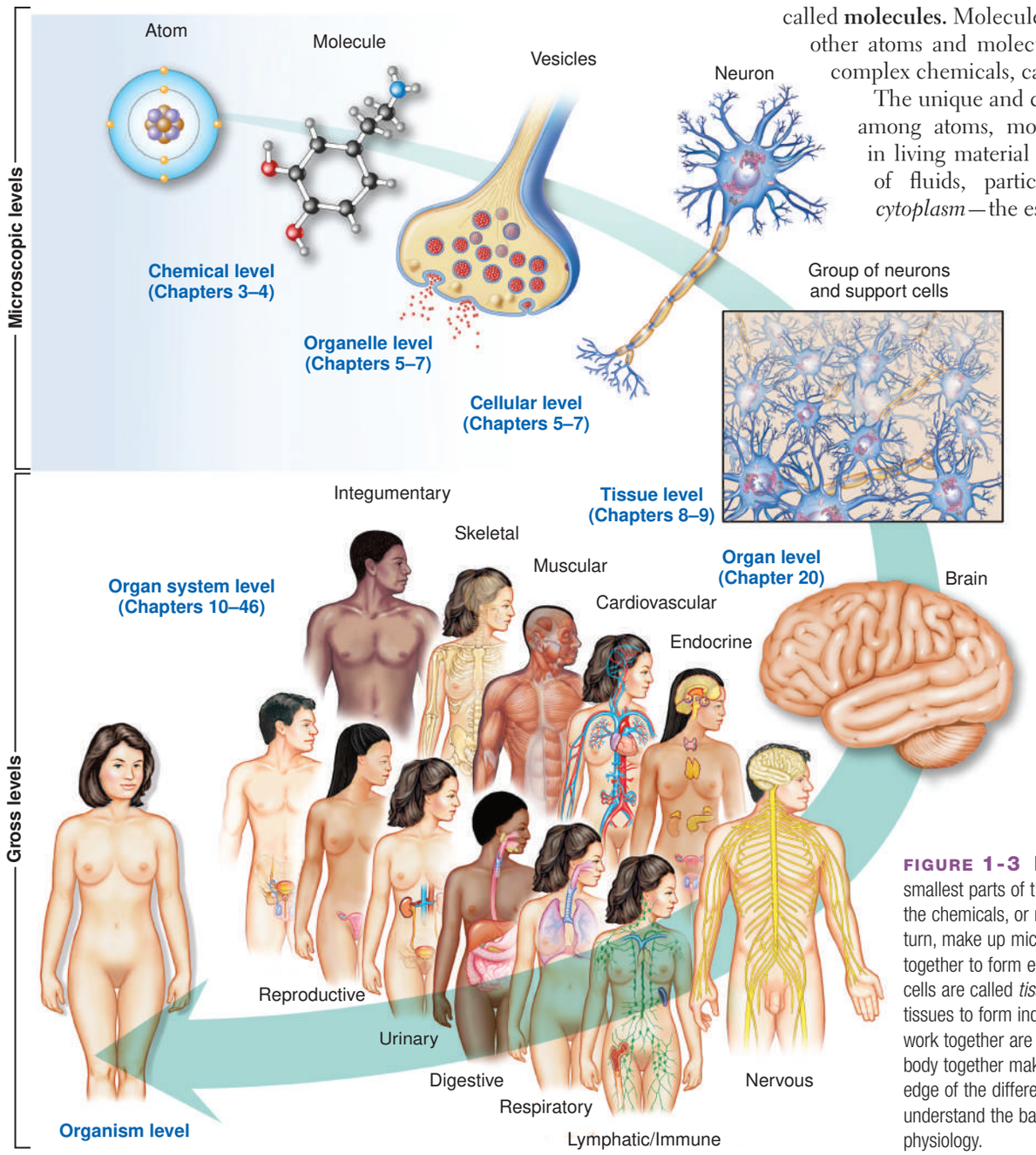


FIGURE 1-3 Levels of organization. The smallest parts of the body are the atoms that make up the chemicals, or molecules, of the body. Molecules, in turn, make up microscopic parts called *organelles* that fit together to form each cell of the body. Groups of similar cells are called *tissues,* which combine with other tissues to form individual organs. Groups of organs that work together are called *systems.* All the systems of the body together make up an individual organism. Knowledge of the different levels of organization will help you understand the basic concepts of human anatomy and physiology.

Organelle Level

Chemical structures may be organized within larger units called *cells* to form various structures called **organelles,** the next level of organization (see **Figure 1-3**). An organelle may be defined as a structure made of molecules organized in such a way that it can perform a specific function. Organelles are the "tiny organs" that allow each cell to live. Organelles cannot survive outside the cell, but without organelles the cell itself could not survive either.

Dozens of different kinds of organelles have been identified. A few examples:

- **Mitochondria**—the "powerhouses" of cells that provide energy needed by the cell to carry on day-to-day functioning, growth, and repair
- **Golgi apparatus**—set of sacs that provides a "packaging" service to the cell by storing material for future internal use or for export from the cell
- **Endoplasmic reticulum (ER)**—network of channels within the cell that act as "highways" for the movement of chemicals and as sites for chemical processing

Chapter 5 contains a more complete discussion of important organelles and their functions.

Cellular Level

The characteristics of life ultimately result from a hierarchy of structure and function that begins with the organization of atoms, molecules, and macromolecules. Further organization that results in organelles is the next step. However, in the view of the anatomist, the most important function of the chemical and organelle levels of organization is that of furnishing the basic building blocks required for the next higher level of body structure—*the cellular level.*

Cells are the smallest and most numerous structural units that possess and exhibit the basic characteristics of living matter. How many cells are there in the body? One estimate places the number of cells in a 150-pound adult human body at 100,000,000,000,000.

In case you are having trouble translating this number—1 with 14 zeroes after it—it is 100 trillion! or 100,000 billion! or 100 million million!

Each cell is surrounded by a membrane and is characterized by a single nucleus surrounded by cytoplasm that includes the numerous organelles required for the normal processes of living.

Although all cells have certain features in common, they specialize or **differentiate** to perform unique functions. Fat cells, for example, are structurally modified to permit the storage of fats, whereas other cells, such as cardiac muscle cells, are able to contract with great force (see **Figure 1-3**). Muscle, bone, nerve, and blood cells are other examples of structurally and functionally unique cells.

Tissue Level

The next higher level of organization beyond the cell is the *tissue level* (see **Figure 1-3**). Tissues represent another step in the progressive organization of living matter. By definition, a **tissue** is a group of a great many similar cells that all developed together from the same part of the embryo and all perform a certain function. Tissue cells are surrounded by varying amounts and kinds of nonliving, intercellular substances, or the **matrix.** Tissues are the "fabric" of the body.

There are four major or principal tissue types: **epithelial, connective, muscle,** and **nervous.** Considering the complex nature of the human body, this is a surprisingly short list of major tissues. Each of the four major tissues, however, can be subdivided into several distinct subtypes. Together the body tissues are able to meet all the structural and functional needs of the body.

The tissue used as an example in **Figure 1-3** is nervous tissue. Note how the cells are branching and interconnected. The details of tissue structure and function are covered in Chapters 8 and 9.

Organ Level

Organ units are more complex than tissues. An **organ** is defined as a structure made up of several different kinds of tissues arranged so that, together, they can perform a special function.

If tissues are the "fabric" of the body, an organ is like an item of clothing with a specific function made up of different fabrics. The heart is an example of the *organ level:* muscle and connective tissues give it shape and pump blood; epithelial tissues line the cavities, or chambers; and nervous tissues permit control of the pumping contractions of the heart.

Tissues seldom exist in isolation. Instead, joined together, they form organs that represent discrete, but functionally complex, operational units. Each organ has a unique shape, size, appearance, and placement in the body, and each can be identified by the pattern of tissues that form it. The lungs, heart, brain, kidneys, liver, and spleen are all examples of organs.

System Level

Systems are the most complex of the organizational units of the body. The **system** level of organization involves varying numbers and kinds of organs arranged so that, together, they can perform complex functions for the body.

Eleven major systems compose the human body: integumentary, skeletal, muscular, nervous, endocrine, cardiovascular, lymphatic/immune, respiratory, digestive, urinary, and reproductive. Systems that work together to accomplish the general needs of the body are summarized in **Table 1-2**.

Take a few minutes to read through **Table 1-2**. The left column points out that several different systems often work together to accomplish some overall goal. For example, the first three systems listed (integumentary, skeletal, muscular) make up the framework of the body and therefore provide support and movement. Note also that this table corresponds to the organization of this book. Once we get to the system level of organization, we will study each system one by one, chapter by chapter. To help you navigate through the book, we have organized the chapters into units of several systems each—units that group the systems by common or overlapping functions.

You are probably aware that some systems can be grouped together or split apart. We use those groupings that are most useful to us. For example, because both the skeletal and muscular systems work together to produce athletic movements, an athletic trainer may study them together as the **skeletomuscular system.** A physical therapist may also include concepts of nervous control of movement and study the **neuroskeletomuscular system.** On the other hand, a neurologist may find it useful to keep in mind a distinction between the sensory nervous system and the motor nervous system.

In any case, the idea of levels of organization is universal, and once you know how it works, you can adapt it to suit your own changing needs. The plan of dividing the body into 11 major systems is widely used among biologists, so we will use it as the basis of our study too.

CONNECT IT!

The many important roles of the *microbial systems* of the body, or human **microbiome,** have come to the forefront of human biology. The complex interactions of microorganisms (such as bacteria) in our body with one another, and with our own cells, tissues, and organs, have proven to be critical to maintaining normal structure and function of the body. Learn more in ***The Human Microbiome*** at **Connect It!**

Organism Level

The living human **organism** is certainly more than the sum of its parts. It is a marvelously coordinated team of interactive structures that is able to survive and flourish in an often hostile environment. Not only can the human body reproduce itself (and its genetic information) and maintain ongoing repair and replacement of worn or damaged parts, it can also maintain—in a constant and predictable way—an incredible number of variables required for a human to lead a healthy, productive life.

We are able to maintain a "normal" body temperature and fluid balance under widely varying environmental extremes. We maintain constant blood levels of many important chemicals and nutrients. We experience effective protection against disease, elimination of waste products, and coordinated movement. We correctly and quickly interpret sound, visual images, and other external stimuli with great regularity. These are a few examples of how the different levels of organization in the human organism permit expression of the characteristics associated with life.

As you study the structure and function of the human body, it is too easy to think of each part or function in isolation from the body as a whole. Always remember that you are ultimately dealing with information related to the entire human organism—not information limited to an understanding of the structure and function of a single organelle, cell, tissue, organ, or organ system. Do not limit your learning to the memorization of isolated facts. Instead, connect and integrate factual information so that your understanding of human structure and function is related not to a part of the body but to the body as a whole.

TABLE 1-2 Body Systems (With Unit and Chapter References)

FUNCTIONAL CATEGORY	SYSTEM	PRINCIPAL ORGANS	PRIMARY FUNCTIONS
Support and movement (Unit 2)	Integumentary (Chapter 10)	Skin	Protection, temperature regulation, sensation
	Skeletal (Chapters 11–14)	Bones, ligaments	Support, protection, movement, mineral and fat storage, blood production
	Muscular (Chapters 15–17)	Skeletal muscles, tendons	Movement, posture, heat production
Communication, control, and integration (Unit 3)	Nervous (Chapters 18–24)	Brain, spinal cord, nerves, sensory organs	Control, regulation, and coordination of other systems, sensation, memory
	Endocrine (Chapters 25 and 26)	Pituitary gland, adrenals, pancreas, thyroid, parathyroids, and other glands	Control and regulation of other systems
Transportation and defense (Unit 4)	Cardiovascular (Chapters 27–30)	Heart, arteries, veins, capillaries	Exchange and transport of materials
	Lymphatic/immune (Chapters 31–34)	Lymph nodes, lymphatic vessels, spleen, thymus, tonsils	Immunity, fluid balance
Respiration, nutrition, and excretion (Unit 5)	Respiratory (Chapters 35–37)	Lungs, bronchial tree, trachea, larynx, nasal cavity	Gas exchange, acid-base balance
	Digestive (Chapters 38–41)	Stomach, small and large intestines, esophagus, liver, mouth, pancreas	Breakdown and absorption of nutrients, elimination of waste
	Urinary (Chapters 42–44)	Kidneys, ureters, bladder, urethra	Excretion of waste, fluid and electrolyte balance, acid-base balance
Reproduction and development (Unit 6)	Reproductive (Chapters 45–48)	*Male:* Testes, vas deferens, prostate, seminal vesicles, penis *Female:* Ovaries, fallopian tubes, uterus, vagina, breasts	Reproduction, continuity of genetic information, nurturing of offspring

Quick CHECK

8. List the seven levels of organization.
9. Identify three organelles.
10. List the four major tissue types.
11. List the 11 major organ systems.

ANATOMICAL POSITION

Discussions about the body, how it moves, its posture, or the relationship of one area to another assume that the body as a whole is in a specific position called the **anatomical position.** In this reference position the body is in an erect, or standing, posture with the arms at the sides and palms turned forward (**Figure 1-4**). The head and feet are also pointing forward. The anatomical position is a reference position that gives meaning to the directional terms used to describe the body parts and regions.

Bilateral symmetry is one of the most obvious of the external organizational features in humans. The person shown in **Figure 1-4** is divided by a line into bilaterally symmetrical sides. To say that humans are bilaterally symmetrical simply means that the right and left sides of the body are mirror images of each other and only one plane can divide the body into left and right halves. One of the most

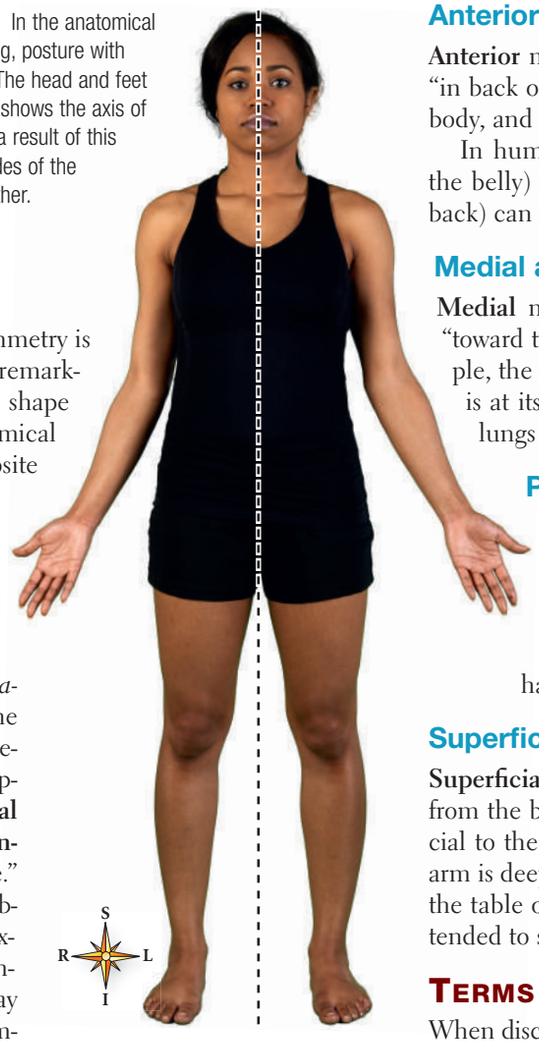


FIGURE 1-4 Anatomical position. In the anatomical position, the body is in an erect, or standing, posture with the arms at the sides and palms forward. The head and feet are also pointing forward. The *dashed line* shows the axis of the body's external bilateral symmetry. As a result of this organizational feature, the right and left sides of the external body are mirror images of each other.

important features of bilateral symmetry is balanced proportions. There is a remarkable correspondence in size and shape when comparing similar anatomical parts or external areas on opposite sides of the body.

Take a moment to look at external bilateral symmetry of the body in Figures 1-1 and 1-2 in the BRIEF ATLAS OF THE HUMAN BODY.

The terms *ipsilateral* and *contralateral* are often used to identify the placement of one body part with respect to another on the same or opposite side of the body. **Ipsilateral** simply means "same side," and **contralateral** means "opposite side." These terms may be used in describing injury to an extremity, for example. If the right knee were injured and swollen, one could say that "the right knee is enlarged compared with the *contralateral knee*."

Supine and **prone** are two terms used to describe the position of the body when it is not in the anatomical position. In the supine position the body is lying face upward, and in the prone position the body is lying face downward.

ANATOMICAL DIRECTIONS

DIRECTIONAL TERMS

To minimize confusion when discussing the relationship between body areas or the location of a particular anatomical structure, specific terms must be used. When the body is in the anatomical position, the following directional terms can be used to describe the location of one body part with respect to another (**Figure 1-5**).

Superior and Inferior

Superior means "toward the head," and **inferior** means "toward the feet." *Superior* also means "upper" or "above," and *inferior* means "lower" or "below." For example, the lungs are located superior to the diaphragm, whereas the stomach is located inferior to it.

The simple terms *upper* and *lower* are sometimes used in professional language as well. For example, the terms *upper respiratory tract* and *lower gastrointestinal tract* are used commonly by anatomists and health professionals.

Anterior and Posterior

Anterior means "front" or "in front of"; **posterior** means "back" or "in back of." For example, the nose is on the anterior surface of the body, and the shoulder blades are on its posterior surface.

In humans—who walk in an upright position—**ventral** (toward the belly) can be used in place of anterior, and **dorsal** (toward the back) can be used for posterior.

Medial and Lateral

Medial means "toward the midline of the body"; **lateral** means "toward the side of the body, or away from its midline." For example, the great toe is at the medial side of the foot, and the little toe is at its lateral side. The heart lies medial to the lungs, and the lungs lie lateral to the heart.

Proximal and Distal

Proximal means "toward or nearest the trunk of the body, or nearest the point of origin of one of its parts"; **distal** means "away from or farthest from the trunk or the point of origin of a body part." For example, the elbow lies at the proximal end of the forearm, whereas the hand lies at its distal end.

Superficial and Deep

Superficial means "nearer the surface"; **deep** means "farther away from the body surface." For example, the skin of the arm is superficial to the muscles below it, and the bone of the upper part of the arm is deep to the muscles that surround and cover it. Refer often to the table of anatomical directions on the inside front cover. It is intended to serve as a useful and ready reference for review.

TERMS RELATED TO ORGANS

When discussing anatomical relationships among organs in a system or region, or anatomical relationships within an organ, additional terms are often useful.

Lumen

Many organs of the body are hollow, such as the stomach, small intestine, airways of the lungs, blood vessels, urinary organs, and so on. The hollow area of any of these organs is called the **lumen.** The term *luminal* means "of or near the lumen." For example, blockage of the respiratory airway may be called a *luminal obstruction.*

Central and Peripheral

Central is plain English and means "near the center." **Peripheral** means "around the boundary." For example, the central nervous system includes the brain and spinal cord, which are near the center of the body. The peripheral nervous system, on the other hand, includes the nerves of the muscles, skin, and other organs that are nearer the periphery, or outer boundaries, of the body.

Medullary and Cortical

Medullary refers to an inner region or core of an organ. **Cortical** refers to an outer region or layer of an organ. For example, the inner region of the kidney is the *medulla*, and any structures there are described as *medullary.* Similarly, the term *cortical* describes structures found in the outer layer of kidney tissue (the *cortex* of the kidney).

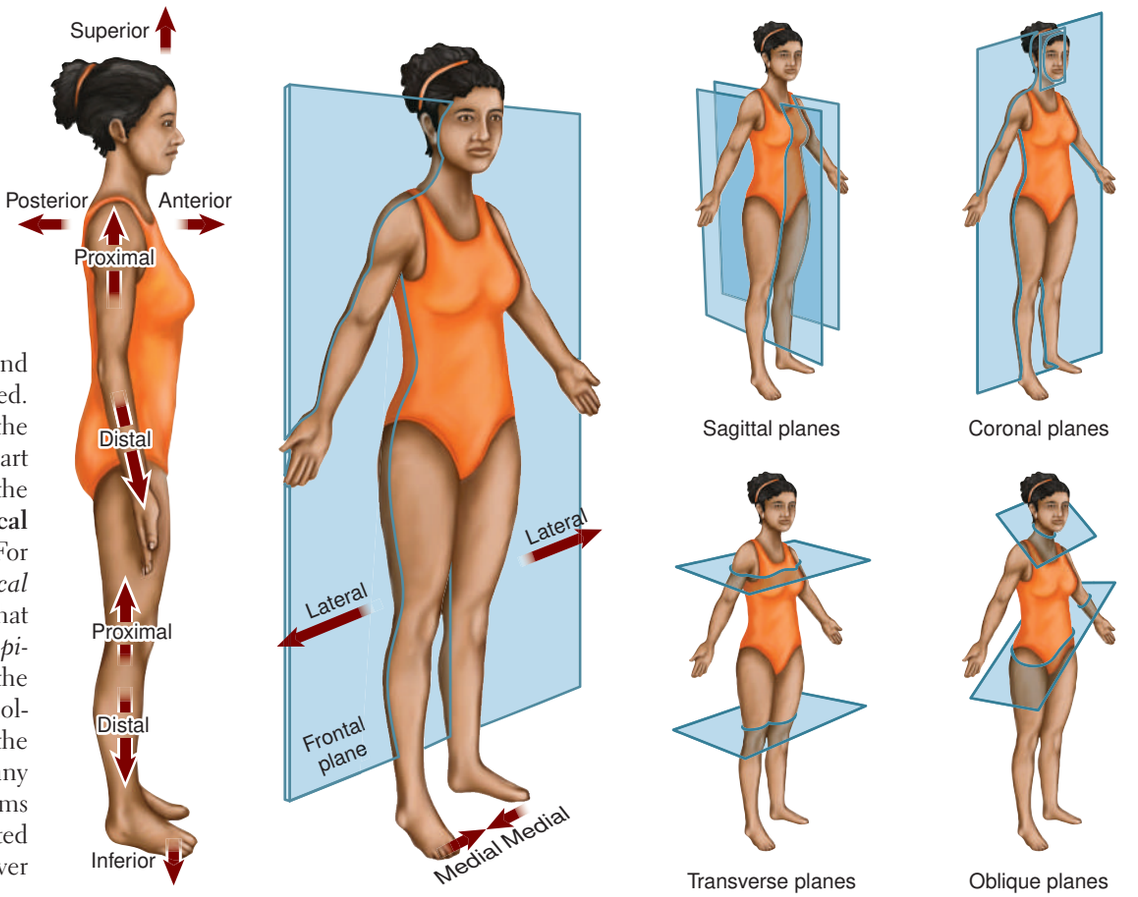


FIGURE 1-5 Directions and planes of the body. The *arrows* show anatomical directions and the *blue plates* show examples of body planes along which cuts or sections are made in visualizing the structure of the body.

Basal and Apical

Some organs, such as the heart and each lung, are somewhat cone-shaped. Thus we borrow terms that describe the point or *apex* of a cone and the flat part or *base* of a cone. **Basal** refers to the base or widest part of an organ. **Apical** refers to the narrow tip of an organ. For example, in the heart the term *apical* refers to the "point" of the heart that rests on the diaphragm. *Basal* and *apical* may also refer to individual cells: the apical surface faces the lumen of a hollow organ, and the basal surface of the cell faces away from the lumen. Many of the more common directional terms that you will use in this course are listed in a handy table inside the front cover of the book.

Anatomical Compass Rosette

To make the reading of anatomical figures a little easier, an *anatomical compass rosette* is used throughout this book. On many figures, such as those on the opposite page, you will notice a small compass rosette similar to those on geographical maps. Rather than being labeled *N*, *S*, *E*, and *W*, the anatomical compass rosette is labeled with abbreviated anatomical directions:

A = Anterior	**P** (opposite A) = Posterior
D = Distal	**P** (opposite D) = Proximal
I = Inferior	**S** = Superior
L (opposite M) = Lateral	**M** = Medial
L (opposite R) = Left	**R** = Right

The anatomical compass rosette sometimes instead uses terms such as *basal* and *apical* if that makes the illustration clearer. For your convenience, the compass rosette and its possible directions, a helpful diagram of the planes and directions of the body, and a summary table are found on the inside front cover of this book. Refer to it frequently until you are familiar enough with anatomy to do without it.

BODY PLANES AND SECTIONS

The transparent glasslike plates in **Figure 1-5** that divide the body into parts represent different *planes* of the body. In geometry, a plane is an imagined flat surface or plate with no thickness. In anatomy, we often section (cut) the body or an organ along such an imagined flat surface—a **body plane.** The resulting cut is called a **section** of the body or organ. An infinite number of sections can be made along an infinite number of planes, and each section made is named after the particular plane along which it occurs.

There are three major body planes that lie at right angles to one another. They are called the *sagittal*, *coronal*, and *transverse* planes.

Sagittal Planes

Any lengthwise plane running from front to back and top to bottom, dividing the body or any of its parts into right and left sides, is called a **sagittal plane.** A flat cut made along a sagittal plane is called a *sagittal section*.

If a sagittal section is made in the exact midline of the body, resulting in equal and symmetrical right and left halves, the section is called a *median sagittal section* or *midsagittal section* (see **Figure 1-5**).

Coronal Planes

Any lengthwise plane running from side to side and top to bottom, dividing the body or any of its parts into anterior and posterior portions, is called a **coronal plane.** A coronal plane may also be called a *frontal plane*. A cut made along a coronal plane is called a *coronal section* or a *frontal section*.

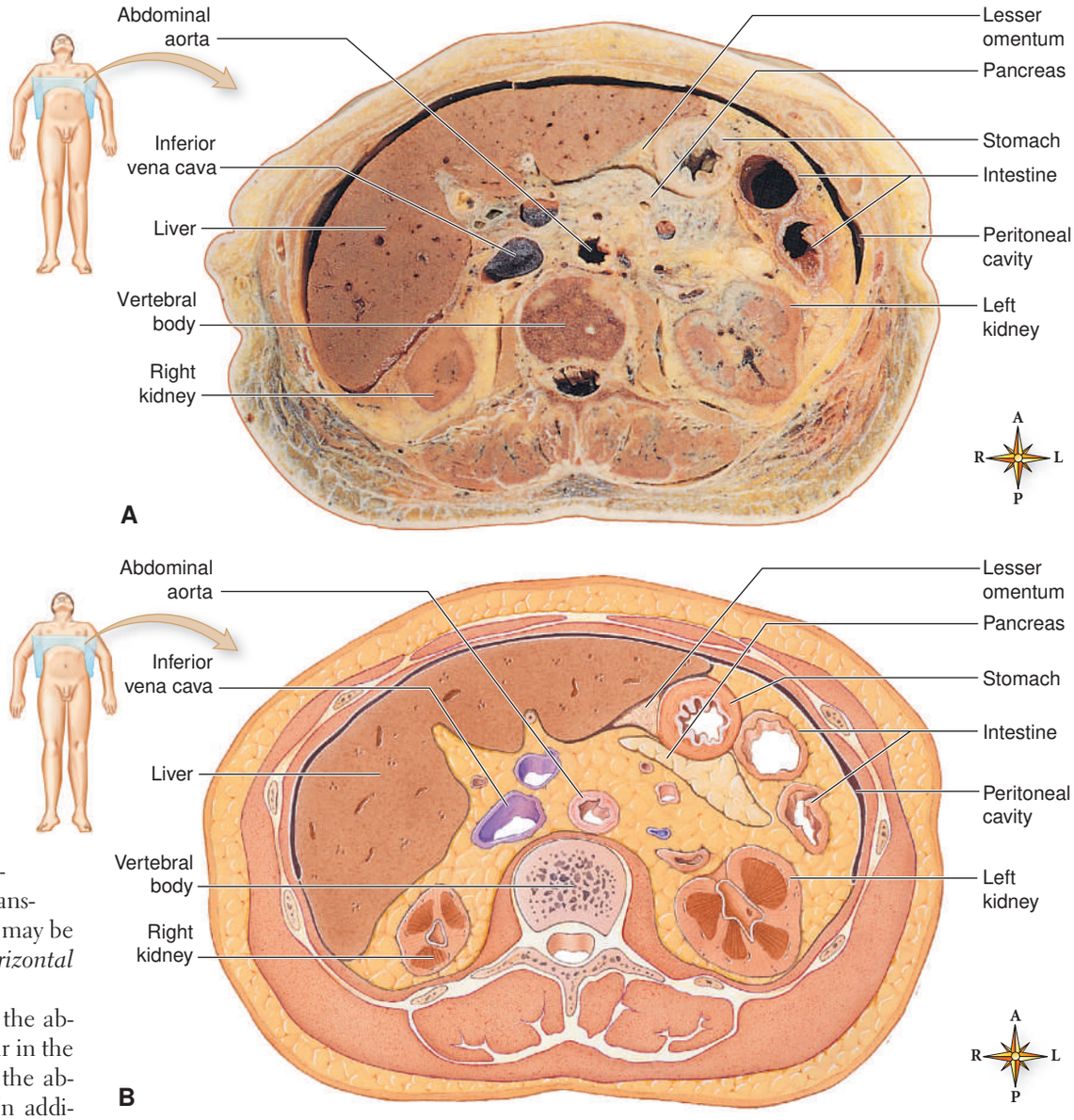


FIGURE 1-6 Transverse section of the abdomen. A, A transverse, or horizontal, plane through the abdomen shows the position of various organs within the cavity. **B,** A drawing of the photograph helps clarify the photo. Compare these views, both seen from below, with the medical image shown in the box on p. 12.

Transverse Planes

Any crosswise plane that divides the body or any of its parts into upper and lower parts is called a **transverse plane.** A transverse plane is sometimes called a *horizontal plane*. A cut along any transverse plane of the body or an organ may be called a *transverse section* or *horizontal section*.

Figure 1-6 shows the organs of the abdominal cavity as they would appear in the transverse plane or "cut" through the abdomen represented in the inset. In addition to the actual photograph, a simplified line diagram helps in identifying the primary organs. Note that organs near the bottom of the photo or line drawing are in a posterior position. The cut vertebra of the spine, for example, can be identified in its position behind, or posterior, to the stomach. The kidneys are located on either side of the vertebra—they are *lateral* and the vertebra is *medial*.

Note also in **Figure 1-6** that the transverse sections are viewed *from below*. This may be at odds with your natural tendency to think of viewing sections from above, so it is important to remember that it is common in anatomical and medical images to show transverse sections from below.

Other Planes and Sections

In anatomy, it is common to use additional terms to help clarify the plane of cutting. For example, a cut along a plane parallel with the short axis of an organ is called a **cross-section.** A cross-section of the whole body would be a transverse section. A cut along the long axis of an organ is called a **longitudinal section.** If you cut off the tip of the finger, you have made a cross-section. If instead you have split a finger down the middle, from the fingertip to the hand, you have made a longitudinal section.

Sometimes it is helpful to make a cut along a plane that is not at right angles to the planes we have already mentioned. Such diagonal cuts are called **oblique sections.**

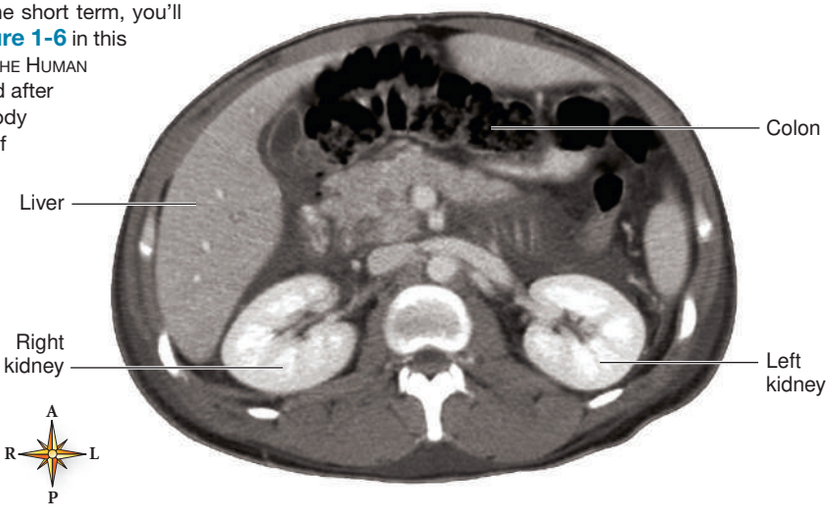
Quick CHECK

12. Define and contrast each term in these pairs: superior/inferior, anterior/posterior, medial/lateral, dorsal/ventral.
13. How is anatomical left different from your left?
14. Explain how an anatomical compass rosette is used in anatomical illustrations.
15. List and define the three major planes that are used to divide the body into parts.

CONNECT IT!

Why bother to learn about planes and sections of the body? In the short term, you'll need to understand how to interpret the many illustrations like **Figure 1-6** in this book—or the series of photographs in Part 4 of the BRIEF ATLAS OF THE HUMAN BODY. Also explore the CLEAR VIEW OF THE HUMAN BODY insert located after p. 378 in this book, which shows many sectioned images of the body in different planes. In the long term, you will use the concept of planes and sections in clinical settings—as in medical imaging.

Cadavers (preserved human bodies used for scientific study) can be cut into sagittal, frontal, or transverse sections for easy viewing of internal structures, but living bodies, of course, cannot. This fact has been troublesome for medical professionals who must determine whether internal organs are injured or diseased. In some cases the only sure way to detect a lesion or variation from normal is extensive exploratory surgery. Fortunately, advances in medical imaging allow physicians to visualize internal structures of the body without risking the trauma or other complications associated with extensive surgery. This figure shows a CT (computed tomography) scan similar to the perspective of **Figure 1-6**. CT scanning and some of the other widely used techniques are illustrated and described in ***Medical Imaging of the Body*** online at **Connect It!**



BODY CAVITIES

The body contains many hollows or *cavities* that each house compact arrangements of internal organs. The location and outlines of major body cavities are illustrated in **Figure 1-7**.

DORSAL CAVITIES

The **dorsal cavities** form along the *dorsum* or back of the body early in development as bones grow around the tube that eventually forms our central nervous system. The dorsal cavities include the *cranial cavity* and *spinal cavity*.

The cranial cavity is the space within the skull that houses the brain. The spinal cavity, the location of the spinal cord, lies within the hollow spinal canal formed by a stacked column of donutlike vertebrae.

VENTRAL CAVITIES

During early development, a huge internal body cavity subdivides into two major **ventral cavities**—the thoracic cavity (chest cavity) and the abdominopelvic cavity.

Thoracic Cavity

The **thoracic cavity** has a midportion called the **mediastinum,** which contains the heart and other structures surrounded by fibrous tissue. On the left and right sides of the mediastinum are spaces called **pleural cavities** in which the lungs reside.

The mediastinum houses the heart, the trachea, right and left bronchi, the esophagus, the thymus, various blood vessels (e.g., thoracic aorta, superior vena cava), the thoracic duct and other lymphatic vessels, various lymph nodes, and nerves (such as the phrenic and vagus nerves).

The heart is surrounded by a fibrous sac lined with a thin, slippery membrane that doubles back on itself to form a lubricating, fluid-filled pocket around the heart. **Figure 1-8** demonstrates how this structure resembles a water-filled balloon with a fist thrust into it.

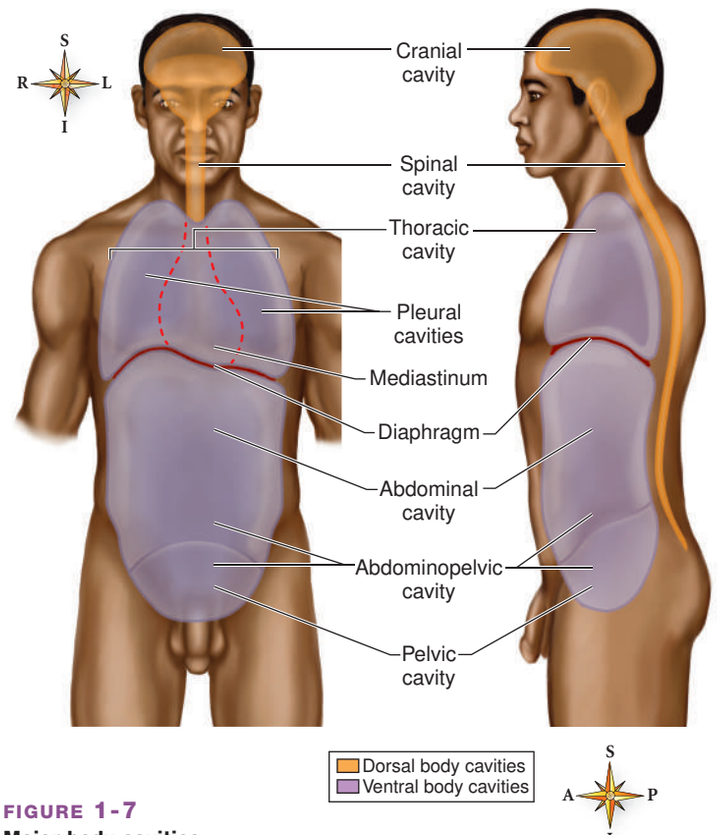


FIGURE 1-7
Major body cavities.
The dorsal body cavities are in the dorsal (back) part of the body and include a cranial cavity above and a spinal cavity below. The ventral body cavities are on the ventral (front) side of the trunk and include the thoracic cavity above the diaphragm and the abdominopelvic cavity below the diaphragm. The thoracic cavity is subdivided into the mediastinum in the center and pleural cavities to the sides. The abdominopelvic cavity is subdivided into the abdominal cavity above the pelvis and the pelvic cavity within the pelvis.

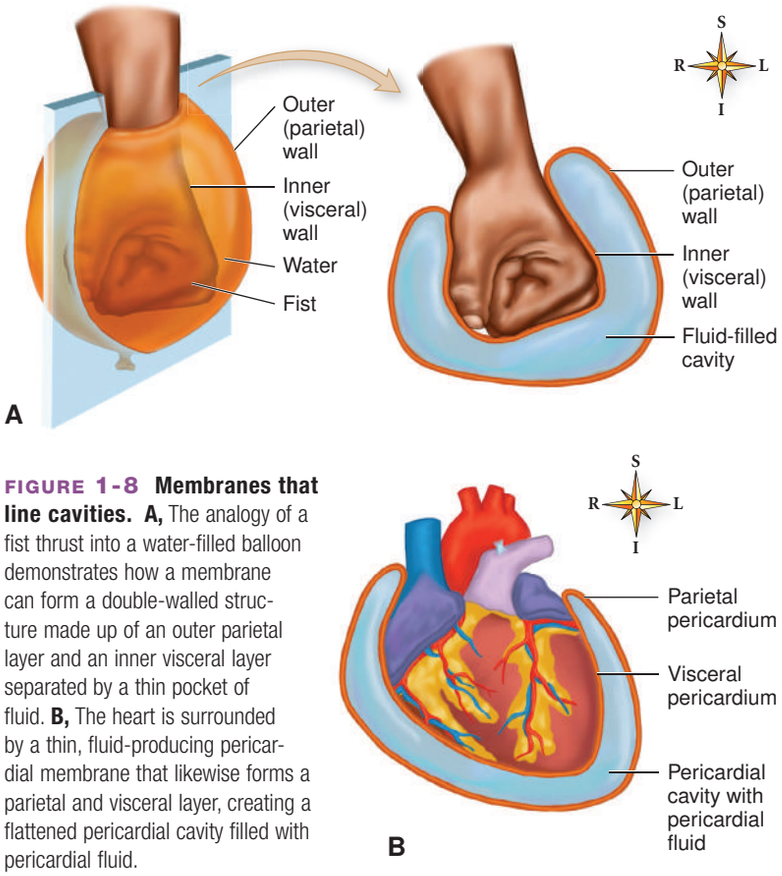


FIGURE 1-8 Membranes that line cavities. A, The analogy of a fist thrust into a water-filled balloon demonstrates how a membrane can form a double-walled structure made up of an outer parietal layer and an inner visceral layer separated by a thin pocket of fluid. **B,** The heart is surrounded by a thin, fluid-producing pericardial membrane that likewise forms a parietal and visceral layer, creating a flattened pericardial cavity filled with pericardial fluid.

TABLE 1-3 Body Cavities

AREAS	ORGAN(S)
Dorsal Body Cavities	
Cranial cavity	Brain
Spinal cavity	Spinal cord
Ventral Body Cavities	
Thoracic Cavity	
Right pleural cavity	Right lung
Mediastinum	Heart Trachea Right and left bronchi Esophagus Thymus gland Aortic arch and thoracic aorta Venae cavae Various lymph nodes and nerves Thoracic duct
Left pleural cavity	Left lung
Abdominopelvic Cavity	
Abdominal cavity	Liver Gallbladder Stomach Pancreas Intestines Spleen Kidneys Ureters
Pelvic cavity	Urinary bladder Female reproductive organs Uterus Uterine tubes Ovaries Male reproductive organs Prostate gland Seminal vesicles Part of vas deferens Part of large intestine, namely, sigmoid colon and rectum

Like the fist surrounded by a double wall of balloon, the heart is surrounded by a double-walled pericardial membrane filled with a small amount of watery pericardial fluid.

This structural pattern, seen commonly within body cavities, will be revisited often throughout your study of human anatomy. Often, one layer of the membrane called the **parietal** layer lines the cavity and doubles back on itself to form a **visceral** layer covering the organs. The "space" of the cavity is thus reduced to the flattened pocket of fluid between the parietal and visceral layers.

This pattern also occurs in each pleural cavity, where a *parietal pleura* hugs the inside of the thoracic wall and doubles back to cover the lung—thus forming a *visceral pleura*. The term **pleural cavity** can refer to the entire space to the side of the mediastinum or to just the potential space left surrounding the lung between the parietal and visceral pleura. Peek ahead to Figure 8-8 on p. 145 to see the double-layer structure of the pleurae.

Abdominopelvic Cavity

The **abdominopelvic cavity** has an upper portion, the *abdominal cavity*, and a lower portion, the *pelvic cavity*. The abdominal cavity contains the liver, gallbladder, stomach, pancreas, intestines, spleen, kidneys, and ureters. The bladder, certain reproductive organs (uterus, uterine tubes, and ovaries in females; prostate gland, seminal vesicles, and part of the vas deferens in males), and part of the large intestine (namely, the sigmoid colon and rectum) lie in the pelvic cavity (**Table 1-3**).

The membrane lining the inside of the abdominal cavity is called the *parietal peritoneum*. The membrane that covers the organs within the abdominal cavity is called the *visceral peritoneum*. Looking back to **Figure 1-6**, you will see that there is a space or opening between the two membranes in the abdomen. This is called the *peritoneal cavity*. Body membranes are discussed in greater detail in Chapter 8.

Abdominopelvic Quadrants

To make it easier to locate organs in the large abdominopelvic cavity, anatomists have divided the abdominopelvic cavity into four *abdominopelvic quadrants*:

1. *Right upper quadrant* or *RUQ* (right superior quadrant)
2. *Right lower quadrant* or *RLQ* (right inferior quadrant)
3. *Left upper quadrant* or *LUQ* (left superior quadrant)
4. *Left lower quadrant* or *LLQ* (left inferior quadrant)

As you can see in **Figure 1-9**, the midsagittal and transverse planes, which were described in the previous section, pass through the navel (umbilicus) and divide the abdominopelvic region into the