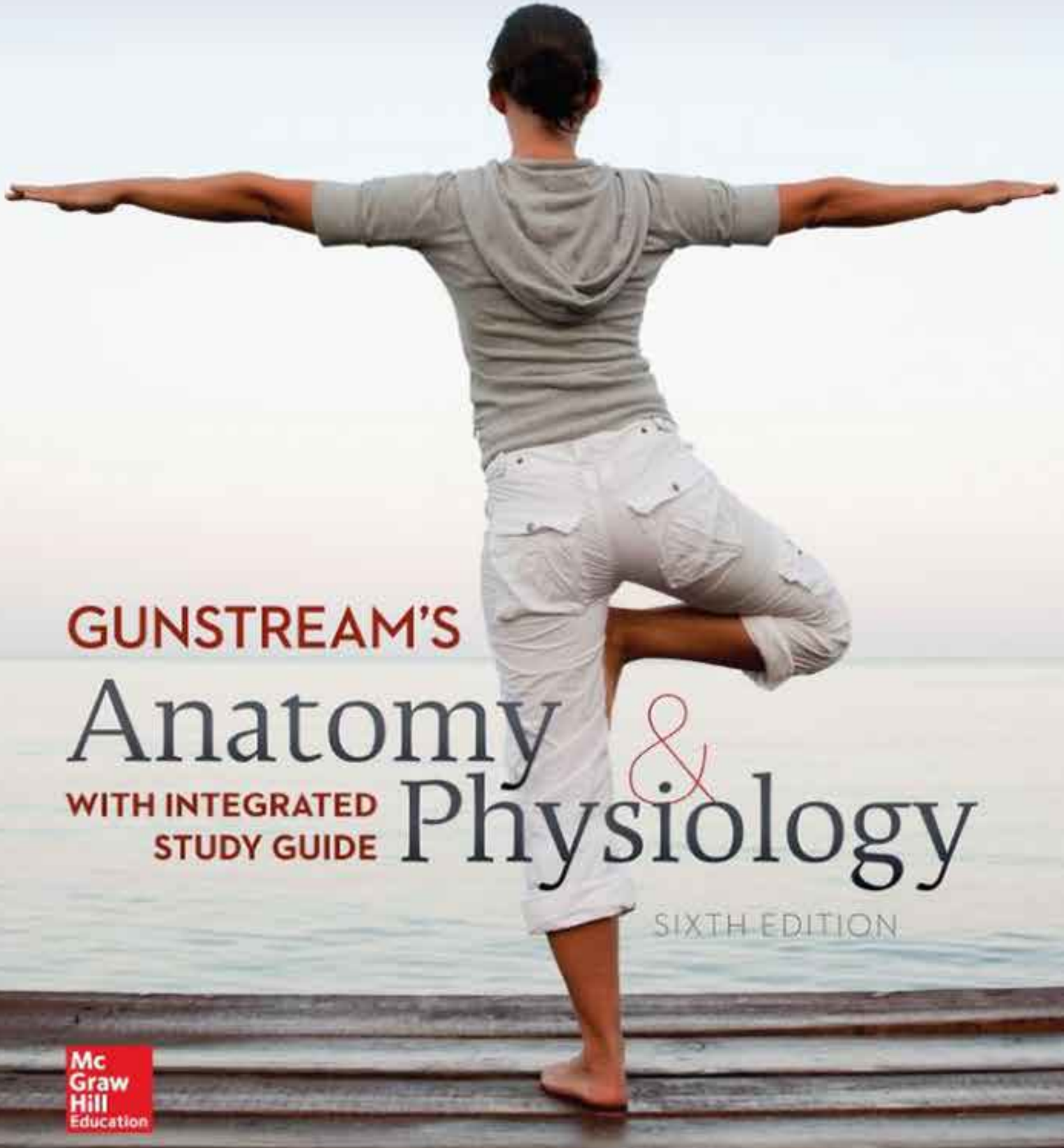
Jason LaPres Beth Kersten Yong Tang



GUNSTREAM'S Anatomy & Physiology

WITH INTEGRATED STUDY GUIDE

SIXTH EDITION

Mc Graw Hill Education

Gunstream's Anatomy & Physiology

With Integrated Study Guide

Jason LaPres
Beth Kersten
Yong Tang

SIXTH EDITION

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GUNSTREAM'S ANATOMY & PHYSIOLOGY: WITH INTEGRATED STUDY GUIDE, SIXTH EDITION

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ABOUT THE AUTHORS

Jason LaPres

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Jason LaPres received his Master's of Health Science degree with an emphasis in Anatomy and Physiology from Grand Valley State University in Allendale, Michigan

Over the past 12 years, Jason has had the good fortune to be associated with a number of colleagues who have mentored him, helped increase his skills, and trusted him with the responsibility of teaching students who will be caring for others. Jason began his career in Michigan, where from 2001-2003 he taught as an adjunct at Henry Ford Community College, Schoolcraft College, and Wayne County Community College, all in the Detroit area. Additionally, at that time he taught high school chemistry and physics at Detroit Charter High School. Jason is currently Director of The Honors College and Professor of Biology at Lone Star College-University Park in Houston, Texas. He has been with LSC since 2003. In his capacity with LSC he has served as Faculty Senate President for two of the six LSC campuses. His academic background is diverse and, although his primary teaching load is in the Human Anatomy and Physiology program, he has also taught classes in Pathophysiology and mentored several Honor Projects.

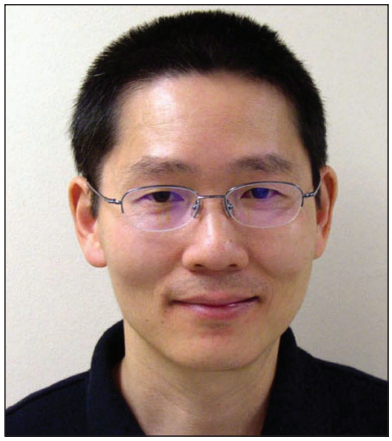
Prior to authoring this textbook, Jason produced dozens of textbook supplements and online resources for many other Anatomy and Physiology textbooks.

Beth Kersten

State College of Florida

Beth Ann Kersten is a tenured professor at the State College of Florida (SCF). Though her primary teaching responsibilities are currently focused on Anatomy and Physiology I and II, she has experience teaching comparative anatomy, histology, developmental biology, and non-major human biology. She authors a custom A&P I laboratory manual for SCF and sponsors a book scholarship for students enrolled in health science programs. She coordinates a peer tutoring program for A&P and is working to extend SCF's STEM initiative to local elementary schools. Beth employs a learning style specific approach to guide students in the development of study skills focused on their learning strengths, in addition to improving other student skills such as time management and note taking. She graduated with a PhD from Temple University where her research focused on neurodevelopment in zebrafish. Her post-doctoral research at the Wadsworth Research Center focused on the response of rat nervous tissue to the implantation of neural prosthetic devices. At Saint Vincent College, she supervised senior research projects on subjects such as the effects of retinoic acid on heart development in zebrafish and the ability of vitamin B12 supplements to regulate PMS symptoms in ovariectomized mice. Beth also maintains memberships in the Society for Neuroscience and the Human Anatomy & Physiology Society.

Beth currently lives in North Port FL with her husband John and daughter Melanie. As former Northerners, they greatly enjoy the ability to swim almost year round both in their pool and in the Gulf of Mexico.



Yong Tang

Front Range Community College

Dr. Tang is an Izaak Walton Killam scholar. He received his M.Sc. in Anatomy and Ph.D. in Physiology from Dalhousie University. He has also received post-doctoral training at the University of British Columbia and physical therapy training at Dalhousie University. Dr. Tang had taught a wide variety of biology courses at Dalhousie University, Saint Mary's University, Northeastern Illinois University, and University of Colorado at Boulder. He is currently a biology professor at Front Range Community College, where he teaches Human Anatomy and Physiology, Human Biology, and Pathophysiology. His research interest focuses on comparative physiology, particularly, the exercise physiology of animals. He has authored many research articles in scientific journals including Journal of Experimental Biology and American Journal of Physiology. He is also very active in developing teaching and learning materials and has written numerous ancillaries of Anatomy and Physiology textbooks.

CONTENTS

PREFACE

GUNSTREAM'S ANATOMY & PHYSIOLOGY WITH INTEGRATED STUDY GUIDE, Sixth Edition, is designed for students who are enrolled in a one-semester course in human anatomy and physiology. The scope, organization, writing style, depth of presentation, and pedagogical aspects of the text have been tailored to meet the needs of students preparing for a career in one of the allied health professions.

These students usually have diverse backgrounds, including limited exposure to biology and chemistry, and this presents a formidable challenge to the instructor. To help meet this challenge, this text is written in clear, concise English and simplifies the complexities of anatomy and physiology in ways that enhance understanding without diluting the essential subject matter.

Themes

There are two unifying themes in this presentation of normal human anatomy and physiology: (1) the relationships between structure and function of body parts, and (2) the mechanisms of homeostasis. In addition, interrelationships of the organ systems are noted where appropriate and useful.

Organization

The sequence of chapters progresses from simple to complex. The simple-to-complex progression is also used within each chapter. Chapters covering an organ system begin with anatomy to ensure that students are well prepared to understand the physiology that follows. Each organ system chapter concludes with a brief consideration of common disorders that the student may encounter in the clinical setting. An integrated study guide, unique among anatomy and physiology texts, is located between the text proper and the appendices.

Study Guide

The *Study Guide* is a proven mechanism for enhancing learning by students and features full-color line art. There is a study guide of four to nine pages for each chapter. Students demonstrate their understanding of the chapter by labeling diagrams and answering completion, matching, and true/false questions. The completion questions "compel" students to write and spell correctly the technical terms that they must know. Each chapter study guide concludes with a few critical-thinking, short-answer essay questions where students apply their knowledge to clinical situations.

Answers to the *Study Guide* are included in the *Instructor's Manual* to allow the instructor flexibility: (1) answers may be posted so students can check their own responses, or (2) they may be graded to assess student progress. Either way, prompt feedback to students is most effective in maximizing learning.

Chapter Opener and Learning Objectives

Each chapter begins with a list of major topics discussed in the chapter along with an opening vignette and image, which introduces and relates the content theme of the chapter. Under each section header within every chapter, the learning objectives are noted. This informs students of the major topics to be covered and their minimal learning responsibilities.

Key Terms

Several features have been incorporated to assist students in learning the necessary technical terms that often are troublesome for beginning students.

1. A list of *Selected Key Terms* with definitions, and including derivations where helpful, is provided at the beginning of the chapter to inform students of some of the key terms to watch for in the chapter.
2. Throughout the text, key terms are in bold or italic type for easy recognition, and they are defined at the time of first usage. A *phonetic pronunciation* follows for students who need help in pronouncing the term. Experience has shown that students learn only terms that they can pronounce.
3. *Keys to Medical Terminology* in appendix A explains how technical terms are structured and provides a list of prefixes, suffixes, and root words to further aid an understanding of medical terminology.

Figures and Tables

Over 350 high quality, full-color illustrations are coordinated with the text to help students visualize anatomical features and physiological concepts. Tables are used throughout to summarize information in a way that is more easily learned by students.

Clinical Insight

Numerous boxes containing related clinical information are strategically placed throughout the text. They serve to provide interesting and useful information related to the topic at hand. The Clinical Insight boxes are identified by a *medical cross* for easy recognition.

Check My Understanding

Review questions at the end of major sections challenge students to assess their understanding before proceeding.

Chapter Summary

The summary is conveniently linked by section while it briefly states the important facts and concepts covered in each chapter.

Self-Review

A brief quiz, composed of completion questions, allows students to evaluate their understanding of chapter topics. Answers are provided in appendix B for immediate feedback.

Critical Thinking

Each chapter concludes with several critical thinking questions, which further challenge students to apply their understanding of key chapter topics.

Changes in the Sixth Edition

The sixth edition has been substantially improved to help beginning students understand the basics of human anatomy and physiology. Many of the changes are based on reviewer feedback.

Global Changes

- Added chapter opening vignette and chapter outline.
- Updated terminology based on *Terminologia Anatomica (TA), Terminologia Histologica (TH) and Terminologia Embryologica (TE).*
- Revised selected key terms lists to include most relevant terms.
- Revised learning objectives that have been moved from the chapter outline to the beginning of major sections.
- Revised self-review and critical thinking questions.
- Revised study guides to match chapter content changes.
- Updated the art throughout for a more vibrant and consistent style.

CHAPTER 1

- Revised planes and sections for clarity, terminology, and inclusion of "longitudinal section" and "cross-section."
- Updated and revised homeostasis discussion.
- Added figures 1.7 and 1.8 (serous membranes), 1.14 (positive-feedback mechanism), and four figures illustrating negative-feedback mechanisms.

CHAPTER 2

- Added Figure 2.1 containing the periodic table with the 12 most abundant elements in humans.

- Added eight figures illustrating challenging chemical concepts.
- Revised and expanded chemical formula discussion.
- Revised chemical bond discussion to include the difference between nonpolar and polar covalent bonds and an updated description of hydrogen bonds.
- Revised section describing water, solutes, and solvents, and their importance in physiology.
- Added the respiratory mechanism and renal mechanism to the section on buffers.
- Added descriptions of dehydration synthesis and hydrolysis to the beginning of the organic compound section.
- Updated discussion of protein structure to include primary through quaternary levels of structure.

CHAPTER 3

- Revised the definitions of cytoplasm, osmosis, hypertonic solution, hypotonic solution, and isotonic solution.
- Added the definitions of cytosol, simple diffusion, facilitated diffusion, channel-mediated diffusion, carrier-mediated diffusion, and facilitated transport.
- Modified all the figures focusing on cell structure and transport mechanisms across plasma membranes.
- Added figures 3.10 (diffusion), 3.13 (carrier-mediated active transport), and 3.14b (exocytosis).
- Revised the paragraph on carrier-mediated active transport.

CHAPTER 4

- Added figures 4.1 (epithelial cell shapes) and 4.2 (classification of epithelial tissues based on number of cell layers).
- Revised the connective tissue section of the chapter to include loose connective tissues (areolar, adipose, and reticular) and dense connective tissues (dense regular, dense irregular, and elastic), with new figures demonstrating reticular, dense irregular, and elastic connective tissues.
- Removed Tables 4.1 through 4.3 because of redundancy with chapter text and expanded figure legends.
- Added figure 4.24 on body membranes.

CHAPTER 5

- Added a discussion of the organization of the epidermis that includes all five layers of the epidermis and updated information on the cell death occurring within the epidermis.
- Updated temperature regulation function of the skin to reflect the adjustments in blood flow within the skin as the primary methods of cooling the body and conserving heat.
- Revised discussion on melanocytes to provide a better description of melanocyte distribution and factors affecting rates of melanin production.
- Added figures 5.2 (illustrating the organization of the epidermis), 5.3 (comparison of thin and thick skin), and 5.4 (illustrating epidermal ridges forming the fingerprint pattern).
- Updated the eccrine sweat gland discussion to include its protective abilities.

CHAPTER 6

- Modified all the figures of long bone structures, axial skeleton, and appendicular skeleton.
- Added figures 6.1 (basic types of bones), 6.7 (surface features of bones), 6.8b (superior view of skull), 6.12b (superior view of skull floor), 6.13 (hyoid bone), 6.16 (general structure of vertebrae), 6.17c (articulation between atlas and axis), 6.19b (articulation between a rib and a vertebra), 6.22 (male and female pelves), 6.24 (types of joints), 6.25 (types of freely movable joints.), 6.26 (common movements at freely movable joints), 6.28 (herniated disc), and 6.29 (abnormal spinal curvatures).
- Added the images of cleft palate, cleft lip, and hip joint prosthesis to the Clinical Insight boxes.
- Revised the section on endochondral ossification and the section on freely movable joints.

CHAPTER 7

- Revised discussion of the connective tissues associated with muscles for clarity and accuracy.
- Expanded discussion of myofilament structure to clarify the changes that occur during muscle contraction.
- Updated discussion on the mechanism of contraction and included a numbered list of steps that is integrated with a new figure 7.6 of the contraction cycle and sliding filament model.
- Updated figure 7.7 on energy sources so that it better matches the chemistry in chapter 2.
- Added figures 7.10 (motor units) and 7.11 (origins and insertions).

CHAPTER 8

- Added section on the Membrane Potential, which describes the resting membrane potential, why it exists, and the role of the Na^+/K^+ pump in maintaining it.
- Added figures 8.7 (resting membrane potential and Na^+/K^+ pump) and 8.8 (steps involved in depolarization and repolarization).
- Revised the section on Nerve Impulse Formation and Repolarization to improve anatomical and physiological accuracy, including the actual voltage changes that occur during each process.
- Added a section on the hypothalamus, which includes the pineal gland and the hormone melatonin.
- Added a paragraph describing the functions of cerebrospinal fluid.
- Added the four major branches of a spinal nerve and what they innervate to improve the understanding of how the anterior rami either form plexuses or intercostal nerves.

CHAPTER 9

- Added "Pressure, Touch, and Stretch" section that focuses on the various types of mechanoreceptors. Receptors included in this section are lamellated corpuscles, free nerve endings, hair root plexuses, tactile corpuscles, tactile discs and tactile cells, baroreceptors, and proprioceptors (muscle spindles and tendon organs).
- Added a section on Chemoreceptors.
- Added a paragraph discussing the number of different olfactory receptors in humans, the average number of odors detectable by a human, gender differences in odor detection, olfactory training, the effects of age on odor detection, the detection of human pheromones, and olfactory epithelium regeneration.
- Added a discussion of common disorders associated with the senses of taste and smell.
- Added a Clinical Insight box on Age-Related Macular Degeneration with figures.

CHAPTER 10

- Added figures 10.1 (exocrine and endocrine secretions), 10.2 (mechanisms of chemical signaling), 10.6 (control of hormone secretions), 10.7 (pituitary gland hormones and their target organs), 10.10 (hormonal control of blood calcium levels), and 10.13 (hormonal control of blood glucose levels).

- Created figure 10.4 with numbered steps by combining figures depicting steroid versus non-steroid mechanisms of action from previous edition.
- Revised and reorganized section on control of hormone secretion.
- Revised section on the role of parathyroid hormone in controlling blood calcium levels, including the addition of the actions of vitamin D.

CHAPTER 11

- Revised figures 11.3 (regulation of erythropoiesis), 11.4 (development of formed elements), and 11.10 (compatibility of blood types).
- Added figures 11.1b (blood smear), 11.6 (hemostasis), and 11.9 (HDN).
- Added Clinical Insight boxes on jaundice, HDL, and LDL.
- Revised the paragraphs on platelets, globulins, nitrogenous wastes, general discussion of blood types, and ABO blood group.
- Added a section of "Compatibility of Blood Types for Transfusions."

CHAPTER 12

- Revised figures 12.7 (systemic and pulmonary circuits), 12.11 (neural control of heart), 12.15 (systemic blood pressure), and 12.17 (locations of pulse).
- Added figures 12.12c (capillary wall), 12.18b (arteries of thoracic cage), 12.23 (veins of thoracic cage), 12.24a (veins of hepatic portal system), and 12.24b (veins of abdominopelvic cavity).
- Revised the definitions of cardiac cycle, systole, diastole, stroke volume, and blood pressure.
- Revised the discussion of autonomic regulation of heart to include sensory information received from chemoreceptors.
- Revised the descriptions of the structure of capillaries, factors affecting blood pressure, and hepatic portal system.
- Moved "Flow of Blood Through the Heart" and "Blood Supply to the Heart" to the "Anatomy of Heart" section.

CHAPTER 13

- Revised the first half of the chapter into a new section called "Lymph and Lymphatic Vessels", which includes information from the "Lymph," "Lymphatic Capillaries and Vessels," and "Transport of Lymph" sections in the previous edition."
- Revised discussion of lymphoid organs to differentiate primary and secondary lymphoid organs.
- Updated the functions of chemical defenses to include complement fixation.
- Improved the accuracy and progression in figure 13.8 showing the development of lymphocytes.
- Updated the "Types of Immunity" section to better define the types and include more relevant examples.

CHAPTER 14

- Revised figures 14.1 (organization of respiratory system and upper respiratory tract), 14.4 (lower respiratory tract), 14.5 (bronchioles and alveoli), 14.7 (mechanisms of breathing), and 14.9 (control of respiration).
- Added figures 14.6 (respiratory muscles) and 14.11 (exchange and transport of O_2 and CO_2).
- Revised the definitions of external respiration, internal respiration, upper respiratory tract, lower respiratory tract, and bronchial tree.
- Revised the descriptions of mechanism of inspiration and the chemical factors influencing breathing.
- Added a paragraph on irritant reflexes.

CHAPTER 15

- Revised "Structure" of the stomach section to include the anatomic specializations of the stomach that accommodate the unique functions of the stomach.
- Updated the description of lipid absorption in the small intestine for content accuracy.
- Added figure 15.17 to demonstrate the revised description of lipid absorption in the small intestine.
- Updated text to reflect that the cellular respiration of one molecule of glucose yields between 36-38 ATP. The text revision explains that electron transport chain can yield between 32 to 34 ATP, depending upon the cell in which it occurs.
- Added a section entitled "My Plate: A Visual Guide to Healthy Eating," with corresponding My Plate figure.

CHAPTER 16

- Reordered and revised discussion of the functions of the urinary system as the first section in the chapter.
- Revised the urine formation discussion to include four steps: glomerular filtration, tubular reabsorption, tubular secretion, and water conservation.
- Revised figure 16.8 on proximal convoluted tubule functions to include both reabsorption and secretion.
- Added figure 16.9 summarizing the functions of the nephron loop, DCT, and collecting duct, including hormonal controls.
- Expanded the acid-base balance section to include respiratory and renal mechanisms.

CHAPTER 17

- Revised figures 17.2 (testis and spermatogenesis), 17.4a (sperm), 17.6 (hormonal control of spermatogenesis and testosterone secretion), and 17.8b (ovarian follicular development).
- Added figures 17.5 (male reproductive organs), 17.8a (ovary), 17.13 (hormonal control of the ovarian cycle), and 17.15a (cervical cap).
- Added the definitions of ovarian follicles, granulosa cells, and tertiary ovarian follicles.
- Revised the definitions of primary, secondary, and mature ovarian follicles.
- Revised the descriptions of the hormonal control of reproduction in males and females, oogenesis, and the female sexual response.
- Added the discussions of random alignment of homologous chromosomes and recombination in spermatogenesis and oogenesis, bulbs of vestibule, benign prostatic hyperplasia, prostate cancer, and testicular cancer.

CHAPTER 18

- Moved the Hormonal Control of Pregnancy to follow Fetal Development.
- Added additional structures formed by the ectoderm, mesoderm, and endoderm to Table 18.1.
- Updated the functions of the hormone relaxin to match what is known in humans.
- Revised the detailed description of the neuroendocrine positive-feedback mechanism promoting labor contractions for clarity and flow.
- Revised the Clinical Insight box on oxytocin to include Pitocin and its clinical uses.
- Updated the inheritance section of the text to include new sections on Incomplete Dominance, Codominance, and Polygenic Inheritance.
- Reorganized the inheritance section to improve content flow by placing the X-Linked Traits section and Table 18.5 immediately after polygenic inheritance.
- Removed several Clinical Insight boxes.

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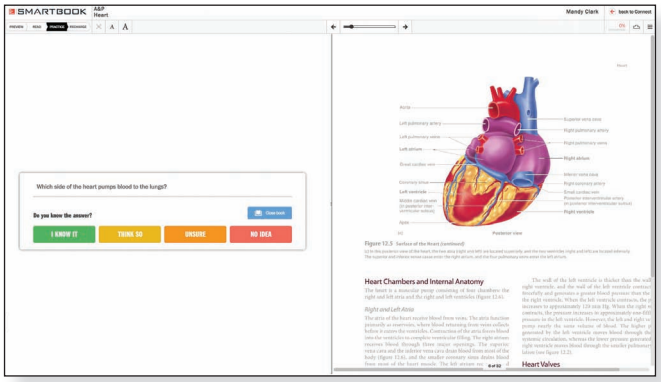

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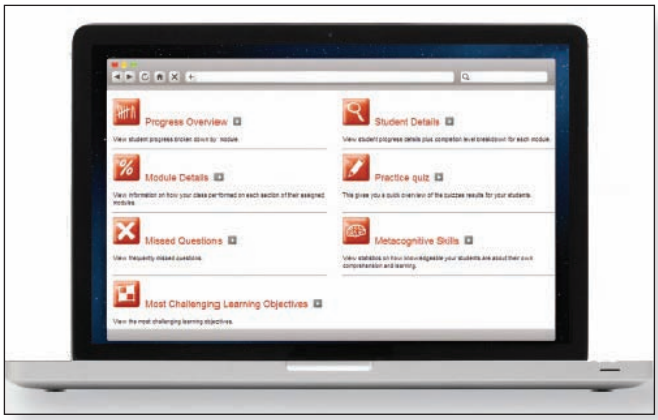

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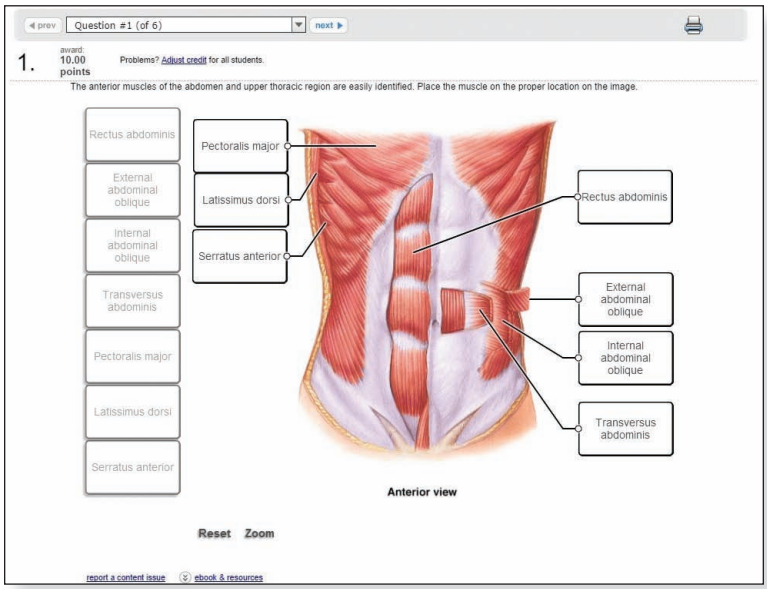

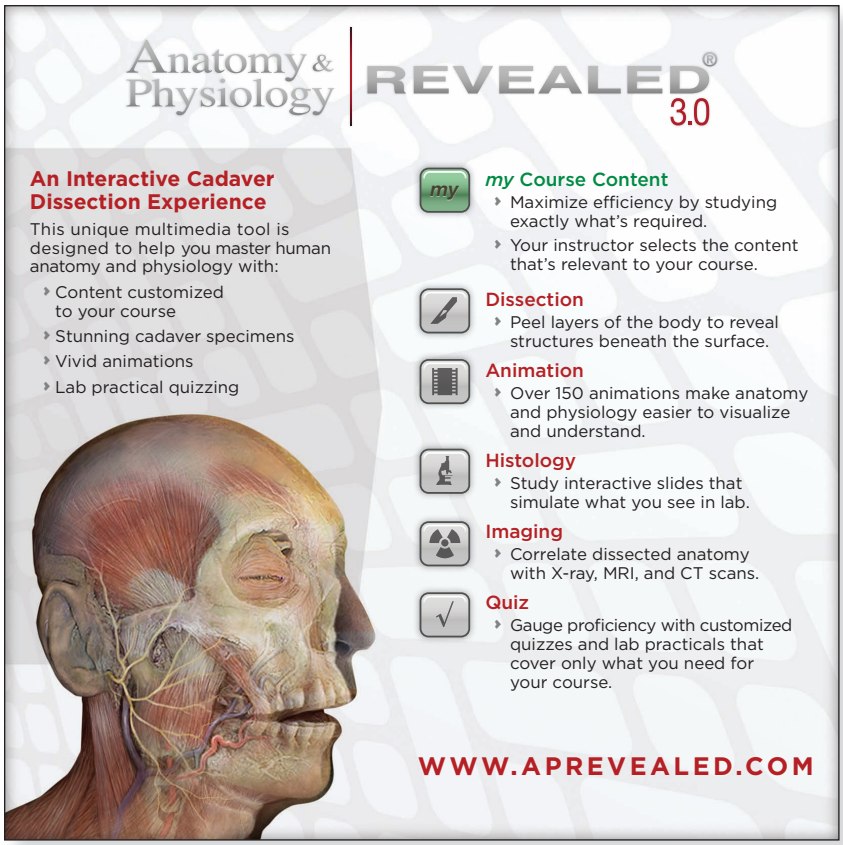

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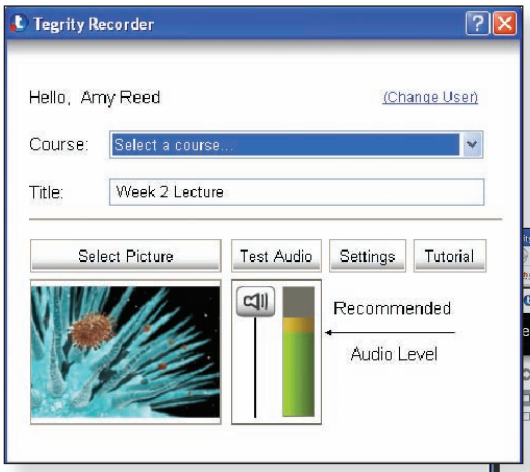

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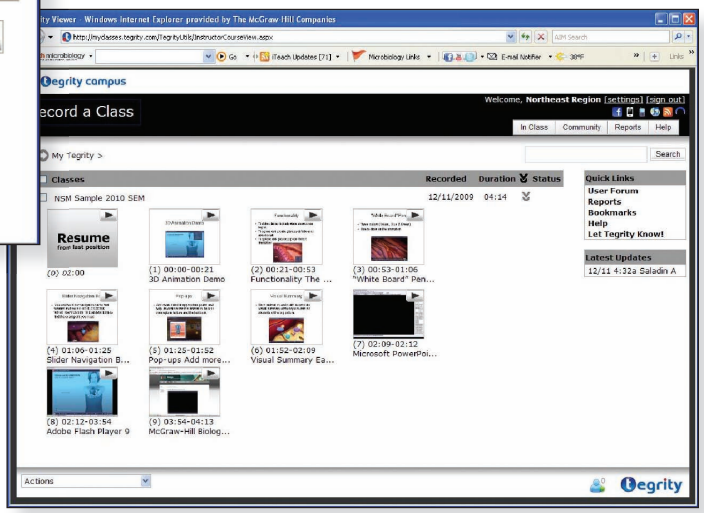

Laboratory Manual

Anatomy & Physiology Laboratory Textbook, Essentials Version, by Stanley E. Gunstream, Harold J. Benson, Arthur Talaro, and Kathleen Talaro, all of Pasadena City College. Kyla Ross of Georgia State University made significiant contributions to the sixth edition of the laboratory manual. This excellent lab text presents the fundamentals of human anatomy and physiology in an easy-to-read manner that is appropriate for students in allied health programs. It is designed especially for the one-semester course; it features a simple, concise writing style, self directing exercises, full-color photomicrographs in the Histology Atlas, and numerous illustrations in each exercise.

Acknowledgments

The development and production of this sixth edition has been the result of a team effort. Our dedicated and creative teammates at McGraw-Hill have contributed greatly to the finished product. We gratefully acknowledge and applaud their efforts. It has been a pleasure to work with these gifted professionals at each step of the process. We are especially appreciative of the support of Amy Reed, Brand Manager, Mandy Clark, Product Developer, and Vicki Krug, Content Project Manager.

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1

CHAPTER

Introduction to the Human Body

Michael, a freshman in college, overslept and is late for his first anatomy and physiology class. He has been dreading this class but it is necessary for his graduation requirements. Because he does not want to get off to a bad start, he sprints across campus. The combination of the warm day and physical exertion raises his body temperature and, as he throws himself into the nearest seat, sweat is pouring out across his body. Michael begins to feel cooler as he relaxes and he stops sweating within a few minutes. As his first lecture begins, he is introduced to the concept of homeostasis, which describes the condition of balance within the body, and the feedback cycles responsible for maintaining his internal "normal." He thinks about his morning, the sweat that cooled his body, and realizes just how amazing the human body really is. What a great semester this is going to be!

CHAPTER OUTLINE

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Module 1
Body Orientation

SELECTED KEY TERMS

Anatomy (ana = apart; tom = to cut) The study of the structure of living organisms.
Appendicular (append = to hang) Pertaining to the upper and lower limbs.
Axial (ax = axis) Pertaining to the longitudinal axis of the body.
Body region (regio = boundary) A portion of the body with a special identifying name.
Directional term (directio = act of guiding) A term that references how the position of a body part relates to the position of another body part.
Effector (efet = result) A structure that functions by performing an action that is directed by an integrating center.
Homeostasis (homeo = same; sta = make stand or stop) Maintenance of a relatively stable internal environment.
Integrating center (integratus = make whole) A structure that functions to interpret information and coordinate a response.
Metabolism (metabole = change) The sum of the chemical reactions in the body.
Parietal (paries = wall) Pertaining to the wall of a body cavity.
Pericardium (peri = around; cardi = heart) The membrane surrounding the heart.
Peritoneum (peri = around; ton = to stretch) The membrane lining the abdominal cavity and covering the abdominal organs.
Physiology (physio = nature; logy = study of) The study of the functioning of living organisms.
Plane (planum = flat surface) Imaginary two-dimensional flat surface that marks the direction of a cut through a structure.
Pleura (pleura = rib) The membrane lining the thoracic cavity and covering the lungs.
Receptor (recipere = receive) A structure that functions to collect information.
Section (sectio = cutting) A flat surface of the body produced by a cut through a plane of the body.
Serous membrane (serum = watery fluid; membrana = thin layer of tissue) A two-layered membrane that lines body cavities and covers the internal organs.
Visceral (viscus = internal organ) Pertaining to organs in a body cavity.

YOU ARE BEGINNING a fascinating and challenging study–the study of the human body. As you progress through this text, you will begin to understand the complex structures and functions of the human organism.

This first chapter provides an overview of the human body to build a foundation of knowledge that is necessary for your continued study. Like the chapters that follow, this chapter introduces a number of new terms for you to learn. It is important that you start to build a vocabulary of technical terms and continue to develop it throughout your study. This vocabulary will help you reach your goal of understanding human anatomy and physiology.

1.1 Anatomy and Physiology

Learning Objective

1. Define anatomy and physiology.

Knowledge of the human organism is obtained primarily from two scientific disciplines–anatomy and physiology–and each consists of a number of subdisciplines.

Human **anatomy** (ah-nat′-ō-mē) is the study of the structure and organization of the body and the study of the relationships of body parts to one another. There are two subdivisions of anatomy. *Gross anatomy* involves the dissection and examination of various parts of the body without magnifying lenses. *Microanatomy*, also known as *histology*, consists of the examination of tissues and cells with various magnification techniques.

Human **physiology** (fiz-ē-ol′-ō-jē) is the study of the function of the body and its parts. Physiology involves observation and experimentation, and it usually requires the use of specialized equipment and materials.

In your study of the human body, you will see that there is always a definite relationship between the anatomy and physiology of the body and body parts. Just as the structure of a knife is well suited for cutting, the structure (anatomy) of a body part enables it to perform specific functions (physiology). For example, the arrangement of bones, muscles, and nerves in your hands enables the grasping of large objects with considerable force and also the delicate manipulation of small objects. Correlating the relationship between structure and function will make your study of the human body much easier.

1.2 Levels of Organization

Learning Objectives

2. Describe the levels of organization in the human body.
3. List the major organs and functions for each organ system.

The human body is complex, so it is not surprising that there are several levels of structural organization, as shown in figure 1.1. The levels of organization from simplest to most complex are chemical, cellular, tissue, organ, organ system, and organismal (the body as a whole).

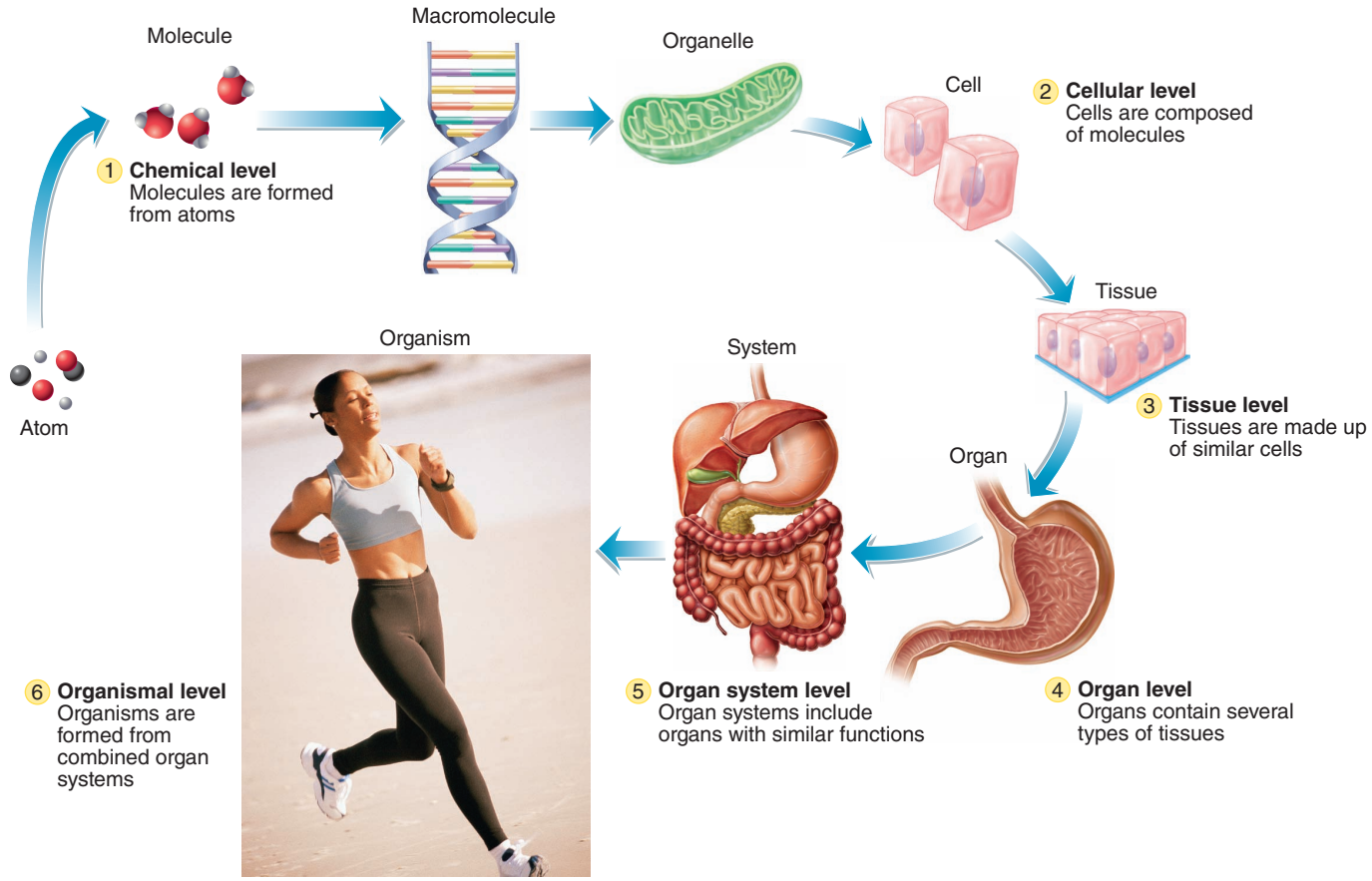


Figure 1.1 Six levels of organization in the human body range from chemical (simplest) to organismal (most complex).

Chemical Level

The *chemical level* consists of *atoms, molecules,* and *macromolecules.* At the simplest level, the body is composed of chemical substances that are formed of atoms and molecules. *Atoms* are the fundamental building blocks of chemicals, and atoms combine in specific ways to form *molecules.* Some molecules are very small, such as water molecules, but others may be very large, such as the macromolecules of proteins. Various small and large molecules are grouped together to form organelles. An **organelle** (or″-ga-nel′) is a microscopic subunit of a cell, somewhat like a tiny organ, that carries out specific functions within a cell. Nuclei, mitochondria, and ribosomes are examples.

Cellular Level

Cells are the basic structural and functional units of the body because all of the processes of life occur within cells. A cell is the lowest level of organization that is alive. The human body is composed of trillions of cells and many different types of cells, such as muscle cells, blood cells, and nerve cells. Each type of cell has a unique structure that enables it to perform specific functions.

Tissue Level

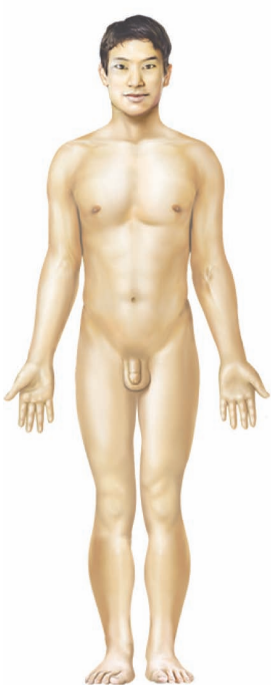
Similar types of cells are usually grouped together in the body to form a tissue. Each body **tissue** consists of an aggregation of similar cells that perform similar functions. There are four major classes of tissues in the body: epithelial, connective, muscle, and nervous tissues.

Organ Level

Each **organ** of the body is composed of two or more tissues that work together, enabling the organ to perform its specific functions. The body contains numerous organs, and each has a definite form and function. The stomach, heart, brain, and even bones are examples of organs.

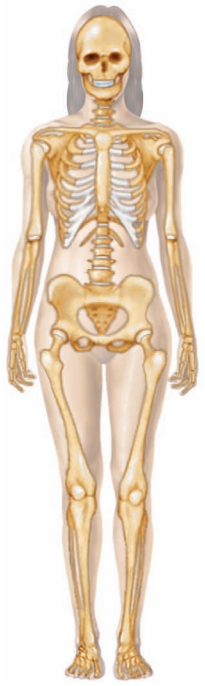
Organ System Level

The organs of the body are arranged in functional groups so that their independent functions are coordinated to perform specific system functions. These coordinated, functional groups are called **organ systems.** The digestive and nervous systems are examples of organ systems. Most organs belong to a single organ system, but a few organs are assigned to more than one organ system. For



Integumentary system

Components: skin, hair, nails, and associated glands
Functions: protects underlying tissues and helps regulate body temperature



Skeletal system

Components: bones, ligaments, and associated cartilages
Functions: supports the body, protects vital organs, stores minerals, and produces formed elements

Muscular system

Components: skeletal muscles
Functions: moves the body and body parts and produces heat

Figure 1.2 The 11 Organ Systems of the Body. AP|R

example, the pancreas belongs to both the digestive and endocrine systems.

Figure 1.2 illustrates the 11 organ systems of the human body and lists the major components and functions for each system. Although each organ system has its own unique functions, all organ systems are interdependent on one another. For example, all organ systems rely on the cardiovascular system to transport materials to and from their cells. Organ systems work together to enable the functioning of the human body.

Organismal Level

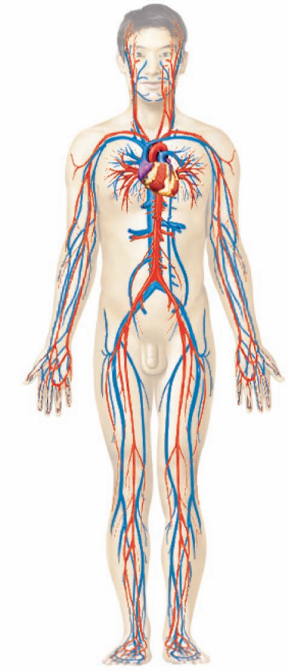
The highest organizational level dealing with an individual is the *organismal level,* the human organism as a whole. It is composed of all of the interacting organ systems. All of the organizational levels from chemicals to organ systems contribute to the functioning of the entire body.

Check My Understanding

1. What are the organizational levels of the human body?
2. What are the major organs and general functions of each organ system?

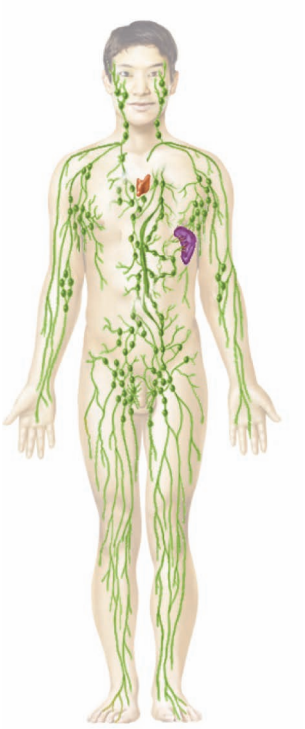
Respiratory system

Components: nose, pharynx, larynx, trachea, bronchi, and lungs
Functions: exchanges O_2 and CO_2 between air and blood in the lungs, pH regulation, and sound production



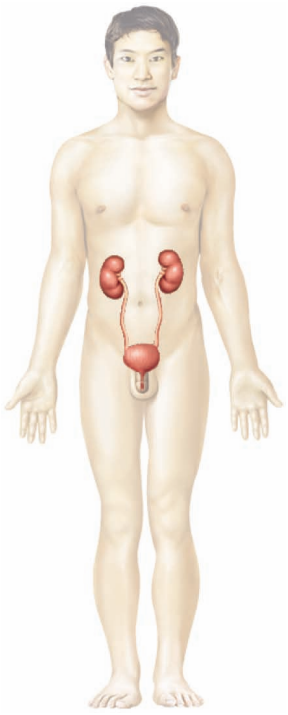
Cardiovascular system

Components: blood, heart, arteries, veins, and capillaries
Functions: transports heat and materials to and from the body cells



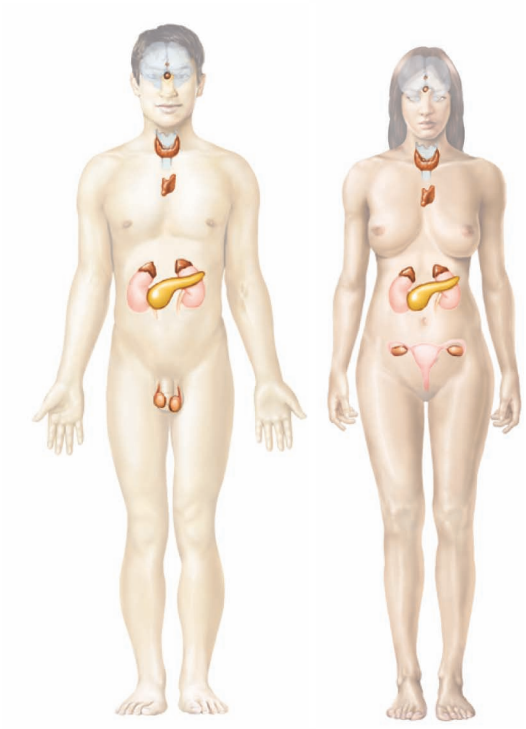
Lymphoid system

Components: lymph, lymphatic vessels, and lymphoid organs and tissues
Functions: collects and cleanses interstitial fluid, and returns it to the blood; provides immunity



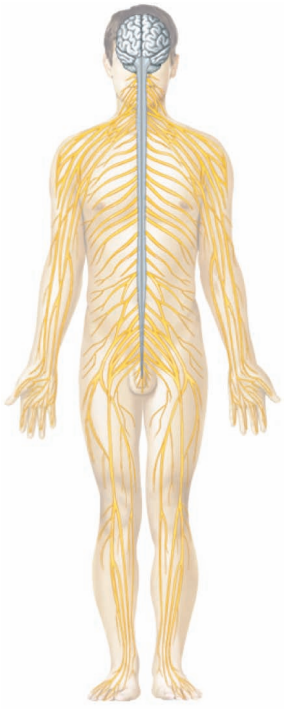
Urinary system

Components: kidneys, ureters, urinary bladder, and urethra
Functions: regulates volume and composition of blood by forming and excreting urine



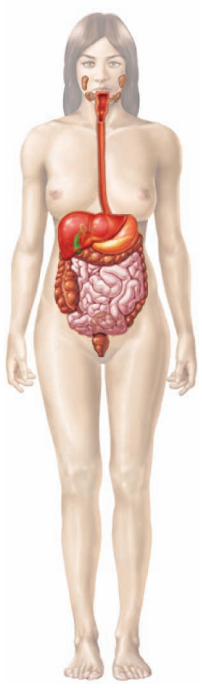
Endocrine system

Components: hormone-producing glands, such as the pituitary and thyroid glands
Functions: secretes hormones that regulate body functions



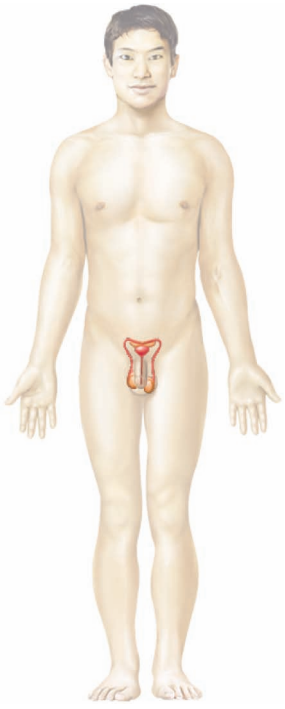
Nervous system

Components: brain, spinal cord, nerves, and sensory receptors
Functions: rapidly coordinates body functions and enables learning and memory



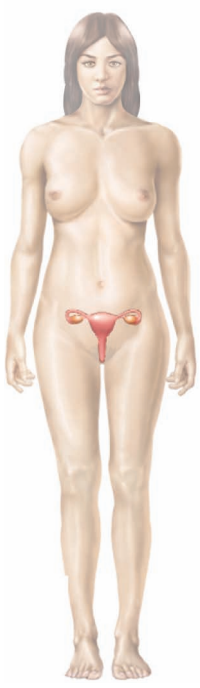
Digestive system

Components: mouth, pharynx, esophagus, stomach, intestines, liver, pancreas, gallbladder, and associated structures
Functions: digests food and absorbs nutrients



Male reproductive system

Components: testes, epididymides, vasa deferentia, prostate gland, bulbo-urethral glands, seminal vesicles, and penis
Functions: produces sperm and transmits them into the female vagina during sexual intercourse



Female reproductive system

Components: ovaries, uterine tubes, uterus, vagina, and vulva
Functions: produces oocytes, receives sperm, provides intrauterine development of offspring, and enables birth of an infant

1.3 Directional Terms

Learning Objective

4. Use directional terms to describe the locations of body parts.

Directional terms are used to describe the relative position of a body part in relationship to another body part. The use of these terms conveys a precise meaning enabling the listener or reader to locate the body part of interest. It is always assumed that the body is in a standard position, the *anatomical position,* in which the body is standing upright with upper limbs at the sides and palms of the hands facing forward, as in figure 1.3. Directional terms occur in pairs, and the members of each pair have opposite meanings, as noted in table 1.1.

1.4 Body Regions

Learning Objective

5. Locate the major body regions on a chart or anatomical model.

The human body consists of an **axial** (ak′-sē-al) **portion,** the head, neck, and trunk, and an **appendicular** (ap-pen-dik′-ū-lar) **portion,** the upper and lower limbs and their girdles. Each of these major portions of the body is divided into regions with special names to facilitate communication and to aid in locating body components.

The major **body regions** are listed in tables 1.2 and 1.3 to allow easy correlation with figure 1.4, which shows the locations of the major regions of the body. Take time to learn the names, pronunciations, and locations of the body regions.

1.5 Body Planes and Sections

Learning Objective

6. Describe the four planes used in making sections of the body or body parts.

In studying the body or organs, you often will be observing the flat surface of a **section** that has been produced by a cut through the body or a body part. Such sections are made along specific **planes.** These well-defined planes–transverse,

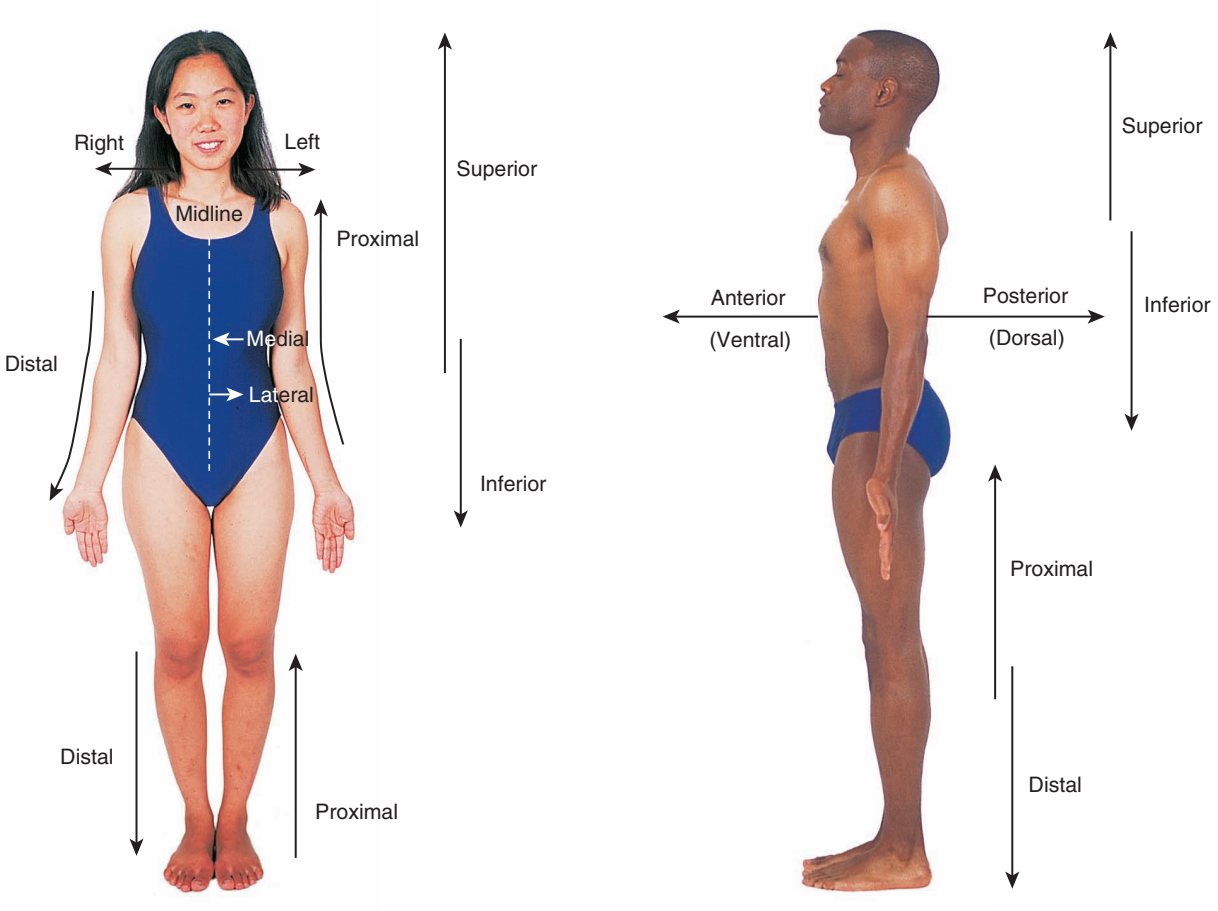


Figure 1.3 Anatomical Position and Directional Terms. AP|R

Table 1.1 Directional Terms

Term	Meaning	Example
Anterior (ventral)	Toward the front or abdominal surface of the body	The abdomen is anterior to the back.
Posterior (dorsal)	Toward the back of the body	The spine is posterior to the face.
Superior (cephalic)	Toward the top/head	The nose is superior to the mouth.
Inferior (caudal)	Away from the top/head	The navel is inferior to the nipples.
Medial	Toward the midline of the body	The breastbone is medial to the nipples.
Lateral	Away from the midline of the body	The ears are lateral to the cheeks.
Parietal	Pertaining to the outer boundary of body cavities	The parietal pleura lines the pleural cavity.
Visceral	Pertaining to the internal organs	The visceral pleura covers the lung.
Superficial (external)	Toward or on the body surface	The skin is superficial to the muscles.
Deep (internal)	Away from the body surface	The intestines are deep to the abdominal muscles.
Proximal	Closer to the beginning	The elbow is proximal to the wrist.
Distal	Farther from the beginning	The hand is distal to the wrist.
Central	At or near the center of the body or organ	The central nervous system is in the middle of the body.
Peripheral	External to or away from the center of the body or organ	The peripheral nervous system extends away from the central nervous system.

Table 1.2 Major Regions of the Head, Neck, and Trunk

Region			
Head and Neck	***Anterior Trunk***	***Posterior Trunk***	***Lateral Trunk***
Buccal (bu-kal)	Abdominal (ab-dom′-i-nal)	Dorsum (dor′-sum)	Axillary (ak′-sil-lary)
Cephalic (se-fal′-ik)	Abdominopelvic (ab-dom-i-nō-pel′-vik)	Gluteal (glu′-tē-al)	Coxal (kok′-sal)
Cervical (ser′-vi-kal)	Inguinal (ing′-gwi-nal)	Lumbar (lum′-bar)	***Inferior Trunk***
Cranial (krā′-nē-al)	Pectoral (pek′-tōr-al)	Sacral (sāk′-ral)	Genital (jen′-i-tal)
Facial (fā′-shal)	Pelvic (pel′-vik)	Vertebral (ver-tē′-bral)	Perineal (per-i-nē′-al)
Nasal (nā-zel)	Sternal (ster′-nal)		
Oral (or-al)	Umbilical (um-bil′-i-kal)		
Orbital (or-bit-al)			
Otic (o-tic)			

Table 1.3 Major Regions of the Limbs

Region		
Upper Limb	Digital (di′-ji-tal)	Femoral (fem′-ōr-al)
Antebrachial (an-tē-brā′-kē-al)	Olecranal (ō-lēk′-ran-al)	Patellar (pa-tel′-lar)
Antecubital (an-tē-kū-bi-tal)	Palmar (pal′-mar)	Pedal (pe′-dal)
Brachial (brā′-kē-al)	***Lower Limb***	Plantar (plan′-tar)
Carpal (kar′-pal)	Crural (krū′-ral)	Popliteal (pop-li-tē′-al)
Deltoid (del-tȯid)	Digital (di′-ji-tal)	Sural (sū′-ral)

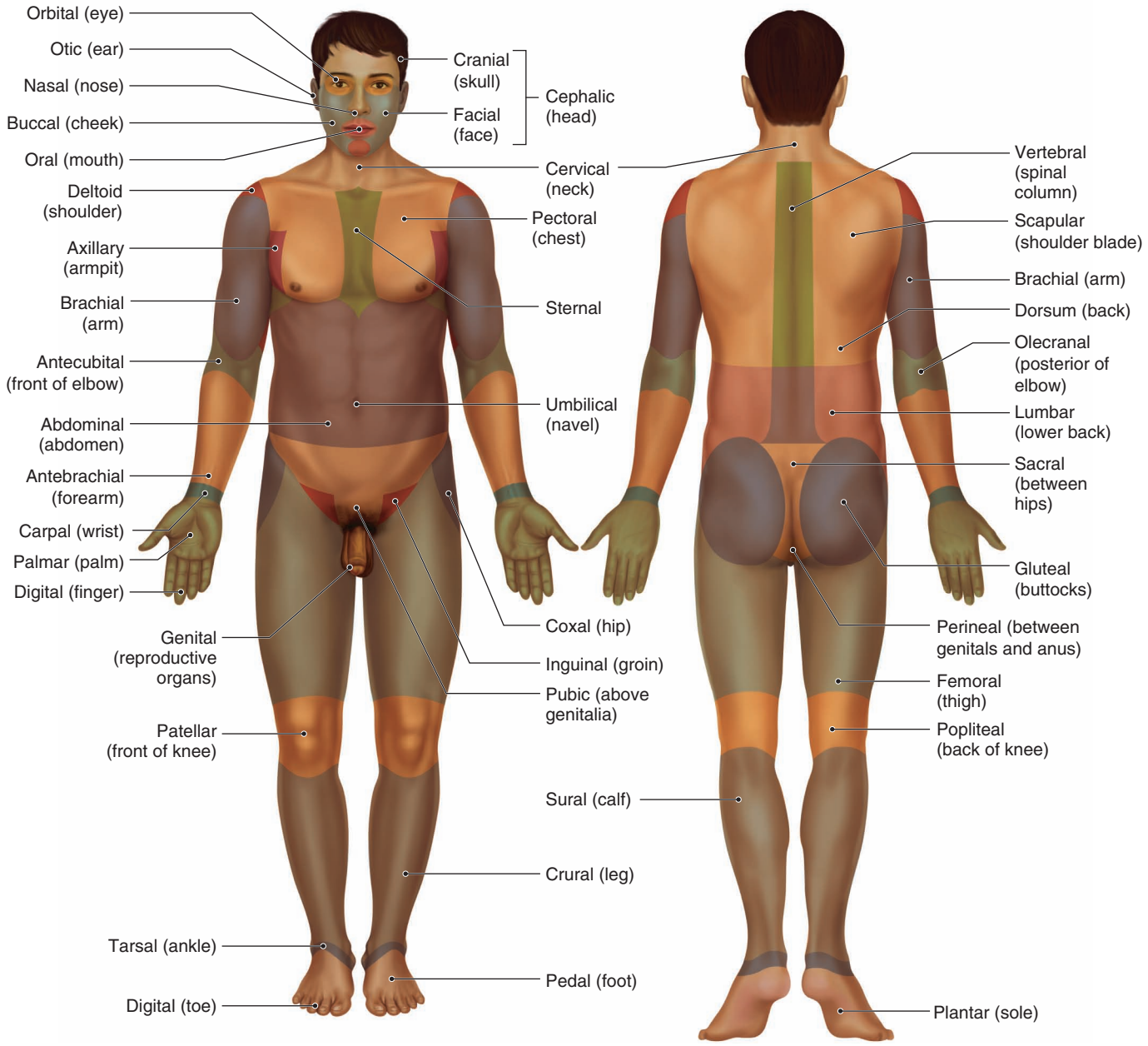


Figure 1.4 Major Regions of the Body. AP|R

sagittal, and frontal planes–lie at right angles to each other as shown in figure 1.5. It is important to understand the nature of the plane along which a section was made in order to understand the three-dimensional structure of an object being observed.

Transverse, or horizontal, **planes** divide the body into superior and inferior portions and are perpendicular to the longitudinal axis of the body.

Sagittal planes divide the body into right and left portions and are parallel to the longitudinal axis of the body. A **median** (midsagittal) **plane** passes through the midline of the body and divides the body into equal left and right halves. A **parasagittal plane** does not pass through the midline of the body.

Frontal (coronal) **planes** divide the body into anterior and posterior portions. These planes are perpendicular to sagittal planes and parallel to the longitudinal axis of the body.

Cuts made through sagittal and frontal planes, which are parallel to the longitudinal axis of the body, produce *longitudinal sections*. However, the term longitudinal section also refers to a section made through the longitudinal axis of an individual organ, tissue, or other structure. Similarly, cuts made through the transverse plane produce *cross*

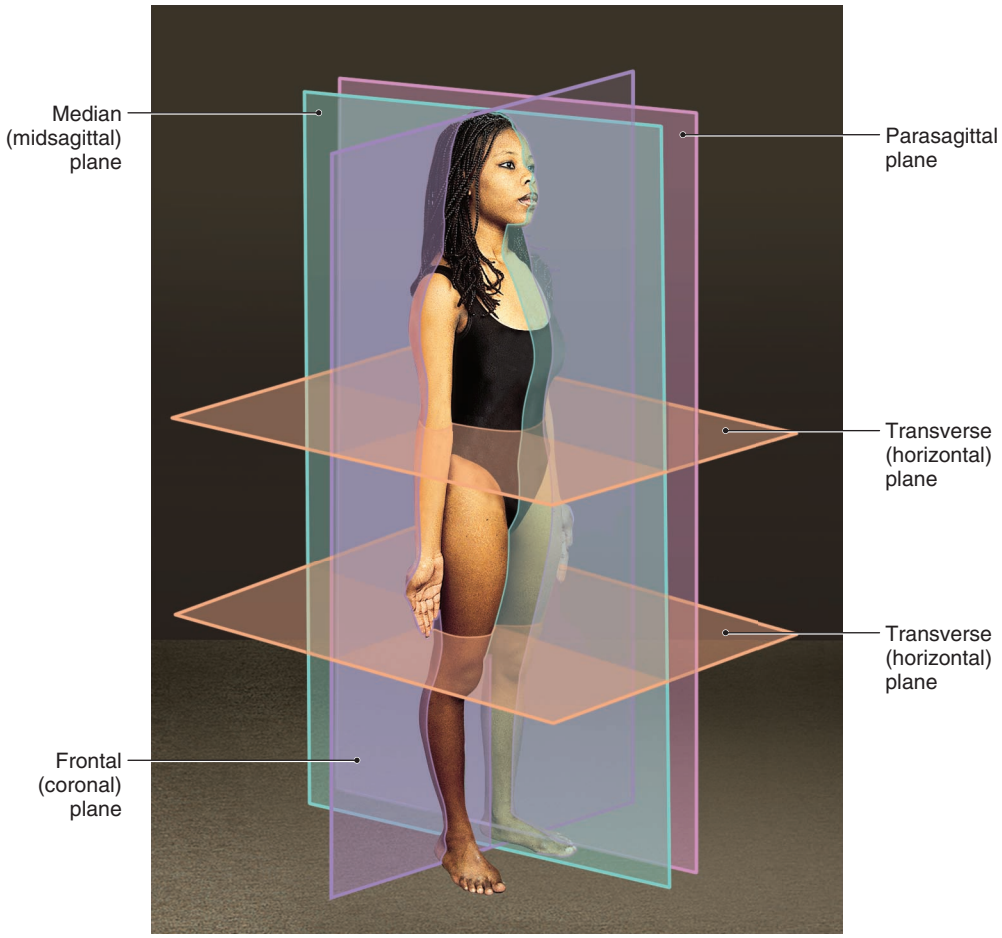


Figure 1.5 Anatomical Planes of Reference. AP|R

sections of the body and can also be produced in organs and tissues when cutting at a 90° angle to the longitudinal axis. *Oblique sections* are created when cuts are made in between the longitudinal and cross-sectional axes.

Check My Understanding

3. How do sagittal, transverse, and frontal planes differ from one another?

1.6 Body Cavities

Learning Objectives

7. Name the two major body cavities, their subdivisions and membranes.
8. Locate the body cavities, their subdivisions and membranes on a diagram.
9. Name the organs located in each body cavity.

There are two major cavities of the body that contain internal organs: the dorsal (posterior) and ventral (anterior) cavities. The body cavities protect and cushion the contained organs and permit changes in their size and shape without impacting surrounding tissues. Note the locations and subdivisions of these cavities in figure 1.6.

The **dorsal cavity** is subdivided into the **cranial cavity,** which houses the brain, and the **vertebral canal,** which contains the spinal cord. Note in figure 1.6 how the cranial bones and the vertebral column form the walls of the dorsal cavity and provide protection for these delicate organs.

The **ventral cavity** is divided by the *diaphragm*, a thin dome-shaped sheet of muscle, into a superior **thoracic cavity** and an inferior **abdominopelvic cavity.** The thoracic cavity is protected by the *rib cage* and contains the heart and lungs. The abdominopelvic cavity is subdivided into a superior **abdominal cavity** and an inferior **pelvic cavity,** but there is no structural separation between them. To visualize the separation, imagine a transverse plane passing through the body just superior to the pelvis. The abdominal cavity contains the stomach, intestines, liver, gallbladder, pancreas, spleen, and kidneys. The pelvic cavity contains the urinary bladder, sigmoid colon, rectum, and internal reproductive organs.

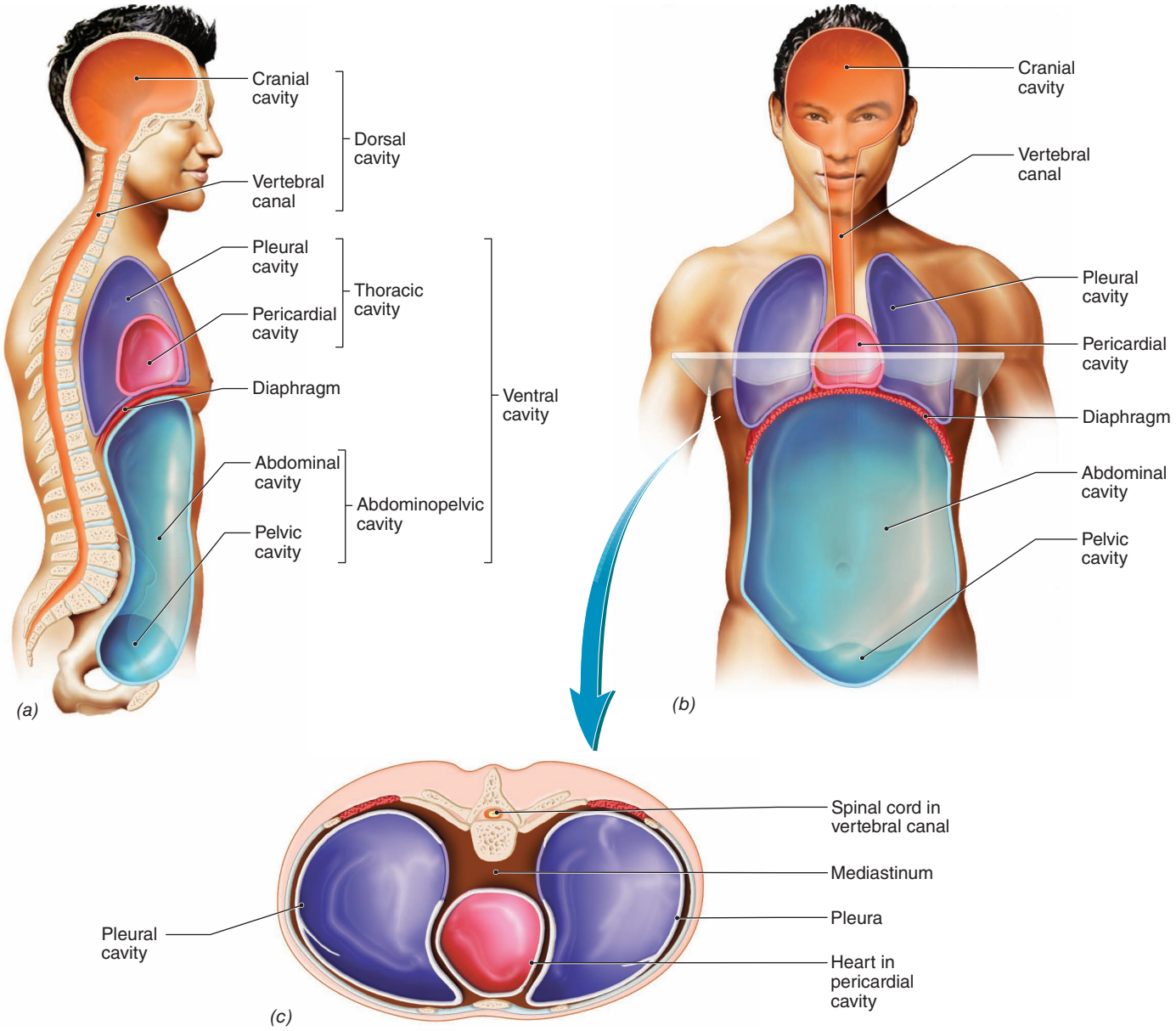


Figure 1.6 Body Cavities and Their Subdivisions.
(a) Sagittal section. *(b)* Frontal section. *(c)* Transverse section through the thoracic cavity. AP|R

Check My Understanding

4. What organs are located in each subdivision of the dorsal cavity?
5. What organs are located in each subdivision of the ventral cavity?

Membranes of Body Cavities

The membranes lining body cavities support and protect the internal organs in the cavities.

Dorsal Cavity Membranes

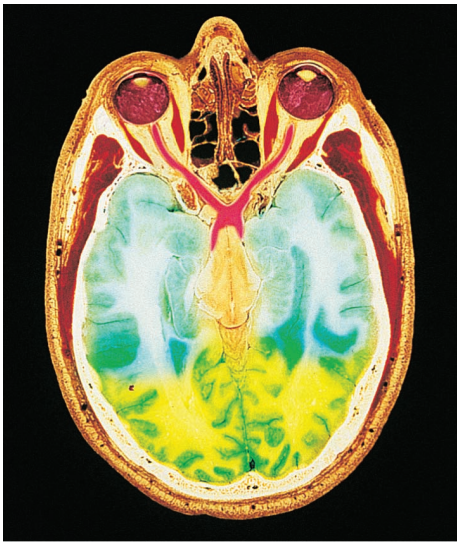
The dorsal cavity is lined by three layers of protective membranes that are collectively called the **meninges** (me-nin′-jēz; singular, *meninx*). The most superficial membrane is attached to the wall of the dorsal cavity, and the deepest membrane tightly envelops the brain and spinal cord. The meninges will be covered in chapter 8.

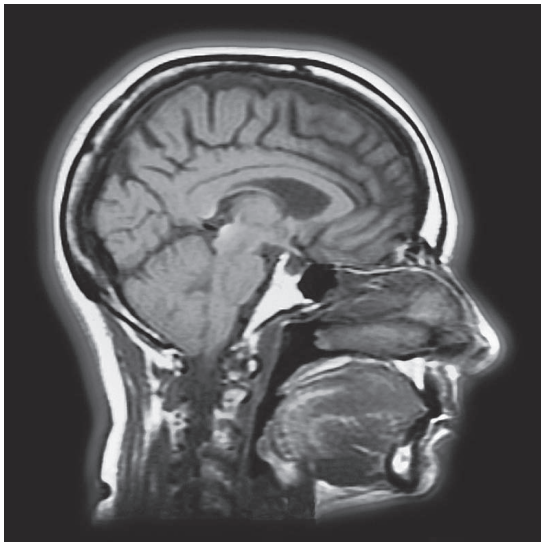
Ventral Cavity Membranes

The ventral body cavity organs are supported and protected by **serosae** (singular, *serosa*), or **serous membranes.**

Clinical Insight

Physicians use certain types of diagnostic imaging systems, for example, *computerized tomography (CT), magnetic resonance imaging (MRI),* and *positron emission tomography (PET)*, to produce images of sections of the body to help them diagnose disorders. In computerized tomography, an X-ray emitter and an X-ray detector rotate around the patient so that the X-ray beam passes through the body from hundreds of different angles. X-rays collected by the detector are then processed by a computer to produce sectional images on a screen for viewing by a radiologist. A good understanding of sectional anatomy is required to interpret CT scans. Transverse sections, such as the image on the left, are always shown in the same way. Convention is to use supine (face up), inferior views as if looking up at the section from the foot of the patient's bed. What structures can you identify in the CT image shown on the right? AP|R





The serous membranes are thin layers of tissue that line the body cavity and cover the internal organs. Serous membranes have a superficial *parietal* (pah-rī′-e-tal) *lay*er that lines the cavity and a deep *visceral* (vis′-er-al) *layer* that covers the organ. The parietal and visceral layers secrete a watery lubricating fluid that is generically called *serous fluid* into the cavity formed between the layers. This arrangement is similar to that of a fist pushed into a balloon (figure 1.7). The serous membranes of the body are the pleura, pericardium, and peritoneum.

The serous membranes lining the thoracic cavity are called **pleurae** (singular, *pleura*), or **pleural membranes.** The walls of the left and right portions of the thoracic cavity are lined by the *parietal pleurae.* The surfaces of the lungs are covered by the *visceral pleurae.* The parietal and visceral pleurae are separated by a thin film of serous fluid called pleural fluid, which reduces friction as the pleurae rub against each other as the lungs expand and contract during breathing. The potential space (not an actual space) between the parietal and visceral pleurae is known as the **pleural cavity.**

The left and right portions of the thoracic cavity are divided by a membranous partition, the *mediastinum* (mē-dē-a-stī′-num). Organs located within the mediastinum include the heart, thymus, esophagus, and trachea.

The heart is enveloped by the **pericardium** (per-i-kar′-dē-um), which is formed by membranes of the mediastinum. The thin *visceral pericardium* is tightly adhered to the surface of the heart. The *parietal pericardium* lines the deep surface of a loosely fitting sac around the heart. The potential space between the visceral and parietal pericardia is the **pericardial cavity,** and it contains serous fluid, called pericardial fluid, that reduces friction as the heart contracts and relaxes.

The walls of the abdominal cavity and the surfaces of abdominal organs are lined with the **peritoneum** (per-i-tō-nē′-um), or **peritoneal membrane.** The *parietal peritoneum* lines the walls of the abdominal cavity but not the pelvic cavity. It descends only to cover the superior portion of the urinary bladder. The kidneys, pancreas, and parts of the intestines are located posterior to the parietal peritoneum in a space known as the *retroperitoneal space.* The *visceral peritoneum,* an extension of the parietal peritoneum, covers the surface of the abdominal organs. Double-layered folds of the visceral peritoneum, the *mesenteries* (mes′-en-ter″-ēs), extend between the abdominal organs

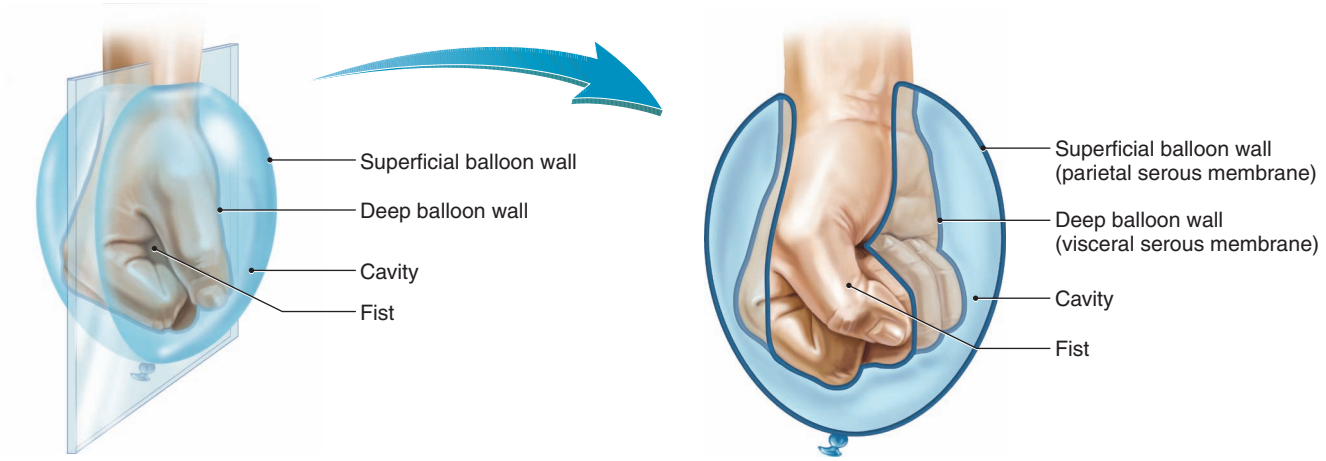


Figure 1.7 Illustration of a fist pushed into a balloon as an analogy to serous membranes. AP|R

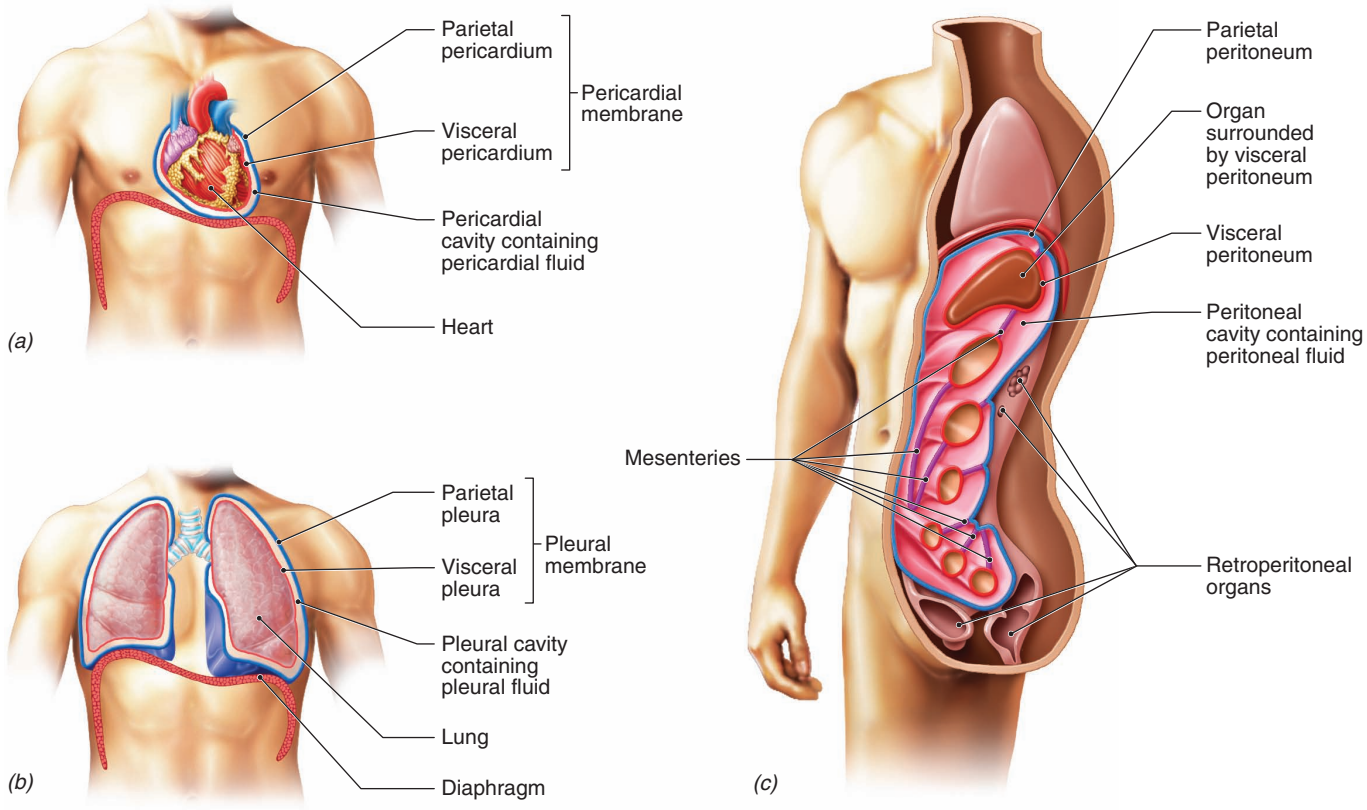


Figure 1.8 Serous Membranes of The Ventral Cavity.
(a) Anterior view of pericardium. *(b)* Anterior view of pleura. *(c)* Sagittal view of peritoneum. AP|R

and provide support for them (see figure 1.8*c*). The potential space between the parietal and visceral peritoneal membranes is called the **peritoneal cavity** and contains a small amount of serous fluid called peritoneal fluid (figure 1.8).

Check My Understanding

6. What membranes line the dorsal and ventral cavities?
7. What is the function of serous fluid?

1.7 Abdominopelvic Subdivisions

Learning Objectives

10. Name the abdominopelvic quadrants and regions.
11. Locate the abdominopelvic quadrants and regions on a diagram.

The abdominopelvic cavity is subdivided into either four quadrants or nine regions to aid health care providers in locating underlying organs in the abdominopelvic cavity. Physicians may feel (palpate) or listen to (auscultate) the abdominopelvic region to examine it. Changes in firmness or sounds may indicate abnormalities in the structures of a quadrant or region.

The four quadrants are formed by two planes that intersect just superior to the umbilicus (navel), as shown in figure 1.9*a*. Note the organs within each quadrant.

The nine regions are formed by the intersection of two sagittal and two transverse planes as shown in figure 1.9*c*. The sagittal planes extend inferiorly from the midpoints of the collarbones. The superior transverse plane lies just inferior to the borders of the 10th costal cartilages, and the inferior transverse plane lies just inferior to the superior border of the hip bones.

Study figures 1.8 and 1.9 to increase your understanding of the locations of the internal organs and associated membranes.

Now examine the colorplates that follow this chapter. They show an anterior view of the body in progressive stages of dissection that reveals major muscles, blood vessels, and internal organs. Study these plates to learn the normal locations of the organs of the ventral cavity. Also, check your understanding of the organs within each abdominopelvic quadrant and region.

Check My Understanding

8. What are the four quadrants and nine regions of the abdominopelvic region?

1.8 Maintenance of Life

Learning Objectives

12. Define metabolism, anabolism, and catabolism.
13. List the five basic needs essential for human life.
14. Define homeostasis.
15. Explain how homeostasis relates to both healthy body functions and disorders.
16. Describe the general mechanisms of negative feedback and positive feedback.

Humans, like all living organisms, exhibit the fundamental processes of life. **Metabolism** (me-tab′ō-lizm) is the term that collectively refers to the sum of all of the chemical reactions that occur in the body.

There are two phases of metabolism: anabolism and catabolism. **Anabolism** (ah-nab′-ō-lizm) refers to processes that use energy and nutrients to build the complex organic molecules that compose the body. **Catabolism** (kah-tab′-ō-lizm) refers to processes that release energy and break down complex molecules into simpler molecules.

Life is fragile. It depends upon the normal functioning of trillions of body cells, which, in turn, depends upon factors needed for survival and the ability of the body to maintain relatively stable internal conditions.

Survival Needs

There are five basic needs that are essential to human life:

1. **Food** provides chemicals that serve as a source of energy and raw materials to grow and to maintain cells of the body.
2. **Water** provides the environment in which the chemical reactions of life occur.
3. **Oxygen** is required to release the energy in organic nutrients, which powers life processes.
4. **Body temperature** must be maintained close to 36.8°C (98.2°F) to allow the chemical reactions of human metabolism to occur.
5. **Atmospheric pressure** is required for breathing to occur.

Homeostasis

Homeostasis is the maintenance of a relatively stable internal environment by self-regulating physiological processes. Homeostasis keeps body temperature and the composition of blood and interstitial fluids within their normal range. This relatively stable internal environment is maintained in spite of the fact that internal and external factors tend to alter body temperature, and materials are continuously entering and exiting the blood and interstitial fluid.

All of the organ systems work in an interdependent manner to maintain homeostasis. For example, changes in one system tend to affect one or more other body systems. Therefore, any disruption in one body system tends to be corrected but may disrupt another body system. The internal environment is maintained via a *dynamic equilibrium* where there is constant fluctuation taking place in order to maintain homeostasis. Malfunctioning or overcompensation in a homeostatic mechanism can lead to disorders and diseases.

The dynamic equilibrium of homeostasis is primarily maintained by physiologic processes called **negative-feedback mechanisms.** Body fluid composition and other physiological variables fluctuate near a normal value, called a *set point*, and negative-feedback mechanisms are

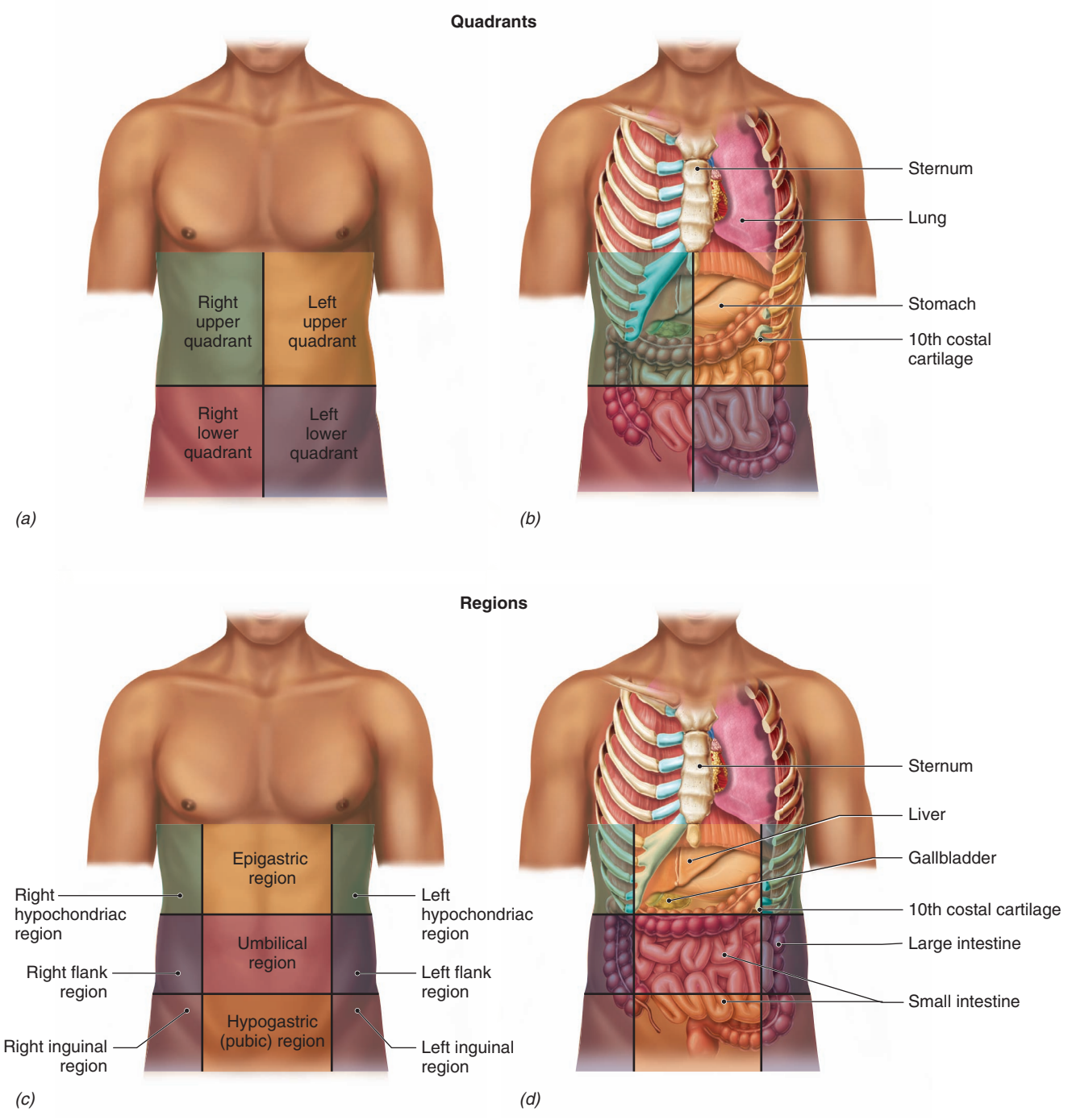
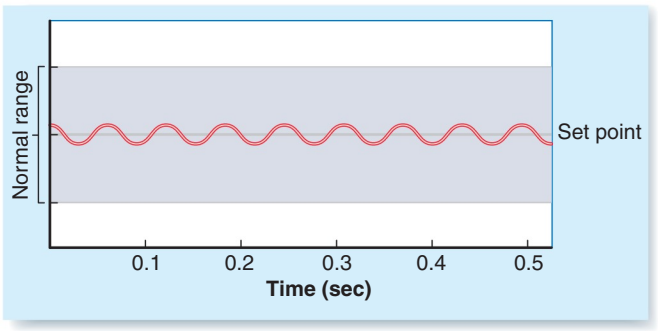
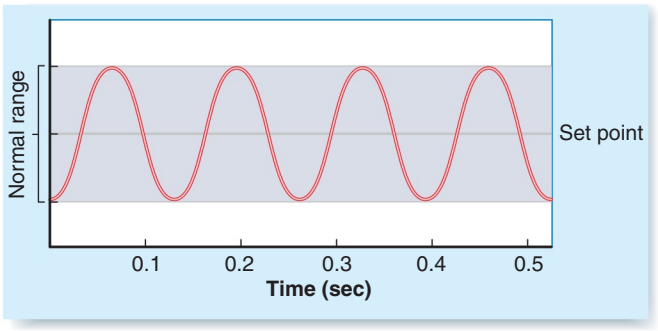


Figure 1.9 The four quadrants and nine regions of the abdominopelvic cavity. AP|R

used to keep these variables within their normal range (figure 1.10). For a negative-feedback mechanism to work, it needs to be able to monitor and respond to any changes in homeostasis. The structure of the negative-feedback mechanism allows it to function in exactly this manner and is a great example of how anatomical structure complements function. To monitor a physiological variable, a negative-feedback mechanism utilizes a **receptor** to detect deviation from the set point and send a signal notifying the integrating center about the deviation. The **integrating center,** which is the body region that knows the set point for the variable, processes the information from a receptor and determines the course of action that is needed. It then sends a signal that activates an **effector.**



(a) High sensitivity



(b) Low sensitivity

Figure 1.10 *(a)* A negative-feedback mechanism with high sensitivity. *(b)* A negative-feedback mechanism with low sensitivity.

The effector will carry out the necessary response according to the directions of the integrating center and return the variable back toward the set point. In a negative-feedback mechanism the response of the effector will always be the opposite of the change detected by the receptor (figure 1.11). Once the set point is reached, the negative-feedback mechanism will automatically turn off.

Our body's ability to maintain relatively constant blood glucose levels relies on negative-feedback mechanisms. When blood glucose levels begin to rise, as they do after a meal, there are receptors in the pancreas that can detect this *stimulus* (change). The beta cells of the pancreas act as an integrating center and release the hormone insulin in response to this change. Insulin travels through the blood to several effectors, one of which is the liver. Insulin causes the liver cells to take excess glucose out of the bloodstream

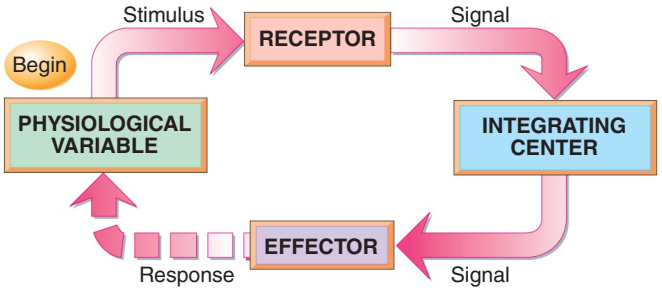


Figure 1.11 A negative-feedback mechanism controlling homeostasis.

and thus decrease the blood glucose level back toward normal. The pancreas possesses other receptors that can detect decreases in blood glucose, such as occurs between meals. The alpha cells of the pancreas, acting as the integrating center, release the hormone glucagon. Glucagon causes the liver to release glucose into the bloodstream, which will increase blood glucose back toward normal (figure 1.12).

It is important to note that the response of the integrating center will be stronger if the original stimulus is farther from normal. For example, if the blood glucose level rises sharply out of the normal range, causing *hyperglycemia* (blood glucose level above normal), the amount of insulin the beta cells release will be more than the amount released if the blood glucose level is elevated but is still within the normal range. This type of response is called a *graded response* because it can respond on different levels (figure 1.13).

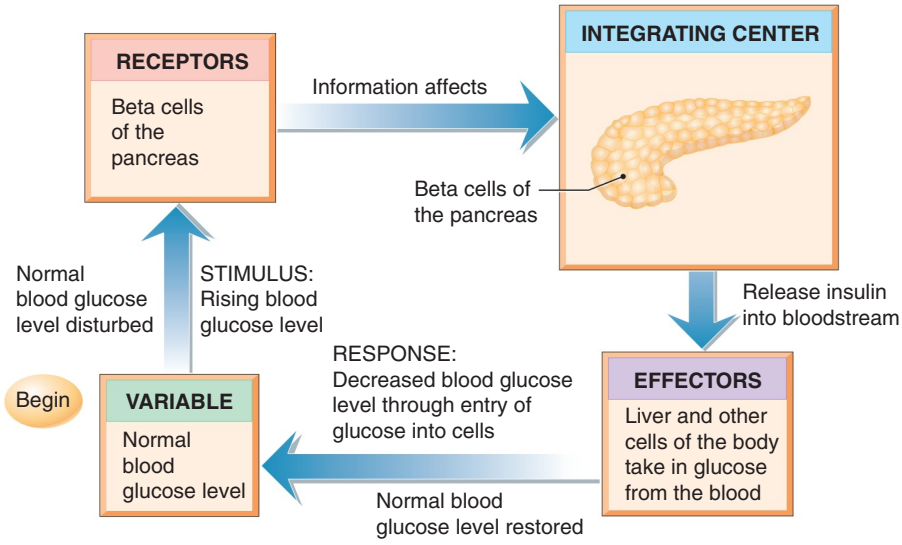


Figure 1.12 The negative-feedback mechanism that regulates blood glucose levels.