<table>
<thead>
<tr>
<th></th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The Human Body: An Orientation</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Basic Chemistry</td>
<td>24</td>
</tr>
<tr>
<td>3</td>
<td>Cells and Tissue</td>
<td>62</td>
</tr>
<tr>
<td>4</td>
<td>Skin and Body Membranes</td>
<td>109</td>
</tr>
<tr>
<td>5</td>
<td>The Skeletal System</td>
<td>134</td>
</tr>
<tr>
<td>6</td>
<td>The Muscular System</td>
<td>181</td>
</tr>
<tr>
<td>7</td>
<td>The Nervous System</td>
<td>225</td>
</tr>
<tr>
<td>8</td>
<td>Special Senses</td>
<td>278</td>
</tr>
<tr>
<td>9</td>
<td>The Endocrine System</td>
<td>308</td>
</tr>
<tr>
<td>10</td>
<td>Blood</td>
<td>337</td>
</tr>
<tr>
<td>11</td>
<td>The Cardiovascular System</td>
<td>356</td>
</tr>
<tr>
<td>12</td>
<td>The Lymphatic System and Body Defenses</td>
<td>398</td>
</tr>
<tr>
<td>13</td>
<td>The Respiratory System</td>
<td>436</td>
</tr>
<tr>
<td>14</td>
<td>The Digestive System and Body Metabolism</td>
<td>463</td>
</tr>
<tr>
<td>15</td>
<td>The Urinary System</td>
<td>511</td>
</tr>
<tr>
<td>16</td>
<td>The Reproductive System</td>
<td>538</td>
</tr>
</tbody>
</table>
## Word Roots, Prefixes, and Suffixes by Chapter

More root words appear in Appendix B on page 584.

### Chapter 1: The Human Body: An Orientation
- **caput-**, **cephal-**: head
- **cervic-**, **cervix**: neck
- **dors-**: the back
- **venter**, **ventr-**: abdomen

### Chapter 3: Cells and Tissues
- **cutic-**, **derm-**: skin
- **cyt-**: cell
- **lip-**, **lipo-**: fat, lipid
- **medull-**, **myelo-**: marrow
- **myo-**: muscle
- **osteo-**: bone

### Chapter 5: The Skeletal System
- **append-**: hang to
- **ax-**, **axi-**, **axo-**: axis, axle

### Chapter 7: The Nervous System
- **cerebro-**, **enceph-**: brain
- **neuro-**: nerve
- **oculo-**, **ophthalmo-**: eye
- **oto-**: ear
- **psycho-**: mind

### Chapter 11: The Cardiovascular System
- **angi-**: vessel
- **aort-**: great artery
- **cardi-**, **cardio-**: heart
- **hema-**, **hemato-**, **hemo-**: blood
- **phleb-**: vein
- **thromb-**: clot

### Chapter 13: The Respiratory System
- **aero-**: air
- **broncho-**: bronchus (pl. bronchi)
- **pleur-**: side, rib
- **pneumo-**: air, wind
- **pulmo-**: lung
- **rhin-**, **rhino-**: nose

### Chapter 14: The Digestive System and Body Metabolism
- **bucco-**: cheek
- **chole-**: bile
- **entero-**, **ile-**: intestine
- **eso-**: within esophagus
- **gastri-**, **gastro-**: stomach
- **glosso-**, **lingua-**: tongue
- **hepat-**: liver
- **labi-**, **labri-**: lip
- **odontoi-**, **odont-**: teeth

### Chapter 15: The Urinary System
- **adren-**: toward the kidney
- **cyst-**: sac, bladder
- **diure-**, **mictur-**: urinate
- **nephro-**, **ren-**: kidney

### Chapter 16: The Reproductive System
- **cervic-**, **cervix**: neck (i.e. of uterus)
- **hyster-**, **hystero-**: uterus, womb
- **orchid-**: testis
- **ov-**, **ovi-**: egg
- **peri-**: around
- **vagin-**: a sheath
- **vulv-**: a covering

### Miscellaneous
- **gene-**: beginning, origin
- **kin-**, **kines-**: move
- **lymph-**: water
- **oligo-**: few
- **phobia-**: fear
- **photo-**: light
- **pyo-**: pus
- **roentgen**: X-ray
Learn the Essential *What, How & Why* of Human Anatomy & Physiology


### NEW! *What, How & Why* chapter previews introduce key examples of anatomy and physiology concepts that will be covered in the chapter. This technique helps learners hone in on what they are studying, how it functions, and why it is important for them to learn.

### NEW! Building Vocabulary Coaching Activities in MasteringA&P help students learn the essential language of A&P.

#### 11 The Cardiovascular System

**WHAT**

The cardiovascular system delivers oxygen and nutrients to the body tissues and carries away wastes such as carbon dioxide via blood.

**HOW**

The heart pumps blood throughout the body in blood vessels. Blood flow requires both the pumping action of the heart and changes in blood pressure.

**WHY**

If the cardiovascular system cannot perform its functions, wastes build up in tissues. Body organs fail to function properly, and then, once oxygen becomes depleted, they will die.

When most people hear the term cardiovascular system, they immediately think of the heart. We have all felt our own heart “pound” from time to time when we are nervous. The crucial importance of the heart has been recognized for ages. However, the cardiovascular system is much more than just the heart, and from a scientific and medical standpoint, it is important to understand why this system is so vital to life.

Night and day, minute after minute, our trillions of cells take up nutrients and excrete wastes. Although the pace of these exchanges slows during sleep, they must go on continuously when they stop, we die. Cells can make such exchanges only with the interstitial fluid in their immediate vicinity. Thus, some means of changing and “refreshing” these fluids is necessary to renew the nutrients and prevent pollution caused by the buildup of wastes. Like a bustling factory, the body must have a transportation system to carry its various “cargoes” back and forth. Instead of roads, railway tracks, and subways, the body’s delivery routes are its hollow blood vessels.

Most simply stated, the major function of the cardiovascular system is transportation. Using blood as the transport vehicle, the system carries oxygen, nutrients, cell wastes, hormones, and many other substances vital for body homeostasis to and from the cells. The force to move the blood

See p. 356.
Throughout every chapter, the text’s conversational writing style and straightforward explanations have been strengthened with familiar analogies and abundant mnemonic cues to help students learn and remember concepts.

**UPDATED!** Exceptionally clear photos and illustrations, including dozens of new and improved figures, present concepts and processes at the right level of detail. Many figures from the text are assignable as Art-Labeling Activities in MasteringA&P.

**Unique Concept Links** reinforce previously-learned concepts and help students make connections across body systems while learning new material.

---

**CONCEPT LINK**
The terms for the connective tissue coverings of a nerve should seem familiar: We discussed similar structures in the muscle chapter (Figure 6.1, p. 183). Names of muscle structures include the root word *mys*, whereas the root word *neuro* tells you that the structure relates to a nerve. For example, the endomyxium covers one individual muscle fiber, whereas the endoneurium covers one individual neuron fiber.

---

**See p. 111.**

**See p. 256.**
Explore Essential Careers and Clinical Examples

To inspire and inform students who are preparing for future healthcare careers, **up-to-date clinical applications** are integrated in context with discussions about the human body.

**UPDATED!** Homeostatic Imbalance discussions are clinical examples that revisit the text’s unique theme by describing how the loss of homeostasis leads to pathology or disease. Related assessment questions are assignable in MasteringA&P, along with Clinical Case Study coaching activities.

---

**Homeostatic Imbalance 7.11**

In difficult deliveries, temporary lack of oxygen may lead to cerebral palsy (pawl’ze), but this is only one of the suspected causes. Cerebral palsy is a neuromuscular disability in which the voluntary muscles are poorly controlled and spastic because of brain damage. About half of its victims have seizures, are intellectually disabled, and/or have impaired hearing or vision. Cerebral palsy is the largest single cause of physical dis-

---

**Focus on Careers essays** feature conversations with working professionals and explain the relevance of anatomy and physiology course topics across a wide range of allied health careers. Featured careers include:

- Ch. 2 Pharmacy Technician
- Ch. 4 Medical Transcriptionist
- Ch. 5 Radiologic Technologist
- Ch. 8 Physical Therapy Assistant
- Ch. 10 Phlebotomy Technician
- Ch. 15 Licensed Practical Nurse

Students can visit the MasteringA&P Study Area for more information about career options that are relevant to studying anatomy and physiology.

---

See p. 269.

See p. 56.
Mastering A&P improves results by engaging students before, during, and after class.

### Before Class

**Dynamic Study Modules** enable students to study more effectively on their own. With the Dynamic Study Modules mobile app, students can quickly access and learn the concepts they need to be more successful on quizzes and exams. **NEW!** Instructors can now select which questions to assign to students within each module.

Instructors can further encourage students to prepare for class by assigning **NEW! Building Vocabulary activities**, reading questions, art labeling activities, and more.
During Class

NEW! Learning Catalytics is a “bring your own device” (laptop, smartphone, or tablet) engagement, assessment, and classroom intelligence system. Students use their device to respond to open-ended questions and then discuss answers in groups based on their responses. Visit learningcatalytics.com to learn more.

After Class

A wide variety of interactive coaching activities can be assigned to students as homework, including Art-Labeling Activities, Interactive Physiology 2.0 tutorials, Clinical Case Studies, and activities featuring A&P Flix 3-D movie-quality animations of key physiological processes.
Media references in the text direct learners to digital resources in the MasteringA&P Study Area, including practice tests and quizzes, flashcards, a complete glossary, and more.

**NEW! Interactive Physiology 2.0**

NEW! Interactive Physiology 2.0 helps students advance beyond memorization to a genuine understanding of complex physiological processes. Fun, interactive tutorials, games, and quizzes give students additional explanations to help them grasp difficult concepts. IP 2.0 features brand-new graphics, quicker navigation, and more robust interactivity.

**Practice Anatomy Lab (PAL™ 3.0)** is a virtual anatomy study and practice tool that gives students 24/7 access to the most widely used lab specimens, including the human cadaver, anatomical models, histology, cat, and fetal pig. PAL 3.0 is easy to use and includes built-in audio pronunciations, rotatable bones, and simulated fill-in-the-blank lab practical exams.
NEW! The Twelfth Edition is available in Pearson’s fully-accessible eText 2.0 platform.*

NEW! The eText 2.0 mobile app offers offline access and can be downloaded for most iOS and Android phones and tablets from the iTunes or Google Play stores.

Powerful interactive and customization functions include instructor and student note-taking, highlighting, bookmarking, search, and links to glossary terms.

*The eText 2.0 edition will be live for Fall 2017 classes.
Additional Support for Students and Instructors

NEW! Anatomy & Physiology Coloring Workbook Twelfth Edition by Elaine N. Marieb and Simone Brito

The perfect companion to Essentials of Human Anatomy & Physiology, this engaging interactive workbook helps students get the most out of their study time. The Twelfth Edition includes NEW! crossword puzzles for every chapter, along with coloring activities, self-assessments, “At the Clinic” questions, and unique “Incredible Journey” visualization exercises that guide learners into memorable explorations of anatomical structures and physiological functions.

NEW! IN FULL COLOR! Essentials of Human Anatomy & Physiology Laboratory Manual Seventh Edition by Elaine N. Marieb and Pamela B. Jackson

This popular lab manual provides 27 exercises for a wide range of hands-on laboratory experiences, designed especially for a short A&P Lab course. This edition, which includes a Histology Atlas with 55 photomicrographs, features NEW! full-color illustrations, photos, and page design that help students navigate and learn the material faster and easier than ever before. Each concise lab exercise includes a Pre-Lab Quiz, brief background information, integrated learning objectives, student-friendly review sheets, and more.

The Instructor Resources Area in MasteringA&P includes the following downloadable tools:

• All of the figures, photos, and tables from the text in JPEG and PowerPoint® formats, in labelled and unlabeled versions, and with customizable labels and leader lines
• Step-edit Powerpoint slides that present multi-step process figures step-by-step
• Clicker Questions and Quiz Show Game questions that encourage class interaction
• A&PFlx™ animations bring human anatomy and physiology concepts to life
• Customizable PowerPoint® lecture outlines save valuable class prep time
• A comprehensive Instructor’s Guide includes lecture outlines, classroom activities, and teaching demonstrations for each chapter.
• Test Bank provides a wide variety of customizable questions across Bloom’s taxonomy levels. Includes art labeling questions, and available in Microsoft® Word and TestGen® formats.
ESSENTIALS
OF HUMAN ANATOMY & PHYSIOLOGY

ELAINE N. MARIEB, R.N., PH.D.,
HOLYOKE COMMUNITY COLLEGE

SUZANNE M. KELLER, PH.D.,
INDIAN HILLS COMMUNITY COLLEGE
Elaine 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 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 January 2012, Florida Gulf Coast University named a new health professions facility in her honor. The Dr. Elaine Nicpon Marieb Hall houses several specialized laboratories for the School of Nursing, made possible by Dr. Marieb’s generous support.

Suzanne Keller  
Suzanne M. Keller began her teaching career while she was still in graduate school at the University of Texas Health Science Center in San Antonio, Texas. Inspired by her lifelong passion for learning, Dr. Keller quickly adopted a teaching style focused on translating challenging concepts into easily understood parts using analogies and stories from her own experiences. An Iowa native, Dr. Keller uses her expertise to teach microbiology and anatomy and physiology at Indian Hills Community College, where most of her students are studying nursing or other health science programs.

Dr. Keller values education as a way for students to express their values through the careers they pursue. She supports those endeavors both in and out of the classroom by participating in her local Lions Club, by donating money to the Indian Hills Foundation to fund scholarships, and by financially supporting service-learning trips for students. Dr. Keller also enjoys sponsoring children in need with gifts for the holidays.

Dr. Keller is a member of the Human Anatomy and Physiology Society (HAPS) and the Iowa Academy of Science. Additionally, while engaged as an author, Dr. Keller has served on multiple advisory boards for various projects at Pearson and has authored assignments for the MasteringA&P online program. When not teaching or writing, Dr. Keller enjoys reading, traveling, family gatherings, and relaxing at home under the watchful eyes of her two canine children.
New to the Twelfth Edition

This edition has been thoroughly updated. New “What, How, Why” art opens each chapter, highlighting key concepts relating to the chapter topic. Other specific chapter-by-chapter changes include the following:

Chapter 1: The Human Body: An Orientation
- Updated description of the integumentary system to include vitamin D production in the presence of sunlight.
- Updated definition of the term cranial to specify the anterior leg, or shin.
- New “Critical Thinking and Clinical Application” question on blood clotting and feedback regulation.
- New “Critical Thinking and Clinical Application” question on using anatomical language to describe the location of a spinal injury and identifying the best medical imaging technique to diagnose a spinal problem.
- Updated “A Closer Look: Medical Imaging” with new discussion and images of mammogram and bone densitometry.
- New “Did You Get It?” questions throughout the chapter.

Chapter 2: Basic Chemistry
- New example of atomic symbol and Latin derivative for potassium.
- Revised discussion of hydrogen bonds to clarify that electrons are not involved in this type of bond as they are in covalent and ionic bonds.
- New example of importance of hydrogen bond in holding DNA strands together.
- All references to hydroxyl ion have been corrected to hydroxide ion.
- New sports analogies for acids and bases: putting electrons “in the game,” to represent free protons versus taking electrons “out of the game,” to represent binding a proton so it cannot contribute to a shift in pH.
- New “Did You Get It?” question part on the difference in pH between solutions at pH 11 and pH 5.
- Introduced concepts of hydrophobic and hydrophilic in discussion of phospholipids to help explain the functions of the polar head and fatty acid tails in cell membranes.
- Updated “Did You Get It?” question on lipids to include both phospholipids and cholesterol as cell membrane components.
- New analogy comparing the alpha (α)-helix to a metal spring.
- New analogy comparing a beta (β)-sheet to a pleated skirt, or strand of RNA to a piece of fabric.
- New description of RNA function as DNA’s “molecular assistant.”
- New shorthand symbols for messenger (mRNA), transfer (tRNA) and ribosomal (rRNA) added.
- New analogy comparing glucose and ATP to crude oil and gasoline; energy must be in the proper form before it can be used by cells.
- New explanation of why the terminal phosphate bonds in ATP are high energy.
- New “Critical Thinking and Clinical Application” question on sickle cell anemia.

Chapter 3: Cells and Tissues
- New description of the principle of complementarity.
- New information about how mitochondria divide.
- New “cargo” in the form of a membrane-bound receptor protein added to pathway 2 of Figure 3.6.
- New analogy for lysosomes as “cellular stomachs.”
- New art of plasma membrane and new detail of mitochondrial function including aerobic respiration in Table 3.1.
- New analogy of dust “crowd surfing” on the mucus that cilia carry from the lungs.
- New description of neuron function includes production of neurotransmitters.
- New colors used in Figure 3.14 DNA images to help students track new and old strands of DNA.
- New description of each chromosome being composed of two sister chromatids.
- New explanation of protein synthesis includes the role of the large ribosomal subunit in peptide bond formation.
- New Figure 3.18 descriptions of nuclei lining up in simple columnar and not lining up in pseudostratified epithelia.
- New description of cell shapes in different layers of stratified epithelia as “squished” and variable.
- New analogy for mucus produced by goblet cells as a “sticky trap” for dust and debris.
- New Figure 3.19 labels for osteocytes, the elastic and collagen fibers in areolar connective tissue, and the fluid matrix of blood; new art for dense fibrous connective tissue.
- New analogy for reticular tissue as “cellular bleachers” where other cells rest to monitor the body.
- Updated Figure 3.21 to include the term neuroglia to describe supporting cells.
- New information added to Figure 3.22: cartilage added to the connective tissue list and two major hallmarks of each of the four tissue types.
- New example of atrophy: when a broken leg is in a cast, lack of use causes muscles to atrophy during healing.
- Revised “A Closer Look: Cancer—An Intimate Enemy” and updated art.
- New “Short Answer Essay” questions on the components of the plasma membrane and their functions and on contrasting cytokinesis, interphase, and mitosis.
- New “Critical Thinking and Clinical Application” question on IV fluids and toxicity.
- New “Did You Get It?” questions throughout the chapter.

Chapter 4: Skin and Body Membranes
- New Figure 4.1 on epithelial membranes.
- New description of sensory receptors as part of nervous system including a list of the stimuli detected.
- New text updates on Figure 4.4 on epidermal structure; included a new figure question on stratum lucidum.
- New analogy for epidermal dendritic cells as “sentries” guarding the skin.
- New photo of stage 2 decubitus ulcer added to Homeostatic Imbalance 4.2.
- New layout for Figure 4.7 combining scanning electron micrograph of hair shaft with existing art of the hair root and follicle.
- New discussion of fourth-degree burns.
- New criteria for determining whether a burn is critical, including circumferential burns, burns of the airway, and burns to the genital area.
- New images of basal cell and squamous cell carcinoma in Figure 4.11.
- New component added to ABCDE rule: now includes “Evolution,” changes in a skin lesion over time.
- New “Short Answer Essay” questions on the risks of full-thickness burns, contrasting eccrine and apocrine sweat glands, and the relative severity of different skin infections.
- New “Critical Thinking and Clinical Application” question on burns.
- New “Did You Get It?” questions throughout the chapter.

Chapter 5: The Skeletal System
- Updated description of long bones.
- New analogy comparing lubrication over articular cartilage at joints to a slick marble floor.
Chapter 6: The Muscular System

- Updated descriptions of red and yellow bone marrow.
- Updated descriptions of sagittal and coronal sutures.
- Updated description of the capitulum of the humerus.
- New analogy comparing the trochlea meeting the trochlear notch to a curved "tongue-in-groove" joint.
- Updated description of buttock injections to include the consequences of hitting a nerve.
- Updated description of a synovial membrane to include areolar connective tissue.
- Updated description of cartilaginous joints.
- New description of saddle joints including a reference to opposable thumbs.
- Updated list of triggers for rheumatoid arthritis.
- Discussion of the fetal skull and fontanelles moved to the Developmental Aspects section.
- New analogy likening skulls of small children to "bobble heads."
- Updated review question on bones that articulate with the sphenoid to reflect only bones shown in the figures of Chapter 5.
- Updated "Short Answer Essay" question on synovial joints to include osteoarthritis.
- New "Short Answer Essay" question contrasting the foramen magnum and obturator foramen.
- New "Critical Thinking and Clinical Application" question on gouty arthritis.
- New statistics, information, and images added to "A Closer Look: Joint Ventures."
- Updated description of comminuted fractures on Table 5.2.
- Updated Figure 5.6 to include osteoblasts and osteoclasts in the descriptions of bone addition and resorption, respectively.
- Updated Systems In Sync with respect to the descriptions of relationships of cardiovascular and muscular systems to the skeletal system.

Chapter 7: The Nervous System

- Updated Figure 7.13 to use superior and inferior instead of cephalad and caudal.
- Updated Figure 7.24 to clarify why there are eight cervical nerves but only seven cervical vertebrae.
- New Learning Outcome on the structures and functions of neurons and neurolgia.
- Updated description of Nissl body function.
- New description clarifying the difference between a synapse and synaptic cleft.
- New analogy for a myelin sheath as the wrapping on an electrical cord.
- New explanation clarifying the differences between myelin sheaths in the CNS and PNS.
- New explanation clarifying the "short circuit" event in multiple sclerosis means that the signal may stop or "jump" to an unmyelinated neuron.
- New analogy for the structure of a unipolar cell body as a "cul-de-sac" off the "main road" that is the axon.
- Replaced references to the term basal ganglia with the more accurate term basal nuclei.
- Replaced the term arachnoid villi with arachnoid granulations.
- New statistics on stroke as the fifth leading cause of death in the United States (formerly identified as the third leading cause).
- New statistics regarding the rate of survival after a stroke.
- Replaced the phrase "mentally retarded" in the discussion of cerebral palsy with "intellectually disabled."
- New information incorporated in "A Closer Look: Tracking Down CNS Problems" to include a new dopamine imaging technique called DaTscan.

Chapter 8: Special Senses

- New description of lacrimal caruncle.
- New description of optic disc and the resulting blind spot.
- New analogy comparing the ability to see intermediate colors (between the red, green, and blue cones) to mixing paint.
- Updated the description of catacysts.
- New example of motion detected by dynamic equilibrium: a spinning carnival ride.
- New analogy for bending of the cupula as divers' fins in water.
- New description of foliate papillae on the side of the tongue, another location for taste buds.
- New analogy for the structure of a unipolar cell body as a "cul-de-sac" off the "main road" that is the axon.
- New "Did You Get It?" questions throughout the chapter.

Chapter 9: The Endocrine System

- Updated discussion of the mechanism of hormone action, including Figure 9.1 and its caption, to reflect that steroid hormones can act via either second messenger or direct gene activation.
- Updated explanation of how hormones alter cell activity.
- New analogy comparing second-messenger systems to delivering a letter.
- Revised coverage of endocrine glands to reflect their location in body from superior to inferior; Table 9.1 has also been revised to reflect the new order.
- Updated description explaining why a goiter forms in the absence of iodine.
- Updated description of body proportions in cretinism.
- New "Did You Get It?" question on adrenal cortex hormones.

Chapter 10: Blood

- Updated explanation of why the normal temperature of blood is a bit higher than body temperature.
- Added definitions for the suffixes -cytosis and -penta.
- Updated the analogy comparing the shape of the eosinophil nucleus to earmuffs.
- Updated the role of monocytes to include activation of lymphocytes.
- Updated the list of locations where red marrow is found in adults.
- Updated the major anticoagulants to include warfarin.
- New description of petechiae includes comparison to a skin rash.
• Added a learning tool about blood type reminding readers that a person does not make antibodies against their own blood type antigen(s).
• Updated discussion of lack of vitamin B12 as the cause of pernicious anemia and how this relates to intrinsic factor.

Chapter 11: The Cardiovascular System
• Updated description of pericardium.
• Revised discussion of the function of the atria to clarify that they assist with ventricular filling.
• Arteries and veins are now introduced in terms of the direction of blood flow with respect to the heart.
• New analogy comparing valve cusps filling with blood to a parachute filling with air.
• New analogy comparing the intrinsic conduction system setting heart rhythm to a drummer setting the beat for a rock band playing a song.
• New discussion of AEDs (automatic external defibrillators) included in the discussion of fibrillation.
• Reorganized section on the cardiac cycle to include five stages.
• New “Did You Get It?” question about isovolumetric contraction.
• Updated description of the effect of congestive heart failure on stroke volume.
• Updated description of pulmonary congestion.
• Updated description of pulmonary embolism.
• Discussion of fetal circulation moved to the Developmental Aspects section.
• Updated description of the blood pressure gradient to include a pressure of zero in the right atrium.
• New layout of Figure 11.8 reflecting five stages of the cardiac cycle.
• Updated Figure 11.9 description to clarify that any change in heart rate or stroke volume will also cause a change in cardiac output.
• Updated description of Figures 11.13 and 11.14 to include a statement that all vessels are bilateral unless otherwise stated in the text.
• Updated “A Closer Look” box on atherosclerosis.

Chapter 12: The Lymphatic System and Body Defenses
• Updated Figure 12.10 on lysis by complement to reflect water flowing into the cell to cause lysis.
• Added the role of B cells in antigen presentation to Figure 12.19.
• New information added regarding discovery of lymphatics in the central nervous system.
• Updated the description of adaptive defenses as defenses that fight antigens that get past the innate defenses.
• New description of how natural killer cells kill: via perforin and granzymes.
• Updated the description of positive chemotaxis to include movement toward the stimulus.
• Revised description of interferon to clarify that interferon fights only viral pathogens, not bacteria or fungi.
• New antibody function has been listed: opsonization.
• New description of Graves’ disease explaining that excess production of thyroxine is in response to antibodies that mimic TSH (thyroid-stimulating hormone).
• New descriptions of two additional types of hypersensitivities: reactions resulting in cell lysis and those forming antigen-antibody complexes.
• New example of when epinephrine is used during acute hypersensitivity: EpPen® injection.
• New Short Answer Essay question provided on mechanisms of killing used by the immune system, including lysozyme, perforin, and granzymes, and membrane attack complex (MAC).
• Updated “A Closer Look” box on AIDS, including new title.
• Updated Table 12.1 regarding the role of nasal hairs to include filtration of airborne particles.
• Updated Table 12.3 entry for “Cytokines: Perforin and granzymes” to include natural killer (NK) cells.
• New “Did You Get It?” questions throughout the chapter.

Chapter 13: The Respiratory System
• New information explaining neural regulation of breathing with respect to the dorsal and ventral respiratory groups of the medulla.
• New Short Answer Essay question contrasting hyperventilation and hyperpnea.
• Updated “A Closer Look” on cleanliness and asthma.
• New “Did You Get It?” questions throughout the chapter.

Chapter 14: The Digestive System
• New illustration outlining the parietal and visceral layers of the peritoneum (Figure 14.5).
• New illustrations showing both deciduous and permanent teeth in greater detail.
• Updated description of circular folds to provide students with a visual image of a corkscrew that slows progression of food and increases surface area at the same time.
• Added detail that rennin in infants is the same enzyme used to curdle milk in cheesemaking.
• Added narcotic pain medications to the list of causes of constipation, with stool softeners as a method of treatment.
• New “Did You Get It?” question on the four types of teeth and their functions.
• Added brief discussion of nucleic acid digestion, including the source of the enzymes and the reminder that nucleotides are the building blocks.
• Revised “A Closer Look” box on obesity to update references, statistics, and methods used to determine body composition, such as DEXA, the Bod Pod, and underwater weighing.

Chapter 15: The Urinary System
• Updated descriptions of the arterioles that connect to the glomerulus.
• Included a new learning tool describing the internal urethral sphincter as involuntary.
• New “Short Answer Essay” question contrasting the homeostatic imbalances oliguria, anuria, polyuria, and nocturia.
• New “Critical Thinking and Clinical Application” question about the relationship between hypertension and impaired kidney function, and tests that are used for determining impaired kidney function.
• New information included in “A Closer Look: Renal Failure and the Artificial Kidney” about a blood test to determine the creatinine level in order to estimate the rate of glomerular filtration.
• Did You Get It?

Chapter 16: The Reproductive System
• New explanation of the purpose of polar bodies: to reduce the chromosome number during oogenesis.
• Update of suggested age range for women to begin having regular mammograms: between 45 and 54.
• New Concept Link on chemotaxis.
• New photomicrograph showing sperm swarming an oocyte in Figure 16.16.
• New explanation of how an egg blocks additional sperm from entering; the surface sperm receptors on an oocyte are shed after the first sperm enters the cell.
• New clarification with updated definitions of miscarriage and abortion.
Many people contributed to our efforts in the creation of this twelfth edition. We offer our profound thanks to the following reviewers, whose thoughtful critiques informed and enhanced our development of this edition:

- William Brazelle, University of South Florida
- Sheree Daniel, Trinity Valley Community College
- Trevor Day, Mount Royal University
- Camille Di Scala, Chandler-Gilbert Community College
- Pamela Boyter Jackson, Piedmont Technical College
- Roop Jayaraman, Central Michigan University
- Kimberly Kushner, Pueblo Community College
- Frances Mills, Lake Michigan College
- Diane Pelletier, Green River Community College
- Heidi Peterson, Indian Hills Community College
- Kenneth Ryan, Alexandria Technical and Community College
- Holly Sanders, Gwinnett Technical College
- Scott Schaeffer, Harford Community College
- I-Chia Shih, Leeward Community College, University of Hawaii
- K. Dale Smoak, Piedmont Technical College
- Bill Snyder, Bluegrass Community and Technical College
- Greg Tefft, Northwest State Community College
- Sandra Uyeshiro, Modesto Junior College
- Khursheed Wankadiya, Central Piedmont Community College
- Carol T. Wismer, College of Lake County

Thanks are also extended to the reviewers of the Eleventh Edition: Carmen Carpenter, South University; Steven D. Collins, Niagara College; Janie Corbitt, Central Georgia Technical College–Milledgeville Campus; Eric D. Forman, Sauk Valley Community College; Andrew Goliszek, North Carolina A&T State University; Amy Goode, Illinois Central College; Jeannette Hafey, Springfield College; Ashley Hagler, Gaston College; Frances Miles, Lake Michigan College–Napier Avenue Campus; Margaret Ott, Tyler Junior College; Heidi Peterson, Indian Hills Community College–Ottumwa Campus; Laura Ritt, Burlington County College; Holly Sanders, Gwinnett Technical College; Leba Sarkis, Aims Community College; Gustavo A. Solis, Forsyth Technical Community College; Ginny Stokes, Nash Community College; Robert Suddith, Cape Fear Community College; John F. Tarpey, City College of San Francisco; Deborah S. Temperly, Delta College; Claudia Williams, Campbell University.

The entire group from Pearson and beyond deserves our heartfelt thanks for being the best team around! They have provided support, guidance, and humor throughout the writing process, which made the process fun and was most appreciated. Special thanks to Serina Beauparlant, Editor-In-Chief, Brooke Suchomel, Sr. Acquisitions Editor, and Tiffany Mok, Program Manager who passed the reins to Lauren Harp, Sr. Portfolio Manager, for crossing the finish line. Thanks also to Nicky Montalvo, Editorial Coordinator. Thank you to the content development team—Suzanne Olivier, Alice Fugate, and Lauren Hill for supervising an impressive variety of media content that will benefit both students and instructors. A special thank-you to Gary Hespenheide for the book’s beautiful and creative new interior and cover designs. The work of Kristin Piljay, Photo Researcher, resulted in some striking new photos for this edition; and Sally Peyrefitte, our excellent and diligent copyeditor, ensured a consistent style throughout the book. Proofreader Betsy Dietrich skillfully reviewed every page proof, and Sallie Steele provided a thorough and accurate index. Our talented art house, Imagineering STA Media Services, Inc., and compositor, Aptara, worked tirelessly to provide stunning artwork and student-friendly page layouts. Stacey Weinberger, Senior Manufacturing Buyer, Allison Rona, and Derek
Perrigo deserve special thanks for their expertise in delivering and presenting the final product to the market. A special thank you goes to David Novak, our Production and Art Coordinator, for taking on the role of two people during this edition and flawlessly handling every text and art-related production detail—David made the whole process smooth and successful. And last, but not least, Michele Mangelli—a tremendous thank-you for your skillful oversight of all aspects of the 12th edition, including assisting a first-time co-author in all things publishing . . . you’re an unflappable rock star!

Elaine N. Marieb

Suzanne M. Keller
Anatomy and Physiology
Pearson Education
1301 Sansome Street
San Francisco, CA 94111
## Contents

### 1 The Human Body: An Orientation

**Summary** 21

**Review Questions** 22

**Critical Thinking and Clinical Application Questions** 23

**A Closer Look**  
Medical Imaging: Illuminating the Body 10

- **Basic Chemistry** 24

#### 2 Concepts of Matter and Energy

- **Matter** 24
- **Energy** 25
  - Forms of Energy • Energy Form Conversions

#### 3 Composition of Matter

- **Elements and Atoms** 26
- **Atomic Structure** 26
  - The Basic Atomic Subparticles • Planetary and Orbital Models of an Atom
- **Identifying Elements** 28
  - Atomic Number • Atomic Mass Number • Atomic Weight and Isotopes

#### 4 Molecules and Compounds

#### 5 Chemical Bonds and Chemical Reactions

- **Bond Formation** 32
  - Role of Electrons • Types of Chemical Bonds
- **Patterns of Chemical Reactions** 36
  - Synthesis Reactions • Decomposition Reactions • Exchange Reactions • Factors Influencing the Rate of Chemical Reactions

#### 6 Biochemistry: The Chemical Composition of Living Matter

- **Inorganic Compounds** 39
  - Water • Salts • Acids and Bases
Chapter 2, continued

Organic Compounds  42
Carbohydrates • Lipids • Proteins • Nucleic Acids • Adenosine Triphosphate (ATP)

SUMMARY  57
REVIEW QUESTIONS  59
CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS  61
FOCUS ON CAREERS  Pharmacy Technician  56

Cells and Tissues  62

PART I: CELLS  62
Overview of the Cellular Basis of Life  62
Anatomy of a Generalized Cell  63
The Nucleus  63
Nuclear Envelope • Nucleolus • Chromatin
The Plasma Membrane  64
The Fluid Mosaic Model • Cell Membrane Junctions
The Cytoplasm  67
Cytosol and Inclusions • Organelles
Cell Extensions  71
Cilia and Flagella • Microvilli
Cell Diversity  74

Cell Physiology  76
Membrane Transport  76
Passive Processes: Diffusion and Filtration • Active Processes
Cell Division  82
Preparations: DNA Replication • Events of Cell Division
Protein Synthesis  85
Genes: The Blueprint for Protein Structure • The Role of RNA • The Process of Protein Synthesis

PART II: BODY TISSUES  88
Epithelial Tissue  88
Hallmarks of Epithelium  88

Classification of Epithelia  89
Simple Epithelia • Stratified Epithelia • Glandular Epithelium

Connective Tissue  93
Hallmarks of Connective Tissue  93
Extracellular Matrix  94
Types of Connective Tissue  94
Bone • Cartilage • Dense Connective Tissue • Loose Connective Tissue • Blood

Muscle Tissue  98
Skeletal Muscle  98
Cardiac Muscle  98
Smooth Muscle  100

Nervous Tissue  100
Tissue Repair (Wound Healing)  100

PART III: DEVELOPMENTAL ASPECTS OF CELLS AND TISSUES  102

SUMMARY  104
REVIEW QUESTIONS  107
CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS  108

A CLOSER LOOK  IV Therapy and Cellular “Tonics”  79
A CLOSER LOOK  Cancer—An Intimate Enemy  104

Skin and Body Membranes  109

Classification of Body Membranes  109
Epithelial Membranes  110
Cutaneous Membrane • Mucous Membranes • Serous Membranes
Connective Tissue Membranes  110
The Integumentary System (Skin) 112
Functions of the Integumentary System 112
Structure of the Skin 113
Epidermis • Dermis
Skin Color 118
Appendages of the Skin 119
Cutaneous Glands • Hair and Hair Follicles • Nails
Homeostatic Imbalances of Skin 123
Infections and Allergies • Burns • Skin Cancer

Developmental Aspects of Skin and Body Membranes 127

SUMMARY 130
REVIEW QUESTIONS 131
CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 132
A CLOSER LOOK A Wrinkle Out of Time 117
FOCUS ON CAREERS Medical Transcriptionist 128
SYSTEMS IN SYNC 129

5 The Skeletal System 134

Bones: An Overview 134
Functions of the Bones 135
Classification of Bones 135
Structure of Bone 137
Gross Anatomy of a Long Bone • Microscopic Anatomy
Bone Formation, Growth, and Remodeling 141
Bone Formation and Growth • Bone Remodeling
Bone Fractures 144

Axial Skeleton 146
Skull 146
Cranium • Facial Bones • The Hyoid Bone
Vertebral Column (Spine) 152

Appendicular Skeleton 158
Bones of the Shoulder Girdle 158
Bones of the Upper Limbs 158
Arm • Forearm • Hand
Bones of the Pelvic Girdle 162
Bones of the Lower Limbs 164
Thigh • Leg • Foot

Developmental Aspects of the Skeleton 173
Birth to Adulthood 173
Older Adults 175

SUMMARY 177
REVIEW QUESTIONS 178
CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 180
FOCUS ON CAREERS Radiologic Technologist 143
A CLOSER LOOK Joint Ventures 166
SYSTEMS IN SYNC 176

6 The Muscular System 181

Overview of Muscle Tissues 181
Muscle Types 181
Skeletal Muscle • Smooth Muscle • Cardiac Muscle
Muscle Functions 185
Produce Movement • Maintain Posture and Body Position • Stabilize Joints • Generate Heat • Additional Functions
PART III: CHEMICAL SENSES: SMELL AND TASTE  298
Olfactory Receptors and the Sense of Smell  298
Taste Buds and the Sense of Taste  300

PART IV: DEVELOPMENTAL ASPECTS OF THE SPECIAL SENSES  301
SUMMARY  303
REVIEW QUESTIONS  305
CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS  306
A CLOSER LOOK Visual Pigments—The Actual Photoreceptors  285
A CLOSER LOOK Bringing Things into Focus  289
FOCUS ON CAREERS Physical Therapy Assistant  295

The Endocrine System  308

The Endocrine System and Hormone Function—An Overview  309
The Chemistry of Hormones  309
Hormone Action  309
Direct Gene Activation • Second-Messenger System
Stimuli for Control of Hormone Release  311
Hormonal Stimuli • Humoral Stimuli • Neural Stimuli

The Major Endocrine Organs  312
Pituitary Gland and Hypothalamus  313
Pituitary-Hypothalamus Relationships
Pineal Gland  317
Thyroid Gland  317
Parathyroid Glands  319
Thymus  320
Chapter 9, continued

Adrenal Glands 320
- Hormones of the Adrenal Cortex • Hormones of the Adrenal Medulla
Pancreatic Islets 323
Gonads 327
- Hormones of the Ovaries • Hormones of the Testes

Other Hormone-Producing Tissues and Organs 327

Developmental Aspects of the Endocrine System 331
SUMMARY 333
REVIEW QUESTIONS 335
CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 336
A CLOSER LOOK Potential Uses for Growth Hormone 316
SYSTEMS IN SYNC 332

10 Blood 337

Composition and Functions of Blood 337
- Components 338
  - Physical Characteristics and Volume 338
  - Plasma 338
  - Formed Elements 340
    - Erythrocytes • Leukocytes • Platelets
  - Hematopoiesis (Blood Cell Formation) 345
    - Formation of Red Blood Cells • Formation of White Blood Cells and Platelets

Hemostasis 347
- Phases of Hemostasis 347
- Disorders of Hemostasis 348

Blood Groups and Transfusions 349
- Human Blood Groups 349
- Blood Typing 352

Developmental Aspects of Blood 352

SUMMARY 353
REVIEW QUESTIONS 354
CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 355
FOCUS ON CAREERS Phlebotomy Technician 350

11 The Cardiovascular System 356

The Heart 357
- Anatomy of the Heart 357
  - Size, Location, and Orientation • Coverings and Walls of the Heart
- Chambers and Associated Great Vessels 358
- Heart Valves 361
  - Cardiac Circulation
- Physiology of the Heart 364
  - Intrinsic Conduction System of the Heart: Setting the Basic Rhythm • Cardiac Cycle and Heart Sounds • Cardiac Output

Blood Vessels 370
- Microscopic Anatomy of Blood Vessels 370
  - Tunicas • Structural Differences in Arteries, Veins, and Capillaries
- Gross Anatomy of Blood Vessels 373
  - Major Arteries of the Systemic Circulation • Major Veins of the Systemic Circulation • Special Circulations
- Physiology of Circulation 380
  - Arterial Pulse • Blood Pressure • Capillary Exchange of Gases and Nutrients • Fluid Movements at Capillary Beds

Developmental Aspects of the Cardiovascular System 389

SUMMARY 392
REVIEW QUESTIONS 394
CRITICAL THINKING AND CLINICAL APPLICATION QUESTIONS 396
A CLOSER LOOK Electrocardiography: (Don’t) Be Still My Heart 367