ESSENTIALS
of Human
Anatomy &
Physiology

Elaine N. Marieb, R.N., Ph.D.,
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In the case of Anatomy & Physiology, a good picture is indeed worth a thousand words, and in the case of high school students, there is nothing more useful than a textbook that is well-written. Elaine Marieb’s Essentials of Human Anatomy and Physiology takes the difficult task of teaching A&P to high school students, and makes it easier than ever. Her writing style features simple, yet meaningful analogies, straight-forward language, and an effective use of bold-faced and italicized words to emphasize important terms and concepts. The illustrations are phenomenal—they are clearly-labeled, colorful, and focused on key structures and concepts. Homeostatic Imbalance features appear throughout, showing students what happens when body function is impaired, and keeps them interested in the material. Plus, the Chapter Summaries (at the end of each chapter) are like pre-made study guides, and I strongly encourage all of my students to use them when preparing for exams.

In addition to helping students learn, the text comes with ancillary materials to help you successfully present the material. I regularly use the resources provided on the Instructor Resources DVD (also available in MasteringA&P). My favorite resources are the well-written PowerPoint® lecture outlines, which follow the text and enable me to point-out important structures in figures and tables, in class. The TestGen® electronic test generator is another tool I use frequently, and confidently—knowing that my tests are challenging, fair, and aligned with material the students are studying.

The Eleventh Edition features a MasteringA&P course with 3-D movie-quality A&PFlix animations, Get Ready for A&P video tutors, and case-study coaching activities that help students apply the concepts they’re learning to real-life scenarios—keeping them interested in the topic and how it relates to their future careers. Many of our students are interested in allied health fields, including sports training, physical therapy, and chiropractic studies, and several graduates come back to tell me that their A&P course, taught with Elaine Marieb’s book, has been a great help to them in their college studies. (Any teacher will tell you—that is the best possible endorsement). The 11th edition also features brand new clinical photos and a new Concept Link feature that helps students relate previously learned material to the concept at-hand, to make sure students have a solid grasp on the most difficult topics in A&P.

Elaine Marieb’s Essentials of Human Anatomy & Physiology is truly an invaluable teaching tool that is thorough, accurate, and easy to learn from. I highly recommend it to any teacher who is teaching a high school level anatomy class.

Eugene Malaterra
Saint Joseph Regional High School
Montvale, New Jersey
This edition has been thoroughly updated. Specific chapter-by-chapter changes include:

Chapter 1: The Human Body: An Orientation
- New photos of the anatomical position, planes of the body, and MRI scans (Figure 1.6).
- New photo showing the nine abdominopelvic regions (Figure 1.9).
- New Critical Thinking and Clinical Application Question on carpal tunnel syndrome.

Chapter 2: Basic Chemistry
- New coverage of glycolipids (Table 2.5).
- New photo showing water's high surface tension (Figure 2.9).
- New descriptions of amino acid structures (Figure 2.17).

Chapter 3: Cells and Tissues
- New, illustrated Table 3.1: Parts of the Cell. Structure and Function.
- New Concept Link discussing phospholipids as polar molecules.
- New Concept Link discussing the molecular structure of DNA.
- New Concept Link discussing the joining of amino acids by enzymes into peptide bonds, in relation to translation.
- New clinical photo showing post-burn contracture scars, in Homeostatic Imbalance 3.3.

Chapter 4: Skin and Body Membranes
- New clinical photo showing cradle cap in a newborn baby, in Homeostatic Imbalance 4.4.
- New clinical photos of burns (Figure 4.11), cold sores, impetigo, and psoriasis (Figure 4.12), and skin cancer (Figure 4.13).
- New Concept Link discussing the relationship between mitosis, cell division, and cancer.

Chapter 5: The Skeletal System
- New Concept Link discussing the levels of structural organization, in relation to the gross anatomy of a long bone.
- New clinical photo of a child with rickets, in Homeostatic Imbalance 5.1.
- New Concept Link discussing the relationship between regional body terms and bone names, in relation to the axial skeleton.
- New Concept Link discussing the properties of tissues that form the joints.

Chapter 6: The Muscular System
- New Concept Link comparing ATP to a tightly coiled spring.
- New illustrations showing muscle action (Figure 6.14).
- New clinical photo of a patient with myasthenia gravis, in Homeostatic Imbalance 6.4.

Chapter 7: The Nervous System
- New Concept Link relating the concept of a feedback loop to the nervous system.
- New illustrated Table 7.1: Functions of Major Brain Regions.
- New clinical photo of a patient with cerebral palsy, in Homeostatic Imbalance 7.11.

Chapter 8: Special Senses
- New Concept Link relating the basic functions of the nervous system to each of the special senses.
- New clinical photo of an infant with strabismus, in Homeostatic Imbalance 8.11.

Chapter 9: The Endocrine System
- New Concept Link comparing a hormone’s relationship to its target cells with that of an enzyme to its substrate.
- New photo of individuals with disorders of pituitary growth hormones (Figure 9.6).
- New clinical photo of the lips of a patient with the hyperpigmentation of Addison's disease, in Homeostatic Imbalance 9.6.

Chapter 10: Blood
- New Concept Link discussing the structure of globular proteins.
- New Concept Link relating the concept of negative feedback to low blood oxygen levels.
- New clinical photo of a thrombus occluding a small pulmonary blood vessel in a human lung, in Homeostatic Imbalance 10.3.

Chapter 11: The Cardiovascular System
- New clinical photo of a prosthetic aortic heart valve, in Homeostatic Imbalance 11.2.
- New Concept Link relating one-way generation of an action potential to heart rhythm.
- New Concept Link relating the portal circulation that links the hypothalamus of the brain and the anterior pituitary gland to hepatic portal circulation.
- New Concept Link relating the passive process of filtration to blood flow.
- New Concept Link discussing epinephrine.

Chapter 12: The Lymphatic System and Body Defenses
- New Concept Link discussing hydrostatic and osmotic pressures.
- New Concept Link discussing the functions of lymphatic vessels.
- New Concept Link discussing the function of the thymus to produce hormones, in relation to lymphoid organs.
- New clinical photo of an abscess, in Homeostatic Imbalance 12.2.
- New Concept Link relating blood antigens to self-antigens.

Chapter 13: The Respiratory System
- New Concept Link discussing mucous membranes.
- New Concept Link relating pressure changes that drive filtration and blood flow to the mechanics of breathing.
- New clinical photo of a colored chest X-ray film showing a collapsed lung, in Homeostatic Imbalance 13.7.
- New Concept Link discussing blood pH, in relation to gas transport.

Chapter 14: The Digestive System and Body Metabolism
- New Concept Link discussing the function of papillae.
- New Concept Link discussing the basic function of valves.
- New Concept Link discussing hydrolysis reactions.
- New clinical photo of a baby with a cleft lip and palate, in Homeostatic Imbalance 14.15.

Chapter 15: The Urinary System
- New Concept Link discussing filtration as a passive process.
- New Concept Link discussing pH as a measure of hydrogen ion concentration, in relation to tubular secretion.
- New clinical photo of a urogram showing the presence of a kidney stone, in Homeostatic Imbalance 15.3.
- New Concept Link discussing the concept of interrelationships among organ systems, in relation to regulation of water intake and output.

Chapter 16: The Reproductive System
- New clinical photo of abnormal sperm, in Homeostatic Imbalance 16.2.
- New Concept Link discussing the tropic hormone, FSH.
- New Concept Link discussing the concept of the feedback loop.
New! Teachers: Use MasteringA&P to Personalize Your Course

New! Students: Use MasteringA&P to Study
Anytime, Anywhere

Bring A&P Concepts to Life

Introducing Essentials of Human Anatomy and Physiology, 11th edition

When it comes to preventing wrinkles, it helps to have good genes, to not smoke, to use a good sunscreen, and to think pleasant thoughts. Good genes speak for themselves—E's partly the luck of the draw whether you look your age or not. Smoking ages the skin by increasing production of an enzyme that destroys collagen. Collagen supports the skin and provides it with elasticity, so with loss of it, wrinkles appear.

UV radiation damage from too much unprotected exposure to the sun causes elastin fibers to clump, which results in leathery skin. For those wrinkled by years of smoking and sun-damage, a surgical treatment that removes the excess and sagging skin followed by laser resurfacing or microdermabrasion seem to be the only way to benefit the wrinkles.

However, for those who sport frozen lines, furrowed brows, or crow's feet due to frequent and repetitive expressions, cosmetic injections of Botulinum toxin type A, more familiarly called Botox Cosmetic, a toxin produced by the bacterium that causes Botulism, can help. When injected into the affected muscle, the toxin prevents the release of acetylcholine (ACh), a neurotransmitter that helps nerves release muscle activity. By inhibiting the underlying muscles' ability to contract, existing lines are smoothed out and nearly invisible in a week.

Botox was approved in 1989 to treat two eye muscle disorders—blepharospasm (uncontrollable blinking) and strabismus (misaligned eye). The discovery that Botox could be used cosmetically was pure luck—physicians using the toxin to counter abnormal eye contractions noticed that the vertical fine lines between the eyes (which make people look tired, angry, or displeased) had softened.

The recent rise in popularity of Botox "shots" has led to changes in the way it is marketed. Some physicians buy the toxin in bulk and arrange "Botox parties" or "Botox happy hours," get-togethers for 10 to 15 people, which make more less. One by one called, not for about! Examining with Botox is simply no and numb available.

Administering such gaffe a procedure is not a simple dispense of the medicine. There are specific precautions.

Botox is a preservative (beware of the blue "like a botox party"

For additional information on this chapter, visit www.masteringap.com

To recognize how medications affect patients, pharmacy technicians need thorough understanding of anatomy and physiology.

Although pharmacy technicians are legally prohibited from talking to patients about their symptoms, they can translate medical jargon, and discuss medications side effects and other precautions the patient may need to take. For example, doctors may recommend that patients who are on certain drugs avoid any other medications.

Pharmacy technicians must have a good grasp of anatomy and physiology to understand each drug's chemical properties.
Before It's Too Late
Identify Struggling Students

The color-coded gradebook helps you identify vulnerable students at a glance. Assignments are automatically graded, and grades can be easily exported to course management systems or spreadsheets.

Easily Assess Your Students Using Images from PAL™ 3.0

MasteringA&P allows you to assign multiple choice and open-ended questions using the images from PAL 3.0.

New! Assign Learning Objectives and Homeostatic Imbalance Content

The Learning Objectives and Homeostatic Imbalance sections in the book are now numbered, with corresponding assessments in MasteringA&P, making it easy for you to assign them for homework.

Composition and Functions of Blood

10-1 Describe the composition and volume of whole blood.
10-2 Describe its importance.

Blood is unique: It is the only tissue in the body. Although blood appears to be a thick, homogenous liquid, the microscope reveals that it is a previously undetected structure.

Identify Struggling Students Before It's Too Late

The color-coded gradebook helps you identify vulnerable students at a glance. Assignments are automatically graded, and grades can be easily exported to course management systems or spreadsheets.

Other Text Features Assignable in MasteringA&P:

- A&P Flix Coaching Activities offer stunning 3-D visuals of core concepts with in-depth assessments to test student understanding.
- Art-Based Questions gauge students' understanding of concepts illustrated in the book's figures. Wrong-answer feedback provides further guidance.
- Reading Questions keep students on track and are pre-built for easy assignment and grading.
- Test Bank questions are fully revised for the 11th edition, providing an easy way to assess your students.
STUDENTS: Use MasteringA&P® to Study Anytime, Anywhere

New! Study on the Go with the Dynamic Study Modules App
Dynamic Study Modules help you learn more information faster, whenever you have a few extra minutes to study.

New! Walk Through Key A&P Concepts with New Coaching Activities
Using animations and art from the book, coaching activities are accompanied by questions with specific hints and feedback.

Assess Your Knowledge of Terms and Structures with Art-Labeling Activities
Featuring art from the book, art labeling activities challenge students to identify key terms and structures. Corresponding figures in the book now refer students to these online activities for timely, interactive learning.
Help A&P Students Study & Retain Information

**New! Concept Links**
appear throughout the book and help students recall previously learned material, apply what they’ve learned to new material, and make connections across body systems.

**New! References to MasteringA&P** appear with relevant figures and show students where to go online for extra practice.

**Elaine Marieb's Conversational Writing Style** presents the material without technical jargon, and draws on the author's years of experience as a professor and former nursing student, using meaningful analogies that relate A&P to familiar, everyday concepts.

**Many short courses** in anatomy and physiology lack the time to consider chemistry as a topic. So why include it here? The answer is simple. The food you eat and the medicines you take when you are ill are composed of chemicals. Indeed, your entire body is made up of chemicals—thousands of them—continuously interacting with one another at an incredible pace.

It is possible to study anatomy without referring much to chemistry, but chemical reactions underlie all body processes—movement, digestion, the pumping of your heart, and even your thoughts. In this chapter we present the basics of
Did You Get It? Questions challenge students to stop, think, and answer concept check questions before moving forward.

Did You Get It?

12. Gary is trying with all his might to pull a tree stump out of the ground. It does not budge. Which type of contraction are his muscles undergoing?

13. What is meant by the term oxygen deficit?

14. To develop big, beautiful skeletal muscles, you should focus on which type of exercise: aerobic or resistance exercise?

(For answers, see Appendix D.)
Bring A&P Concepts to Life

3-D Anatomy Illustrations are dramatically dynamic and realistic, featuring vibrant, saturated colors to help students visualize key anatomical structures.

A Closer Look boxes discuss new advances in science and topics you may hear about in the news, and describe how they relate to the study of A&P.

A CLOSER LOOK Visual Pigments—The Actual Photoreceptors

A CLOSER LOOK IV Therapy and Cellular “Tonics”

A CLOSER LOOK Joint Ventures

Why is it important that red blood cells maintain their proper functions? By examining the red blood cell, you will gain insight into the processes that occur inside cells, and learn how these processes can be affected by changes in cell volume.

A Closer Look Joint Ventures

The technology for fashioning joints in modern suits of armor developed over centuries. The technology for creating the pavilion for joint replacement is based on what we understand today to be an osmotic process involving water movement.

In each type of photoreceptor, there is a region called an outer segment, attached to the cell body. The outer segment corresponds to an elongated neuron, whereas the fatter cones taper to pointed tips. The tiny photoreceptor cells of the retina have names that cause nerve impulses to be transmitted to the brain for visual interpretation.

Pigment regeneration ensures that you are not blinded by the dim light. The purple pigment found in rods (see figure below). It is the visual yellow.

The cone pigments, although similar to rhodopsin, differ in the specific form of retinal and recombined with opsin in an ATP-requiring process. They continue its conversion until it is once again vitamin A. The behavior of the visual pigments is dramatic. When light strikes the outer segment, attached to the cell body. The outer segment corresponds to an elongated neuron, whereas the fatter cones taper to pointed tips. The tiny photoreceptor cells of the retina have names that cause nerve impulses to be transmitted to the brain for visual interpretation.

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Bring the Real World into the Classroom

Focus on Careers boxes feature interviews with working professionals to show the relevance of anatomy and physiology across a wide range of allied health careers. Additional Focus on Careers content is available in the MasteringA&P Study Area.

Medical Transcriptionist

"If you have a basic understanding of anatomy and physiology, you will be much more accurate at interpreting and transcribing what you hear."

"You speak up a lot" or maintaining things. A medical transcriptionist interprets and selects sentences and medical terminology. They may also work on transcribing dictations and if necessary, they may also work on transcribing dictations and medical reports.

Physical Therapy Assistant

"Patients need to regain mobility rely on physical therapy assistants."

"It's not as much about the mechanics as it is about understanding the patient's needs and working with them to create a treatment plan."

Radiologic Technologist

"Radiologic technologists apply critical information that clinicians need to make accurate diagnoses."

"The medical environment is a lot more physically demanding than it looks. You need to be able to lift patients and move them quickly and safely."

You don’t want to make errors, because one thing you do wrong could cost this patient his or her life.

"I didn’t realize how big a field it was."

Homeostatic Imbalance 3.3

Scar tissue is strong, but it lacks the flexibility of most normal tissues. Perhaps even more important is its inability to perform the normal functions of the tissue it replaces. Thus, if scar tissue forms in the wall of the bladder, heart, or another muscular organ, it may severely harm the functioning of that organ.

New! Clinical Photos now accompany Homeostatic Imbalance sections, to help students visualize diseases they may encounter in their future careers. These sections stress the concept that loss of homeostasis leads to pathology or disease.

Photo showing post-burn contracture scars on the neck. A contracture is a permanent tightening of the skin affecting the underlying tendons or muscles. Contractures develop during the healing process as inelastic fibrous tissue replaces the normal elastic connective tissues. Because fibrous tissue resists stretching, movement of the affected area may be limited.
Resources for Students and Teachers

**MasteringA&P®**

MasteringA&P with Pearson eText for Essentials of Human Anatomy & Physiology is an online learning and assessment system proven to help students learn. It helps teachers maximize class time with customizable, easy-to-assign, automatically graded assessments that motivate students to learn outside of class and arrive prepared. The powerful gradebook provides unique insight into student and class performance, even before the first exam. As a result, teachers can spend valuable class time where students need it most. The Mastering system empowers students to take charge of their learning through activities aimed at different learning styles and engages them through practice and step-by-step guidance—at their convenience, 24/7. Upon textbook purchase, students and teachers are granted access to MasteringA&P with Pearson eText. Teachers can obtain preview or adoption access for MasteringA&P in one of the following ways:

**Preview Access**
- Teachers can request preview access online by visiting PearsonSchool.com/Access_Request (choose Initial Access then Option 2). Preview Access information will be sent to the teacher via email.

**Adoption Access**
- A Pearson Adoption Access Card, with codes and complete instructions, will be delivered with your textbook purchase (ISBN: 0-13-034391-9).
- OR Visit PearsonSchool.com/Access_Request (choose Initial Access then option 3). Adoption access information will be sent to the teacher via email. Students, ask your teacher for access.

**STUDENT Supplements**

Learn the structures and functions of the human body from a microscopic to macroscopic level using a wide variety of visual and written exercises and activities.

**Essentials of Human Anatomy and Physiology Laboratory Manual, 6th edition**
This brief hands-on lab manual includes 27 exercises featuring a wide range of activities and a four-color Histology Atlas with 55 photomicrographs. Each exercise includes a Pre-Lab Quiz, a materials list, background information, integrated objectives for focused learning, summaries of key concepts, a variety of hands-on activities, and challenging review sheets.

**Essentials of Interactive Physiology CD-ROM**
This brief version of the award-winning Interactive Physiology®10-System Suite is specifically adapted for the one-semester course, covering A&P concepts at just the right level and depth. Students benefit from animated tutorials that give insight into the following body systems: muscular, nervous, cardiovascular, respiratory, urinary, endocrine, digestive, and immune, plus coverage of fluids and electrolytes.

**TEACHER Supplements**

Some 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 Instructor Resource Center. You 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 you via email. Once logged into the IRC, enter ISBN 978-0-13-348166-2 in the “Search our Catalog” box to locate resources. Electronic teacher supplements are also available within the Instructor’s tab of MasteringA&P.

**Instructor’s Resource DVD**
The Instructor’s Resource DVD (IR-DVD) organizes all instructor media resources into one convenient location. The IR-DVD includes all of the figures and tables from the text in JPEG and PowerPoint® format; label-edit art with editable labels and leader lines; step-edit art that walks students progressively through multistep figures; Clicker Questions and Quiz Show Game questions to encourage student interaction; A&P Flix™ animations; PowerPoint® lecture outlines, the Instructor’s Guide/Test Bank in Microsoft® Word and PDF format; the TestGen® electronic test bank; and answers to Worksheets for Essentials of Interactive Physiology.

**Instructor’s Guide/Test Bank**
This fully updated all-in-one volume provides a wealth of resources for instructors. The Instructor’s Guide includes chapter summaries, suggested lecture outlines, teaching and media tips, chapter learning objectives, resources for teaching online, lecture hints, classroom demonstrations and student activities, relevant multimedia and software resources, and a new list of chapter objectives. The Test Bank includes multiple choice, true/false, matching, and essay questions. Test Bank questions are also assignable in MasteringA&P, where they are correlated to book learning objectives and sections, Global Science outcomes, and Bloom’s taxonomy.
Many people contributed to my efforts in the creation of this eleventh edition.

First, I would like to thank the following reviewers for their thoughtful critiques, which helped me with this revision: 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.

A very special thank you goes to Suzanne Keller of Indian Hills Community College–Ottumwa for her significant contributions to this edition, in the form of the new Concept Link feature.

The staff at Pearson contributed immensely in the form of support and guidance and deserve a hearty round of applause, one and all. Special thanks to Brooke Suchomel, Sr. Acquisitions Editor, and Shannon Cutt, my devoted Project Editor. Thanks also to Ashley Williams, Assistant Editor, for handling all administrative tasks necessary to set-up the project, and for overseeing revision of the Coloring Workbook. Thank you Natalie Pettry, Associate Content Producer, for supervising an impressive variety of media content that will benefit both students and instructors.

A special thank you to Tani Hasegawa for the book’s beautiful and creative new interior and cover design. The work of Kristin Piljay, Photo Researcher, resulted in an array of striking new photos for this edition; and Sally Peyrefitte, my excellent and diligent copyeditor, ensured a consistent style throughout the book. Proofreader Betsy Dietrich skillfully reviewed every page proof, and Kathy Pitcoff provided a thorough and accurate index.

Thank you Donna Kalal, Photo Image Lead, and Jenell Forscher, Rights & Permissions Project Manager, for your resourcefulness in clearing the photo and text permissions in a timely manner. My talented art house, Imagineering STA Media Services, Inc. and compositor, Cenveo® Publisher Services worked tirelessly to provide stunning artwork and student-friendly page layout. Stacey Weinberger, Senior Manufacturing Buyer and Allison Rona, Senior Marketing Manager deserve special thanks for their expertise in delivering and presenting the final product to the market. Last, an emphatic thank you goes to David Novak, my 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. Michele Mangelli—a tremendous thank you for your skillful oversight of all aspects of the 11th edition...you’ve never let me down.

Elaine N. Marieb

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About the Author

For Elaine N. Marieb, R.N., Ph.D., taking the needs of nursing and other allied health students 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, 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. This experience, along with continual feedback from health care professionals (including generations of former students taught by Dr. Marieb), has inspired the unique perspective and accessibility for which this book is known.

Dr. Marieb’s commitment to students extends beyond teaching and writing. Recognizing the challenges students face, Dr. Marieb contributes to the New Directions—Pathways 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. She also 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 Mount Holyoke’s Clapp Laboratory. Recognizing the severe national shortage of nursing faculty, Dr. Marieb also underwrites the Nursing Scholars of the Future Grant Program at the University of Massachusetts at Amherst.

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.

In January 2012, Florida Gulf Coast University named a new health professions facility: the Dr. Elaine Nicpon Marieb Hall. This facility contains laboratories in the School of Nursing that simulate an operating room, intensive-care unit, a labor and delivery room, and general medical surgical suites. She has also established a scholarship endowment for nontraditional students in the health professions and an endowment to enhance the activities of faculty, students, and staff within the health professions to support education, research, and community outreach.

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 Pearson Interactive Physiology® CD-ROM series. This text—Essentials of Human Anatomy & Physiology, Eleventh Edition—is the latest expression of her commitment to the needs of students pursuing the study of A&P.

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 board of directors of the famed Marie Selby Botanical Gardens and on the scholarship committee of the Women’s Resources Center of Sarasota County. She is an enthusiastic supporter of the local arts and enjoys a competitive match of doubles tennis.
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An Overview of Anatomy and Physiology

1-1 Define anatomy and physiology.
1-2 Explain how anatomy and physiology are related.

Most of us are naturally curious about our bodies; we want to know what makes us tick. Infants can keep themselves happy for a long time staring at their own hands or pulling their mother’s nose. Older children wonder where food goes when they swallow it, and some believe that they will grow a watermelon in their belly if they swallow the seeds. They scream loudly when approached by medical personnel (fearing shots that sting), but they like to play doctor. Adults become upset when their hearts pound, when they have uncontrollable hot flashes, or when they cannot keep their weight down.

Anatomy and physiology, subdivisions of biology, explore many of these topics as they describe how our bodies are put together and how they work.

Anatomy
Anatomy (ah-nat’o-me) is the study of the structure and shape of the body and its parts and their...
Relationships to one another. Whenever we look at our own body or study large body structures such as the heart or bones, we are observing gross anatomy; that is, we are studying large, easily observable structures. Indeed, the term anatomy, derived from the Greek words meaning to cut (tomato) apart (ana), is related most closely to gross anatomical studies because in such studies preserved animals or their organs are dissected (cut up) to be examined. Microscopic anatomy, in contrast, is the study of body structures that are too small to be seen with the naked eye. The cells and tissues of the body can only be seen through a microscope.

Physiology

Physiology (fiz’-e-ol’-o-je) is the study of how the body and its parts work or function (physio = nature; ology = the study of). Like anatomy, physiology has many subdivisions. For example, neurophysiology explains the workings of the nervous system, and cardiac physiology studies the function of the heart, which acts as a muscular pump to keep blood flowing throughout the body.

Relationship between Anatomy and Physiology

Anatomy and physiology are always related. The parts of your body form a well-organized unit, and each of those parts has a job to do to make the body operate as a whole. Structure determines what functions can take place. For example, the lungs are not muscular chambers like the heart and cannot pump blood through the body, but because the walls of their air sacs are very thin, they can exchange gases and provide oxygen to the body. We stress the intimate relationship between anatomy and physiology throughout this text to make your learning meaningful.

Did You Get It?

1. Why would you have a hard time learning and understanding physiology if you did not also understand anatomy?
2. Kidney function, bone growth, and beating of the heart are all topics of anatomy. True or false?

(For answers, see Appendix D.)
Figure 1.1 Levels of structural organization. In this diagram, components of the cardiovascular system are used to illustrate the levels of structural organization in a human being.

work together to accomplish a common purpose. For example, the heart and blood vessels of the cardiovascular system circulate blood continuously to carry nutrients and oxygen to all body cells.

In all, 11 organ systems make up the living human being, or the organism, which represents the highest level of structural organization, the organismal level. The organismal level is the sum total of all structural levels working together to keep us alive. (The major organs of each system are shown in Figure 1.2 on pp. 5–6). Refer to the figure as you read through the following descriptions of the organ systems.

Organ System Overview

Integumentary System

The integumentary (in-teg"u-men"tar-e) system is the external covering of the body, or the skin. It waterproofs the body and cushions and protects
the deeper tissues from injury. It also excretes salts and urea in perspiration and helps regulate body temperature. Temperature, pressure, and pain receptors located in the skin alert us to what is happening at the body surface.

**Skeletal System**
The **skeletal system** consists of bones, cartilages, ligaments, and joints. It supports the body and provides a framework that the skeletal muscles use to cause movement. It also has a protective function (for example, the skull encloses and protects the brain). Hematopoiesis (hem’ah-to-poi-e’sis), or formation of blood cells, takes place within the cavities of the skeleton. The hard substance of bones acts as a storehouse for minerals.

**Muscular System**
The muscles of the body have only one function—
to contract, or shorten. When this happens, movement occurs. Hence, muscles can be viewed as the “machines” of the body. The mobility of the body as a whole reflects the activity of **skeletal muscles**, the large, fleshy muscles attached to bones. When these contract, you are able to stand erect, walk, leap, grasp, throw a ball, or smile. The skeletal muscles form the **muscular system**. These muscles are distinct from the muscles of the heart and of other hollow organs, which move fluids (blood, urine) or other substances (such as food) along definite pathways within the body.

**Nervous System**
The **nervous system** is the body’s fast-acting control system. It consists of the brain, spinal cord, nerves, and sensory receptors. The body must be able to respond to irritants or stimuli coming from outside the body (such as light, sound, or changes in temperature) and from inside the body (such as decreases in oxygen or stretching of tissue). The sensory receptors detect these changes and send messages (via electrical signals called nerve impulses) to the central nervous system (brain and spinal cord) so that it is constantly informed about what is going on. The central nervous system then assesses this information and responds by activating the appropriate body effectors (muscles or glands).

**Endocrine System**
Like the nervous system, the **endocrine** (en’doh-krin) system controls body activities, but it acts much more slowly. The endocrine glands produce chemical molecules called hormones and release them into the blood to travel to relatively distant target organs.

The endocrine glands include the pituitary, thyroid, parathyroids, adrenals, thymus, pancreas, pineal, ovaries (in the female), and testes (in the male). The endocrine glands are not connected anatomically in the same way that parts of the other organ systems are. What they have in common is that they all secrete hormones, which regulate other structures. The body functions controlled by hormones are many and varied, involving every cell in the body. Growth, reproduction, and food use by cells are all controlled (at least in part) by hormones.

**Cardiovascular System**
The primary organs of the **cardiovascular system** are the heart and blood vessels. Using blood as the transporting fluid, the cardiovascular system carries oxygen, nutrients, hormones, and other substances to and from the tissue cells where exchanges are made. White blood cells and chemicals in the blood help to protect the body from such foreign invaders as bacteria, toxins, and tumor cells. The heart acts as the blood pump, propelling blood out of its chambers into the blood vessels to be transported to all body tissues.

**Lymphatic System**
The role of the **lymphatic system** complements that of the cardiovascular system. Its organs include lymphatic vessels, lymph nodes, and other lymphoid organs such as the spleen and tonsils. The lymphatic vessels return fluid leaked from the blood back to the blood vessels so that blood can be kept continuously circulating through the body. The lymph nodes and other lymphoid organs help to cleanse the blood and house cells involved in immunity.

**Respiratory System**
The job of the **respiratory system** is to keep the body constantly supplied with oxygen and to remove carbon dioxide. The respiratory system consists of the nasal passages, pharynx, larynx, trachea, bronchi, and lungs. Within the lungs are tiny air sacs. Gases are transported to and from the blood through the thin walls of these air sacs.

**Digestive System**
The digestive system is basically a tube running through the body from mouth to anus. The organs of
Figure 1.2 The body’s organ systems.

(a) Integumentary System
Forms the external body covering; protects deeper tissue from injury; synthesizes vitamin D; location of cutaneous receptors (pain, pressure, etc.) and sweat and oil glands.

(b) Skeletal System
Protects and supports body organs; provides a framework the muscles use to cause movement; blood cells are formed within bones; stores minerals.

(c) Muscular System
Allows manipulation of the environment, locomotion, and facial expression; maintains posture; produces heat.

(d) Nervous System
Fast-acting control system of the body; responds to internal and external changes by activating appropriate muscles and glands.

(e) Endocrine System
Glands secrete hormones that regulate processes such as growth, reproduction, and nutrient use by body cells.

(f) Cardiovascular System
Blood vessels transport blood, which carries oxygen, carbon dioxide, nutrients, wastes, etc.; the heart pumps blood.

(Figure continues on page 6.)
Figure 1.2 (continued) The body's organ systems.

(g) Lymphatic System
Picks up fluid leaked from blood vessels and returns it to blood; disposes of debris in the lymphatic stream; houses white blood cells involved in immunity.

(h) Respiratory System
Keeps blood constantly supplied with oxygen and removes carbon dioxide; the gaseous exchanges occur through the walls of the air sacs of the lungs.

(i) Digestive System
Breaks food down into absorbable units that enter the blood for distribution to body cells; indigestible foodstuffs are eliminated as feces.

(j) Urinary System
Eliminates nitrogen-containing wastes from the body; regulates water, electrolyte, and acid-base balance of the blood.

(k) Male Reproductive System
(l) Female Reproductive System
Overall function of the reproductive system is production of offspring. Testes produce sperm and male sex hormone; ducts and glands aid in delivery of viable sperm to the female reproductive tract. Ovaries produce eggs and female sex hormones; remaining structures serve as sites for fertilization and development of the fetus. Mammary glands of female breast produce milk to nourish the newborn.
the digestive system include the oral cavity (mouth), esophagus, stomach, small and large intestines, and rectum plus a number of accessory organs (liver, salivary glands, pancreas, and others). Their role is to break down food and deliver the products to the blood for dispersal to the body cells. The undigested food that remains in the tract leaves the body through the anus as feces. The breakdown activities that begin in the mouth are completed in the small intestine. From that point on, the major function of the digestive system is to reclaim water. The liver is considered a digestive organ because the bile it produces helps to break down fats. The pancreas, which delivers digestive enzymes to the small intestine, also is functionally a digestive organ.

**Urinary System**

The body produces wastes as by-products of its normal functions, and these wastes must be disposed of. One type of waste contains nitrogen (examples are urea and uric acid), which results when the body cells break down proteins and nucleic acids. The **urinary system** removes the nitrogen-containing wastes from the blood and flushes them from the body in urine. This system, often called the **excretory system**, is composed of the kidneys, ureters, bladder, and urethra. Other important functions of this system include maintaining the body's water and salt (electrolyte) balance and regulating the acid-base balance of the blood.

**Reproductive System**

The **reproductive system** exists primarily to produce offspring. The testes of the male produce sperm. Other male reproductive system structures are the scrotum, penis, accessory glands, and the duct system, which carries sperm to the outside of the body. The ovaries of the female produce eggs, or ova; the female duct system consists of the uterine tubes, uterus, and vagina. The uterus provides the site for the development of the fetus (immature infant) once fertilization has occurred.

**Did You Get It?**

3. At which level of structural organization is the stomach? At which level is a glucose molecule?

4. Which organ system includes the trachea, lungs, nasal cavity, and bronchi?

(For answers, see Appendix D.)
then to react to them. For example, if you cut your hand on broken glass, you involuntarily pull your hand away from the painful stimulus (the broken glass). You do not need to think about it—it just happens! Likewise, when the amount of carbon dioxide in your blood rises to dangerously high levels, your breathing rate speeds up to blow off the excess carbon dioxide.

**Responsiveness**

*Responsiveness, or irritability,* is the ability to sense changes (stimuli) in the environment and then to react to them. For example, if you cut your hand on broken glass, you involuntarily pull your hand away from the painful stimulus (the broken glass). You do not need to think about it—it just happens! Likewise, when the amount of carbon dioxide in your blood rises to dangerously high levels, your breathing rate speeds up to blow off the excess carbon dioxide.