Human Anatomy

Second Edition

Elaine N. Marieb

Jon Mallatt

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Elaine N. Marieb, R.N., Ph.D.

Edison Community College

Holyoke Community College, Emeritus

Jon Mallatt, Ph.D.

Washington State University

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About the Authors

Elaine Marieb and Jon Mallatt are keenly aware of the challenges faced by all anatomy instructors. It is important to communicate a vast amount of information to students in a way that stimulates their interest. Forty-three combined years of teaching experience in both the laboratory and the classroom have enhanced the authors' sensibilities about pedagogy and presentation. The insights gained from this experience are distilled in this updated second edition of *Human Anatomy*—a book that aims to address the problems students encounter in this course.

This is a strong and highly experienced team of authors. Dr. Marieb started her teaching career at Springfield College, where she taught anatomy and physiology to physical education majors. She then joined the faculty of the Biological Sciences Division of Holyoke Community College in 1969 after receiving her Ph.D. in Zoology from the University of Massachusetts at Amherst. As a result of her contact with students at Holyoke Community College, many of whom were pursuing degrees in nursing, she developed a desire to better understand the relationship of the scientific study of the human body to the clinical aspects of nursing practice. While continuing to teach full-time, Dr. Marieb earned an associate degree in nursing in 1980 from Holyoke Community College. She continued her nursing education, receiving a bachelor's degree in nursing from Fitchburg State College and then a master's degree in gerontological nursing from the University of Massachusetts in 1985. Dr. Marieb was honored with the "Outstanding Education Award" for excellence in classroom instruction at Holyoke Community College. In 1994 she became Professor Emeritus at Holyoke and is now a visiting professor at Edison Community College in southwestern Florida. She has enjoyed the honors of being the keynote speaker at the 1990 *Human Anatomy and Physiology Society* meeting in Madison, Wisconsin and serving on the Instrumentation Committee of the National Science Foundation.

Dr. Marieb is an accomplished author, with several successful textbooks and laboratory manuals to her credit. Most recently, Dr. Marieb has been working on the interactive human physiology modules co-developed by Benjamin/Cummings and A.D.A.M. Software, Inc.

With a Ph.D. in Anatomy from the University of Chicago, Dr. Mallatt is currently Associate Professor of Zoology at Washington State University, where he has been teaching human anatomy to undergraduates of all backgrounds for 17 years. He is also a member of the department of Basic Medical Sciences, where he teaches courses in Histology and Anatomy of the Trunk in the WAMI Medical Program. WAMI honored him with their "Excellence in Teaching Award" in 1992, 1993, and 1995. Additionally, Dr. Mallatt holds a position as adjunct Associate Professor in the department of Biological Structure at the University of Washington. His particular areas of expertise in the study of anatomy are histology, comparative anatomy, embryology, and anatomical drawing. Dr. Mallatt is an accomplished researcher with 25 scientific publications in the field of anatomy to his credit.

Both authors began their careers in publishing over 15 years ago as reviewers for textbooks in Human Anatomy and Human Anatomy and Physiology.

A Brief Guided Tour to *Human Anatomy*

In so many ways, Marieb and Mallatt make anatomy clear, memorable, and lively to your students.

Marieb and Mallatt include the most current anatomical research.

Supporting Cells

All neurons associate closely with non-nervous **supporting cells**, of which there are six types. Four of these are in the CNS, and two are in the PNS (Figure 11.11). Each type of supporting cell has a unique function, but in general, these cells provide a supportive scaffolding for the neurons. Furthermore, supporting cells cover all parts of the neurons that are not involved in synapses. Such masking insulates the neurons and prevents the electrical activities of adjacent neurons from interfering with each other.

Anatomy is presented with a functional approach.

The importance of supporting cells in insulating nerve fibers from one another is illustrated in the painful disorder called **tic douloureux** (tik doo″loo-roo′; "wincing in pain"). In this condition, the supporting cells around the sensory nerve fibers in the main nerve of the face (the trigeminal nerve) degenerate and are lost. As a result, impulses in nerve fibers that carry *touch* sensations proceed to influence and stimulate the uninsulated *pain* fibers in the same nerve, leading to a perception of pain by the brain. Because of this crossover, the softest touch to the face can produce agonizing pain. For more information on tic douloureux, see Table 13.2, page 371. ■

Clinical applications are integrated into the text and distinguished by a red cross icon.

Extensive cross-referencing ties concepts together and helps students see relationships among different body systems.

Supporting Cells in the CNS

The supporting cells in the CNS are collectively called the **neuroglia** (nu-rog′le-ah; "nerve glue") or **glial** (gle′al) **cells**. (Most authorities restrict the name *neuroglia* to the supporting cells in the CNS, but others consider all supporting cells neuroglia, including those in the PNS.) Like neurons, most glial cells have branching processes and a central cell body (Figure 11.11a–d). Neuroglia can be distinguished from neurons, however, by their much smaller size and by their darker-staining nuclei (Figure 11.4). Neuroglia outnumber neurons in the CNS by as much as 50 to 1, and they make up about half the mass of the brain. Unlike neurons, glial cells can divide throughout life.

By recognizing scientific controversy, Marieb and Mallatt present anatomy as a "live" science.

Can you deduce which of the two cell types in neural tissue—neurons or neuroglia—gives rise to more brain tumors?

The glial cells do. Since glial cells can divide regularly, they accumulate the "mistakes" in DNA replication that may transform them into neoplastic cells. This does not occur in neurons, which do not divide. Therefore, most tumors that originate in the brain (60%) are **gliomas** (tumors formed by uncontrolled proliferation of glial cells). ■

Critical-thinking questions—and answers—are integrated into the text and flagged with a puzzle icon.

Star-shaped **astrocytes** (as′tro-sītz; "star cells") are the most abundant glial cells (Figure 11.11a). They have many radiating processes with bulbous ends. Some of these bulbs cling to neurons, whereas others cling to capillaries. Because of these connections, some scientists believe that astrocytes transfer nutrients from the capillary blood to the neurons, thereby "nursing" the nerve cells. While their nutritive function is still disputed, most agree that astrocytes help control the ionic environment around neurons: The concentrations of various ions outside the axons must be kept within narrow limits for nerve impulses to be generated and conducted. Additionally, astrocytes recapture (and recycle) released neurotransmitters.

Microglia are the smallest and least abundant of the neuroglia (Figure 11.11b). They have elongated cell bodies and cell processes with many pointed projections, like a thorny bush. The microglia are phagocytes, the macrophages of the CNS. They engulf invading microorganisms and injured or dead neurons. The origin of microglia is controversial. Some authorities believe they originate, like the other macrophages of the body, from a type of blood cell called a monocyte. Others claim that microglia derive from the ectoderm of the embryonic neural tube, as do the other neuroglial cells.

You will recall from Chapter 3 (p. 55) that the CNS originates in the embryo as a hollow neural tube and retains a central cavity throughout life. **Ependymal cells** (ĕ-pen′dĭ-mal; "wrapping garment") form a simple epithelium that lines the central cavity of the spinal cord and brain (Figure 11.11c). Here, these cells provide a fairly permeable layer between the cerebrospinal fluid that fills this cavity and the tissue fluid that bathes the cells of the CNS. Ependymal cells bear cilia that help circulate the cerebrospinal fluid.

Oligodendrocytes (ol″ĭ-go-den′dro-sītz) (Figure 11.11d) have fewer branches than astrocytes. Indeed, their name means "few-branch cells." Oligodendrocytes line up in small groups along the thicker axons in the CNS. They wrap their cell processes around these axons, producing insulating coverings called *myelin sheaths* (discussed in detail below).

Supporting Cells in the PNS

The two kinds of supporting cells in the PNS are *satellite cells* and *Schwann cells*. These very similar cell types differ mainly in location. **Satellite cells** surround neuron cell bodies within ganglia (Figure 11.11e). Their name comes from a fancied resemblance to the moons (satellites) around a planet. **Schwann cells** (also called *neurolemmocytes*) surround all axons in the PNS and form myelin sheaths around many of these axons.

Myelin

Myelin (mi′ĕ-lin), a lipoprotein, is a fatty substance that surrounds the thicker axons of the body. It takes

Boldfaced key terms accompanied by their pronunciation and word derivations, as well as definitions, are easier to remember.

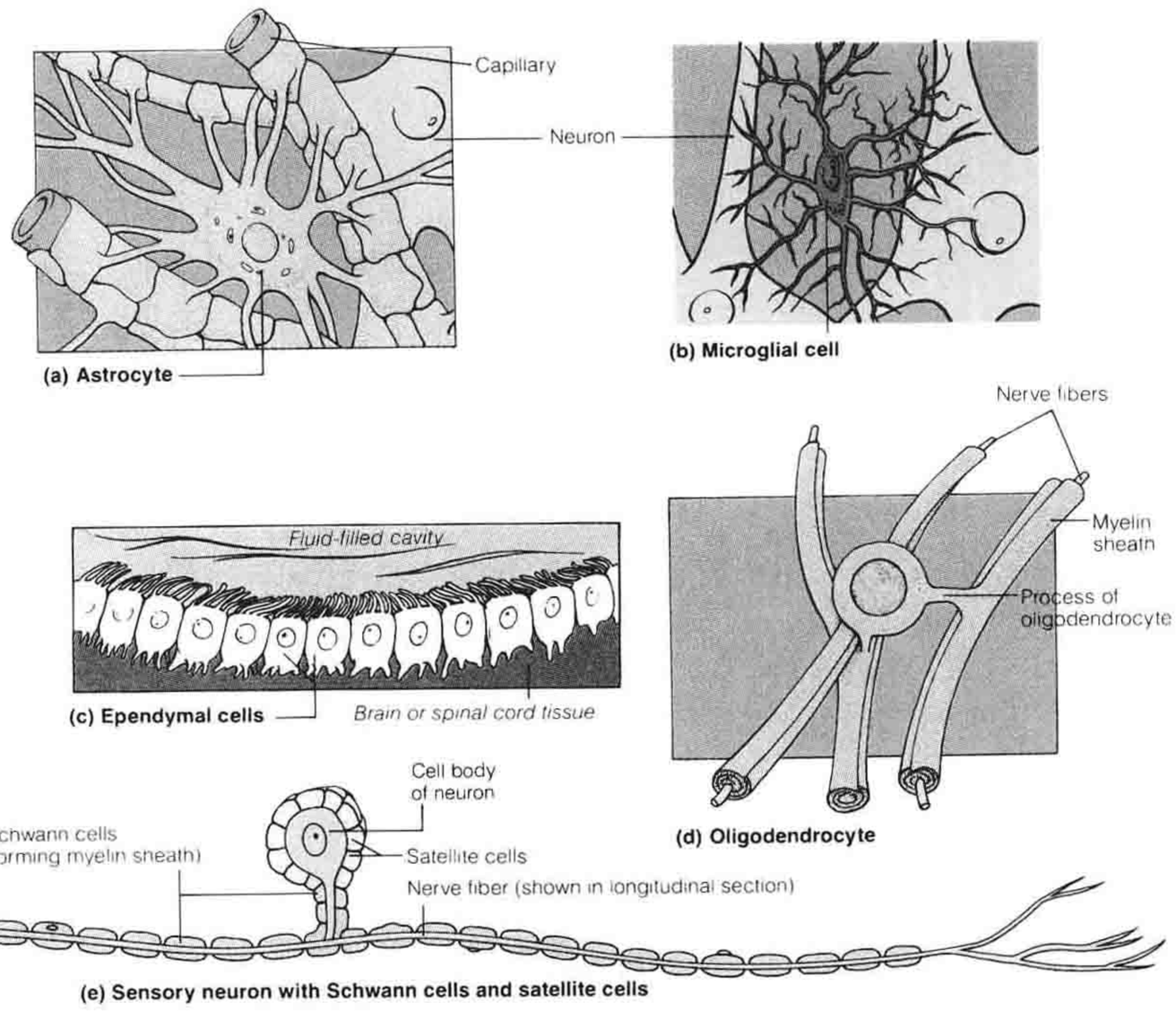

Figure 11.11 Supporting cells of nervous tissue. (**a–d**) The four types of neuroglial cells in the CNS. In (**c**), note that ependymal cells line the fluid-filled central cavity of the spinal cord and brain. (**e**) The two types of supporting cells in the PNS: Schwann cells and satellite cells around a sensory neuron.

the form of a segmented **myelin sheath** (Figures 11.12 and 11.13). This sheath consists of the plasma membrane of supporting cells—a membrane that is arranged in concentric rolls around the axon. By acting as an insulating layer that prevents the leakage of electrical current from the axon, the myelin sheath increases the speed of impulse conduction along the axon.

Myelin in the PNS. As we stated above, the myelin sheaths in the PNS are formed by Schwann cells (Figure 11.12a). Myelin forms during the fetal period and the first year or so of postnatal life. To form myelin, the Schwann cells first indent to receive the axon and then wrap themselves around the axon repeatedly, in a jellyroll fashion (Figure 11.13a–d). Initially the wrapping is loose, but the cytoplasm of the Schwann cell gradually squeezes out from between the membrane layers. When the wrapping process is finished, many concentric layers of Schwann cell plasma membrane enclose the axon. This coil of membranes is the true myelin sheath. The nucleus and most of the cytoplasm of the Schwann cell end up just external to the myelin layers. This external material is called the **neurilemma** ("neuron sheath") (Figure 11.13d).

Since the adjacent Schwann cells along a myelinated axon do not touch one another, there are gaps in the myelin sheath. These gaps, called **nodes of Ranvier**, or *neurofibral nodes*, occur at regular intervals about 1 mm apart (Figures 11.12 and 11.13e). As nerve impulses pass along the axon, they jump quickly from one node to the next without traveling along the myelin-covered neuronal membrane in between.

Only the thick, rapidly conducting axons are sheathed with myelin. Thin, slowly conducting axons that lack a myelin sheath are called **unmyelinated**

Colored corner tabs, coded by organ system, allow for quick and easy reference.

Text and art support each other through close integration and adjacent placement.

Use of modern terminology includes both scientific names and more traditional eponyms.

Marieb and Mallatt use analogies to clarify concepts by relating them to things students are familiar with.

Preface to the Instructor

The philosophy behind this updated second edition remains the same as in the first edition. As a teacher, you know that teaching anatomy is not just the presentation of facts. You must provide information in a framework that encourages genuine understanding, devise new presentations to help students remember large amounts of material, and help students apply what they have learned to new situations. All the while you hope that you inspire in the students a real love of the subject.

After many years of teaching human anatomy, we became convinced that new approaches to the subject could excite and challenge the students' natural curiosity. That is why we decided to write this book. We were fortunate to have collaborated with Benjamin/Cummings, a publisher that shared our goal: to set a new standard for pedagogical and visual effectiveness in an anatomy text.

Intended Audience and Objectives of the Book

This book is designed for one-semester or one-quarter introductory anatomy courses that serve students in prenursing, allied health, physical education and athletic training, premedical, prephysical therapy, radiological technology, physician assistant training, predentistry, and other fields. We present the basic concepts of anatomy—gross, microscopic, developmental, and clinical—in a manner that is clearly written, effectively organized, up-to-date, and well-illustrated. We realize that anatomy involves gargantuan amounts of factual material, and we have tried to make this material as logical and accessible as possible. To this end, we present anatomy as a "story" that can be explained and understood—convincing the students that the structure of the body makes sense.

To maximize clarity of presentation, we use the following devices:

- **Functional approach.** Wherever possible, we explain how the shape and composition of the anatomical structures allow them to perform their functions. Such functional anatomy is not physiology (which focuses on biological mechanisms), but is more akin to "design analysis." This approach is not used by other texts at this level.
- **Relation to real life.** To further encourage understanding, this interactive book asks students—as they read along—to relate the material to their life experiences and to answer conceptual questions.
- **Pedagogy.** Extensive, easy-to-use pedagogical devices, color coding, and art function as teaching tools.
- **Technology.** This book is linked to A.D.A.M., an interactive computer program designed to teach body structure.

These features will especially benefit students who may be less thoroughly or less recently prepared for a rigorous science course.

Organization

This book organizes the human body by organ systems. Chapter 1 introduces the terms and presents fundamental concepts of anatomy and the basic organization of the body. Chapter 2 covers the cell and its organelles. Chapter 3 presents the basics of embryology. Chapter 4 introduces the types of tissues. Chapter 5 covers the skin and its appendages, as an example of a simple organ system. Chapters 6 and 7 explain the skeleton, Chapter 8, the joints, and Chapters 9 and 10, the muscles. Chapters 11–15 present the nervous system: Chapter 11 introduces nervous tissue and also explains the basic organization of the nervous system; Chapter 12 covers the central nervous system; Chapter 13, the peripheral nervous system; Chapter 14, the autonomic nervous system; and

Chapter 15, the special senses. Chapters 16–19 present the circulatory system: Chapter 16 deals with blood; Chapter 17, the heart; Chapter 18, blood vessels; and Chapter 19, the lymphatic system. Chapters 20–24 cover the visceral organ systems: Chapter 20 discusses the respiratory system; Chapter 21, the digestive system; Chapter 22, the urinary system; Chapter 23, the reproductive system; and Chapter 24, the endocrine system and hormones. The final chapter, Chapter 25, deals with surface anatomy, encouraging the students to review as much anatomy as possible by examining their own bodies.

This organizational scheme has some unique aspects that were well received in the first edition of *Human Anatomy*.

- Among the many anatomy books that have appeared in the last thirty years, this book alone covers the basics of embryology early in the book (Chapter 3); this presentation provides the students with the background they need to understand the development of the specific organ systems in later chapters.
- We placed the endocrine chapter (Chapter 24) near the end of the book—after, rather than before, the chapters on the visceral organ systems (digestive, urinary, reproductive). We chose this sequence because we feel that students must understand the visceral functions before they can remember the numerous and varied roles hormones play on the visceral organ systems. Nonetheless, we realize that many anatomy courses teach the endocrine system with the nervous system, so we designed the endocrine chapter so that it can also be interjected and understood at that earlier point of the course.
- The surface anatomy chapter (Chapter 25) is placed at the end of the book, so that it can cover more of the clinical information related to surface body features. Other books place this chapter earlier, after bones and muscles, thereby forfeiting the opportunity to discuss the surface anatomy of blood vessels (pulse points), lymph nodes, nerves, and the visceral organs. Because it is in the last chapter, our coverage of surface anatomy provides the students with a unique summary of the entire body.

Development of this Book

This book, like most major anatomy books in this market, is based on a larger anatomy and physiology text—in this case, *Human Anatomy and Physiology* by Elaine N. Marieb. However, special effort was made to assure that this is not just a "spin-off" but an entirely new product, specifically written and developed for the anatomy market. As our users know, *Human Anatomy* features many sections that are not present in the parent text. For example, the embryology and surface anatomy chapters are completely different, and the chapters on the autonomic nervous system, lymphatic system, digestive system, and endocrine system were extensively reworked from an anatomical perspective. New sections that provide overviews of the organ systems were added to the chapter on muscles (pp. 241–243) and the introductory nervous system chapter (pp. 310–312). In keeping with the functional anatomy emphasis of this book, new sections were added on the design characteristics of long bones (p. 124) and the structural basis of capillary permeability (p. 486). Presentations of microscopic anatomy were refined and expanded throughout the text.

Unique Approach to Anatomy

We have worked diligently to distinguish this book from the many other anatomy books currently available. First, we emphasize strongly the *functional anatomy theme*, giving careful consideration to the adaptive characteristics of the anatomical structures of the body (see pp. 120, 124, and 486 for examples).

Second, this book is as *current* as possible. We believe that the other undergraduate anatomy texts presently available are about fifteen years out-of-date in light of modern anatomical knowledge. We attempt to close this gap, while keeping our book readable and accessible to the undergraduate audience. In this second edition, we have integrated the book with computer technology by linking it to the A.D.A.M. software (version 2.0) for exploring the human body.

Third, the production team has developed an *effective art program*, using step-by-step diagrams of developmental processes (see Figures 3.11, 12.3, 17.16, 24.13 and others), many figures with insets and orientational diagrams to guide students to key structures (e.g., see Chapters 2 and 3), and placement of figures as close as possible to their text references. We are especially proud of the renderings of the skeletal muscles in Chapter 10 and the color photos of surface anatomy in Chapter 25.

Fourth, we provide an effective treatment of *microscopic anatomy.* Many undergraduate texts treat histology as a specialized and minor subfield of anatomy that takes a back seat to gross anatomy. This is unfortunate, because most physiological and

disease processes take place at the cell and tissue level, and most allied health students require a solid background in histology to prepare them for their physiology courses.

Fifth, we provide an anatomically valid treatment of *embryology*. The understanding of adult anatomy is enriched by a simultaneous presentation of how the structures develop. Currently, all major anatomy texts present separate information on the embryology with each organ system—as does this text. However, all competing texts place the fundamentals of embryology at the very end of the book, in the section on the female reproductive organs. We are convinced that the fundamentals should be presented early in the text, before the more advanced discussions of the developing organ systems. Therefore, we wrote Chapter 3 as an introduction to embryology. Because a comprehensive presentation of development early in the book could be intimidating to students, we have used a "velvet glove" approach, providing only the most important concepts in a concise, understandable way (see pp. 48–63).

Sixth, we present more *regional* anatomy, carefully describing the locations of the various organs. For example, the vertebrae in the spinal column are used as a yardstick to indicate the positions of various visceral organs in the trunk, and the courses of the vessels and nerves of the limbs are described in relation to nearby muscle groups. This not only helps students locate structures in the laboratory, but also allows them to appreciate the effects of injuries that are confined to limited body regions. The surface anatomy chapter (Chapter 25) provides the best demonstration of the use of regional anatomy.

Finally, this book is an *interactive learning tool* that encourages understanding, rather than an encyclopedia that encourages rote memorization. Whereas many scientific textbooks read like long lists of terms, this book reads like an instructor talking to, explaining to, and challenging the student. Many of the chapters include special topic boxes that present interesting information in a lighter, more inviting format. For those organs and systems that include large numbers of parts (e.g., skeletal muscles, cranial nerves, sensory receptors), we present these parts in illustrated tables that organize the information in a logical way (pp. 246–292; 366–367; 371–377). In-text Critical Thinking questions and Clinical Application sections challenge the student and encourage synthesis of information. The complex terminology of anatomy is always the most difficult aspect of the subject to make interesting and accessible. To this end, we have included the Latin or Greek translations of virtually every term as it is introduced in the text. Our anatomy book presents the definitions directly where the terms are introduced in the text.

Special Features

Art and Photo Program

Art plays a critical role in helping students visualize anatomical structures and concepts. Writing this text has been a process of translating our knowledge of anatomy into words and pictures. Our team of medical illustrators read the manuscript, did additional research when necessary, and provided highly accurate figures to depict the anatomy. Each illustration was carefully reviewed at every stage of its development to ensure accuracy.

The art program is full color throughout. The color is used not only for aesthetic purposes but also in a functional sense. For example, the color protocol for the embryonic germ layers seen in Chapter 3 (ectoderm in blue, mesoderm in red, endoderm in yellow) is used throughout the later embryology figures of this book. Additionally, throughout the nervous system unit, sensory neurons are always shown in blue (and green), motor neurons in red (and yellow). Consistency of this nature encourages automatic learning by the student and aids information retention. In many figures, the body location or general structure of a body part is first illustrated in a simple diagram for orientation, and then the structures of interest are shown in enlarged, detailed view. Not only are light and scanning electron micrographs used abundantly, but images produced by modern medical scanning techniques (CT, PET, and MRI) are inserted where appropriate to enhance the students' interest and grasp of structure. Additionally, the highly acclaimed Bassett photographs of dissected cadavers are sprinkled throughout the book. These photos should especially benefit the many anatomy courses in which human cadavers are unavailable.

Illustrated Tables

The use of illustrations within summary tables is a highly effective and efficient method of helping students learn important and detailed information. Thus, many chapters include illustrated summary tables. These tables run the gamut in level of complexity from the exceptionally complete tissue tables in Chapter 4 (presented as Figures 4.3, 4.15, 4.17, and 4.18) to the simple but highly effective table showing bone fractures in Chapter 6 (p. 132). In particular, the tables illustrating the skeletal muscles in Chapter 10 are noteworthy, because, in addition to doing what all muscle tables do (summarizing the locations, attachments, and functions of the muscles), every table includes an introductory essay explaining general

concepts about a functional group of muscles. Other illustrated tables cover the stages of the fetal period (Table 3.2), various bones of the skeleton (Tables 7.3–7.5), the synovial joints of the body (Table 8.1), the classes of sensory receptors (Table 13.1), the cranial nerves (Table 13.2), and more.

Color-Coded Pages

Each body system has been assigned a specific color. For example, the chapters on the cardiovascular system, Chapters 16–18, are identified by a red color tab at the top corner of each page. Thus, if you wish to flip quickly to the chapters on this system, you simply open the book to the red-edged pages. This makes the book much easier to use, greatly simplifying the task of looking up information. The Brief Contents on p. xvii provides a guide to the color-coding scheme.

Closer Look Boxes

Many chapters of this book have special topic boxes ("A Closer Look"), generally of a clinical nature. Some of these boxes deal with timely topics, such as artificial joints (p. 210), bone transplants (p. 184), the effects of steroid use on the physique of athletes (p. 233), AIDS (p. 522), and clinical uses of growth hormone (p. 669). Other boxes address timeless topics that interest students, such as the general aspects of cancer (p. 42), problems with visual focusing (p. 426), atherosclerosis and coronary bypass surgery (p. 484), and lung cancer and smoking (p. 554). Porphyria, a vampire-like disorder of the skin (p. 112), and special properties of cartilage (p. 120) are topics of other boxes.

Life Span Approach

Most chapters close with a "Throughout Life" section that summarizes the embryonic development of organs of the system and then examines how these organs change throughout the life span. Diseases particularly common during certain periods of life are pointed out, and effects of aging are considered. The implications of aging are particularly important to students in the health-related curricula because many of their patients will be in the senior age group.

Clinical Applications Throughout the Text

Clinical material that applies anatomical concepts is always of interest to students in the allied health and physical education fields. Such material is included  in each chapter, set off by a **red cross symbol.** Furthermore, most of the Closer Look boxes and Critical Thinking questions (described below) contain clinical material, and lists of Related Clinical Terms are provided at the end of each chapter.

Critical Thinking Questions Throughout the Text

As part of the interactive nature of this book, a number of Critical Thinking questions are included in the text portion of each chapter. These questions are  indicated by a symbol that resembles a **square puzzle,** and answers are provided directly below each question. They ask the student to synthesize information from previous paragraphs, or to call on their own life experiences. "Learning by doing" is an effective learning tool, and we believe the students will enjoy the challenge of these questions. Although some of the Critical Thinking questions are purely anatomical, most are clinical in nature. Additional Critical Thinking questions are included in the Review Questions at the end of each chapter. There are approximately 10 Critical Thinking questions per chapter.

A.D.A.M. Questions

As a companion to the A.D.A.M. series of anatomical CD-ROMS, this text includes a set of questions that use A.D.A.M. to explore the human body. These  questions appear at the end of most chapters and are indicated by the **A.D.A.M. walking man symbol.** Because not everyone has access to A.D.A.M., we designed these questions so they can also be answered by studying the text alone; instructions for this are provided by a TEXT ALTERNATIVE (textbook alternative) heading in each A.D.A.M. question.

A.D.A.M. Reference Guide

Accompanying this text is a handy reference guide that links text figures and their key structures with the appropriate views and layers in A.D.A.M. Standard.

In-Text Learning Aids

Numerous pedagogical devices have been incorporated into *Human Anatomy* to enhance its utility as a learning tool.

Chapter Outlines and Student Objectives

Each chapter begins with an outline of the major topics of the chapter, followed directly by a list of specific objectives that the student should strive to master. Page references allow students to relate the outline and objectives to specific text passages.

Word Pronunciations and Derivations

The introduction of each technical term in the text is directly followed by its pronunciation and, when helpful, by the literal meaning of the term (usually its Greek or Latin derivation). The pronunciations are adopted from the *Encyclopedia and Dictionary of Medicine, Nursing, and Allied Health*, Fourth Edition, by B. Miller and C. Keane, 1987, Philadelphia, W.B. Saunders. (The pronunciation scheme is explained at the end of the Preface to the Student.)

Related Clinical Terms

A list of clinical terms that are relevant to the content of the chapter is provided at the end of each chapter.

Chapter Summary

Thorough chapter summaries in a study outline format with page references will help students review the chapter they have just read.

Review Questions

Numerous end-of-chapter questions are provided. These questions are grouped into several sections: short, objective questions ("Multiple Choice and Matching"), longer questions ("Short Answer and Essay"), and "Critical Thinking and Clinical Application Questions." The latter, which are identified by the **square puzzle,** challenge the students to synthesize information and solve new problems. For this second edition, additional Short Answer and Critical Thinking Questions have been added to most chapters, along with questions that can be answered using A.D.A.M. software (version 2.0). These A.D.A.M. Questions are indicated by the **A.D.A.M. walking man symbol.**

Appendices

The appendices offer several useful references for the student. They include Appendix A: The Metric System; Appendix B: Answers to Multiple Choice and Matching Questions from the individual chapters; and Appendix C: Word Roots, Prefixes, Suffixes, and Combining Forms.

Glossary

Near the end of this book (p. 717), students will find an extensive glossary that includes both the definitions and phonetic pronunciation of key terms.

Teaching Package

The teaching package accompanying *Human Anatomy* has been developed to help instructors and students derive the greatest benefit from this text.

Laboratory Manual

Elaine Marieb's *Human Anatomy Laboratory Manual with Cat Dissection*, Second Edition (1997), which accompanies this text, contains 29 gross anatomy and histology exercises for all major body systems. Illustrated in full color, with a convenient spiral binding, this lab manual has an accompanying *Instructor's Guide* by Linda Kollett of Massasoit Community College.

Instructor's Guide and Test Bank

An *Instructor's Guide and Test Bank* has been prepared for this textbook by Jon Mallatt and Elaine Marieb. It provides detailed annotated lecture outlines, suggested class activities and discussion topics, additional clinical terminology, lists of suggested reading, recommended audiovisual aids, and the answers to all the subjective questions in the textbook (i.e., to the Short Answer and Essay Questions, the Critical Thinking and Clinical Application Questions, and the A.D.A.M. Questions). The Test Bank section of the manual offers approximately 2,000 new multiple choice questions for use in course exams. It contains two different Tests per book chapter (Tests A and B), each of which consists of 25–30 questions. At the end of the test bank are two Final Exams, each consisting of over 200 questions. The instructor may use the tests intact or may choose only those questions that are most appropriate. The questions in the Test Bank are entirely new and different from those provided in the textbook itself.

Computerized Test Bank

The Test Bank is also available on a microcomputer test generation program for the IBM PC and Macintosh computers. This software is available to qualified adopters of *Human Anatomy* through the publisher or your local representative.

Overhead Acetate Transparencies

A package of acetates, for use with overhead projectors during lecture presentations, is available. On all acetates, the type has been enlarged for easy viewing in larger lecture halls.

A.D.A.M. Multimedia

Developed over 3 years by a cadre of medical illustrators at A.D.A.M. Software, Inc., *A.D.A.M. Standard* is a powerful interactive tool for anatomy instructors. This interactive CD-ROM has over 10,000 highly detailed, full-color anatomical drawings to support lecture presentations and lab activities. Specific end-of-chapter questions link figures in the text to the appropriate views in *A.D.A.M. Standard* versions 2.0 or earlier.

A.D.A.M. multimedia is available for purchase through Benjamin/Cummings, the only licensed undergraduate academic publishing source for A.D.A.M. multimedia products. A variety of workshops and publications is also available to support multimedia use in the classroom. Additionally, each copy of this book is provided with an A.D.A.M. Reference Guide in which selected figures from *Human Anatomy* are listed with the appropriate view and layer from *A.D.A.M. Standard* (versions 2.0 or earlier).

Student Workbook for A.D.A.M.

Written by Rose Leigh Vines, Ph.D. of California State University, Sacramento, this navigational tool guides students through A.D.A.M. software and provides a thorough review as they explore the intricacies of human anatomy. Exercises include true/false, multiple choice, matching, fill-in-the-blank, and special "sketch" questions that ask the student to draw and label anatomical features. Answers can be checked at the back of the Workbook.

Photo Atlas

Authored by Robert A. Chase, M.D., Professor of Anatomy at Stanford University, *The Bassett Atlas of Human Anatomy* offers an extraordinary collection of full-color dissection photos. An inexpensive alternative to the costly collections now available, it will be extremely useful to your students in their anatomy laboratory.

Human Dissection Slides

Qualified adopters of this *Human Anatomy* text will be eligible for a set of 86 complimentary dissection slides from *The Bassett Atlas of Human Anatomy*.

Histology Slides

This set of 135 full-color slides was photographed by Allen Bell of the University of New England and Victor Eroschenko of the University of Idaho.

Coloring Atlas

A *Coloring Atlas of Human Anatomy* has been prepared by Steve Langjahr and Bob Brister of Antelope Valley College. Accompanying Macintosh software, keyed to this atlas, is available.

The Anatomy Tutor

Programmed by Dr. Marvin Branstrom of Cañada College, these student tutorials include a module for each organ system on a total of four disks for the Macintosh computer. Each module, class tested and reviewed for accuracy and ease of use, is designed to help the student review the anatomy of the body systems.

Videotapes

This series of videotapes takes students through a guided tour of various systems in the human body. The videotapes may be used to orient students to particular structures before a lecture, or they can be stopped and started at will to clarify particular structures during lecture or lab. Videotapes in the series include:

- *The Human Cardiovascular System: The Heart*
  by Rose Leigh Vines and University Media Services, California State University, Sacramento
- *The Human Cardiovascular System: The Blood Vessels*
  by Rose Leigh Vines and University Media Services, California State University, Sacramento
- *The Human Nervous System: The Brain and Cranial Nerves*
  by Rose Leigh Vines and Rosalee Carter, California State University, Sacramento
- *The Human Nervous System: The Spinal Cord and Spinal Nerves*
  by Rose Leigh Vines and Rosalee Carter, California State University, Sacramento
- *Human Musculature*
  by Rose Leigh Vines and Allen Hinderstein, California State University, Sacramento

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Our artists, whose names are listed on page 731, have been superb. There is little doubt that their illustrations will imbue students with lasting, colorful imagery from their anatomy studies.

Last but not least, we thank our spouses, "Zeb" Marieb and Marisa de los Santos, for their loving and patient support of our work on this project.

Elaine N. Marieb

Jon Mallatt

Text, Art, and Photo Reviewers for the First and Second Editions

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Preface to the Student

This book is written for you. In a way, it was written by our students, because it incorporates their suggestions, the answers to questions they most often ask, and explanatory approaches that have been most successful in helping them learn about the human body. Together, we have accumulated 43 years of experience in teaching human anatomy (we don't feel that old!), and we have listened to our students all along.

Human anatomy is more than just an important and intellectually challenging field—it is interesting. To help you get involved in the study of this exciting subject, a number of special features are incorporated throughout the book.

We want you to enjoy your learning experience, so the tone of this book is intentionally informal and unintimidating. The book is a guide to the understanding of your own body, not an encyclopedia of human anatomy. Certainly you will be learning many new names and structures, but we will show you that all of this information makes sense: The anatomy of body structures reflects their functions in a logical way, and the complex scientific names of body structures actually have simple meanings (for example, the *brachiocephalic* artery literally means "arm-head" artery, and it supplies blood to precisely those body parts). Throughout the book, we will point out various features that make anatomy understandable and easier to remember. We explain anatomical concepts thoroughly, using abundant analogies, and we present examples from familiar events whenever possible.

The illustrations and tables are designed with your learning needs in mind. Most of the tables are summaries of important information in the text and should be valuable resources for reviewing for exams. In all cases, the figures have been placed as close as possible to their text references. Special topic boxes, entitled "A Closer Look," alert you to advances in medicine or new scientific discoveries that can be applied to your daily life. Shorter pieces of clinical information that relate to anatomy are interspersed throughout the text, and are identified by a **red cross symbol.**

Quiz shows on television are interesting and challenging entertainment, and this book contains its own "quiz show" in the form of Critical Thinking questions. Several times in each chapter you will encounter this **square puzzle,** which indicates that a question will follow. Most of these questions relate to clinical anatomy, although others test your understanding of purely anatomical concepts. Your job is to deduce the answer, based on the information ("clues") presented in the material you have been reading to that point. The answer is written directly after each question, so you will probably want to cover the answer with your hand as you are thinking. Do not be frustrated if you cannot answer the question right away, but do try to figure out the essential point. We think you will be surprised at how well you perform, and at how effective these quiz questions are in keeping your mind focused on the subject matter you are reading.

To help you organize your reading and studying, each chapter of this book begins with an outline of its major topics, with specific learning objectives listed for each topic. All chapters end with a comprehensive summary and several dozen review questions to help you review your understanding of the material. Some of the review questions in each chapter are of the Critical Thinking type—similar to those interspersed through the text—which test your ability to synthesize and apply your knowledge to clinical situations. Furthermore, most chapters have A.D.A.M. Questions, which link to the A.D.A.M. (version 2.0) multimedia software that you may use for learning anatomy. Look for the **A.D.A.M. walking man symbol.**

Learning anatomy has been compared to learning a foreign language. Anyone taking an anatomy course must learn several thousand new names, most of which are in the form of long Greek and Latin words. To help you learn the vocabulary, important terms within the text are highlighted in bold or italic type. They are followed by a literal translation of the word meaning, and for hard-to-pronounce terms, a phonetic spelling.

We would appreciate hearing from you about your experiences with this textbook or suggestions for improvements in future editions. Please address your comments to the authors, Elaine N. Marieb and Jon Mallatt, c/o Benjamin/Cummings 2725 Sand Hill Road, Menlo Park, CA 94025.

We hope that you enjoy *Human Anatomy* and that this book makes learning about the body's structure an exciting and rewarding experience. Perhaps the best bit of advice we can give you is that memory depends on understanding. Thus, if you try to achieve understanding instead of rote memorization, your memory will not fail you very often.

Elaine N. Marieb and Jon Mallatt

Pronunciation Key

The pronunciations in this book are very easy to use *if you know the rules.* Our pronunciation key takes advantage of the fact that, in scientific terms, long vowels usually occur at the end of syllables, whereas short vowels usually occur at the beginning or in the middle of syllables. Therefore:

1. When vowels are *unmarked,* they have a long sound when they occur at the end of a syllable, and a short sound when they are at the beginning or in the middle of a syllable. For example, in the word *kidney* (kid′ne), you automatically know that the middle 'i' is short and the terminal 'e' sound is long. In the word *renal* (re′nal), the 'e' is long, and the 'a' is short.
2. When a vowel sound violates the above rule, it is marked with a short or long symbol. Only those short vowels that come at the end of a syllable are marked with the short symbol, called a breve (˘); and only those long vowels that occur at the start or middle of a syllable are marked with a long symbol (¯). For example, in the word *pelvirectal* (pel″vĭ-rek′tal), all four vowels are short, but only the 'i' is marked as short, because it is the only vowel that falls at the end of a syllable. In *methane* (meth′ān), the long 'a' is marked as such because it does not fall at the end of a syllable.
3. Short 'a' is *never* marked with a breve. Instead, short 'a' at the end of a syllable is indicated by 'ah'. For example, in the word *papilla* (pah-pil′ah), each 'a' is short and pronounced as 'ah'.
4. In words that have more than one syllable, the syllable with the strongest accent is followed by a prime (′) mark, and syllables with the second strongest accent, where present, are indicated with a double prime (″). The unaccented syllables are followed by dashes. An example of these principles is the word *anesthetic* (an″es-thet′ik), in which thet′ is emphasized most strongly, an″ has a secondary emphasis, and the other two syllables are not spoken with any emphasis.

Brief Contents