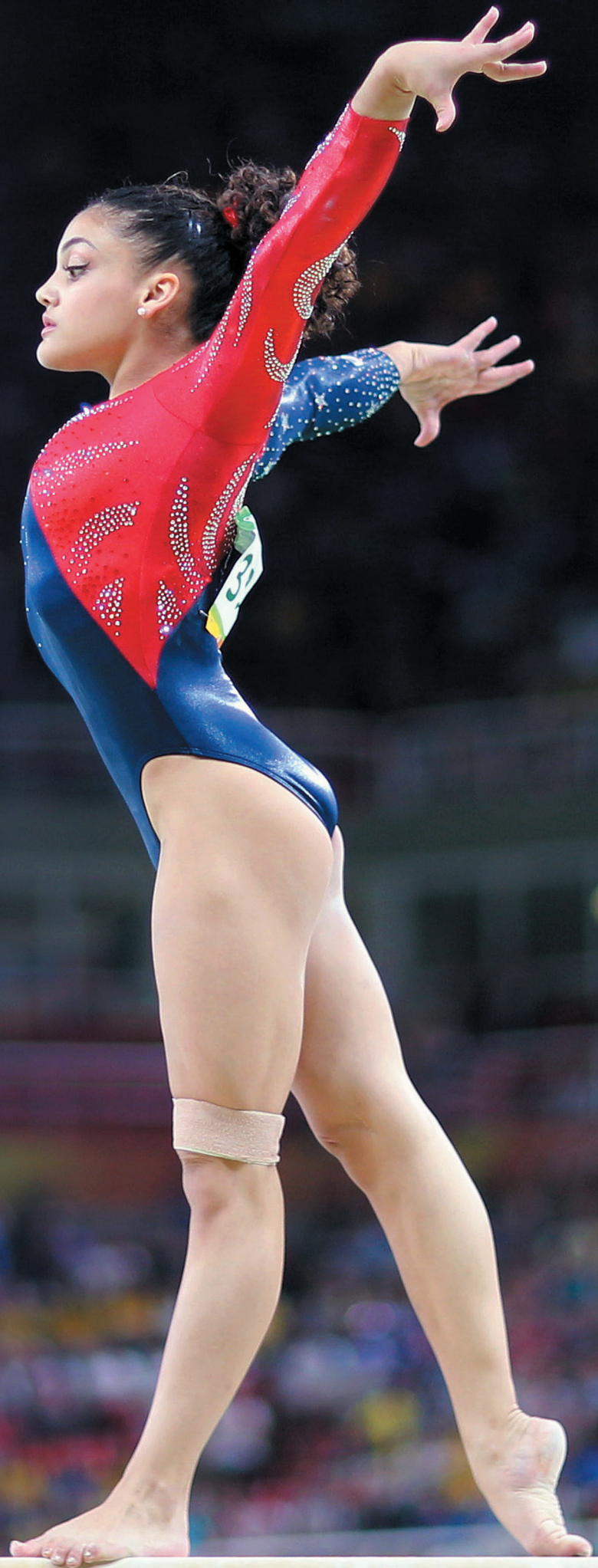


ELEVENTH EDITION

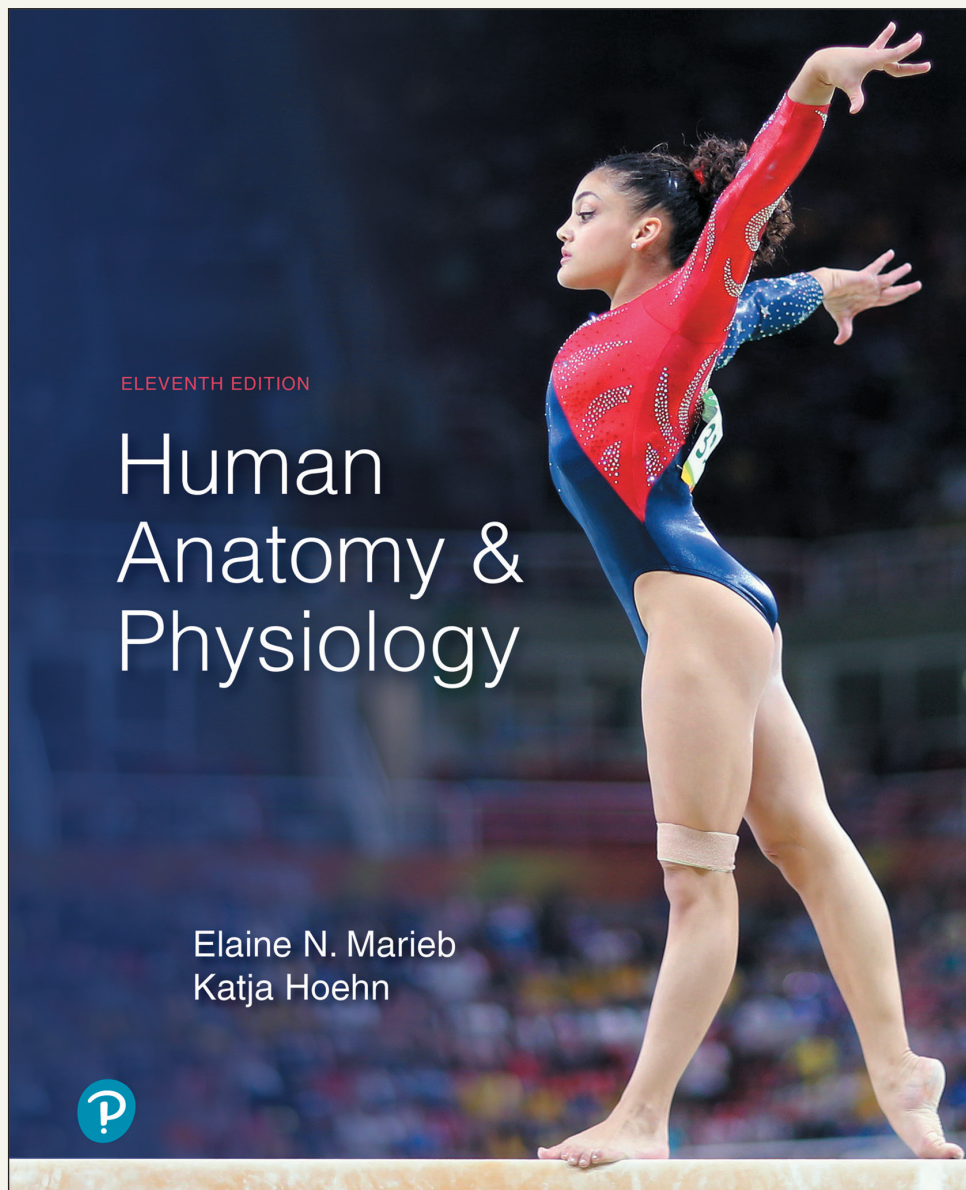
Human Anatomy & Physiology

Elaine N. Marieb
Katja Hoehn



Equipping You with 21st-Century Skills to Succeed in A&P *and Beyond...*

The **11th Edition** of Elaine Marieb and Katja Hoehn's best-selling A&P text and media program motivates and supports both novice learners and expert students, more than ever before. Each carefully-paced chapter guides you in advancing from mastering terminology to applying knowledge in clinical scenarios, to practicing the critical thinking and problem-solving skills that are required for entry to nursing, allied health, and exercise science programs.



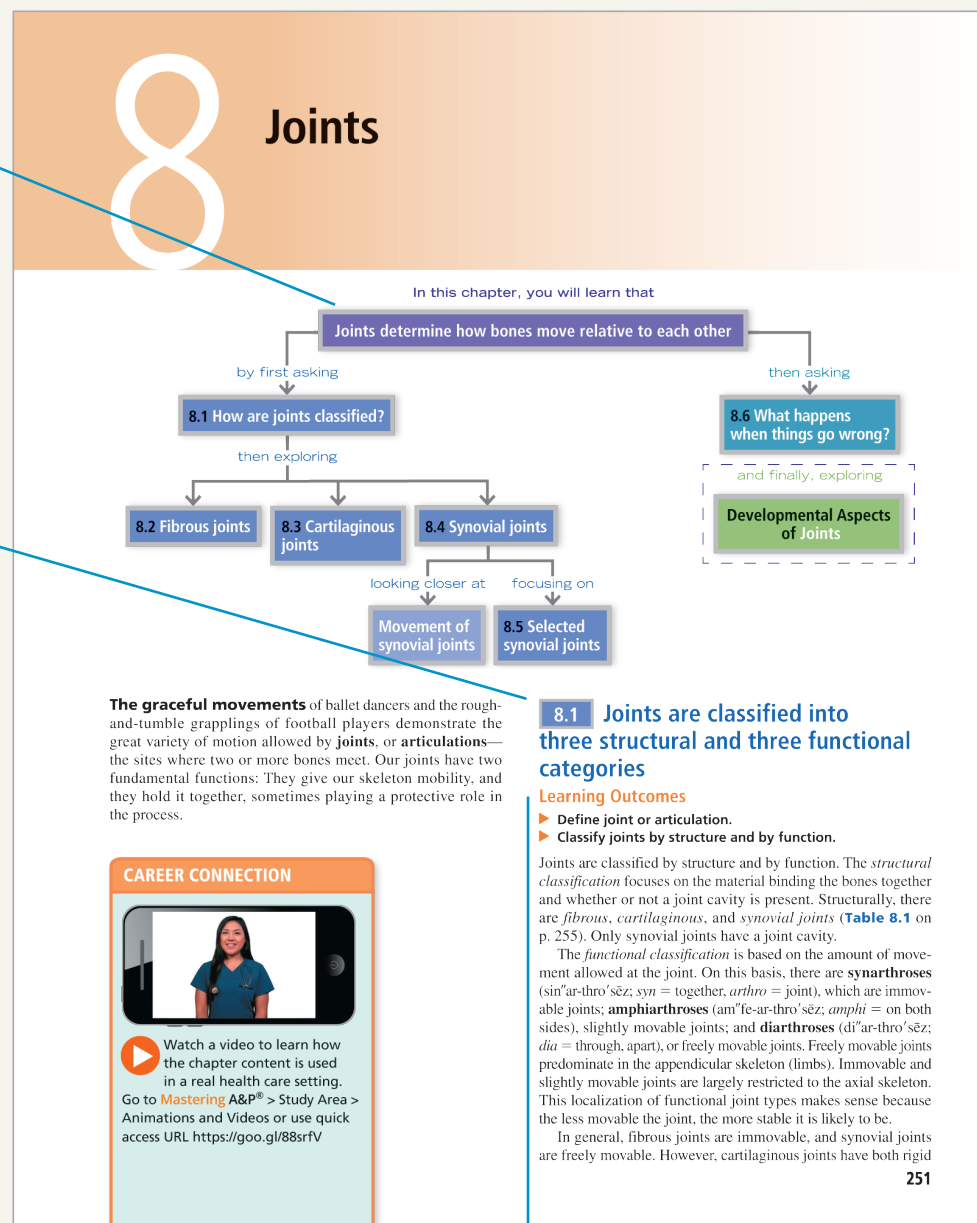
Identify “Big Picture” Concepts Before Exploring Details

Before you look up details and information within a chapter, read the **Chapter-Opening Roadmap**, which visually groups and organizes “big picture” concepts and shows how they are related. To focus your studying, review the numbered **Key Concept Headings**, **Learning Outcomes**, and summaries.

UNIQUE! Chapter Roadmaps provide a visual overview of the key concepts in the chapter and show how they relate to each other. Each key concept “brick” in the roadmap corresponds to a numbered section within the chapter.

Each numbered section within the chapter begins with a **Key Concept Heading** that helps you quickly grasp the “big idea” of the discussion that follows.

UPDATED! Career Connection Videos feature a health care professional who describes how the chapter content relates to their everyday work. You can access all of the Career Connections videos through an open access web page at <https://goo.gl/88srfV>.

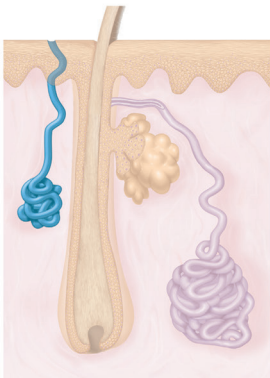
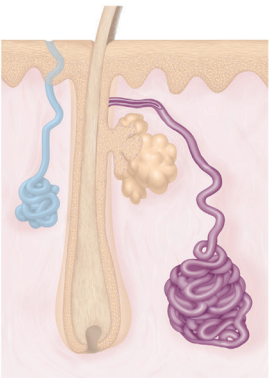
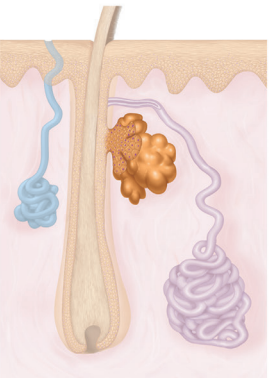


See p. 251

Learning Outcomes are presented at the beginning of each chapter section to give you a preview of essential information to study.

Pace Yourself: Learn & Review the Basics

EXPANDED! Summary Tables present key information and serve as “one-stop shopping” study tools. 13 new Summary Tables have been added to this edition.

	ECCRINE SWEAT GLANDS	APOCRINE SWEAT GLANDS	SEBACEOUS GLANDS
			
Functions	<ul style="list-style-type: none"> • Temperature control • Some antibacterial properties 	May act as sexual scent glands	<ul style="list-style-type: none"> • Lubricate skin and hair • Help prevent water loss • Antibacterial properties
Type of Secretion	Hypotonic filtrate of blood plasma	Filtrate of blood plasma with added proteins and fatty substances	Sebum (an oily secretion)
Method of Secretion	Merocrine (exocytosis)	Merocrine (exocytosis)	Holocrine
Secretion Exits Duct At	Skin surface	Usually upper part of hair follicle; rarely, skin surface	Usually upper part of hair follicle; sometimes, skin surface
Body Location	Everywhere, but especially palms, soles, forehead	Mostly axillary and anogenital regions	Everywhere except palms and soles

See p. 162

Sebaceous Glands

The **sebaceous glands** (se-ba'shus; “greasy”), or *oil glands* (Figure 5.9a), are simple branched alveolar glands that are found all over the body except in the thick skin of the palms and soles. They are small on the body trunk and limbs, but quite large on the face, neck, and upper chest. These glands secrete an oily substance called **sebum** (se'bum). The central cells of the alveoli accumulate oily lipids until they become so engorged that they burst, so functionally these glands are *holocrine glands* (◀ p. 126). The accumulated lipids and cell fragments constitute sebum.

NEW! Text Recall icons guide you to review specific pages where a concept was first introduced.

See p. 163

NEW! Building Vocabulary Coaching Activities in Mastering A&P® are a fun way to learn word roots and A&P terminology while building and practicing important language skills.

Study the Figures as You Read the Text

Anatomy and Physiology is a visual science. To succeed, you need to practice and develop visual literacy skills for understanding and interpreting information. To help you achieve this goal, the text and associated figures are tightly integrated so that you never have to flip pages back and forth to connect visuals with words.

EXPANDED! 6 new Focus Figures (for a total of 26) walk you through complex processes using exceptionally clear, easy-to-follow illustrations with integrated text explanations.

NEW Focus Figures are as follows:

3.1 The Plasma Membrane, pp. 64–65

11.4 Postsynaptic Potentials and Their Summation, pp. 418–419

16.2 Stress and the Adrenal Gland, pp. 628–629

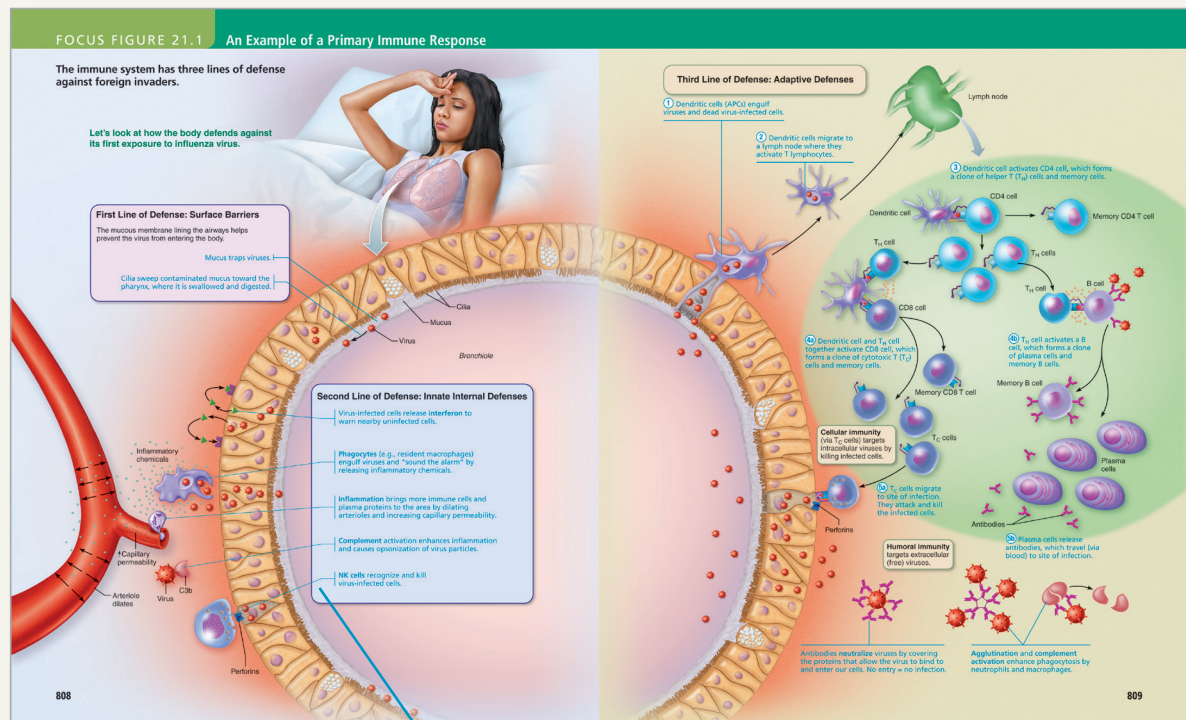
18.2 The Cardiac Cycle, pp. 694–695

21.1 An Example of a Primary Immune Response, pp. 808–809

28.2 Fetal and Newborn Circulation, pp. 1108–1109

See pp.
808–809

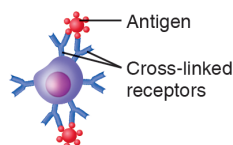
**NEW! Focus Figure
“Mini-Animation”
Coaching Activities**
bring the 6 new Focus
Figures to life using
short video segments.



Blue text represents the voice of an A&P instructor, highlighting important points to remember.

Activation and Differentiation of B Cells

An immunocompetent but naive B lymphocyte is *activated* when matching antigens bind to its surface receptors and cross-link adjacent receptors together. Antigen binding is quickly followed by receptor-mediated endocytosis of the cross-linked antigen-receptor complexes. As we described previously, this is called *clonal selection* and is fol-



**EXPANDED! 31 unique In-Line
Figures** are strategically placed within
the text to visually reinforce the text
discussion.

See p. 796

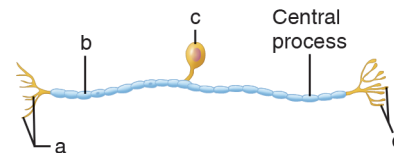
Apply Your Knowledge to a Range & Variety of Questions

As you build your knowledge and confidence in A&P, practice responding to the more challenging questions—you are likely to encounter similar questions on a test or licensing exam. Your extra effort will pay off at exam time!

NEW! A greater **variety and range of self-assessment questions** have been added to the **Check Your Understanding** sections within each chapter and include **Apply, Predict, What If?, Draw, and Make Connections**. Dozens of new **visual questions** ask you to label structures or interpret visual information.

Check Your Understanding

5. How does a nucleus within the brain differ from a nucleus within a neuron?
6. How is a myelin sheath formed in the CNS, and what is its function?
7. What is the structural classification of the neuron shown below? What is its usual functional classification? Name the parts labeled a–d.



8. **APPLY** Which structural and functional type of neuron is activated first when you burn your finger? Which type is activated last to move your finger away from the source of heat?
9. **MAKE CONNECTIONS** Which part of the neuron is its fiber? How do nerve fibers differ from the fibers of connective tissue (see Chapter 4) and the fibers in muscle (see Chapter 9)?

For answers, see Answers Appendix.

See p. 400

NEW! “Draw” questions ask you to create visuals that reinforce important concepts by drawing a structure, annotating a figure, or creating a summary table.

3. **DRAW** Create a summary table to help you study the pharynx by comparing and contrasting its three parts. For each part, identify what it conducts (air, food, or both), the type of epithelium found there, and the associated tonsils.

	Conducts	Epithelium	Tonsils
Nasopharynx	Air	Pseudostratified ciliated columnar	Pharyngeal Tubal
Oropharynx	Air and food	Stratified squamous	Palatine Lingual
Laryngopharynx	Air and food	Stratified squamous	— (none)

See p. 824 and Answers Appendix

NEW! All of the **End-of-Chapter Review questions** are now organized into 3 levels of difficulty based on **Bloom’s Taxonomy categories**:

Level 1: Remember/Understand
Level 2: Apply/Analyze
Level 3: Evaluate/Synthesize

Prepare for Your Future Career & Practice Solving Real-World Problems

The authors of this text, Elaine Marieb and Katja Hoehn, share insights from their own clinical experience to help you prepare for your future career in health care. All clinical examples and applications are signaled with an easy-to-find “Clinical” label.

UPDATED! Homeostatic Imbalance discussions alert you to the consequences of body systems not functioning optimally. Relevant photos have been added to selected discussions for visual reinforcement.



HOMEOSTATIC IMBALANCE 5.6

CLINICAL

Changes in nail appearance can help diagnose certain conditions. For example, yellow-tinged nails may indicate a respiratory or thyroid gland disorder. (Thickened yellow nails are usually due to a fungus infecting the nail.) An outward concavity of the nail (*koilonychia* or “spoon nail,” **Figure 5.8**) may signal an iron deficiency.



Figure 5.8 Koilonychia.

Horizontal lines (Beau’s lines) across the nails can be a sign of severe illness that affects the whole body such as uncontrolled diabetes, a heart attack, or cancer chemotherapy.

See p. 161

UPDATED! Clinical Case Studies are provided at the end of Chapters 5–29 and challenge you to apply your knowledge to realistic clinical scenarios.

NEW! Each Clinical Case Study includes “**NCLEX-Style**” questions for practice with the kinds of challenge questions that you will eventually encounter on a licensing exam. Practice answering these questions on your own or in collaboration with classmates. Your instructor can also assign **new NCLEX-Style questions in Mastering A&P®**, along with Homeostatic Imbalance questions, Clinical Case Study Coaching Activities, and Nurses Need Physiology Case Studies.

CLINICAL CASE STUDY

70-Year-Old Male with Polyuria

Mr. Gutteman, a 70-year-old male, was brought into the ER. He had been sick several days with the flu, and was found confused and barely conscious by his daughter.

Mr. Gutteman is breathing rapidly and has a fever of 39°C (102°F). His skin is dry and flaccid, his mucous membranes



are dry, and his eyes are sunken. The physician ordered:

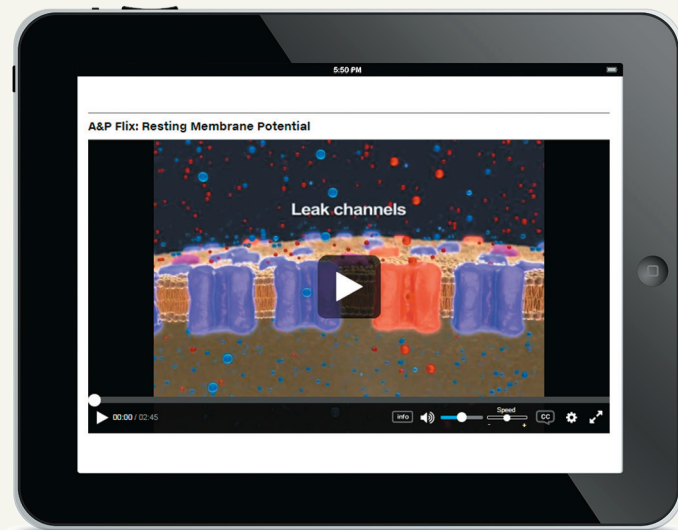
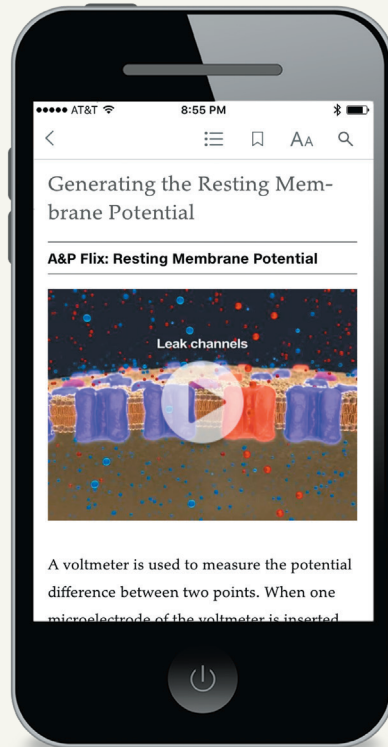
- IV (intravenous) fluid and electrolyte replacement
 - Blood and urine tests for presence of glucose and ketones
 - Strict I&O [careful measurement of fluid intake (e.g., IV, drinking) and output (e.g., urine)]
1. **+ NCLEX-STYLE** You would expect high levels of blood glucose and the presence of glucose and ketones in Mr. Gutteman’s urine if:
 - a. His pancreas is secreting too much insulin
 - b. His liver is secreting too little insulin
 - c. His pancreas is secreting too little insulin
 - d. His liver is secreting too much glucagon

See p. 641

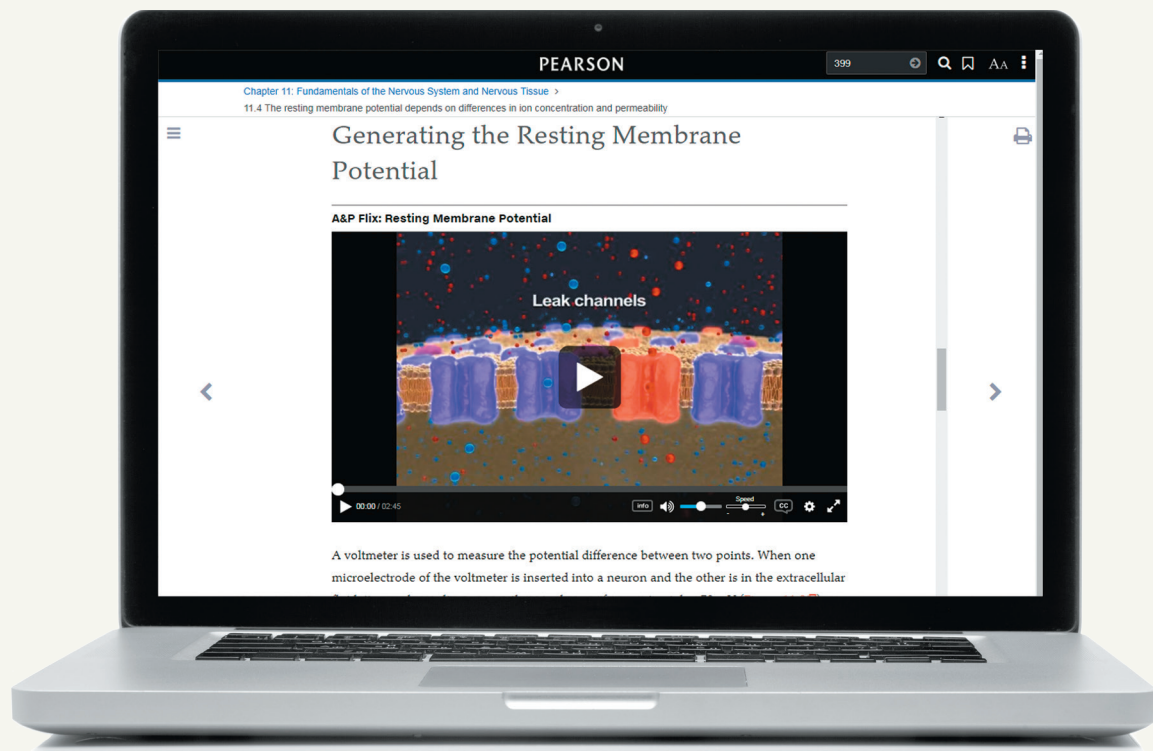
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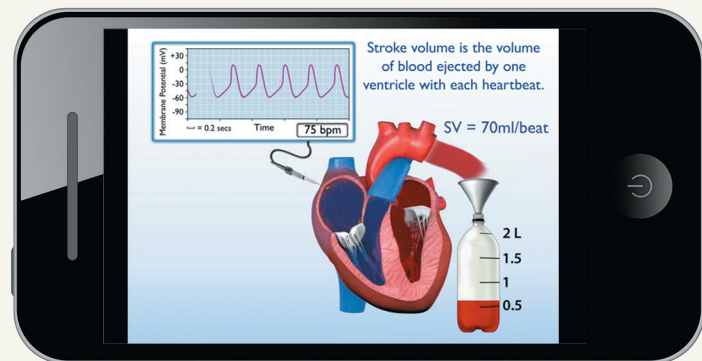
Powerful interactive and customization functions include instructor and student note-taking, highlighting, bookmarking, search, and links to glossary terms. The Marieb/ Hoehn eText also includes dozens of embedded videos and animations that bring A&P concepts to life.



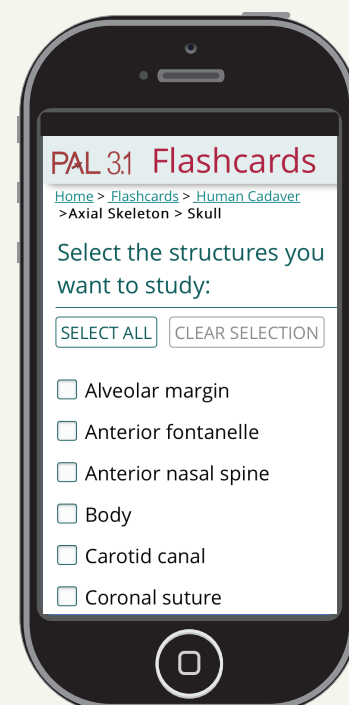
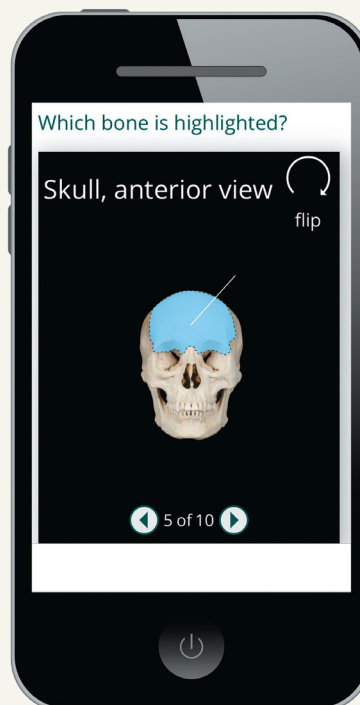
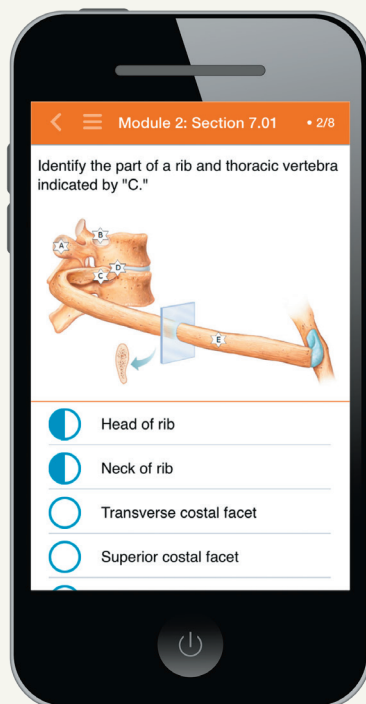
Get Online Practice and Coaching with Mastering A&P®

Mastering A&P® provides tutorials and review questions that you can access before, during, and after class.

EXPANDED! Interactive Physiology 2.0 Coaching Activities teach complex physiology processes using exceptionally clear animations, interactive tutorials, games, and quizzes. IP2 features new graphics, quicker navigation, and a mobile-friendly design. New topics include Generation of an Action Potential and Cardiac Cycle. IP2 and IP animations can be assigned from the Mastering A&P® item library or accessed through the Study Area.



NEW! PAL 3.1 Customizable Flashcards allow you to create a personalized, mobile-friendly deck of flashcards and quizzes using images from Practice Anatomy Lab. Use the checklist to select only those structures covered in your course.




Dynamic Study Modules are manageable, mobile-friendly sets of questions with extensive feedback for you to test, learn, and retest yourself on basic concepts. **NEW!** Instructors can select or deselect specific questions for assignments from more than 3,000 questions, organized by chapter section.

New for Instructors: Ready-to-Go Teaching Modules

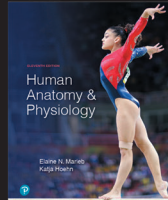

NEW! Ready-to-Go Teaching Modules help instructors efficiently make use of the best teaching tools before, during, and after class. Accessed through the Instructor Resources area of Mastering A&P® and prepared by expert A&P instructors, each module includes a variety of teaching ideas and ready-to-use resources for teaching 10 challenging course topics.











Marieb/Hoehn
Human Anatomy & Physiology, 11th Edition
**Ready-To-Go
Teaching Modules**



Ready-to-Go Teaching Modules make use of teaching tools for before, during, and after class, including new ideas for in-class activities.

The modules incorporate the best that the text, Mastering A&P™, and Learning Catalytics have to offer and guide instructors through using these resources in the most effective way.



 Skeletal System	 Neurophysiology
 Muscular System Physiology	 Kidney Physiology
 Nervous System	 Endocrine System
 Cardiovascular Physiology	 Respiratory System
 Digestive System	 Fluid, Electrolyte, and Acid/Base Balance

Learning Catalytics allows students to use their smartphone, tablet, or laptop to respond to questions in class. Visit learningcatalytics.com to learn more.



Mastering A&P[®]

Features and Access

Mastering A&P[®] offers thousands of tutorials, activities, and questions that can be assigned for homework and practice. Highlights of new assignment options include:

- **NEW! Building Vocabulary Coaching Activities** give you practice learning and using word roots in context as you learn new A&P terms.
- **NEW! Focus Figure “Mini-Animation” Coaching Activities** bring the 6 new Focus Figures to life and include assessment questions.
- **IMPROVED! Concept Map Coaching Activities** support the concept maps in the text without requiring students to submit their own concept map for grading.
- **NEW! NCLEX-Style Questions** give students practice with the kinds of questions that will eventually appear on a licensing exam.

The Mastering A&P[®] Instructor Resources Area includes the following downloadable tools for instructors who adopt the Eleventh Edition for their classes:

- **NEW! Ready-to-Go Teaching Modules** provide teaching tools for 10 challenging topics in A&P.
- **Customizable PowerPoint[®] lecture outlines** include customizable images and provide a springboard for lecture prep.
- **All of the figures, photos, and tables from the text** are available in JPEG and PowerPoint[®] formats, in labeled and unlabeled versions, and with customizable labels and leader lines.
- **Test bank** provides thousands of customizable questions across Bloom’s Taxonomy levels. Each question is tagged to chapter learning outcomes that can also be tracked within Mastering A&P[®] assessments. Available in Microsoft[®] Word and TestGen[®] formats.
- **Animations and videos** bring A&P concepts to life and include A&P Flix 3-D Animations.
- **A comprehensive Instructor Guide to Text and Media**, co-authored by Elaine Marieb and Laura Steele, includes a detailed teaching outline for each chapter, along with a wealth of activities, examples, and analogies that have been thoroughly class-tested with thousands of students.

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Human Anatomy & Physiology

ELEVENTH EDITION

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

Holyoke Community College

Katja Hoehn, M.D., Ph.D.

Mount Royal University



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Senior Courseware Portfolio Manager: Lauren Harp
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About the Authors

We dedicate this work to our students both present and past, who always inspire us to “push the envelope.”

Elaine N. Marieb

After receiving her Ph.D. in zoology from the University of Massachusetts at Amherst, Elaine N. Marieb joined the faculty of the Biological Science Division of Holyoke Community College. While teaching at Holyoke Community College, where many of her students were pursuing nursing degrees, she developed a desire to better understand the relationship between the scientific study of the human body and the clinical aspects of the nursing practice. To that end, while continuing to teach full time, Dr. Marieb pursued her nursing education, which culminated in a Master of Science degree with a clinical specialization in gerontology from the University of Massachusetts. It is this experience that has informed the development of the unique perspective and accessibility for which her publications are known.

Dr. Marieb has given generously to provide opportunities for students to further their education. She funds the E.N.

Marieb Science Research Awards at Mount Holyoke College, which promotes research by undergraduate science majors, and has underwritten renovation of the biology labs in Clapp Laboratory at that college. Dr. Marieb also contributes to the University of Massachusetts at Amherst, where she provided funding for reconstruction and instrumentation of a cutting-edge cytology research laboratory. Recognizing the severe national shortage of nursing faculty, she underwrites the Nursing Scholars of the Future Grant Program at the university.

In 2012 and 2017, Dr. Marieb gave generous philanthropic support to Florida Gulf Coast University as a long-term investment in education, research, and training for healthcare and human services professionals in the local community. In honor of her contributions, the university is now home to the Elaine Nicpon Marieb College of Health and Human Services.



Katja Hoehn

Dr. Katja Hoehn is a professor in the Department of Biology at Mount Royal University in Calgary, Canada. Dr. Hoehn's first love is teaching. Her teaching excellence has been recognized by several awards during her 24 years at Mount Royal University. These include a PanCanadian Educational Technology Faculty Award (1999), a Teaching Excellence Award from the Students' Association of Mount Royal (2001), and the Mount Royal Distinguished Faculty Teaching Award (2004).

Dr. Hoehn received her M.D. (with Distinction) from the University of Saskatchewan, and her Ph.D. in Pharmacology from Dalhousie University. In 1991, the Dalhousie Medical Research Foundation presented her with the Max Forman (Jr.) Prize for excellence in medical research. During her Ph.D. and postdoctoral studies, she also pursued her passion for teaching by presenting guest lectures to first- and second-year medical students at Dalhousie University and at the University of Calgary.

Dr. Hoehn has been a contributor to several books, written numerous research papers in Neuroscience and Pharmacology,

and has co-authored the previous four editions of this textbook. For many years, she has also reviewed and authored electronic media that accompanies Pearson anatomy and physiology books.

Following Dr. Marieb's example, Dr. Hoehn provides financial support for students in the form of a scholarship that she established in 2006 for nursing students at Mount Royal University.

Dr. Hoehn is also actively involved in the Human Anatomy and Physiology Society (HAPS) and is a member of the American Association of Anatomists. When not teaching, she likes to spend time outdoors with her husband and two sons. She also enjoys competing in long-course triathlons, and playing Irish flute down at the local pub.



Preface

Today's students have access to an enormous amount of information about anatomy and physiology. As educators, our biggest challenge is to help students focus on mastering the basic concepts of this field. Providing this firm foundation will help students to become lifelong learners who can critically evaluate new information, connect that information to the

foundation they have already established, and apply it in a clinical setting. How can we help students build a strong foundation in anatomy and physiology? We believe that this new edition of our textbook will help learners by building on the strengths of previous editions while using new and innovative ways to help students visualize connections between various concepts.

Unifying Themes

Three unifying themes that have helped to organize and set the tone of this textbook continue to be valid and are retained in this edition. These themes are:

Interrelationships of body organ systems. This theme emphasizes the fact that nearly all regulatory mechanisms have interactions with several organ systems. The respiratory system, for example, cannot carry out its role of gas exchange in the body if there are problems with the cardiovascular system that prevent the normal delivery of blood throughout the body. The System Connections feature and Make Connections questions throughout the book help students connect new information to old information and think of the body as a community of dynamic parts instead of a number of independent units.

Homeostasis. Homeostasis is the normal and most desirable condition of the body. Its loss is always associated with past or present pathology. This theme is not included to emphasize pathological conditions, but rather to illustrate what happens in the body “when things go wrong” and homeostasis is lost. Whenever students see a red balance beam symbol accompanied by an associated clinical topic, their understanding of how the body works to stay in balance is reinforced.

Complementarity of structure and function. This theme encourages students to understand the structure of some body part (ranging from a molecule to an organ) in order to understand the function of that structure. For example, muscle cells can produce movement because they are contractile cells.

New to the Eleventh Edition


New and augmented elements aim to help learners in the following ways.

To help students make connections between new and previously learned material. In order for students to master new concepts, they must link these new concepts with concepts they already understand. In this edition, we help them do this by adding:


- **Text recall icons (◀).** These icons direct the student back to the specific pages where a concept was first introduced.
- **Make Connections questions.** We've added more of this type of question to the Check Your Understanding review questions that follow each module within a chapter. To answer these questions, the student must employ concepts learned previously (most often in previous chapters).
- **New kinds of higher-level questions.** Each chapter now has at least five higher-level questions that require students to think more deeply, pulling together strands from multiple concepts. These questions are clearly identified as **APPLY**, **DRAW**, **PREDICT**, **MAKE CONNECTIONS**, and **WHAT IF?** questions.
- **New summary tables.** Students have told us that they want more summary tables. In response, 13 new summary tables (two with illustrations) have been added in order to help students see the big picture.

To enhance students' visual literacy. Anatomy is and has always been taught principally through images. Increasingly, however, physiological data is also represented as images, whether it be molecular interactions or graphical descriptions of

processes. Throughout their future health care careers, students will need to be able to understand and interpret information presented visually. In this edition, we help them do this by:

- **Adding new Focus figures.** Focus figures are illustrations that use a “big picture” layout and dramatic art to guide the student through difficult physiological processes in a step-by-step way. Our previous Focus figures have been a hit with both students and instructors. In response to requests for additional Focus figures, we are pleased to present six new two-page features.
- **Adding  questions in each chapter.** Students often think that they understand an illustration simply by looking at it, but to truly comprehend an illustration and cement its concepts requires a more active learning approach. For this reason we now include at least one higher-level review question within each chapter that requires a student either to draw an illustration or to add to an existing diagram.
- **Adding questions about illustrations.** To help students practice their visual literacy skills, we have added 47 new Check Your Understanding questions that include an illustration as part of the question. Some of these are as simple as labeling exercises, but many require more advanced interpretation.
- **Updating art to improve its teaching effectiveness.** As always, this is a major part of the revision. Today’s students are accustomed to seeing sophisticated photorealistically rendered images. However, many students are not adept at extracting, and thinking critically about, the relevant information contained in such illustrations. With this in mind we continue to refine and update our illustrations as students’ needs change, improving their ability to teach important concepts. In many cases we have added blue “instructor’s voice” text within the figure to guide a student through it, replacing much of the more remote figure legend. In addition, new photos were painstakingly chosen and labeled to enhance the learning process.
- **Adding new illustrations to existing tables and adding new illustrated tables.** Students find illustrated tables particularly effective because they provide a visual cue that helps them remember a topic. In this edition, we have added illustrations to two tables and added two new illustrated tables.
- **Adding in-line figures.** These are small (less than a half-column wide) illustrations or photos strategically located within the text that discuss the concept they illustrate. This edition now has 31 such in-line figures, most of them newly added.

To help students clinically apply what they have learned

- **Updated Homeostatic Imbalance features.** Many of the Homeostatic Imbalance features have been updated and relevant photos have been added to some. All have been reviewed for accuracy and relevancy. In addition, the updated book design makes these features stand out more clearly.
- **Updated Clinical Case Studies in Chapters 5-29 with added new  questions.** The end-of-chapter

review questions, which are now organized into three levels of difficulty based on Bloom’s Taxonomy categories, culminate in a clinical case study that allows students to apply some of the concepts they have learned to a clinical scenario. These case studies have been extensively revised and each case study has two questions that are similar in style to those in the NCLEX exam.

- **New clinically relevant photos.** We have added or updated a number of photos that have clinical relevance (procedures, conditions, etc.) that will help students apply what they are reading to real-life situations and to their future careers.

In this edition, certain chapters have received the bulk of our attention and have been more heavily revised. As you can see in the Highlights of New Content (below), these are Chapters 2–4, 9, and 27–29.

As in the previous edition, we have taken painstaking care to ensure that almost all the text and the associated art are covered on the same two-page spread. Although this sounds like a simple goal, it actually takes a great deal of work and has not usually been achieved by other textbooks. We make this effort because it is invaluable to student learning to not have to flip pages back and forth between art and text. Finally, you will notice the appearance of new icons referencing MasteringA&P® interspersed within the text. This guides students to go to the relevant on-line activities to supplement their learning.

Other Highlights of New Content

Chapter 1 The Human Body: An Orientation

- New Figure 1.1 illustrates complementarity of structure and function.
- Updated *A Closer Look* feature on types of medical imaging and added five new photos.
- New Homeostatic Imbalance features about hiatal hernias and about “wrong site surgery.”

Chapter 2 Chemistry Comes Alive

- New Homeostatic Imbalance feature about patient’s pH predicting outcome of CPR.
- New figures illustrate triglyceride structure (2.16); the difference between saturated and unsaturated fatty acids (2.17); phospholipids (2.18); and protein functions (2.20).
- Revised Figures 2.6 (formation of ionic bonds) and 2.12 (dissociation of salt in water) teach more effectively.
- New summary tables reinforce information about chemical bonds (Table 2.2) and about macromolecules and their monomers and polymers (Table 2.5).

Chapter 3 Cells: The Living Units

- Added Focus Figure 3.1 about the plasma membrane, and reorganized accompanying text.
- Reorganized text about passive membrane transport for improved clarity; updated and reorganized discussion of autophagy and apoptosis.
- Updated information about Tay-Sachs disease.

- New micrographs show micro- and intermediate filaments (Figure 3.20).
- Improved teaching effectiveness of Figures 3.5 (diffusion), 3.17 (processing and distribution of newly synthesized proteins), and 3.30 (stages of transcription).
- New information about telomeres in cancer cells.
- New Homeostatic Imbalance feature about progeria.

Chapter 4 Tissue: The Living Fabric

- New images of cilia show the difference between transmission and scanning electron microscopy (Figure 4.2).
- New in-line figure illustrates apical and basal surfaces of epithelial cells.
- Revised art for epithelial and connective tissue for clarity (Figures 4.4 and 4.11).
- New Figure 4.5 shows how exocrine and endocrine glands differ, and new Figure 4.10 gives an overview of the classification of connective tissue.
- Updated *A Closer Look* feature about cancer.

Chapter 5 The Integumentary System

- New illustrated summary table comparing cutaneous glands (Table 5.1).
- Revised Figures 5.3 and 5.4 for better teaching effectiveness.
- Updated information about skin color and disease states.
- Updated Homeostatic Imbalance features about hirsutism and about hair loss.
- New Homeostatic Imbalance feature about nail changes with disease.
- Updated statistics for and treatment of melanoma, with new photo (Figure 5.11c).

Chapter 6 Bones and Skeletal Tissues

- New summary Table 6.1 compares cartilage and bone tissue.
- New photos of an osteoclast (Figure 6.7); of a femur in longitudinal section to show compact and spongy bone (Figure 6.3); and of a section of a flat bone (skull bone) (Figure 6.4 top).
- Extensive revision of Figure 6.12, which teaches bone growth at epiphyseal plates, including new X ray to show epiphyseal plates, and new photomicrograph of epiphyseal cartilage.
- Updated information about bone remodeling, hormonal regulation of bone growth, and osteoporosis.

Chapter 7 The Skeleton

- New drawings to illustrate the location of the true and false pelvis, and the pelvic inlet and outlet (Figure 7.33).
- Updated Homeostatic Imbalance features about pes planus (flat feet) and about developmental dysplasia of the hip.
- New photos of bimalleolar fracture (Figure 7.35) and of cleft lip and palate (Figure 7.39).

Chapter 8 Joints

- New Homeostatic Imbalance feature about shoulder dislocations.
- New Table 8.3 summarizes movements at synovial joints.

- Revised Figure 8.4 (bursae and tendon sheaths).
- Updated *A Closer Look* about prostheses.

Chapter 9 Muscles and Muscle Tissue

- New “Background and Overview” section begins the discussion of the mechanisms of excitation and contraction of skeletal muscle, including a new “big picture” overview in Figure 9.7.
- New introduction to ion channels with art helps students understand skeletal muscle excitation and contraction.
- Reorganized discussions of graded muscle contractions and of smooth muscle, including new Figure 9.24 showing calcium sources for smooth muscle contraction.
- Updated discussion of muscle fatigue.
- Updated Homeostatic Imbalance feature on Duchenne muscular dystrophy.
- Updated *A Closer Look* feature about anabolic steroids.

Chapter 10 The Muscular System

- Revised art about levers for clarity (Figure 10.2 and 10.3).
- New cadaver dissection photos show dissection of muscles of the anterior neck and throat, superficial muscles of the thorax and shoulder in posterior view, and posterior muscles of the thigh and hip (Figures 10.9, 10.14, and 10.21).
- New photos illustrate thumb movements and show torticollis.

Chapter 11 Fundamentals of the Nervous System and Nervous Tissue

- New Focus Figure 11.4 illustrates postsynaptic potentials and their summation.
- Improved teaching effectiveness of Figure 11.12 (coding of action potentials for stimulus intensity) and Figure 11.19 (illustrating a reflex).
- New information about synthetic opiates in *A Closer Look*, with new PET scans showing effects of drug addiction.
- Added new research findings associating synaptic pruning and development of schizophrenia.

Chapter 12 The Central Nervous System

- New Figure 12.26 and revised text teach more effectively about the blood brain barrier.
- New Figure 12.30 shows spinal cord segment location in relation to vertebral column.
- New Table 12.2 summarizes spinal cord cross-sectional anatomy.
- Updated Homeostatic Imbalance features about hypothalamic disorders, cerebral palsy, anencephaly, and spina bifida, and about narcolepsy and insomnia, including new use of orexin receptor antagonists to treat insomnia.
- New type of MRI photo shows fiber tracts in brain and spinal cord.

Chapter 13 The Peripheral Nervous System and Reflex Activity

- New drawings of nerves of cervical, brachial, lumbar, and sacral plexuses show their position in relationship to the vertebrae (and hip bone in some cases) (Figures 13.9–13.12).

- New images illustrating the results of damage to the ulnar and radial nerves.
- New summary table of nerve plexuses (Table 13.7).
- New Homeostatic Imbalance feature and photo about an abnormal plantar reflex (Babinski's sign).
- Redrawn figure illustrating crossed-extensor reflex for improved student understanding.

Chapter 14 The Autonomic Nervous System

- New Figure 14.8 shows sympathetic innervation of the adrenal medulla.
- Clarified section about visceral sensory neurons.
- New photo illustrates Raynaud's disease.
- Revised Figure 14.5 on the sympathetic trunk for better teaching effectiveness.

Chapter 15 The Special Senses

- Revised Figure 15.2 (the lacrimal apparatus) for better teaching effectiveness.
- New photo of fundus of retina (Figure 15.7).

Chapter 16 The Endocrine System

- New Table 16.1 compares the endocrine and nervous systems.
- New Focus Figure 16.2 describes short- and long-term stress responses.
- Figures 16.5 (effects of growth hormone) and 16.9 (synthesis of thyroid hormone) revised for clarity.
- Updated information about diabetes mellitus, Addison's disease, and thyroid deficiency in childhood.

Chapter 17 Blood

- Updated information about anticoagulant medications.
- New photo shows petechiae resulting from thrombocytopenia (Figure 17.16).

Chapter 18 The Cardiovascular System: The Heart

- New Focus Figure 18.2 teaches students how to understand the cardiac cycle, with accompanying text reorganized.
- New photo shows an individual having an ECG (Figure 18.16).

Chapter 19 The Cardiovascular System: Blood Vessels

- New "drinking straw" analogy and art to explain resistance.
- New Figure 19.4 shows the structure of most capillary beds according to current understanding, and new text describes those capillary beds.
- Revised Figure 19.6 on proportions of blood volume throughout the vascular tree for greater teaching effectiveness.
- New illustration of cerebral arterial circle (circle of Willis) (Figure 19.24).

Chapter 20 The Lymphatic System and Lymphoid Organs and Tissues

- New illustrated Table 20.1 summarizes key characteristics of the major lymphoid organs.
- Revised Figure 20.9 with orientation diagrams helps students locate Peyer's patches (aggregated lymphoid nodules).
- Updated information about lymphatic drainage of the CNS.

Chapter 21 The Immune System: Innate and Adaptive Body Defenses

- New Focus Figure 21.1 gives an example of a primary immune response and summarizes innate and adaptive defenses.
- New illustrated Table 21.8 summarizes the components of adaptive immunity and complements the new Focus figure.
- New photo of a macrophage engulfing bacteria.
- Revised Figure 21.4 and text on inflammation, Figure 21.6 on complement activation, and Figure 21.11 on clonal selection of a B cell for greater teaching effectiveness.

Chapter 22 The Respiratory System

- New Figure 22.1 illustrates the four respiratory processes.
- Added section about sleep apnea.
- New scanning electron micrographs of emphysematous and normal lung tissue (Figure 22.22).
- Updated statistics about lung cancer and trends in asthma prevalence.

Chapter 23 The Digestive System

- New Figure 23.25 teaches the enterohepatic circulation of bile salts, and new Figure 23.30 shows the macroscopic anatomy of the small intestine.
- Improved teaching effectiveness of Figure 23.7 (neural reflex pathways in the gastrointestinal tract) and 23.16 (microscopic anatomy of the stomach).
- Added Homeostatic Imbalance features about dry mouth (xerostomia) and about tooth decay in primary teeth.
- Updated Homeostatic Imbalance feature about acute appendicitis to state that surgery is no longer always the first choice of treatment.

Chapter 24 Nutrition, Metabolism, and Energy Balance

- New Figure 24.24 shows the size and composition of various lipoproteins.
- Improved teaching effectiveness of Figure 24.21 (insulin effects during the postabsorptive stage).
- Updated Homeostatic Imbalance features with mechanism of cell death in frostbite, and diet recommendations for individuals with phenylketonuria.
- New information about environmental factors that may contribute to the obesity epidemic in *A Closer Look*.
- Updated nutritional information about lipids, and updated statistics about the prevalence of obesity in adults and children and about the prevalence of diabetes mellitus.

Chapter 25 The Urinary System

- New Figure 25.18 shows the medullary osmotic gradient and interstitial fluid osmolalities in the renal cortex and medulla.
- New Table 25.1 summarizes the regulation of glomerular filtration rate.
- Improved teaching effectiveness of Figures 25.9 (blood vessels of the renal cortex), 25.12 (the filtration membrane), 25.15 (routes for tubular reabsorption), and 25.16 (tubular reabsorption of water and nutrients).

- New pyelogram shows anatomy of kidneys, ureters, and urinary bladder (Figure 25.23).
- Added Homeostatic Imbalance feature about renal trauma.
- Updated Homeostatic Imbalance feature about kidney stones.

Chapter 26 Fluid, Electrolyte, and Acid-Base Balance

- New Figure 26.12 summarizes the body's chemical buffers.
- Improved teaching effectiveness of Figure 26.1 (major fluid compartments of the body), 26.2 (electrolyte composition of blood plasma, interstitial fluid, and intracellular fluid), and 26.7 (disturbances in water balance).
- Clarified definitions of sensible and insensible water loss.

Chapter 27 The Reproductive System

- This chapter has been extensively updated, revised, and reorganized. Almost every figure has been reconceptualized and several new figures have been added. These changes have been made for better teaching effectiveness.
- New opening module now compares male and female reproductive system anatomy and physiology and highlights common features, allowing students to make connections more easily. Homologous structures, patterns of hormone release, and meiosis are included in this section.
- New Figure 27.1 illustrates the basic pattern of interactions along the hypothalamic-pituitary-gonadal (HPG) axis in both males and females.
- The section about meiosis has been extensively rewritten to help increase student understanding. New in-line figures help introduce the basic terminology and some of the concepts before meiosis is discussed in detail.
- A new big-picture overview of meiosis introduces the major events before the details of each step are presented.
- Figures 27.22 (events of oogenesis) and 27.24 (regulation of the ovarian cycle) are extensively revised and updated for increased teaching effectiveness and accuracy.
- New Figure 27.26 depicts the genetic determination of sex.

Chapter 28 Pregnancy and Human Development

- New photo of sperm surrounding an oocyte (Figure 28.2).
- New Figure 28.5 illustrates implantation of a blastocyst.
- New photo of a 22-day embryo illustrates lateral folding (Figure 28.10d).
- Figure 28.12 (neurulation and early mesodermal differentiation) revised for clarity.
- New Focus Figure 28.2 (*Focus on Fetal and Newborn Circulation*) teaches the special features of fetal circulation and changes that occur in this circulation after birth.
- New Table 28.1 summarizes the special structures of the fetal circulation, their functions, and their postnatal structure.
- Updated information about placental hormone secretion and about the hormonal control of the initiation of labor.
- New information about fetal cells that enter the maternal circulation.
- New Homeostatic Imbalance feature about preeclampsia.

Chapter 29 Heredity

- Added Punnett square showing X-linked inheritance.
- Figure 29.1 (preparing a karyotype) and 29.4 (genotype and phenotype probabilities) revised for clarity.
- New photo of a couple with achondroplasia.
- Updated information about small noncoding RNAs.
- It has become increasingly clear that very few benign traits in humans follow a simple dominant-recessive inheritance pattern. Tongue rolling, astigmatism, freckles, dimples, phenylthiocarbamide tasting, widow's peak, and double-jointed thumb were all at one time thought to follow this pattern of inheritance. Closer examination has revealed compelling evidence against each of these. Consequently, the examples throughout the chapter have changed.

Acknowledgments

Producing a new edition of this book is an enormous undertaking. Let us take you through the steps and introduce you to the people behind the scenes that have helped make this book what it is. Every new edition begins with a revision plan. We'd like to thank all of the students and instructors who have provided the feedback (gathered by our editorial team) that forms the basis of this plan. Once this plan was in place, Barbara Price (our text Development Editor) scoured each chapter. This was Barbara's first exposure to the book and her fresh eyes on the text found opportunities to further clarify the presentation. In addition, she noted places where additional chunking of the text (such as bulleted lists) would help the students. Her excellent work has made this text better. We incorporated her ideas, and reviewer feedback, together with our own updates and ideas for reorganization of the text and art. Thanks to Patricia Bowne for contributing to the Clinical Case Studies and Wendy Mercier for reviewing all of the Case Studies. We also very much appreciate the help of Karen Dougherty, who used her expertise as a physician and educator to review all of the Homeostatic Imbalance features and help us revise and update them.

We then laid out each chapter to maintain text-art correlation before passing the manuscript off to Michele Mangelli. Michele wore many different hats during this revision. She was both the Program Manager for the editorial side of things as well as the Goddess of Production. She reviewed the revised manuscript before she sent it to ace copyeditor Anita Hueftle. Anita saved us on many occasions from public embarrassment by finding our spelling and grammar errors, our logical lapses, and various other inconsistencies. We can't thank Anita enough for her meticulous and outstanding work! (Any remaining errors are our fault.)

At the same time the text was in revision, the art program was going through a similar process. This book would not be what it is without the help of Laura Southworth, our superb Art Development Editor. Laura's creativity, attention to detail, and her sense of what will teach well and what won't have helped us immensely. She has worked tirelessly to make our Focus figures and other art even better. Finding good, usable photos is never easy, and we are grateful for the hard work of Kristin Piljay (Photo Researcher). It was also a pleasure to work with Jean Lake again, who expertly juggled the administrative aspects of the art program and kept us all on track. This team ensured that the artists at Imagineering had all the information they needed to produce beautiful final art products.

As the manuscript made the transition from Editorial to Production, Michelle Mangelli (wearing a different hat—this

one as the Production and Design Manager) took over again. As head honcho and skilled handler of all aspects of production, everyone answered to her from this point on. Kudos to our excellent production coordinator, Karen Gulliver, who did much of the hands-on handling, routing, and scheduling of the manuscript. We'd also like to thank Martha Ghent (Proofreader), Betsy Dietrich (Art Proofreader), Sallie Steele (Indexer), Alicia Elliot (Project Manager at Imagineering), and Cenveo (Compositor). Izak Paul meticulously read every chapter for scientific accuracy, and we are very grateful for his careful work. Thanks also to Gary Hespenheide for his stunning design work on the cover, chapter opening pages, and the text.

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Kudos to our entire team. We feel we have once again prepared a superb textbook. We hope you agree.

Many people reviewed parts of this text—both professors and students, either individually or in focus groups—and we would like to thank them. Input from the following reviewers has contributed to the continued excellence and accuracy of this text and its accompanying MasteringA&P® assignment options, including Interactive Physiology 2.0:

Matthew Abbott, *Des Moines Area Community College*

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Lynne Anderson, *Meridian Community College*

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 J. Gordon Betts, *Tyler Junior College*
 Diana Bourke, *Community College of Allegheny County*
 Sherry Bowen, *Indian River State College*
 Michael Brady, *Columbia Basin College*
 Betsy Brantley, *Valencia College*
 Beth Braun, *Truman College*
 Carol A. Britson, *University of Mississippi*
 C. Steven Cahill, *West Kentucky Community and Technical College*
 Christie Campbell, *Ozarks Technical Community College*
 Maria C. Carles, *Northern Essex Community College*
 Tamyra Carmona, *Cosumnes River College*
 Marien Cendon, *Miami Dade College*
 Brendon Chastain, *West Kentucky Community Technical College*
 Sam Chen, *Moraine Valley Community College*
 Alexander G. Cheroske, *Mesa Community College–Red Mountain*
 Brandi Childress, *Georgia Perimeter College*
 William M. Clark, *Lone Star College–Kingwood*
 Joseph Comber, *Villanova University*
 Teresa Cowan, *Baker College–Auburn Hills*
 Donna Crapanzano, *Stony Brook University*
 Maurice M. Culver, *Florida State College at Jacksonville*
 Jason Dechant, *University of Pittsburgh*
 Smruti A. Desai, *Lone Star College–CyFair*
 Karen H. Dougherty, *Hopkinsville Community College*
 Sondra Dubowsky, *McLennan Community College*
 Karen Dunbar Kareiva, *Ivy Tech Community College*
 Kathryn Durham, *Lorain County Community College*
 Karen Eastman, *Chattanooga State Community College*
 Sharon S. Ellerton, *Queensborough Community College–CUNY*
 Paul Emerick, *Monroe Community College*
 Elyce Ervin, *University of Toledo*
 Martha Eshleman, *Pulaski Technical College*
 Colin Everhart, *St. Petersburg Community College*
 Brian D. Feige, *Mott Community College*
 Michele Finn, *Monroe Community College*
 John E. Fishback, *Ozarks Technical Community College*
 Maria Florez, *Lone Star College–CyFair*
 Reza Forough, *Bellevue College*
 Juanita A. Forrester, *Chattahoochee Technical College*
 Aaron Fried, *Mohawk Valley Community College*

Dean Furbish, *Wake Technical Community College*
 Marie Gabbard, *College of Western Idaho*
 Sophia Garcia, *Tarrant County College*
 Jane E. Gavin, *University of South Dakota*
 Peter Germroth, *Hillsborough Community College*
 Emily K. Getty, *Ivy Tech Community College*
 Amy Giesecke, *Chattahoochee Technical College*
 Anna Gilletly, *Central New Mexico Community College*
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 Richard Gonzalez-Diaz, *Seminole State College of Florida*
 Abigail Goosie, *Walters State Community College*
 Pattie S. Green, *Tacoma Community College*
 Edwin Griff, *University of Cincinnati*
 George G. Hanak, *Pasco-Hernando State College*
 Mary Beth Hanlin, *Des Moines Area Community College–Boone*
 Heidi Hawkins, *College of Southern Idaho*
 Martie Heath-Sinclair, *Hawkeye Community College*
 Nora Hebert, *Red Rocks Community College*
 Nadia Hedhli, *Hudson County Community College*
 D.J. Hennager, *Kirkwood Community College*
 Jennifer Hill, *Montgomery College–Takoma Park–Silver Spring*
 Shannon K. Hill, *Temple College*
 Mark Hollier, *Georgia Perimeter College*
 H. Rodney Holmes, *Waubensee Community College*
 Mark J. Hubley, *Prince George’s Community College*
 Carolyn Huffman, *Wichita Area Technical College*
 Julie Huggins, *Arkansas State University*
 Jason Hunt, *Brigham Young University–Idaho*
 Alexander Ibe, *Weatherford College*
 Alexander Imholtz, *Prince George’s Community College*
 Virginia Irintcheva, *Black Hawk College*
 Brian E. Jordan, *C.S. Mott Community College*
 Thomas Jordan, *Pima Community College*
 Christopher Jung, *University of Alaska Anchorage*
 William M. Karkow, *University of Dubuque*
 Suzanne Keller, *Indian Hills Community College*
 Michael Kielb, *Eastern Michigan University*
 Marta Klesath, *North Carolina State University*
 Nelson H. Kraus, *University of Indianapolis*
 Paul M. Lea IV, *Northern Virginia Community College*
 Steven Lewis, *Metropolitan Community College–Penn Valley*
 Juanita Limas, *Kirkwood Community College*
 Jerri K. Lindsey, *Tarrant County College–Northeast*
 Chelsea Loafman, *Central Texas College*
 Paul Luyster, *Tarrant County College*
 Ken Malachowsky, *Florence-Darlington Technical College*
 Theresa Martin, *College of San Mateo*
 Nicole Mashburn, *Calhoun Community College*
 Abdallah M. Matari, *Hudson County Community College*
 Bhavya Mathur, *Chattahoochee Technical College*

Tiffany Beth McFalls-Smith, *Elizabethtown Community and Technical College*
Jennifer Menon, *Johnson County Community College*
Jaime Mergliano, *John Tyler Community College*
Sharon Miles, *Itawamba Community College*
Todd Miller, *Hunter College of CUNY*
Louise Millis, *North Hennepin Community College*
Justin Moore, *American River College*
Christine Morin, *Prince George's Community College*
Qian F. Moss, *Des Moines Area Community College*
Regina Munro, *Chandler-Gilbert Community College*
Necia Nicholas, *Calhoun Community College*
Maria Oehler, *Florida State College–Jacksonville*
Betsy Ott, *Tyler Junior College*
Ellen Ott-Reeves, *Blinn College–Bryan*
Stephen Page, *Community College of Baltimore County & Townson University*
Vikash Patel, *Nevada State College*
Dennis Pearson, *Morton College*
Diane Pelletier, *Green River Community College*
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Jason Pienaar, *University of Alabama*
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Brian Sailer, *Central New Mexico Community College*
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Mark Schmidt, *Clark State Community College*
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Amy Skibiel, *Auburn University*
Lori Smith, *American River College–Los Rios*
Kerry Smith, *Oakland Community College–Auburn Hills*
Tom Sobat, *Ivy Tech Community College*
Kay Sourbeer, *Tidewater Community College*
Ashley Spring-Beerensson, *Eastern Florida State College*
Justin R. St. Juliana, *Ivy Tech Community College*
Cindy Stanfield, *University of South Alabama*
Laura Steele, *Ivy Tech Community College–Northeast*
George A. Steer, *Jefferson College of Health Sciences*
Michelle Stettner, *Meridian Community College*
Sherry Stewart, *Navarro College*

Susan E. Tappen, *Central New Mexico Community College*
Dean Thornton, *South Georgia State College*
Rita A. Thrasher, *Pensacola State College*
Brenda Tondi, *George Mason University*
Sheela Vemu, *Waubensee Community College*
Khursheed Wankadiya, *Central Piedmont Community College*
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We really would appreciate hearing from you concerning your opinion—suggestions and constructive criticisms—of this text. It is this type of feedback that will help us in the next revision and underlies the continued improvement of this text.



Elaine Marieb



Katja Hoehn

Elaine N. Marieb and Katja Hoehn
 Pearson Education
 1301 Sansome Street
 San Francisco, CA 94111

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