

Human Anatomy & Physiology

Ninth Edition

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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

For Elaine N. Marieb, taking the student’s perspective into account has always been an integral part of her teaching style. Dr. Marieb began her teaching career at Springfield College, where she taught anatomy and physiology to physical education majors. She then joined the faculty of the Biological Science Division of Holyoke Community College in 1969 after receiving her Ph.D. in zoology from the University of Massachusetts at Amherst. 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 partnered with Benjamin Cummings for over 30 years. Her first work was *Human Anatomy & Physiology Laboratory Manual (Cat Version)*, which came out in 1981. In the years since, several other lab manual versions and study guides, as well as the softcover *Essentials of Human Anatomy & Physiology* textbook, have hit the campus bookstores. This textbook, now in its 9th edition, made its appearance in 1989 and is the latest expression of her commitment to the needs of students studying human anatomy and physiology.

Dr. Marieb has given generously to provide opportunities for students to further their education. She contributes to the New Directions, New Careers Program at Holyoke Community College by funding a staffed drop-in center and by providing several full-tuition scholarships each year for women who

are returning to college after a hiatus or attending college for the first time and who would be unable to continue their studies without financial support. She funds the E. N. Marieb Science Research Awards at Mount Holyoke College, which promotes research by undergraduate science majors, and has underwritten renovation and updating of one of the biology labs in Clapp Laboratory at that college. Dr. Marieb also contributes to the University of Massachusetts at Amherst where she generously 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 1994, Dr. Marieb received the Benefactor Award from the National Council for Resource Development, American Association of Community Colleges, which recognizes her ongoing sponsorship of student scholarships, faculty teaching awards, and other academic contributions to Holyoke Community College. In May 2000, the science building at Holyoke Community College was named in her honor.

Dr. Marieb is an active member of the Human Anatomy and Physiology Society (HAPS) and the American Association for the Advancement of Science (AAAS). Additionally, while actively engaged as an author, Dr. Marieb serves as a consultant for the Benjamin Cummings *Interactive Physiology*® CD-ROM series.

When not involved in academic pursuits, Dr. Marieb is a world traveler and has vowed to visit every country on this planet. Shorter term, she serves on the scholarship committee of the Women’s Resources Center and on the board of directors of several charitable institutions in Sarasota County. She is an enthusiastic supporter of the local arts and enjoys a competitive match of doubles tennis.



Katja Hoehn

Dr. Katja Hoehn is an associate professor in the Department of Chemical and Biological Sciences 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 17 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 and has written numerous research papers in Neuroscience and Pharmacology. She oversaw a recent revision of the Benjamin Cummings *Interactive Physiology*[®] CD-ROM series modules, and coauthored the newest module, *The Immune System*.

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, compete in triathlons, and play Irish flute.

Introduce yourself to the chapter

Improved readability and navigability makes the text more accessible and easier to study.

14



The Autonomic Nervous System

Chapter Outlines

Chapter outlines provide a preview of the chapter and help you locate information easily.

Learning Objectives

Learning objectives are integrated into the chapter and give you a preview of what content is to come and what you are expected to learn.

Bulleted Narrative

The narrative has been bulleted wherever possible to make the text easier to read and navigate.

Check Your Understanding

Concept check questions are tied to the sections' Learning Objectives and ask you to stop, think, and check your understanding before moving on.

- **Overview** (pp. 524–527)
Comparison of the Somatic and Autonomic Nervous Systems (pp. 525–526)
ANS Divisions (pp. 526–527)
- **ANS Anatomy** (pp. 527–533)

ANS Anatomy

- ✓ For the parasympathetic and sympathetic divisions, describe the site of CNS origin, locations of ganglia, and general fiber pathways.

Anatomically, the sympathetic and parasympathetic divisions differ in

- **Sites of origin.** Parasympathetic fibers are craniosacral—they originate in the brain (cranium) and sacral spinal cord. Sympathetic fibers are thoracolumbar—they originate in the thoracic and lumbar regions of the spinal cord.
- **Relative lengths of their fibers.** The parasympathetic division has long preganglionic and short postganglionic fibers. The sympathetic division has the opposite condition—the preganglionic fibers are short and the postganglionic fibers are long.

✓ Check Your Understanding

1. Name the three types of effectors of the autonomic nervous system.
2. Which relays instructions from the CNS to muscles more quickly, the somatic nervous system or the ANS? Explain why.
3. Which branch of the ANS would predominate if you were lying on the beach enjoying the sun and the sound of the waves? Which branch would predominate if you were on a surfboard and a shark appeared within a few feet of you?

For answers, see Appendix H.

The human body is exquisitely sensitive to changes in its internal environment, and engages in a lifelong struggle to balance competing demands for resources under ever-changing conditions. Although all body systems contribute, the stability of our internal environment depends largely on the **autonomic nervous system (ANS)**, the system of motor neurons that innervates smooth and cardiac muscle and glands (**Figure 14.1**).

At every moment, signals stream from visceral organs into the CNS, and autonomic nerves make adjustments as necessary to ensure optimal support for body activities. In response to changing conditions, the ANS shunts blood to “needy” areas, speeds or slows heart rate, adjusts blood pressure and body temperature, and increases or decreases stomach secretions.

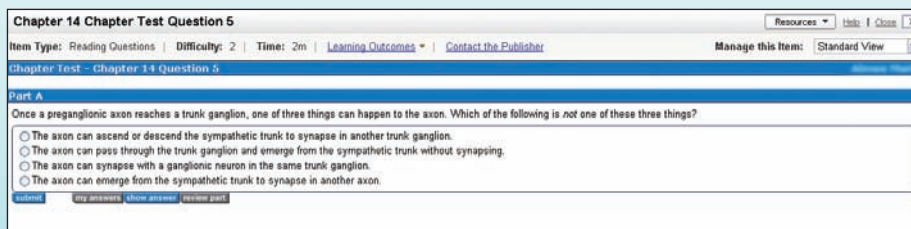
Most of this fine-tuning occurs without our awareness or attention. Can you tell when your arteries are constricting or your pupils are dilating? Probably not—but if you’ve ever been stuck in a checkout line, and your full bladder was contracting as if it had a mind of its own, you’ve been very aware of visceral activity. The ANS controls all these functions, both those we’re aware of and those we’re not. Indeed, as the term *autonomic* (*auto* = self; *nom* = govern) implies, this motor subdivision of the peripheral nervous system has a certain amount of functional independence. The ANS is also called the **involuntary nervous system**, which reflects its subconscious control, or the **general visceral motor system**, which indicates the location of most of its effectors.

Overview

- ✓ Define autonomic nervous system and explain its relationship to the peripheral nervous system.
- ✓ Compare the somatic and autonomic nervous systems relative to effectors, efferent pathways, and neurotransmitters released.
- ✓ Compare and contrast the functions of the parasympathetic and sympathetic divisions.

MasteringA&P®

Reading Questions keep you on track.



Follow complex processes step by step

Focus Figures help you grasp tough topics in A&P by walking you through carefully developed step-by-step illustrations that use a big-picture layout and dramatic art to provide a context for understanding the process.

Overview

Each Overview quickly summarizes the key idea of the figure.

Big Picture Orientation

The big picture provides you with a concrete starting point for the process.

Blue Text

This text acts as the teacher's voice and explains difficult concepts. In some figures the text is broken into numbered steps to help you more easily understand difficult processes.

FOCUS Bulk Flow Across Capillary Walls

Figure 19.17 Bulk fluid flow across capillary walls causes continuous mixing of fluid between the plasma and the interstitial fluid compartments, and maintains the interstitial environment.

The big picture
Fluid filters from capillaries at their arteriolar end and flows through the interstitial space. Most is reabsorbed at the venous end.

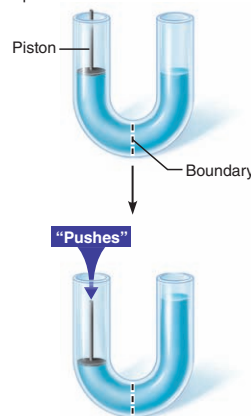
For all capillary beds, 20 L of fluid is filtered out per day—almost 7 times the total plasma volume!

Fluid moves through the interstitial space.

Net filtration pressure (NFP) determines the direction of fluid movement. Two kinds of pressure drive fluid flow:

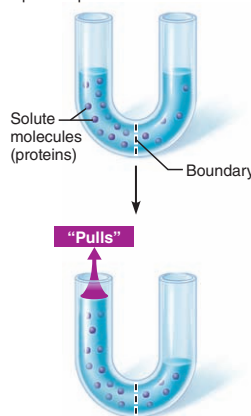
Hydrostatic pressure (HP)

- Due to fluid pressing against a boundary
- HP "pushes" fluid across the boundary
- In blood vessels, is due to blood pressure



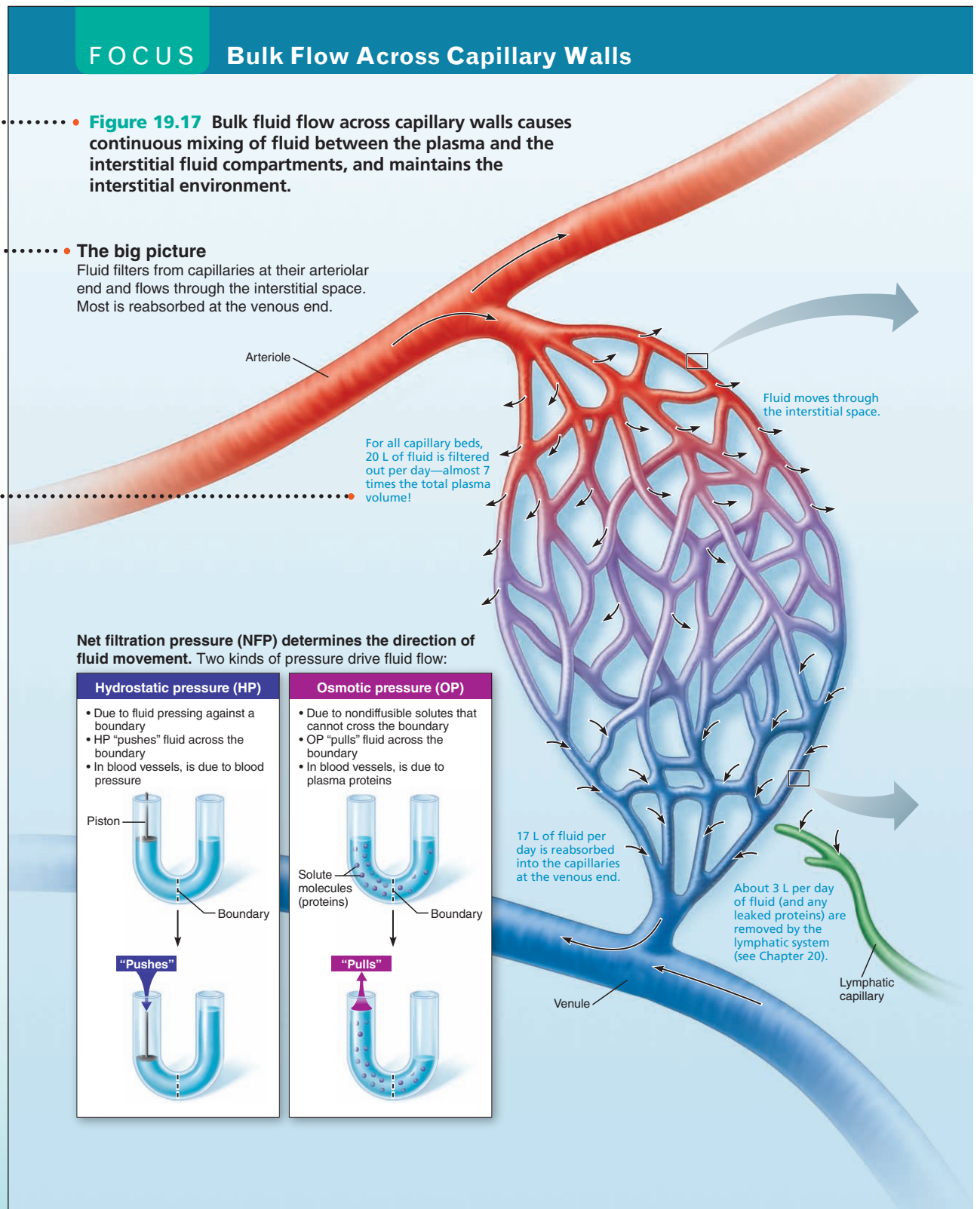
Osmotic pressure (OP)

- Due to nondiffusible solutes that cannot cross the boundary
- OP "pulls" fluid across the boundary
- In blood vessels, is due to plasma proteins



17 L of fluid per day is reabsorbed into the capillaries at the venous end.

About 3 L per day of fluid (and any leaked proteins) are removed by the lymphatic system (see Chapter 20).

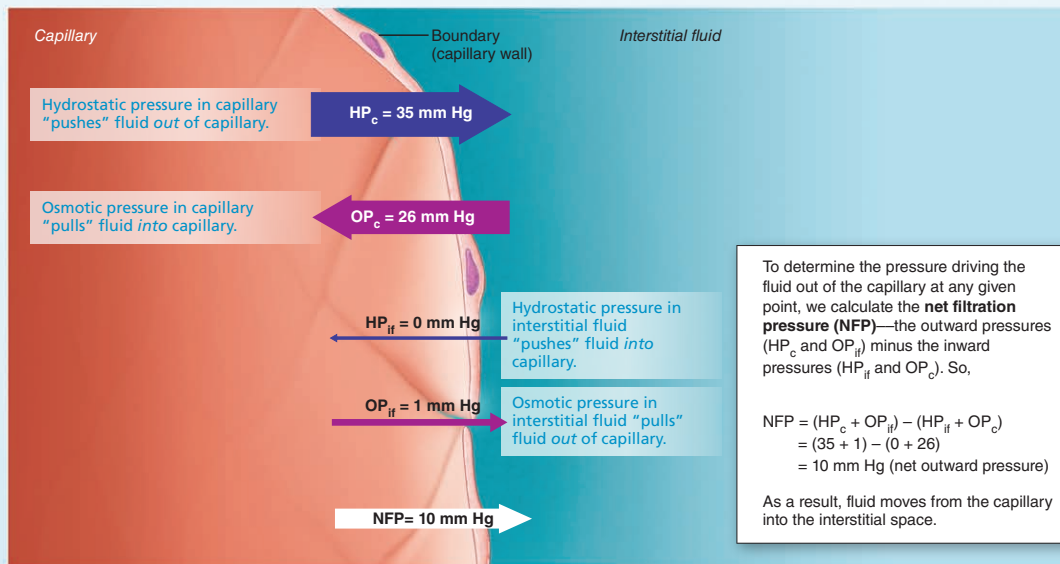


Focus Figure Tutorials

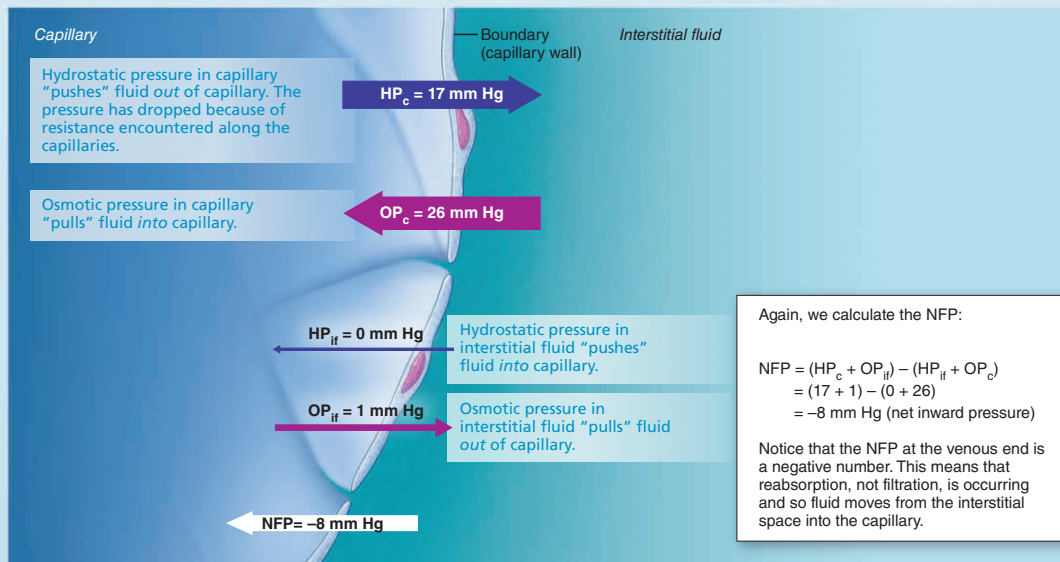
All Focus Figures have related tutorials in MasteringA&P that your teacher can assign and that will guide you through the figures step by step.

How do the pressures drive fluid flow across a capillary?

Net filtration occurs at the arteriolar end of a capillary.



Net reabsorption occurs at the venous end of a capillary.

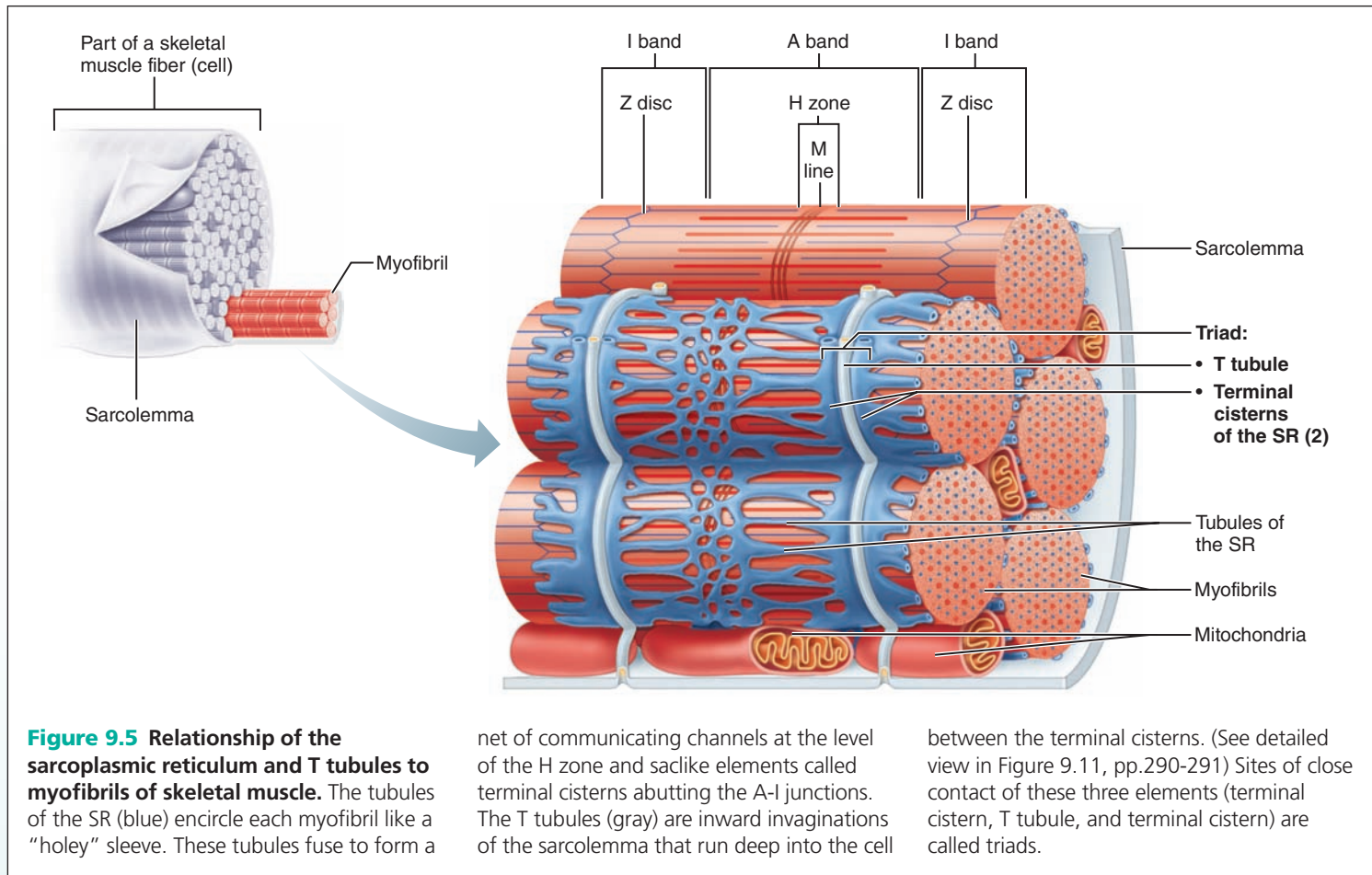


Study figures as you read the text

Select pieces of art provide more visual content and often have step-by-step text that helps you better understand structure, functions, and processes.

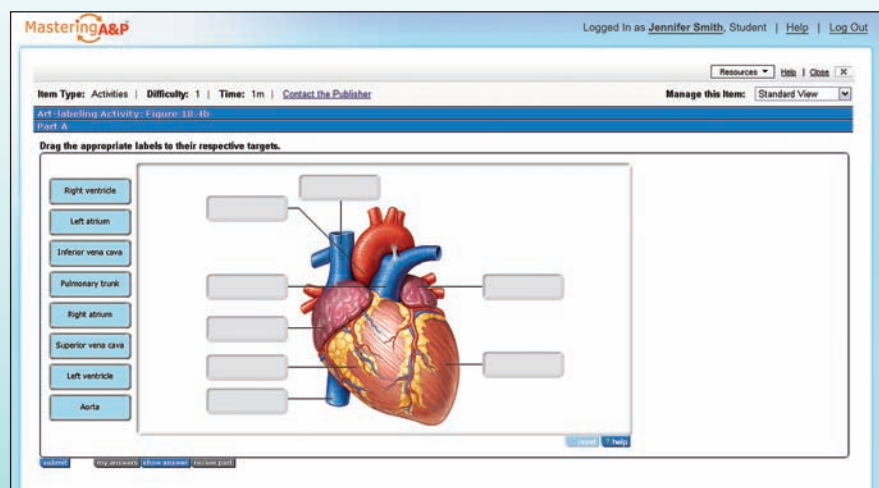
▼ 3-D anatomy art

Stunning 3-D anatomy art is rendered in a dramatically more dynamic, realistic style that uses vibrant, saturated colors to help you visualize key anatomical structures.



MasteringA&P®

NEW! Art Labeling and Ranking/Sorting Questions are drag and drop activities that allow you to assess your knowledge of terms and structures as well as the order of steps and elements involved in physiological processes.



Prepare for your future career

Clinical coverage and case studies have been expanded throughout.

Homeostatic Imbalance 6.1

Minute changes from the homeostatic range for blood calcium can lead to severe neuromuscular problems ranging from hyperexcitability (when blood Ca^{2+} levels are too low) to nonresponsiveness and inability to function (with high blood Ca^{2+} levels). In addition, sustained high blood levels of Ca^{2+} , a condition known as *hypercalcemia* (hi'per-kal-se'me-ah), can lead to undesirable deposits of calcium salts in the blood vessels, kidneys, and other soft organs, which may hamper their function. +

Homeostatic Imbalance

Homeostatic Imbalance sections are integrated within the text and alert you to the consequences of body systems not functioning optimally. These pathological conditions are integrated with the text to clarify and illuminate normal functioning.

MasteringA&P®

NEW! Homeostatic Imbalance Clinical Questions can be assigned to you by your teacher on MasteringA&P. They help strengthen your understanding of how the body works to stay in balance and what happens when it falls out of balance.

MasteringA&P
Logged in as Jennifer Smith, Student | Help | Log Out

Homeostatic Imbalance Question 1
Resources | Help | Close X

Item Type: | Difficulty: -- | Time: <1m | Contact the Publisher | Manage this Item: Standard View

Homeostatic Imbalance Question 1
Part A

During rigor mortis, cross bridge formation between myosin heads and actin molecules is caused by the elevation of calcium ion concentration in the cytosol. During rigor mortis, this elevation of calcium ion concentration in the cytosol is permanent because:

mitochondria stop producing ATP molecules required by the SR's calcium ion pumps
 troponin molecules bind irreversibly to calcium ions to prevent them from being removed from the cytosol
 tropomyosin molecules bind irreversibly to calcium ions to prevent them from being removed from the cytosol
 acetylcholine continues to stimulate the release of calcium ions from the SR

Continue | See Score and Provide Feedback

AT THE CLINIC

Case Study Muscular System



Let's continue our tale of Mrs. DeStephano's medical problems, this time looking at the notes made detailing observations of her skeletal musculature.

- Severe lacerations of the muscles of the right leg and knee
- Damage to the blood vessels serving the right leg and knee
- Transaction of the sciatic nerve (the large nerve serving most of the lower limb), just above the right knee

Her physician orders daily passive range-of-motion (ROM) exercise and electrical stimulation for her right leg and a diet high in protein, carbohydrates, and vitamin C.

- Describe the step-by-step process of wound healing that will occur in her fleshy (muscle) wounds, and note the consequences of the specific restorative process that occurs.
- What complications in healing can be anticipated owing to vascular (blood vessel) damage in the right leg?
- What complications in muscle structure and function result from transection of the sciatic nerve? Why are passive ROM and electrical stimulation of her right leg muscles ordered?
- Explain the reasoning behind the dietary recommendations.

(Answers in Appendix H)

NEW! At the Clinic

End-of-chapter sections now contain an At the Clinic feature, which help you apply what you've learned. By learning related clinical terms and reading short Case Studies and answering questions, you will begin to prepare for your future career.

MasteringA&P®

NEW! Case Study Coaching Activities increase your problem-solving skills and prepare you for your future career.

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Case Study Prototype: Dangerously Thin
Resources | Help | Close X

Item Type: | Difficulty: -- | Time: <1m | Contact the Publisher | Manage this Item: Standard View

Dangerously Thin: A Case Study on the Genetic Code

Part A

Consider a portion of a gene that contains 48 nucleotides. How many amino acids will be coded for by this section of the gene?

24
 48
 96
 192

Part B

If the nucleotide sequence on the coding strand of a piece of DNA is ATGCCGAAT what would the sequence on the template strand be?

TACGGCTTA
 ATGCCGAAT
 UACGGCTTA
 AUGCCGAUU

Part C

GTC is a sequence of nucleotides found on the template strand of a gene. Which of the following represents the amino acid that is being coded for in this portion of the gene and the anticodon of the tRNA molecule that carries that amino acid? (Note: refer to the genetic code chart to help you with this question.)

A tRNA molecule with a GUC anticodon carrying the amino acid Glutamine (Gln)
 A tRNA molecule with a CAG anticodon carrying the amino acid Glutamine (Gln)
 A tRNA molecule with a CAG anticodon carrying the amino acid Glutamate (Glu)
 A tRNA molecule with a GUC anticodon carrying the amino acid Glutamate (Glu)

Part D

Henry has a close relative who carries the gene for sickle cell anemia. In this genetic disease, the 6th amino acid in hemoglobin is changed from Glutamate (Glu) to Valine (Val). If the nucleotides in the DNA coding for these 6 amino acids were numbered, which nucleotide is most likely to be involved in this mutation?

E. The 17th nucleotide
 F. The 5th nucleotide

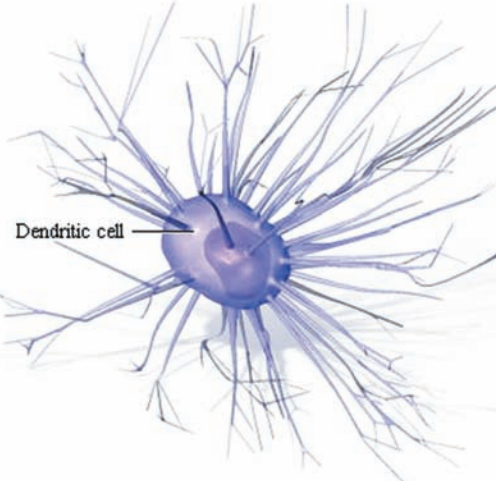
Practice what you don't understand with MasteringA&P®

MasteringA&P includes a Study Area that has many tools to help you succeed, including:

Only a few kinds of cells have **class II MHC** proteins. These are the **antigen-presenting cells**: dendritic cells, macrophages, and B cells. These cells communicate with **CD4 cells**, which are destined to become, or have already become, **helper T cells**. The antigens that are presented on class II MHC proteins are **exogenous antigens**—they originate from outside the cell.

Let's follow an exogenous antigen on its way to being displayed on a class II MHC protein.

Click the dendritic cell to begin this process.

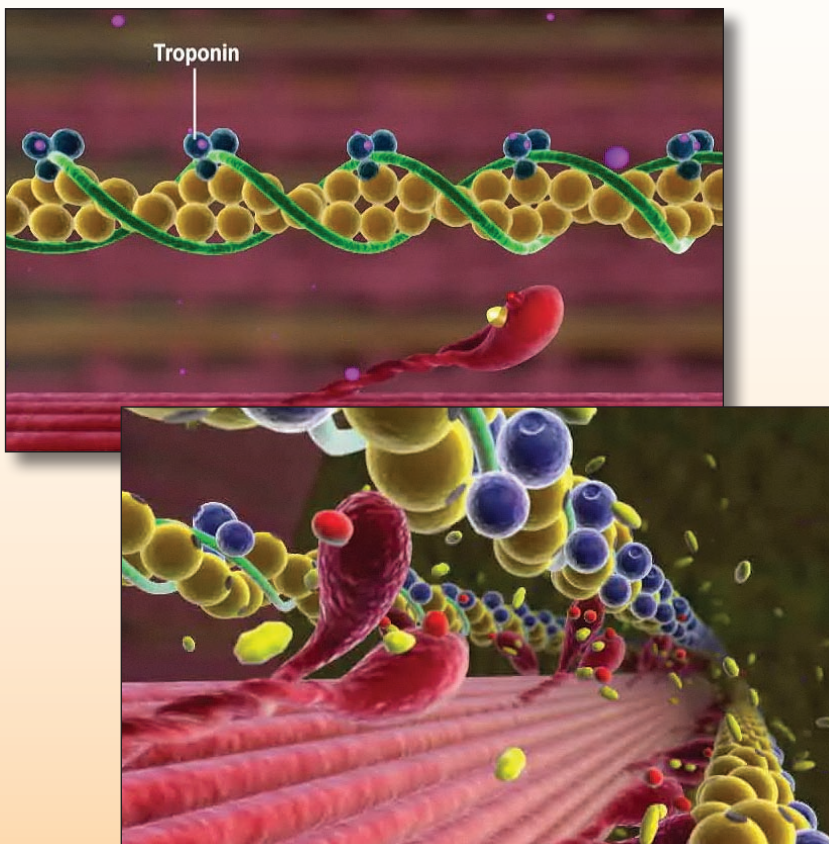


◀ Interactive Physiology® iP 10-System Suite

IP helps you understand the hardest part of A&P: physiology. Fun, interactive tutorials, games, and quizzes give you additional explanations to help you grasp difficult concepts.

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- Nervous System I
- Nervous System II
- Cardiovascular System
- Respiratory System
- Urinary System
- Fluids & Electrolytes
- Endocrine System
- Digestive System
- Immune System



◀ A&P Flix

A&P Flix™ are 3-D movie-quality animations with self-paced tutorials and gradable quizzes that help you master the toughest topics in A&P:

Cell Physiology

- Membrane Transport
- DNA Replication
- Mitosis
- Protein Synthesis

Muscle Physiology

- Events at the Neuromuscular Junction
- Excitation-Contraction Coupling
- Cross-Bridge Cycle

Neurophysiology

- Resting Membrane Potential
- Generation of an Action Potential
- Propagation of an Action Potential

Origins, Insertions, Actions, Innervations

- 63 animations on this topic

Group Muscle Actions & Joints

- 54 animations on this topic



PAL | practice anatomy lab

Practice Anatomy Lab™ (PAL™) 3.0 is a virtual anatomy study and practice tool that gives you 24/7 access to the most widely used lab specimens, including the human cadaver, anatomical models, histology, cat, and fetal pig. PAL 3.0 retains all of the key advantages of version 2.0, including ease of use, built-in audio pronunciations, rotatable bones, and simulated fill-in-the-blank lab practical exams.

Annotation Function

Allows you to take notes.

Google®-based search function.

Highlight Function

Lets you highlight what you want to remember.

Zoom

Lets you zoom in and out for better viewing.

Pearson eText

Pearson eText gives you access to the text whenever and wherever you can access the Internet. The eText pages look exactly like the printed text, plus you get powerful interactive and customization features.

The screenshot shows the Pearson eText interface for 'UNIT 1 Organization of the Body'. It includes a 'Table of Contents' on the left, a main text area with anatomical diagrams (Figures 1.10 and 1.11), and a 'Glossary' on the right. The interface features a search bar, navigation buttons, and a 'Settings' menu.

Interactive Glossary

Provides pop-up definitions and terms.

Teacher Notes

Your teacher might also share his or her notes and highlights with the class.

Hyperlinks

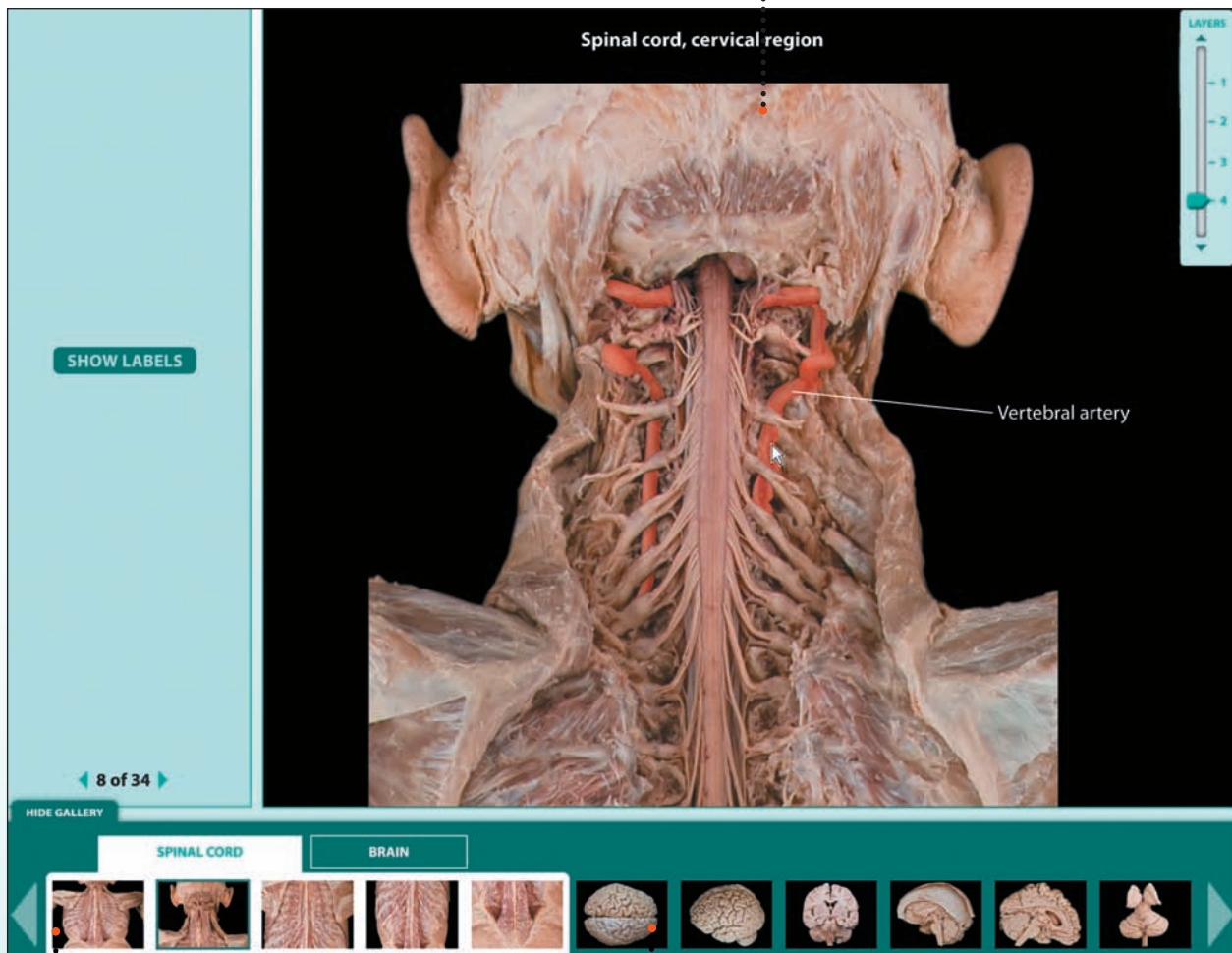
Links to quizzes, tests, activities, and animations.

Get 24/7 lab practice

NEW! PAL | practice
anatomy
lab

PAL 3.0 is an indispensable virtual anatomy study and practice tool that gives you 24/7 access to the most widely used lab specimens, including the human cadaver, anatomical models, histology, cat, and fetal pig. PAL 3.0 retains all of the key advantages of version 2.0, including ease of use, built-in audio pronunciations, rotatable bones, and simulated fill-in-the-blank lab practical exams.

- **NEW!** Carefully prepared dissections show nerves, blood vessels, and arteries across body systems.



- **NEW!** Layering slider allows you to peel back layers of the human cadaver and view and explore hundreds of brand-new dissections especially commissioned for 3.0.

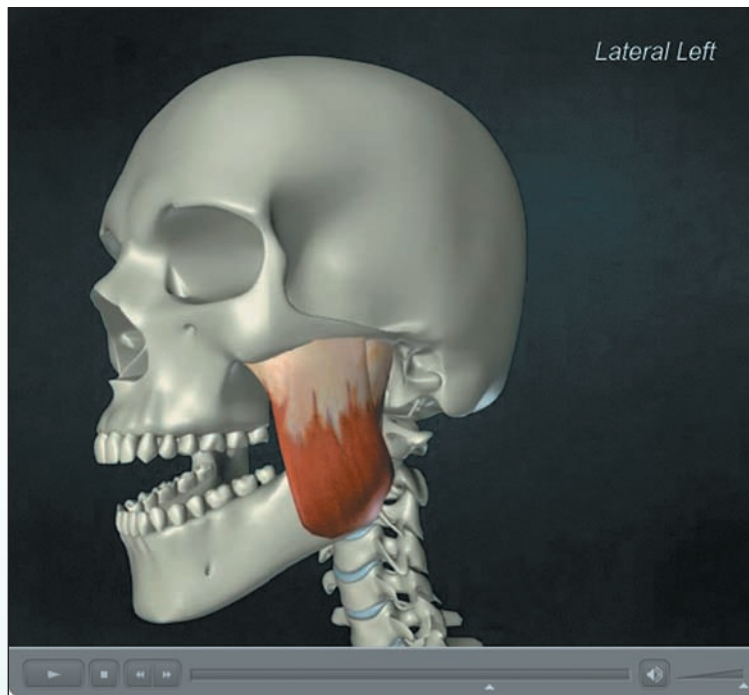
- **NEW!** Photo gallery allows you to quickly see thumbnails of images for a particular region or sub region.

PAL 3.0 is available in the Study Area of MasteringA&P (www.masteringaandp.com). The PAL 3.0 DVD is also available for purchase.



◀ NEW! Interactive Histology

Interactive Histology module allows you to view the same tissue slide at varying magnifications, thereby helping you identify structures and their characteristics.



◀ 3-D Anatomy Animations

3-D Anatomy Animations of origins, insertions, actions, and innervations of over 65 muscles are now viewable in both Cadaver and Anatomical Models and modules. A new closed-captioning option provides textual presentation of narration to help you retain information and supports ADA compliance.

PAL | practice anatomy lab

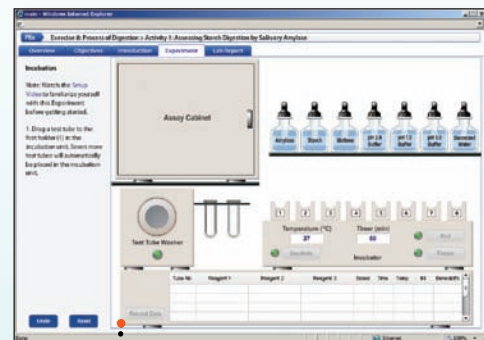
PAL 3.0 also includes:

- **NEW!** Question randomization feature gives you more opportunities for practice and self-assessment. Each time you retake a quiz or lab practical, a new set of questions is generated.
- **NEW!** Hundreds of new images and views are included, especially of the human cadaver, anatomical models, and histology.
- **NEW!** Turn-off highlight feature in quizzes and lab practicals gives you the option to see a structure without the highlight overlay.

physioEX™
VERSION 9

NEW! PhysioEx 9.0

PhysioEx 9.0: Laboratory Simulations in Physiology is easy-to-use laboratory simulation software with an accompanying lab manual that consists of 12 exercises containing 63 physiology lab activities. It can be used to supplement or substitute for wet labs. PhysioEx allows you to repeat labs as often as you like, perform experiments without harming live animals, and conduct experiments that are difficult to perform in a wet lab environment because of time, cost, or safety concerns.

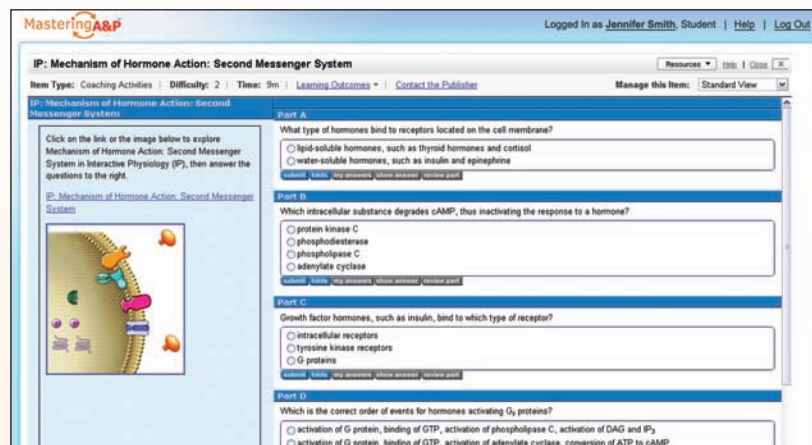


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All text features of *Human Anatomy & Physiology* are now assignable in MasteringA&P, providing students with unlimited opportunities to study.

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Focus Figure Tutorials guide students through key parts of each Focus Figure, assessing their understanding of the major concepts through a variety of assessment tools—multiple choice questions with hints and specific wrong-answer feedback, interactive ranking and sorting exercises, and labeling activities.

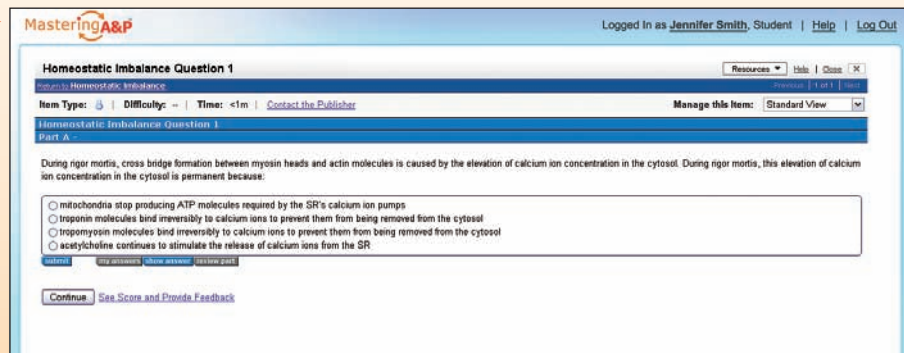


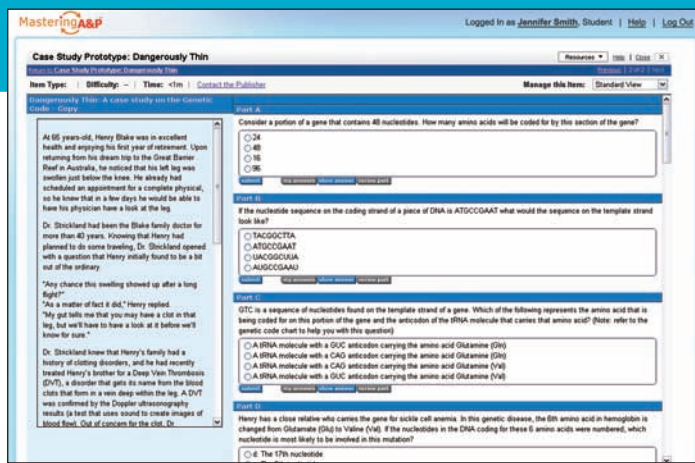
Interactive Physiology Coaching Activities

20 new *Interactive Physiology* Coaching Activities have been added to the Item Library.

NEW! Homeostatic Imbalance Clinical Questions

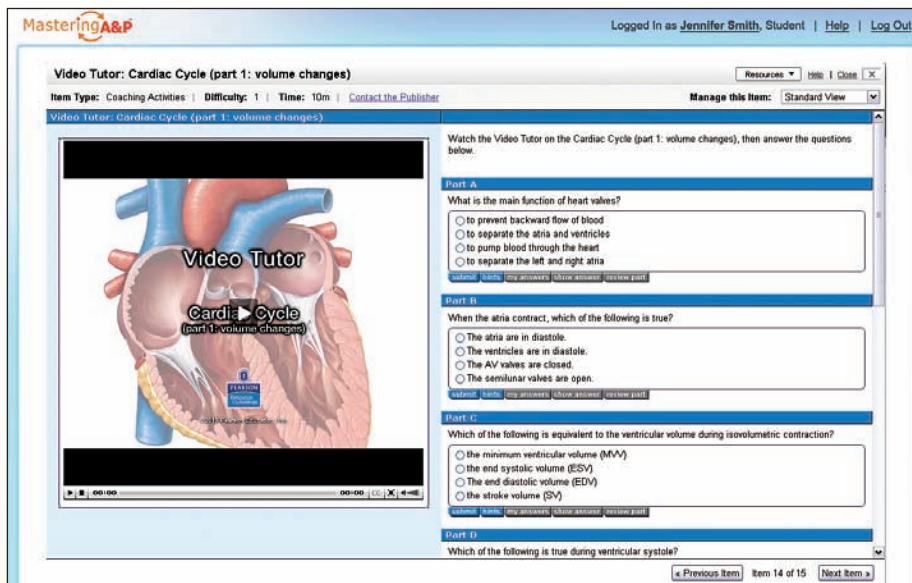
Homeostatic Imbalance Clinical Questions are higher-order thinking questions that assess students on their comprehension of the Homeostatic Imbalance content in each chapter, making one of the text's hallmark features now assignable.





NEW! Case Study Coaching Activities

Case Study Coaching Activities increase problem-solving skills and prepare students for future careers in allied health. Corresponding Teaching Notes give teachers valuable tips on when and how to use case studies in the classroom.



Video Tutor Coaching Activities

Video Tutors instruct and coach students on key A&P concepts using art from the book and are accompanied by questions with video hints and feedback specific to their misconceptions.

Other Text Features Now Assignable in MasteringA&P:

- A&P Flix™ Coaching Activities offer stunning 3-D visuals of core concepts and tough physiological concepts with in-depth assessments to test student understanding. Seven new topics have been added to the Ninth Edition.
- Art-Based Questions are conceptual questions related to art and instruct students with wrong-answer feedback.
- Art Labeling and Ranking/Sorting Questions are drag and drop activities that allow students to assess their knowledge of terms and structures as well as the order of steps and elements involved in physiological processes.
- PAL™ 3.0 and assessments
- PhysioEx™ 9.0 and assessments
- Clinical Application questions (under Test Bank) give students the opportunity to apply their knowledge to clinical scenarios.
- Reading Questions keep students on track and are pre-built for easy set-up and delivery.
- Test Bank questions have been heavily revised with up to 600 new questions to help better assess your students.

Tools for Teachers and Students

Teacher Resources

Most of the teacher supplements and resources for this text are available electronically to qualified adopters on the Instructor Resource Center (IRC). Upon adoption or to preview, please go to www.PearsonSchool.com/Access_Request and select Option 1. Teachers will be required to complete a brief one-time registration subject to verification of educator status. Upon verification, access information and instructions will be sent to the teacher via email. Once logged into the IRC, enter the text's ISBN in the "Search our Catalog" box to locate the downloadable resources.

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- Instructor Guide to Text & Media (978-0-321-79440-6 / 0-321-79440-0)
- Instructor Resource DVD for Practice Anatomy Lab 3.0 (978-0-321-74963-5 / 0-321-74963-4)
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- Instructor Guide for Essentials of Human Anatomy & Physiology Lab Manual Lab Manual (download only) (0-321-75128-0 / 978-0-321-75128-7)

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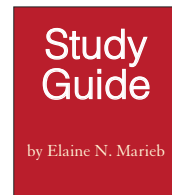
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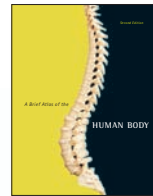
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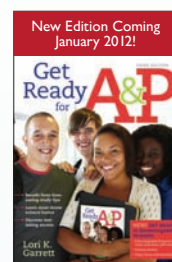
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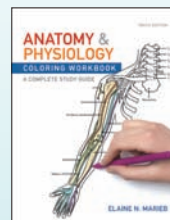
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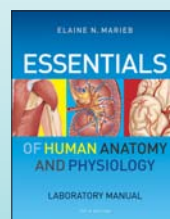
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Preface

As educators, clinically trained individuals, and perennial students, we are continually challenged by the learning mind. What works best to help students apply new information to the world they personally understand? Our clinical backgrounds have served our teaching and writing purposes well. Perhaps even more important, our clinical experience has allowed us to see our presentations through our students' eyes and from the vantage points of their career interests.

For this edition, as for those preceding it, feedback from student and instructor reviews indicated areas of the text that needed to be revised for clarity, timeliness, and just plain reduction of verbal meanness. Overall, feedback was positive, verifying that our approach is effective: Explaining fundamental principles and unifying themes first creates a strong base for what comes later. Backing these explanations up with comfortable analogies and familiar examples enhances students' understanding of the workings of the human body.

Unifying Themes

Three integrating themes that organized, unified, and set the tone of the first edition of this text continue to be valid and are retained in this edition. These themes are:

Interrelationships of body organ systems. The fact that nearly all regulatory mechanisms require interaction of several organ systems is continually emphasized. For example, Chapter 25, which deals with the structure and function of the urinary system, discusses the vital importance of the kidneys not only in maintaining adequate blood volume to ensure normal blood circulation, but also in continually adjusting the chemical composition of blood so that all body cells remain healthy. The unique *System Connections* feature is the culmination of this approach and should help students think of the body as a dynamic community of interdependent parts rather than as a number of isolated structural units.

Homeostasis. The normal and most desirable condition of body functioning is homeostasis. Its loss or destruction always leads to some type of pathology—temporary or permanent. Pathological conditions are integrated with the text to clarify and illuminate normal functioning, not as an end in and of themselves. For example, Chapter 19, which deals with the structure and function of blood vessels, explains how the ability of healthy arteries to expand and recoil ensures continuous blood flow and proper circulation. The chapter goes on to discuss the effects on homeostasis when arteries lose their elasticity: high blood pressure and all of its attendant problems. These homeostatic imbalances are indicated visually by a pink symbol with a fulcrum:



Whenever students see the imbalance symbol in text, the concept of disease as a loss of homeostasis is reinforced. Every Homeostatic Imbalance section has a new, related clinical question that is assignable in MasteringA&P. These new clinical questions help strengthen students' understanding of how the body works to stay in balance.

Complementarity of structure and function. Students are encouraged to understand the structure of an organ, a tissue, or a cell as a prerequisite to comprehending its function. Concepts of physiology are explained and related to structural characteristics that promote or allow the various functions to occur. For example, the lungs can act as a gas exchange site because the walls of their air sacs present an incredibly thin barrier between blood and air.

NEW TO THE NINTH EDITION

With every edition, our goal is powerful but simple—to make anatomy and physiology as engaging, accurate, and relevant as possible for both [instructors](#) and students. The Ninth Edition represents a monumental revision, with changes to the text and art presentation that build upon the hallmark strengths of the previous eight editions. The changes to the Ninth Edition are all driven by the needs of today's students, as we seek to make the learning of key concepts in A&P as easy as possible for them. Key concepts are important because of the overwhelming amount of material in this course. Mastering this material gives

students structure for organizing this wealth of information. Below are the ways in which we've revised the Ninth Edition to make this book the one where learning happens most effectively, followed by a detailed list of specific chapter-by-chapter content changes.

An expanded art program. The drive for this revision began as a simple list. We sat down together and created a chapter-by-chapter list of the key concepts in A&P where students struggle the most. This list became the basis for our art revision plans for both the Eighth and Ninth editions. We first boiled it down to some of the toughest topics to get our list of Focus figures. These Focus figures are illustrations that use a “big picture” layout and dramatic art to walk the student through difficult physiological processes in a step-by-step way. These have been wildly popular with both **instructors** and students. In response to repeated requests for more, we are pleased to present 12 new Focus figures. We hope you'll be as pleased with the results of the added Focus figures in the Ninth Edition as you were in the Eighth.

All of the art in the Eighth Edition was carefully examined and reviewed by both **instructors** and students. Many of their suggested changes have been incorporated into this edition. As always, we have updated many figures to reflect the latest scientific findings and to improve their ability to teach important concepts. Finally, many new photos—histology, cadaver, and others—were painstakingly chosen for this edition to enhance the learning process.

Flipping through the Ninth Edition, you can see that we have built upon the dynamic, three-dimensional, and realistic art style, utilizing dramatic views and perspectives and vibrant, saturated colors.

Improved text presentation. New text features initiated in the Eighth Edition that focus students on key concepts have been retained and expanded in the Ninth Edition. In the current edition, student objectives still appear by topic throughout the chapter and some new *Check Your Understanding* questions have been added at the end of sections. These changes along with a brand-new design make the book easier than ever to study from and navigate. Our hallmark analogies and accessible, friendly style while using simpler, more concise language and shorter paragraphs make the information easier for students to manage.

Factual updates and accuracy. As authors we pride ourselves on keeping our book as up-to-date and as accurate as possible in all areas—a monumental task that requires painstaking selectivity. Although information changes even as a textbook goes to press, be assured that our intent and responsibility to update has been carried out to the best of our ability. We have incorporated current research in the field as much as possible; many of these updates are included in the chapter-by-chapter changes. A more complete list is available ~~from your Pearson sales representative~~ and in the *Instructor Guide to Text and Media*.

Terminology changes. For this edition we've substantially updated the terminology to be in accordance with *Terminologia Anatomica* and *Terminologia Histologica*. Teachers can find a

complete list of terminology changes detailed in the *Instructor Guide to Text and Media*.

Chapter-by-Chapter Changes

Chapter 1 The Human Body: An Orientation

- Updated information on diagnostic uses of MRI scans (*A Closer Look*).
- New MRI photo of frontal section through the torso (Figure 1.8a).
- Enhanced art showing layers of the pericardium (Figure 1.10).

Chapter 2 Chemistry Comes Alive

- Updated information on stress and aging.
- Improved art showing structure of an atom (Figure 2.1).
- New photos of blood (Figure 2.4).
- New photo of a water strider (Figure 2.10).
- Updated art for levels of protein structure (Figure 2.19).

Chapter 3 Cells: The Living Units

- New information on RNA in translation, rRNA, and tRNA.
- Revised Focus Figure 3.10: Primary Active Transport: The Na⁺-K⁺ Pump.
- Revised art for three types of endocytosis (Figure 3.13).
- Improved Focus Figure 3.16: G Proteins.
- New photo of smooth and rough endoplasmic reticulum (Figure 3.18).
- New TEM of lysosomes (Figure 3.21).
- Revised art and new TEM for centrioles (Figure 3.25).
- Revised Focus Figure 3.33: Mitosis.
- New Focus Figure 3.37: Translation.

Chapter 4 Tissue: The Living Fabric

- New photomicrographs of epithelium (Figure 4.3).
- New photomicrographs of connective tissues (Figure 4.8).
- New photomicrographs of muscle (Figure 4.10).
- Simplified explanation of polarity.
- Improved rendering of goblet cell (Figure 4.4), with more realistic details.
- Improved teaching effectiveness of Figure 4.11 (classes of membranes).
- Improved layout of Figure 4.12 (tissue repair).
- Added explanation to art for embryonic germ layers (Figure 4.13).

Chapter 5 The Integumentary System

- Updated information on the skin's epithelial cells and stratum corneum.
- New information on tinea versicolor (“sunspots”) and friction ridges.
- Updated information on importance of the stratum corneum as a physical barrier.
- Added new term scleroderma, an autoimmune disorder characterized by hardened skin, in *At the Clinic: Related Clinical Terms*.
- New research on the role of friction ridges in the sense of touch.

Chapter 6 Bones and Skeletal Tissues

- Updated information on bone resorption and remodeling.
- New bone-related information on serotonin, glucose intolerance, and diabetes mellitus.
- Updated information on osteogenic cells and microscopic anatomy of bone cells.
- New information on osteoporosis in prostate cancer patients who receive androgen-suppressing therapy.
- New information on osteocalcin, a hormone which helps regulate bone formation and also protects against obesity, glucose intolerance, and diabetes mellitus.
- New information on the monoclonal antibody drug denosumab as a treatment for osteoporosis.

Chapter 7 The Skeleton

- New Clinical Case Study.
- New photos of the skull, temporal bone, sphenoid and ethmoid bones, mandible, and orbits (Figures 7.5–7.12).
- New photos of defects in spinal curvature (Figure 7.17).
- New photos of proximal tibia (Figure 7.33).

Chapter 8 Joints

- New Clinical Case Study.
- New Focus Figure 8.7: Types of Synovial Joints.
- Added information on meniscal transplant surgery.
- Updated information on treatment of sprains.
- Updated statistics on arthritis; updated treatment of rheumatoid arthritis.
- Updated description of sinovitis.
- Updated statistics on joint replacements in the U.S.
- Updated research aimed at future treatments of joint problems.

Chapter 9 Muscles and Muscle Tissue

- New discussion of EPOC (excess postexercise oxygen consumption).
- New photomicrograph of skeletal muscle (Figure 9.1).
- New Figure 9.9 (skeletal muscle action potentials).
- Added information of myosin head orientation in smooth muscle.
- Updated information on treatments for Duchenne muscular dystrophy.
- Streamlined discussion of muscle fatigue.
- Added skeletal muscle fibers to Figure 9.17 for better teaching effectiveness.

Chapter 10 The Muscular System

- New Focus Figure 10.1: Muscle Action.
- New Clinical Case Study.
- New photo of hip and thigh muscles (Figure 10.21).

Chapter 11 Fundamentals of the Nervous System and Nervous Tissue

- Update on multiple sclerosis risk factors and treatment.
- New information on addiction treatment and prescription drug abuse (*A Closer Look*).
- New Clinical Case Study.
- Updated discussion on neuronal transport.
- New information on gasotransmitters.
- Update on shingles and vaccination available for its prevention.

- Discuss direct and indirect neurotransmitter receptor mechanisms in two figures (Figures 11.20 and 11.21). Added relay-runner motif to G-protein linked receptor figure (Figure 11.21) to tie it to previous G-protein figure in Chapter 3.

Chapter 12 The Central Nervous System

- New Clinical Case Study.
- Updated information on premotor cortex and the role of the basal nuclei.
- New information on Alzheimer's disease and Parkinson's disease.
- Update on amyotrophic lateral sclerosis.
- Updated information on genetic causes of autism.
- New photos of brain sections (Figures 12.9, 12.10, and 12.12).
- New photo of spinal cord (Figure 12.26).

Chapter 13 The Peripheral Nervous System and Reflex Activity

- New information on vanilloid receptors, pain tolerance, and Bell's palsy.
- New SEM of nerve cross-section (Figure 13.4).
- New photos of brachial and sacral plexuses (Figures 13.10 and 13.12).
- New Clinical Case Study.

Chapter 14 The Autonomic Nervous System

- Updated information on aging and blood pressure receptors.
- Streamlined discussion of sympathetic trunks and pathways.
- More explicit statement about the "background" firing rate of neurons along sympathetic and parasympathetic axons in ANS.

Chapter 15 The Special Senses

- New Clinical Case Study.
- New information on link between vitamin C and cataract formation.
- New photos of retina (Figure 15.7), cataract (Figure 15.9), and refraction (Figure 15.11).
- New summary Table 15.1—differences between rods and cones.
- Updated discussion of olfactory processing.
- New summary Table 15.2—structures of internal ear and their functions.

Chapter 16 The Endocrine System

- New research on ghrelin and growth hormone release.
- New photo showing effects of growth hormone excess and deficiency (Figure 16.7).
- Updated information on type 1 diabetes.
- New Focus Figure 16.5: Hypothalamus and Pituitary Interactions.
- New photomicrographs of thyroid (Figure 16.8), parathyroid (Figure 16.12), adrenal gland (Figure 16.14), and pancreas (Figure 16.18).
- New flowchart of parathyroid hormone effects (Figure 16.13).

Chapter 17 Blood

- New Clinical Case Study.
- New SEMs of normal and sickled RBCs (Figure 17.8).

- New photomicrographs of leukocytes (Figure 17.10).
- Updated Figure 17.11 (leukocyte formation).
- Updated statistics on sickle cell anemia and malaria.
- Improved teaching effectiveness of Figure 17.14 (pathways of coagulation).

Chapter 18 The Cardiovascular System: The Heart

- New Clinical Case Study.
- New Focus Figure 18.9: Blood Flow Through the Heart.
- Updated information on ischemic cell death in myocardial infarction.
- New photos of the heart (Figures 18.4 and 18.6).
- Expanded overview of systemic and pulmonary circuits (in response to focus group feedback).
- Reorganized presentation of heart anatomy.
- Updated the effects of hyperkalemia and hypercalcemia on the heart.

Chapter 19 The Cardiovascular System: Blood Vessels

- Update on obesity-linked hypertension.
- New Focus Figure 19.17: Bulk Flow Across Capillary Walls.
- New photomicrograph of artery and vein (Figure 19.1).
- Added information on C-reactive protein as a marker of systemic inflammation and a predictor of future heart attacks and strokes.
- Reorganized Figure 19.15 for better teaching effectiveness.
- Reorganized section on venous return.
- Reorganized discussion of baroreceptor reflex.
- Consolidated discussion of renal regulation of blood pressure by adding material previously in Chapter 25. Moved details of renin-angiotensin-aldosterone mechanism from Figure 25.10 to Figure 19.10.
- Reorganized presentation on homeostatic imbalances of blood pressure.

Chapter 20 The Lymphatic System and Lymphoid Organs and Tissues

- New information on the spleen as a monocyte reservoir.
- New photomicrographs of thymus (Figure 20.7) and tonsil (Figure 20.8).
- Improved discussion of lymphoid cells and lymphoid tissues.
- Reorganized section on mucosa-associated lymphoid tissue (MALT).
- Updated statistics for non-Hodgkin's lymphoma.

Chapter 21 The Immune System: Innate and Adaptive Body Defenses

- Major revision of chapter to streamline presentation.
- New Clinical Case Study.
- Added coverage of lectin pathway (Figure 21.6).
- New SEM of macrophage engaged in phagocytosis (Figure 21.2).
- Two new summary tables (Tables 21.3 and 21.5).

Chapter 22 The Respiratory System

- Update on early detection of lung cancer.
- Updated discussion of cystic fibrosis.
- New Focus Figure 22.20: Oxygen-Hemoglobin Dissociation Curve.

- New photomicrograph of lung tissue (Figure 22.8).
- New SEM of pulmonary capillary casts (Figure 22.9).

Chapter 23 The Digestive System

- New photomicrograph of esophagus-stomach junction (Figure 23.12).
- New photograph of gastric ulcer (Figure 23.16).
- New photomicrograph of pancreas (Figure 23.26).
- New art on the absorption of monosaccharides (Figure 23.35).

Chapter 24 Nutrition, Metabolism, and Body Temperature Regulation

- Coverage of the USDA's new MyPlate logo (Figure 24.1) and dietary recommendations.
- New Focus Figure 24.8: Oxidative Phosphorylation.
- New Clinical Case Study.
- Updated information on obesity (*A Closer Look*).

Chapter 25 The Urinary System

- Major revision of chapter to streamline presentation.
- New Focus Figure 25.16: Medullary Osmotic Gradient.
- New information on symptoms and manifestations of renal failure.
- New Clinical Case Study.
- New SEM of nephron blood vessel casts (Figure 25.7).
- New illustration of net filtration forces (Figure 25.11).
- New illustration on tubular reabsorption and secretion (Figure 25.15).
- New photo of kidney (Figure 25.3).

Chapter 26 Fluid, Electrolyte, and Acid-Base Balance

- Updated discussion of regulation of sodium and water balance, and dehydration.
- New text and summary table (Table 26.2) contrasting extracellular fluid sodium concentration and body sodium content.

Chapter 27 The Reproductive System

- New photo of testis (Figure 27.3).
- New illustration of male perineum (Figure 27.4).
- New SEM of seminiferous tubules (Figure 27.8).
- New graph of plasma testosterone versus age (Figure 27.11).
- New photomicrograph of ovary (Figure 27.13).
- Update on circumcision and statistics on reduction in risk of HIV and other infections.

Chapter 28 Pregnancy and Human Development

- New Focus Figure 28.2: Sperm Penetration and the Cortical Reaction.
- Updated contraception methods (*A Closer Look*).
- New Clinical Case Study.
- Updated information on role of hCG.
- Updated information on assisted reproductive technologies.
- Simplified Figure 28.10 to improve teaching effectiveness.
- New photo of nursing mother (Figure 28.19).

Chapter 29 Heredity

- New Clinical Case Study.
- New photos of karyotyping (Figure 29.1).

Acknowledgments

Each new edition of this textbook holds out a promise to its authors. “You’re done—the book is perfect!” Not! Although it would appear that this would be so after all the work bestowed upon it over eight editions, it still takes the better part of two years, demands our participation in many focus groups, mobilizes our library research skills, and tests our creativity once again before we finally put the last page of the new edition to rest. It never really gets easier as we grind away—the grist finer with each edition.

In all fairness, we don’t work alone. Many people shared the work of this edition and deserve their proper due. Once the first draft of each chapter was complete in our estimations, it was sent off to Alice Fugate, the text developmental editor, who wielded her pen to ensure readability and consistency—factors very important to student success. Backing up Alice’s work was the director of development Barbara Yien, well known for her ability to see the whole picture. After we perused and processed Alice’s suggestions, the manuscript went to Shannon Cutt. Shannon, our cheery associate project editor, checked every aspect of the newly modified text before sending it on to production. Nobody escapes Shannon’s ministrations—especially her amazing ability to chase down things that threaten to fall through the cracks. If we failed to meet her deadlines, a barrage of emails rained down, all asking us in the sweetest way to get the missing item in. After Shannon had assured herself that all was well, the manuscript went to Anita Wagner, our skilled copyeditor for the last several editions. Anita knows our text as well or better than we do. She checks grammar, spelling of new drugs or procedures, and verifies statistics; much of the superb accuracy of this text is to her credit as a copyeditor par excellence.

Whew! But that’s not all, folks. Once the writing and editing part of the revision is complete, the manuscript goes to the production department, where the text and art come together. This business-like domain is headed by Michele Mangelli, our production manager once again. Always knowledgeable, Michele guides the production process with great skill and works seamlessly with the members of her excellent staff. She makes sure the artists are on schedule producing art with the appropriate look and accuracy, directs the industrious photo researcher Kristin Piljay, and oversees the work of David Novak (the conscientious production supervisor) and that hard-working art coordinator Jean Lake.

The last edition of this text touched every figure—making each piece of art more timely, more colorful, more accurate, or better pedagogically. The really big success in the art arena was the fabulous one- to two-page Focus figures introduced in the Eighth Edition. These new figures selected physiological concepts that students have the most difficulty with and “unpacked them.” They say you never really have too much of a good thing, so this edition has 12 new Focus Figures. We hope you will like these as much as you did the last offerings. Helping to ensure that you will is Laura Southworth, the art developmental manager who worked tirelessly on these figures. She is not only the art manager but also a skilled professional artist who can illustrate just about any concept we ask for. This capability ensures that the art manuscript delivered to the talented artists of Imagineering and Electronic Publishing Services, who drew the final art, had all the information they needed to produce a quality product. Laura is truly amazing. Important in a different art arena was Lisa Lee, who supplied several of our histology photos and served as a consultant on images from other sources. Tom Fink (East Carolina University), William Karkow (Dubuque University), and Olga Malakhova and Charles Poulton (both from University of Florida College of Medicine, Gainesville) provided histology and cadaver images on an incredibly tight schedule. Thanks so much!

We also thank two people who contributed significantly to this edition: James Hewlett and William Karkow. Working on a tight schedule, James Hewlett contributed 13 new case studies, which were expertly reviewed for clinical accuracy by thoracic surgeon William Karkow.

Thanks also to Yvo Riezebos, cover designer, and tani hasegawa, text designer. Their creativity helped to produce a truly beautiful book. We are very happy that our cover photo is of the best known female goalkeeper in the world—Hope Solo. Hope won an Olympic gold medal in 2008, was named Women’s Professional Soccer’s Goalkeeper of the Year in 2009, and was awarded the Golden Glove at the 2011 World Cup. Sustaining the effort to produce a beautiful book all the way to press were our excellent proofreader, Martha Ghent, and S4Carlisle Publishing Services, the proficient compositor who assembled the final pages with their customary expertise.

The sponsoring editor for the last edition, Serina Beauparlant, has a jazzy new title, “Editor-in-Chief.” Even with a slew of new duties, she is resolute about producing the best educational product possible—both in textbook and media. Her replacement for this edition, who took over a large number of Serina’s duties, is Gretchen Puttkamer, a real go-getter. We haven’t seen too much of Gretchen because she spends most of her time in the field talking to professors, students, and anyone else that will listen to her. Also contributing were several others that we rarely get to talk to, including: editorial assistants Lisa Damerel and John Maas, managing editor Debbie Cogan, Stacey Weinberger, who has been our expert manufacturing buyer for years, and our crackerjack marketing manager, Derek Perrigo, who goes the extra mile to make sure professors are enlightened about special features of the text. Kudos also to our media staff—Lauren Fogel, director of media development, Aimee Pavy, media producer, and the entire media team for PAL 3.0 and PhysioEx 9.0.

Benjamin Cummings spares no effort in its drive to publish an accurate and instructive book. Over 400 reviews were commissioned, enlisting comments and suggestions from both generalist academicians and specialists in various niches of anatomy and physiology. These reviewers’ contributions have been of inestimable value in the continuing development of this text. We also want to thank the many students and colleagues who were generous with their time and comments. They did not always tell us what we wanted to hear, but assured of the sincerity of their criticism, we always listened. Input from the following reviewers resulted in the continued excellence and accuracy of this text.

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David Babb, West Hills Community College
Stephanie Baiyasi, Delta College
Jamal Bittar, University of Toledo
William Brewer, Rochester Institute of Technology
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 East Carolina University*
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Well, our tenure on this edition is over, but there will be another edition three years hence. We would really appreciate hearing from you concerning your opinion—suggestions and constructive criticisms—of this text. It is this type of feedback that provides the basis of each revision, and underwrites its improvement.



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TEACHER *to* TEACHER

I have developed a hands-on Anatomy & Physiology course that includes: observing several hours in a hospital trauma center, riding with paramedics in an ambulance, working with cadavers at two universities, and interacting with a number of speakers in the health profession. What I was lacking was a text that could bring relevance of the human body systems to everyday life. That changed when I found Elaine Marieb and Katja Hoehn's *Human Anatomy & Physiology*.

There are three unifying themes that are focused throughout the text: the Complementarity of Structure and Function, Interrelationships of Body Systems, and a greater understanding of Homeostasis and how it relates to the systems. The total integration of the themes provides a clear and consistent approach to the study of the human body.

My high school students think it is easy to read and are captivated by the System Connection segments at the end of each body system. Elaine and Katja have done an exceptional job of using real world applications backed by the latest research and clinical innovations, and have improved that feature with end-of-chapter case studies for the 9th edition. Their new Focus Figures take very difficult topics or concepts and by using beautiful step-by-step illustrations and striking 3-D artwork provide

an understanding of the process unmatched by any other text, in my opinion.

The support materials include: formative and summative testing, new A&PFlix animations that bring 3-D representations of structure to life, a MasteringA&P website that includes the award-winning tutorial program called Interactive Physiology, and a new Practice Anatomy Lab. All of these features provide teachers flexibility in creating hands-on activities based on best practices, and gives students a clearer understanding of the systems.

This *Human Anatomy & Physiology* text is a very comprehensive, clinical approach that motivates and promotes student engagement in the study of the human body. Teachers will have all the tools necessary to develop a curriculum that will engage and inspire their students to become our future health care professionals.

Dewey Christensen

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Brief Contents

UNIT 1 Organization of the Body

- 1 The Human Body: An Orientation 1
- 2 Chemistry Comes Alive 23
- 3 Cells: The Living Units 61
- 4 Tissue: The Living Fabric 116

UNIT 2 Covering, Support, and Movement of the Body

- 5 The Integumentary System 150
- 6 Bones and Skeletal Tissues 173
- 7 The Skeleton 199
- 8 Joints 249
- 9 Muscles and Muscle Tissue 276
- 10 The Muscular System 319

UNIT 3 Regulation and Integration of the Body

- 11 Fundamentals of the Nervous System and Nervous Tissue 386
- 12 The Central Nervous System 428
- 13 The Peripheral Nervous System and Reflex Activity 483
- 14 The Autonomic Nervous System 524
- 15 The Special Senses 544
- 16 The Endocrine System 591

UNIT 4 Maintenance of the Body

- 17 Blood 631
- 18 The Cardiovascular System: The Heart 658
- 19 The Cardiovascular System: Blood Vessels 692
- 20 The Lymphatic System and Lymphoid Organs and Tissues 751
- 21 The Immune System: Innate and Adaptive Body Defenses 764
- 22 The Respiratory System 801
- 23 The Digestive System 849
- 24 Nutrition, Metabolism, and Body Temperature Regulation 906
- 25 The Urinary System 954
- 26 Fluid, Electrolyte, and Acid-Base Balance 990

UNIT 5 Continuity

- 27 The Reproductive System 1018
- 28 Pregnancy and Human Development 1064
- 29 Heredity 1095



Contents

UNIT 1 Organization of the Body

1 The Human Body: An Orientation 1

An Overview of Anatomy and Physiology 2
Topics of Anatomy • Topics of Physiology • Complementarity of Structure and Function

Levels of Structural Organization 3

Maintaining Life 4
Necessary Life Functions • Survival Needs

Homeostasis 8
Homeostatic Control • Homeostatic Imbalance

The Language of Anatomy 11
Anatomical Position and Directional Terms • Regional Terms • Anatomical Variability • Body Planes and Sections • Body Cavities and Membranes

A CLOSER LOOK Medical Imaging: Illuminating the Body 16

2 Chemistry Comes Alive 23

PART 1 BASIC CHEMISTRY 23

Definition of Concepts: Matter and Energy 23
Matter • Energy

Composition of Matter: Atoms and Elements 25
Atomic Structure • Identifying Elements • Radioisotopes

How Matter Is Combined: Molecules and Mixtures 28
Molecules and Compounds • Mixtures • Distinguishing Mixtures from Compounds

Chemical Bonds 30
The Role of Electrons in Chemical Bonding • Types of Chemical Bonds

Chemical Reactions 35
Chemical Equations • Patterns of Chemical Reactions • Energy Flow in Chemical Reactions • Reversibility of Chemical

Reactions • Factors Influencing the Rate of Chemical Reactions

PART 2 BIOCHEMISTRY 38

Inorganic Compounds 38
Water • Salts • Acids and Bases

Organic Compounds 41
Carbohydrates • Lipids • Proteins • Nucleic Acids (DNA and RNA) • Adenosine Triphosphate (ATP)

3 Cells: The Living Units 61

The Cellular Basis of Life 62

The Plasma Membrane: Structure 63
The Fluid Mosaic Model • The Glycocalyx • Cell Junctions

The Plasma Membrane: Membrane Transport 67
Passive Processes • Active Processes

The Plasma Membrane: Generation of a Resting Membrane Potential 79
Selective Diffusion Establishes Membrane Potential • Active Transport Maintains Electrochemical Gradients

The Plasma Membrane: Cell-Environment Interactions 80
Roles of Cell Adhesion Molecules (CAMs) • Roles of Plasma Membrane Receptors • Role of Voltage-Gated Membrane Channel Proteins: Electrical Signaling

The Cytoplasm 81
Cytoplasmic Organelles • Cellular Extensions

The Nucleus 91
The Nuclear Envelope • Nucleoli • Chromatin

Cell Growth and Reproduction 96
The Cell Cycle • Protein Synthesis • Other Roles of DNA • Degradation of Organelles and Cytosolic Proteins

Extracellular Materials 110

Developmental Aspects of Cells 110
Apoptosis and Modified Rates of Cell Division • Cell Aging

4 Tissue: The Living Fabric 116

- Preparing Human Tissue for Microscopy 117
- Epithelial Tissue 118
 - Special Characteristics of Epithelium • Classification of Epithelia • Glandular Epithelia
- Connective Tissue 127
 - Common Characteristics of Connective Tissue • Structural Elements of Connective Tissue • Types of Connective Tissue
- Muscle Tissue 136
- Nervous Tissue 140
- Covering and Lining Membranes 140
 - Cutaneous Membrane • Mucous Membranes • Serous Membranes
- Tissue Repair 142
 - Steps of Tissue Repair • Regenerative Capacity of Different Tissues
- Developmental Aspects of Tissues 144
- A CLOSER LOOK** Cancer—The Intimate Enemy 145

UNIT 2 Covering, Support, and Movement of the Body

5 The Integumentary System 150

- The Skin 150
 - Epidermis • Dermis • Skin Color
- Appendages of the Skin 157
 - Hairs and Hair Follicles • Nails • Sweat (Sudoriferous) Glands • Sebaceous (Oil) Glands
- Functions of the Integumentary System 162
 - Protection • Body Temperature Regulation • Cutaneous Sensation • Metabolic Functions • Blood Reservoir • Excretion
- Homeostatic Imbalances of Skin 164
 - Skin Cancer • Burns
- Developmental Aspects of the Integumentary System 167
 - From Infancy to Adulthood • Aging Skin

SYSTEM CONNECTIONS 168

6 Bones and Skeletal Tissues 173

- Skeletal Cartilages 173
 - Basic Structure, Types, and Locations • Growth of Cartilage
- Classification of Bones 174
- Functions of Bones 176

- Bone Structure 177
 - Gross Anatomy • Microscopic Anatomy of Bone • Chemical Composition of Bone
- Bone Development 183
 - Formation of the Bony Skeleton • Postnatal Bone Growth
- Bone Homeostasis: Remodeling and Repair 187
 - Bone Remodeling • Bone Repair
- Homeostatic Imbalances of Bone 192
 - Osteomalacia and Rickets • Osteoporosis • Paget's Disease
- Developmental Aspects of Bones: Timing of Events 193
 - Birth to Young Adulthood • Age-Related Changes in Bone
- SYSTEM CONNECTIONS** 195

7 The Skeleton 199

PART 1 THE AXIAL SKELETON 199

- The Skull 201
 - Overview of Skull Geography • Cranium • Facial Bones • Special Characteristics of the Orbits and Nasal Cavity • The Hyoid Bone
- The Vertebral Column 218
 - General Characteristics • General Structure of Vertebrae • Regional Vertebral Characteristics
- The Thoracic Cage 224
 - Sternum • Ribs

PART 2 THE APPENDICULAR SKELETON 227

- The Pectoral (Shoulder) Girdle 227
 - Clavicles • Scapulae
- The Upper Limb 228
 - Arm • Forearm • Hand
- The Pelvic (Hip) Girdle 234
 - Ilium • Ischium • Pubis • Pelvic Structure and Childbearing
- The Lower Limb 238
 - Thigh • Leg • Foot
- Developmental Aspects of the Skeleton 244

8 Joints 249

- Classification of Joints 249
- Fibrous Joints 250
 - Sutures • Syndesmoses • Gomphoses
- Cartilaginous Joints 251
 - Synchondroses • Symphyses
- Synovial Joints 252
 - General Structure • Bursae and Tendon Sheaths • Factors Influencing the Stability of Synovial Joints • Movements Allowed by Synovial Joints • Types of Synovial Joints • Selected Synovial Joints

Homeostatic Imbalances of Joints 269
Common Joint Injuries • Inflammatory and Degenerative Conditions

Developmental Aspects of Joints 272

A CLOSER LOOK Joints: From Knights in Shining Armor to Bionic Humans 271

9 Muscles and Muscle Tissue 276

Overview of Muscle Tissues 276

Types of Muscle Tissue • Special Characteristics of Muscle Tissue • Muscle Functions

Skeletal Muscle 278

Gross Anatomy of a Skeletal Muscle • Microscopic Anatomy of a Skeletal Muscle Fiber • Sliding Filament Model of Contraction • Physiology of Skeletal Muscle Fibers • Contraction of a Skeletal Muscle • Muscle Metabolism • Force of Muscle Contraction • Velocity and Duration of Contraction • Adaptations to Exercise

Smooth Muscle 305

Microscopic Structure of Smooth Muscle Fibers • Contraction of Smooth Muscle • Types of Smooth Muscle

Developmental Aspects of Muscles 312

A CLOSER LOOK Athletes Looking Good and Doing Better with Anabolic Steroids? 313

SYSTEM CONNECTIONS 314

10 The Muscular System 319

Actions and Interactions of Skeletal Muscles 319

Naming Skeletal Muscles 320

Muscle Mechanics: Importance of Fascicle Arrangement and Leverage 322

Arrangement of Fascicles • Lever Systems: Bone-Muscle Relationships

Major Skeletal Muscles of the Body 324

Table 10.1 Muscles of the Head, Part I: Facial Expression 329

Table 10.2 Muscles of the Head, Part II: Mastication and Tongue Movement 332

Table 10.3 Muscles of the Anterior Neck and Throat: Swallowing 334

Table 10.4 Muscles of the Neck and Vertebral Column: Head Movements and Trunk Extension 336

Table 10.5 Deep Muscles of the Thorax: Breathing 340

Table 10.6 Muscles of the Abdominal Wall: Trunk Movements and Compression of Abdominal Viscera 342

Table 10.7 Muscles of the Pelvic Floor and Perineum: Support of Abdominopelvic Organs 344

Table 10.8 Superficial Muscles of the Anterior and Posterior Thorax: Movements of the Scapula and Arm 346

Table 10.9 Muscles Crossing the Shoulder Joint: Movements of the Arm (Humerus) 350

Table 10.10 Muscles Crossing the Elbow Joint: Flexion and Extension of the Forearm 353

Table 10.11 Muscles of the Forearm: Movements of the Wrist, Hand, and Fingers 354

Table 10.12 Summary: Actions of Muscles Acting on the Arm, Forearm, and Hand 358

Table 10.13 Intrinsic Muscles of the Hand: Fine Movements of the Fingers 360

Table 10.14 Muscles Crossing the Hip and Knee Joints: Movements of the Thigh and Leg 363

Table 10.15 Muscles of the Leg: Movements of the Ankle and Toes 370

Table 10.16 Intrinsic Muscles of the Foot: Toe Movement and Arch Support 376

Table 10.17 Summary: Actions of Muscles Acting on the Thigh, Leg, and Foot 380

UNIT 3 Regulation and Integration of the Body

11 Fundamentals of the Nervous System and Nervous Tissue 386

Functions and Divisions of the Nervous System 387

Histology of Nervous Tissue 387
Neuroglia • Neurons

Membrane Potentials 395
Basic Principles of Electricity •
The Resting Membrane Potential •
Membrane Potentials That Act as Signals

The Synapse 407
Electrical Synapses • Chemical Synapses • Postsynaptic Potentials and Synaptic Integration

Neurotransmitters and Their Receptors 414
Classification of Neurotransmitters by Chemical Structure •
Classification of Neurotransmitters by Function •
Neurotransmitter Receptors

Basic Concepts of Neural Integration 421
Organization of Neurons: Neuronal Pools •
Types of Circuits • Patterns of Neural Processing

Developmental Aspects of Neurons 423

A CLOSER LOOK Pleasure Me, Pleasure Me! 418

12 The Central Nervous System 428

- The Brain 429
 - Embryonic Development • Regions and Organization • Ventricles • Cerebral Hemispheres • Diencephalon • Brain Stem • Cerebellum • Functional Brain Systems
- Higher Mental Functions 452
 - Brain Wave Patterns and the EEG • Consciousness • Sleep and Sleep-Wake Cycles • Language • Memory
- Protection of the Brain 458
 - Meninges • Cerebrospinal Fluid (CSF) • Blood Brain Barrier
- Homeostatic Imbalances of the Brain 462
 - Traumatic Brain Injuries • Cerebrovascular Accidents (CVAs) • Degenerative Brain Disorders
- The Spinal Cord 464
 - Gross Anatomy and Protection • Spinal Cord Cross-Sectional Anatomy • Neuronal Pathways • Spinal Cord Trauma and Disorders
- Diagnostic Procedures for Assessing CNS Dysfunction 474
- Developmental Aspects of the Central Nervous System 475

13 Peripheral Nervous System and Reflex Activity 483

PART 1 SENSORY RECEPTORS AND SENSATION 484

- Sensory Receptors 484
 - Classification by Stimulus Type • Classification by Location • Classification by Receptor Structure
- Sensory Integration: From Sensation to Perception 487
 - General Organization of the Somatosensory System • Perception of Pain

PART 2 TRANSMISSION LINES: NERVES AND THEIR STRUCTURE AND REPAIR 490

- Nerves and Associated Ganglia 490
 - Structure and Classification • Regeneration of Nerve Fibers
- Cranial Nerves 492
 - An Overview • Composition of Cranial Nerves
- Spinal Nerves 501
 - Innervation of Specific Body Regions

PART 3 MOTOR ENDINGS AND MOTOR ACTIVITY 511

- Peripheral Motor Endings 511
 - Innervation of Skeletal Muscle • Innervation of Visceral Muscle and Glands
- Motor Integration: From Intention to Effect 511
 - Levels of Motor Control

PART 4 REFLEX ACTIVITY 513

- The Reflex Arc 513
 - Components of a Reflex Arc
- Spinal Reflexes 513
 - Stretch and Tendon Reflexes • The Flexor and Crossed-Extensor Reflexes • Superficial Reflexes
- Developmental Aspects of the Peripheral Nervous System 519

14 The Autonomic Nervous System 524

- Overview 524
 - Comparison of the Somatic and Autonomic Nervous Systems • ANS Divisions
- ANS Anatomy 527
 - Parasympathetic (Craniosacral) Division • Sympathetic (Thoracolumbar) Division • Visceral Reflexes
- ANS Physiology 533
 - Neurotransmitters and Receptors • The Effects of Drugs • Interactions of the Autonomic Divisions • Control of Autonomic Function
- Homeostatic Imbalances of the ANS 539
- Developmental Aspects of the ANS 539
- SYSTEM CONNECTIONS 540

15 The Special Senses 544

- The Eye and Vision 545
 - Accessory Structures of the Eye • Structure of the Eyeball • Optics and the Eye • Photoreceptors and Phototransduction • Visual Pathways and Processing
- The Chemical Senses: Smell and Taste 565
 - Olfactory Epithelium and the Sense of Smell • Taste Buds and the Sense of Taste • Homeostatic Imbalances of the Chemical Senses
- The Ear: Hearing and Balance 570
 - Structure of the Ear • Physiology of Hearing • Equilibrium and Orientation • Homeostatic Imbalances of Hearing and Equilibrium
- Developmental Aspects of the Special Senses 584
 - Taste and Smell • Vision • Hearing and Balance

16 The Endocrine System 591

- The Endocrine System: An Overview 592
- Hormones 593
 - The Chemistry of Hormones • Mechanisms of Hormone Action • Target Cell Specificity • Control of Hormone

- Release • Half-Life, Onset, and Duration of Hormone Activity • Interaction of Hormones at Target Cells
- The Pituitary Gland and Hypothalamus 598
 - Pituitary-Hypothalamic Relationships • The Posterior Pituitary and Hypothalamic Hormones • Anterior Pituitary Hormones
- The Thyroid Gland 606
 - Location and Structure • Thyroid Hormone (TH) • Calcitonin
- The Parathyroid Glands 610
- The Adrenal (Suprarenal) Glands 611
 - The Adrenal Cortex • The Adrenal Medulla
- The Pineal Gland 617
- Other Endocrine Glands and Tissues 618
 - The Pancreas • The Gonads and Placenta • Hormone Secretion by Other Organs
- Developmental Aspects of the Endocrine System 623
- A CLOSER LOOK** Sweet Revenge: Taming the DM Monster? 624
- SYSTEM CONNECTIONS** 626

UNIT 4 Maintenance of the Body

17 Blood 631

- Overview: Blood Composition and Functions 632
 - Components • Physical Characteristics and Volume • Functions
- Blood Plasma 633
- Formed Elements 634
 - Erythrocytes (Red Blood Cells) • Leukocytes (White Blood Cells) • Platelets
- Hemostasis 646
 - Step 1: Vascular Spasm • Step 2: Platelet Plug Formation • Step 3: Coagulation • Clot Retraction and Fibrinolysis • Factors Limiting Clot Growth or Formation • Disorders of Hemostasis
- Transfusion and Blood Replacement 651
 - Transfusing Red Blood Cells • Restoring Blood Volume
- Diagnostic Blood Tests 653
- Developmental Aspects of Blood 654

18 The Cardiovascular System: The Heart 658

- The Pulmonary and Systemic Circuits 659
- Heart Anatomy 659
 - Size, Location, and Orientation • Coverings of the Heart • Layers of the Heart Wall • Chambers and Associated Great Vessels • Heart Valves • Pathway of Blood Through the Heart • Coronary Circulation

- Cardiac Muscle Fibers 671
 - Microscopic Anatomy • Mechanism and Events of Contraction • Energy Requirements
- Heart Physiology 674
 - Electrical Events • Heart Sounds • Mechanical Events: The Cardiac Cycle • Cardiac Output
- Developmental Aspects of the Heart 685
 - Before Birth • Heart Function Throughout Life

19 The Cardiovascular System: Blood Vessels 692

PART 1 BLOOD VESSEL STRUCTURE AND FUNCTION 693

- Structure of Blood Vessel Walls 693
- Arterial System 693
 - Elastic Arteries • Muscular Arteries • Arterioles
- Capillaries 696
 - Types of Capillaries • Capillary Beds
- Venous System 698
 - Venules • Veins
- Vascular Anastomoses 699

PART 2 PHYSIOLOGY OF CIRCULATION 701

- Introduction to Blood Flow, Blood Pressure, and Resistance 701
 - Definition of Terms • Relationship Between Flow, Pressure, and Resistance
- Systemic Blood Pressure 702
 - Arterial Blood Pressure • Capillary Blood Pressure • Venous Blood Pressure
- Maintaining Blood Pressure 704
 - Short-Term Regulation: Neural Controls • Short-Term Regulation: Hormonal Controls • Long-Term Regulation: Renal Mechanisms • Clinical Monitoring of Circulatory Efficiency • Homeostatic Imbalances in Blood Pressure
- Blood Flow Through Body Tissues: Tissue Perfusion 711
 - Velocity of Blood Flow • Autoregulation: Local Regulation of Blood Flow • Blood Flow in Special Areas • Blood Flow Through Capillaries and Capillary Dynamics • Circulatory Shock

PART 3 CIRCULATORY PATHWAYS: BLOOD VESSELS OF THE BODY 721

- The Two Main Circulations of the Body 721
- Systemic Arteries and Veins: Differences in Pathways and Courses 721
- Principal Vessels of the Systemic Circulation 721
- Table 19.3 Pulmonary and Systemic Circulations 722

Table 19.4 The Aorta and Major Arteries of the Systemic Circulation	724
Table 19.5 Arteries of the Head and Neck	726
Table 19.6 Arteries of the Upper Limbs and Thorax	728
Table 19.7 Arteries of the Abdomen	730
Table 19.8 Arteries of the Pelvis and Lower Limbs	734
Table 19.9 The Venae Cavae and the Major Veins of the Systemic Circulation	736
Table 19.10 Veins of the Head and Neck	738
Table 19.11 Veins of the Upper Limbs and Thorax	740
Table 19.12 Veins of the Abdomen	742
Table 19.13 Veins of the Pelvis and Lower Limbs	744
Developmental Aspects of Blood Vessels	745

A CLOSER LOOK Atherosclerosis? Get Out the Cardiovascular Drãno 700

SYSTEM CONNECTIONS 746

20 The Lymphatic System and Lymphoid Organs and Tissues 751

Lymphatic System	752
Distribution and Structure of Lymphatic Vessels • Lymph Transport	
Lymphoid Cells and Tissues	754
Lymphoid Cells • Lymphoid Tissue	
Lymph Nodes	755
Structure of a Lymph Node • Circulation in the Lymph Nodes	
Other Lymphoid Organs	757
Spleen • Thymus • Mucosa-Associated Lymphoid Tissue (MALT)	
Developmental Aspects of the Lymphatic System and Lymphoid Organs and Tissues	759
SYSTEM CONNECTIONS	761

21 The Immune System: Innate and Adaptive Body Defenses 764

PART 1 INNATE DEFENSES	765
Surface Barriers: Skin and Mucosae	765
Internal Innate Defenses: Cells and Chemicals	766
Phagocytes • Natural Killer (NK) Cells • Inflammation: Tissue Response to Injury • Antimicrobial Proteins • Fever	
PART 2 ADAPTIVE DEFENSES	773
Antigens	773
Complete Antigens and Haptens • Antigenic Determinants • Self-Antigens: MHC Proteins	
Cells of the Adaptive Immune System: An Overview	774
Lymphocytes • Antigen-Presenting Cells (APCs)	

Humoral Immune Response	778
Activation and Differentiation of B Cells • Immunological Memory • Active and Passive Humoral Immunity • Antibodies	
Cellular Immune Response	784
MHC Proteins and Antigen Presentation • Activation and Differentiation of T Cells • Roles of Specific Effector T Cells • Organ Transplants and Prevention of Rejection	
Homeostatic Imbalances of Immunity	792
Immunodeficiencies • Autoimmune Diseases • Hypersensitivities	
Developmental Aspects of the Immune System	796

22 The Respiratory System 801

Functional Anatomy of the Respiratory System	802
The Nose and Paranasal Sinuses • The Pharynx • The Larynx • The Trachea • The Bronchi and Subdivisions • The Lungs and Pleurae	
Mechanics of Breathing	816
Pressure Relationships in the Thoracic Cavity • Pulmonary Ventilation • Physical Factors Influencing Pulmonary Ventilation • Respiratory Volumes and Pulmonary Function Tests • Nonrespiratory Air Movements	
Gas Exchanges Between the Blood, Lungs, and Tissues	824
Basic Properties of Gases • Composition of Alveolar Gas • External Respiration • Internal Respiration	
Transport of Respiratory Gases by Blood	828
Oxygen Transport • Carbon Dioxide Transport	
Control of Respiration	834
Neural Mechanisms • Factors Influencing Breathing Rate and Depth	
Respiratory Adjustments	838
Exercise • High Altitude	
Homeostatic Imbalances of the Respiratory System	839
Chronic Obstructive Pulmonary Disease (COPD) • Asthma • Tuberculosis (TB) • Lung Cancer	
Developmental Aspects of the Respiratory System	841
SYSTEM CONNECTIONS	843

23 The Digestive System 849

PART 1 OVERVIEW OF THE DIGESTIVE SYSTEM	850
Digestive Processes	851
Basic Functional Concepts	852
Digestive System Organs: Relationships	852
Relationship of the Digestive Organs to the Peritoneum • Blood Supply: The Splanchnic Circulation • Histology of the	

Alimentary Canal • Enteric Nervous System of the Alimentary Canal

PART 2 FUNCTIONAL ANATOMY OF THE DIGESTIVE SYSTEM 856

The Mouth and Associated Organs 856

The Mouth • The Tongue • The Salivary Glands • The Teeth

The Pharynx 861

The Esophagus 862

Digestive Processes: Mouth to Esophagus 863

The Stomach 864

Gross Anatomy • Microscopic Anatomy • Digestive Processes in the Stomach • Regulation of Gastric Secretion • Regulation of Gastric Motility and Emptying

The Small Intestine and Associated Structures 874

The Small Intestine • The Liver and Gallbladder • The Pancreas • Regulation of Bile and Pancreatic Secretion and Entry into the Small Intestine • Digestive Processes in the Small Intestine

The Large Intestine 887

Gross Anatomy • Microscopic Anatomy • Bacterial Flora • Digestive Processes in the Large Intestine

PART 3 PHYSIOLOGY OF DIGESTION AND ABSORPTION 892

Digestion 892

Mechanism of Digestion: Enzymatic Hydrolysis • Digestion of Carbohydrates • Digestion of Proteins • Digestion of Lipids • Digestion of Nucleic Acids

Absorption 895

Carbohydrate Absorption • Protein Absorption • Lipid Absorption • Nucleic Acid Absorption • Vitamin Absorption • Electrolyte Absorption • Water Absorption • Malabsorption of Nutrients

Developmental Aspects of the Digestive System 898

Digestive System After Birth • Aging and the Digestive System

SYSTEM CONNECTIONS 900

24 Nutrition, Metabolism, and Body Temperature Regulation 906

Diet and Nutrition 907

Carbohydrates • Lipids • Proteins • Vitamins • Minerals

Overview of Metabolic Reactions 913

Anabolism and Catabolism • Oxidation-Reduction Reactions and the Role of Coenzymes • ATP Synthesis

Metabolism of Major Nutrients 917

Carbohydrate Metabolism • Lipid Metabolism • Protein Metabolism

Metabolic States of the Body 930

Catabolic-Anabolic Steady State of the Body • Absorptive State • Postabsorptive State

The Metabolic Role of the Liver 935

Cholesterol Metabolism and Regulation of Blood Cholesterol Levels

Energy Balance 938

Obesity • Regulation of Food Intake • Metabolic Rate and Heat Production • Regulation of Body Temperature

Developmental Aspects of Nutrition and Metabolism 948

A CLOSER LOOK Obesity: Magical Solution Wanted 942

25 The Urinary System 954

Kidney Anatomy 955

Location and External Anatomy • Internal Gross Anatomy • Blood and Nerve Supply • Nephrons

Kidney Physiology: Mechanisms of Urine Formation 963

Urine Formation, Step 1: Glomerular Filtration • Urine Formation, Step 2: Tubular Reabsorption • Urine Formation, Step 3: Tubular Secretion • Regulation of Urine Concentration and Volume

Clinical Evaluation of Kidney Function 977

Renal Clearance • Urine

Urine Transport, Storage, and Elimination 979

Ureters • Urinary Bladder • Urethra • Micturition

Developmental Aspects of the Urinary System 982

26 Fluid, Electrolyte, and Acid-Base Balance 990

Body Fluids 991

Body Water Content • Fluid Compartments • Composition of Body Fluids • Fluid Movement Among Compartments

Water Balance and ECF Osmolality 993

Regulation of Water Intake • Regulation of Water Output • Influence of Antidiuretic Hormone (ADH) • Disorders of Water Balance

Electrolyte Balance 997

The Central Role of Sodium in Fluid and Electrolyte Balance • Regulation of Sodium Balance • Regulation of Potassium Balance • Regulation of Calcium and Phosphate Balance • Regulation of Anions

Acid-Base Balance 1004

Chemical Buffer Systems • Respiratory Regulation of H⁺ • Renal Mechanisms of Acid-Base Balance • Abnormalities of Acid-Base Balance

Developmental Aspects of Fluid, Electrolyte, and Acid-Base Balance 1012

A CLOSER LOOK Sleuthing: Using Blood Values to Determine the Cause of Acidosis or Alkalosis 1011

SYSTEM CONNECTIONS 1013

UNIT 5 Continuity**27** The Reproductive System 1018

- Anatomy of the Male Reproductive System** 1019
The Scrotum • The Testes • The Male Perineum • The Penis • The Male Duct System • Male Accessory Glands • Semen
- Physiology of the Male Reproductive System** 1026
Male Sexual Response • Spermatogenesis • Hormonal Regulation of Male Reproductive Function
- Anatomy of the Female Reproductive System** 1035
The Ovaries • The Female Duct System • The External Genitalia • The Female Perineum • The Mammary Glands
- Physiology of the Female Reproductive System** 1043
Oogenesis • The Ovarian Cycle • Hormonal Regulation of the Ovarian Cycle • The Uterine (Menstrual) Cycle • Effects of Estrogens and Progesterone • Female Sexual Response
- Sexually Transmitted Infections** 1053
Gonorrhea • Syphilis • Chlamydia • Trichomoniasis • Genital Warts • Genital Herpes
- Developmental Aspects of the Reproductive System** 1054
Embryological and Fetal Events • Puberty • Menopause

SYSTEM CONNECTIONS 1059**28** Pregnancy and Human Development 1064

- From Egg to Zygote** 1065
Accomplishing Fertilization
- Events of Embryonic Development: Zygote to Blastocyst Implantation** 1067
Cleavage and Blastocyst Formation • Implantation • Placentation
- Events of Embryonic Development: Gastrula to Fetus** 1074
Formation and Roles of the Extraembryonic Membranes • Gastrulation: Germ Layer Formation • Organogenesis: Differentiation of the Germ Layers
- Events of Fetal Development** 1081
- Effects of Pregnancy on the Mother** 1082
Anatomical Changes • Metabolic Changes • Physiological Changes
- Parturition (Birth)** 1085
Initiation of Labor • Stages of Labor

- Adjustments of the Infant to Extrauterine Life** 1087
Taking the First Breath and Transition • Occlusion of Special Fetal Blood Vessels and Vascular Shunts

Lactation 1087

Assisted Reproductive Technology and Reproductive Cloning 1089

A CLOSER LOOK Contraception: To Be or Not To Be 1090**29** Heredity 1095

- The Vocabulary of Genetics** 1096
Gene Pairs (Alleles) • Genotype and Phenotype
- Sexual Sources of Genetic Variation** 1097
Chromosome Segregation and Independent Assortment • Crossover of Homologues and Gene Recombination • Random Fertilization
- Types of Inheritance** 1099
Dominant-Recessive Inheritance • Incomplete Dominance • Multiple-Allele Inheritance • Sex-Linked Inheritance • Polygene Inheritance
- Environmental Factors in Gene Expression** 1102
- Nontraditional Inheritance** 1102
Beyond DNA: Regulation of Gene Expression • Extranuclear (Mitochondrial) Inheritance
- Genetic Screening, Counseling, and Therapy** 1103
Carrier Recognition • Fetal Testing • Human Gene Therapy

Appendices

- A** The Metric System A-1
- B** Functional Groups in Organic Molecules A-3
- C** The Amino Acids A-4
- D** Two Important Metabolic Pathways A-5
- E** Periodic Table of the Elements A-8
- F** Reference Values for Selected Blood and Urine Studies A-9
- G** Focus on Innervation of the Upper Limb A-14
Focus on Innervation of the Lower Limb A-16
- H** Answers to Check Your Understanding, Multiple Choice, Matching Questions, and Case Study A-18

Glossary G-1

Photo and Illustration Credits C-1

Index I-1