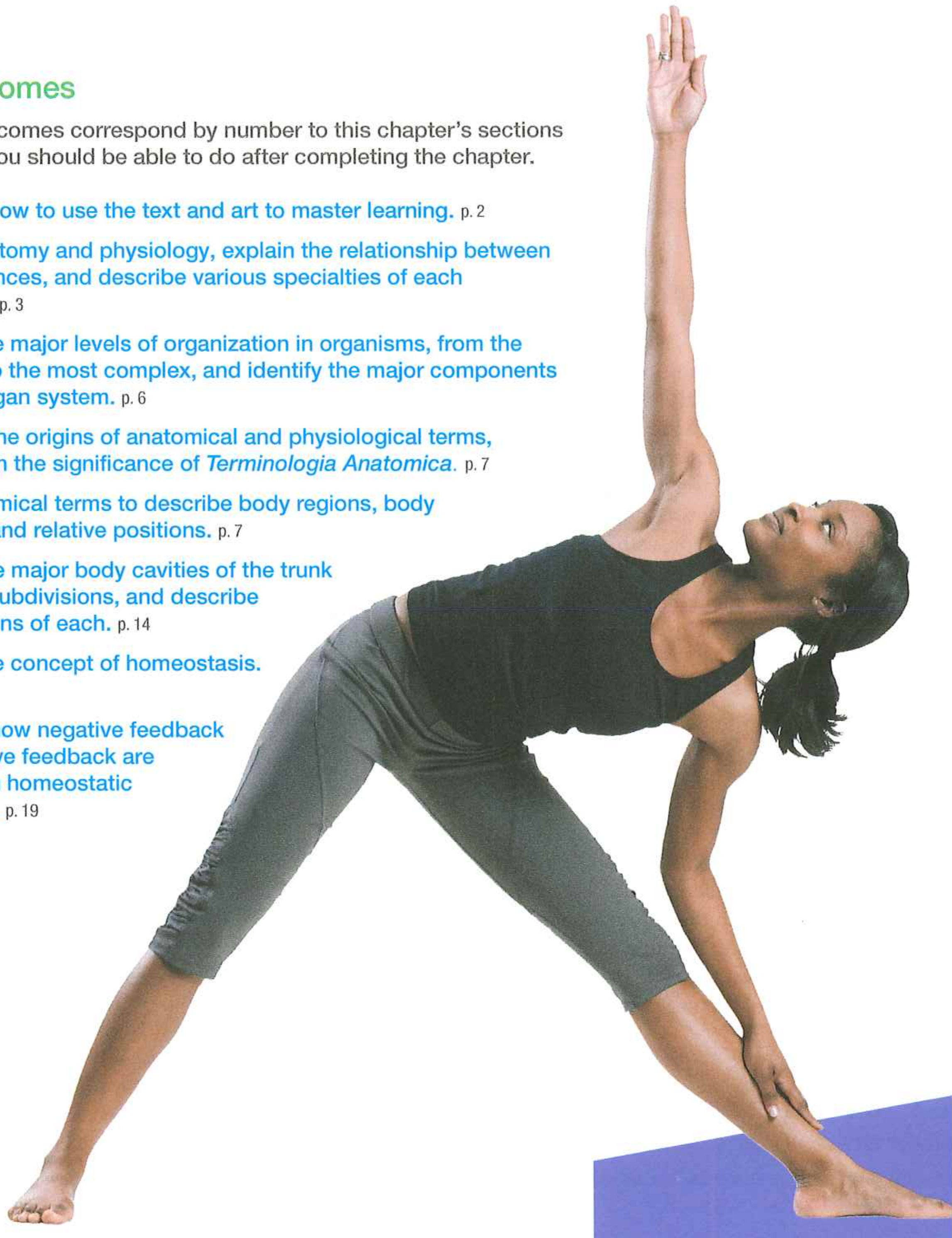
1 An Introduction to Anatomy and Physiology

Learning Outcomes

These Learning Outcomes correspond by number to this chapter's sections and indicate what you should be able to do after completing the chapter.

- 1-1 **Describe how to use the text and art to master learning.** p. 2
- 1-2 **Define anatomy and physiology, explain the relationship between these sciences, and describe various specialties of each discipline.** p. 3
- 1-3 **Identify the major levels of organization in organisms, from the simplest to the most complex, and identify the major components of each organ system.** p. 6
- 1-4 **Describe the origins of anatomical and physiological terms, and explain the significance of *Terminologia Anatomica*.** p. 7
- 1-5 **Use anatomical terms to describe body regions, body sections, and relative positions.** p. 7
- 1-6 **Identify the major body cavities of the trunk and their subdivisions, and describe the functions of each.** p. 14
- 1-7 **Explain the concept of homeostasis.** p. 18
- 1-8 **Describe how negative feedback and positive feedback are involved in homeostatic regulation.** p. 19



CLINICAL CASE Using A&P to Save a Life

An emergency medical technician (EMT) is on the way to the emergency department with a young victim of street violence. A knife with a 6-inch blade had been found next to the bleeding, unconscious man.

"We have a young male with multiple stab wounds. He has lost a lot of blood and we can barely get a blood pressure," the EMT radios to the triage nurse in the emergency department as the ambulance squeals through traffic. "We started an IV and we are pouring in fluid as fast as we can."

"Where are the wounds?" asks the receiving nurse.

"He has a deep wound in his right upper quadrant, just inferior to the diaphragm. I can see bruising from the hub of the knife around the wound, and there is another wound in his anterior right thigh. His pulse is 120 and thready (weak). His blood pressure is 60 over 30."

"How long has he been down?" questions the nurse.

"Less than a half hour. We intubated him (inserted a breathing tube) and started a large-bore IV as soon as we got there. We are 10 minutes out now."

"Keep the fluids going wide open, keep pressure on the thigh, and take him directly to Trauma Room 1," come the instructions. Meanwhile, the nurse orders the trauma team to Trauma Room 1, orders X-Ray to be on standby in the room, and requests 4 units of type O negative whole blood—the universal donor blood—from the blood bank. **Will the team be ready to save this young man?** **To find out, turn to the Clinical Case Wrap-Up on p. 26.**

An Introduction to Studying the Human Body

Welcome to the field of human anatomy and physiology—known simply as A&P! In this textbook we will introduce you to the inner workings of the human body, giving information about both its structure (anatomy) and its function (physiology). Many students who use this book are preparing for jobs in health-related fields; but regardless of your career choice, you will find the information within these pages relevant to your future.

We will focus on the human body, but the principles you will learn apply to other living things as well. Our world contains an enormous diversity of living organisms, which vary widely in appearance and lifestyle. One aim of *biology*—the study of life—is to discover the unity and the patterns that underlie this diversity. As we study human anatomy and physiology, three main concepts will emerge: (1) the principle of complementarity of structure and function, (2) the hierarchy of structural relationships, and (3) homeostasis, the tendency toward internal balance. These principles are the foundation for learning about the human organism.

Before we begin with the science of human anatomy and physiology, let's turn our attention to the science of learning and learning strategies. To make the most of your learning experience, apply these strategies, which were collected from academic research.

1-1 To make the most of your learning, read the text and view the art together

Learning Outcome Describe how to use the text and art to master learning.

Getting to Know Your Textbook

This first section of the book sets the stage for your success in this course and introduces you to the basic principles of learning. Just as there are three underlying concepts in A&P, there are two basic principles to using your textbook effectively to learn A&P. Practicing these principles will help you throughout your college career.

Let's start. Think back to your first childhood book. You most likely began with a "picture book." Then, as you learned the alphabet and developed speech, you progressed to "word books." The next step was "chapter books." Somewhere along the way, you quit looking at pictures and focused solely on the words (text). Maybe the shift in focus to text-based reading without looking at the pictures happened in high school. You began reading words—paragraph upon paragraph, page upon page of words. Now, you are in college, and we need to realign your focus.

In college, you are faced with lots of new terms, abstract concepts, and unfamiliar images. That's great, because college is intended to increase your knowledge and expand your horizons. However, research has shown that undergraduate students have a tendency to simply read the text (also called the *narrative*), without paying attention to the pictures (referred to as visuals, art, diagrams, illustrations, figures, or images). While you can certainly learn from this approach, further research demonstrates that when students *read the text and then look at the corresponding picture, they actually learn the material better*!

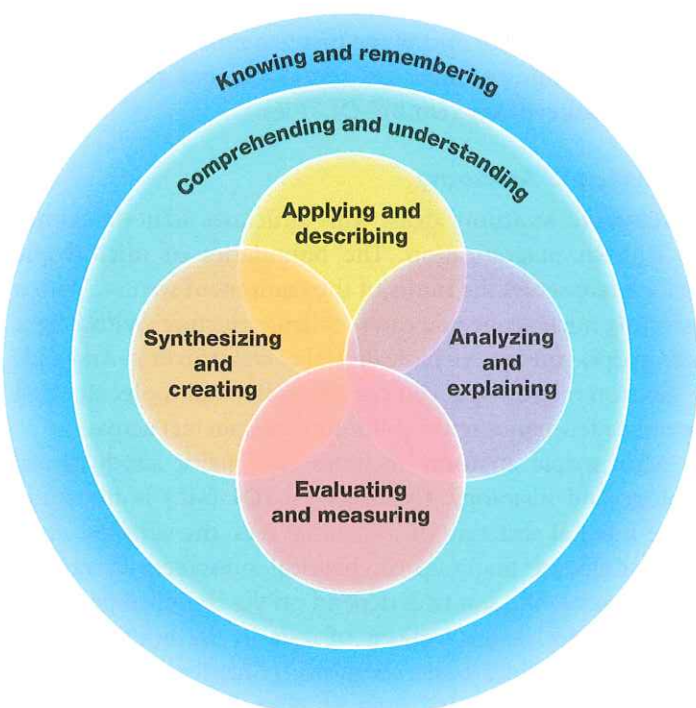
Although this may sound quite intuitive, most students do not do that. So, we wrote a book that truly integrates text with art to help you learn A&P. Please continue reading as we walk you through the process of using a textbook to enhance your learning. Much of what we're about to tell you applies to most of your college textbooks, but we'll focus on this book, since it was designed for students such as you.

Anatomy of a Chapter

Your book is broken down into *sections* with *text–art integration*, and specific *learning outcomes* for each section based on a *learning classification scheme*. A **section** is a unit about a topic that continues to build on previously learned topics. The sectional layout promotes logical, efficient navigation through the material, while callouts to figures integrate the text with the art. **Text–art integration** implies that the figures are close to the lines of text and that the figure legends are adjacent to the art. Look at that figure when you see a callout for it. The figure callouts look like this: (Figure 1–1). They are color-coded on purpose so you can stop reading, look at the figure, and then find your place again when you go back to reading the text. So, *strategy #1 is to read the text and then study the image that goes along with the narrative.*

Learning outcomes are educational objectives that use key verbs and target specific skills, goals, aims, and achievements. The learning outcomes appear at the beginning of each chapter and within the chapter under the sentence-based headings. *Strategy #2 is to pay attention to these learning outcomes because they are tied directly to testing and tell you what you should be able to do after reading that specific section and studying the images.* These learning outcomes are based on a **learning classification scheme**, which identifies the fundamental levels of learning from lower order skills to those of higher-order skills.

Figure 1–1 A Conceptual Framework for Learning.



You'll see key verbs in your learning outcomes and you'll notice some overlap among them within the levels of learning. From lower to higher, these levels are (1) knowing and remembering, (2) comprehending and understanding, (3) applying and describing, (4) analyzing and explaining, (5) evaluating and measuring, and (6) synthesizing and creating (Figure 1–1). (Here is where you can practice using what you just learned: Look at that figure, think about it, and then return to this text.) If you practice these basic strategies—(1) read the narrative and study the image and (2) pay attention to the learning outcomes—you are well on your way to success!

✓ Checkpoint

1. **Describe a learning outcome.**
2. **Explain how to use your textbook most effectively to enhance your learning.**

See the blue Answers tab at the back of the book.

1-2 Anatomy (structure) and physiology (function) are closely integrated

Learning Outcome Define anatomy and physiology, explain the relationship between these sciences, and describe various specialties of each discipline.

Anatomy is the study of internal and external body structures and their physical relationships among other body parts. In contrast, **physiology** is the study of how living organisms perform their vital functions. Someone studying anatomy might, for example, examine where a particular muscle attaches to the skeleton. Someone studying physiology might consider how a muscle contracts or what forces a contracting muscle exerts on the skeleton. You will be studying both anatomy and physiology in this text, so let's look at the relationships between these sciences.

Anatomy and physiology are closely integrated, both in theory and practice. Anatomical information provides clues about functions, and physiological processes can be explained only in terms of the underlying anatomy. This is a very important concept in living systems:

> All specific functions are performed by specific structures, and the form of a structure relates to its function. This is known as the *principle of complementarity of structure and function.*

The link between structure and function is always present, but not always understood. For example, the anatomy of the heart was clearly described in the 15th century, but almost 200 years passed before the heart's pumping action was demonstrated.

Anatomists and physiologists approach the relationship between structure and function from different perspectives. To understand the difference, suppose you asked an anatomist and physiologist to examine a car and report their findings. The natomist might begin by measuring and photographing the arious parts of the car and, if possible, taking it apart and putng it back together. The anatomist could then explain its key *ructural relationships*—for example, how the pistons are seated n the engine cylinders, how the crankshaft is connected to the istons, and how the transmission links the drive shaft to the xles and, thus, to the wheels. The physiologist also would note he relationships among the car's parts, but he or she would ocus mainly on its *functional* characteristics, such as how the ombustion of gasoline in the cylinders moves the pistons up nd down and makes the drive shaft rotate, and how the transnission conveys this motion to the axles and wheels so that the ar moves. Additionally, he or she might also study the amount f power that the engine could generate, the amount of force ansmitted to the wheels in different gears, and so forth.

Our basic approach in this textbook will be to start with he descriptive anatomy of body structures (appearance, size, hape, location, weight, and color) before considering the elated functions. Sometimes the groups of organs that make p an *organ system* perform very diverse functions, and in those ases we consider the functions of each individual organ separately. A good example is our discussion of the digestive system nd its organs. You will learn about the functions of the salivary glands in one section, and the functions of the tongue in nother. In other systems, the organs work together so extenvely that we present an overall discussion of their physiology, fter we describe the system's anatomy. The lymphatic system which contains a network of vessels) and the cardiovascular ystem, for example, are treated using this approach.

natomy

Vhen you look at something, how far away you are from it ften determines what you see. You get a very different view of our neighborhood from a satellite photo than from your front ard. Similarly, your method of observation has a dramatic efect on your understanding of the structure of the human body. ased on the degree of structural detail being considered, we divide **human anatomy**, the study of the structure of the human ody, into *gross (macroscopic) anatomy* and *microscopic anatomy*.

ross Anatomy

ross anatomy, or *macroscopic anatomy*, involves examining airly large structures. Gross anatomy (from the Latin term *grossus*, meaning "thick" or "massive") can be conducted without sing a microscope and can involve the study of anatomy by issecting a cadaver. There are many different forms of gross natomy:

- *Surface anatomy*, or superficial anatomy, is the study of the general form of the body's surface, especially in relation to its deeper parts.
- *Regional anatomy* focuses on the anatomical organization of specific areas of the body, such as the head, neck, or trunk. Many advanced courses in anatomy stress a regional approach, because it emphasizes the spatial relationships among structures already familiar to students.
- *Sectional anatomy* is the study of the relationship of the body's structures by examining cross sections of the tissue or organ.
- *Systemic anatomy* is the study of the structure of *organ systems*, which are groups of organs that function together in a coordinated manner. Examples include the *skeletal system*, composed primarily of bones; the *muscular system*, made up of skeletal muscles; and the *cardiovascular system*, consisting of the heart, blood, and vessels. We take a systemic anatomy approach in this book because this format works better to clarify the functional relationships among the component organs. We introduce the 11 organ systems in the human body later in the chapter.
- *Clinical anatomy* includes a number of subspecialties important in clinical practice. Examples include *pathological anatomy* (anatomical features that change during illness), *radiographic anatomy* (anatomical structures seen using specialized imaging techniques), and *surgical anatomy* (anatomical landmarks important in surgery).
- *Developmental anatomy* describes the changes in form that take place between conception and adulthood. The techniques of developmental anatomists are similar to those used in gross anatomy and in microscopic anatomy (discussed next) because developmental anatomy considers anatomical structures over a broad range of sizes—from a single cell to an adult human. The most extensive structural changes take place during the first two months of development. The study of these early developmental processes is called **embryology** (em-brē-OL-ō-jē).

Microscopic Anatomy

Microscopic anatomy deals with structures that we cannot see without magnification. The boundaries of microscopic anatomy are set by the limits of the equipment we use. With a dissecting microscope you can see tissue structure. With a light microscope, you can see basic details of cell structure. And with an electron microscope, you can see individual molecules that are only a few nanometers (billionths of a meter) across.

Microscopic anatomy includes two major subdivisions: cytology and histology. **Cytology** (sī-TOL-ō-jē) is the study of the internal structure of individual *cells*, the simplest units of life. Cells are made up of chemical substances in various combinations, and our lives depend on the chemical processes that take place in the trillions of cells in the body. For this reason, we consider basic chemistry (Chapter 2) before we examine cell structure (Chapter 3). **Histology** (his-TOL-ō-jē)

Clinical Note *Habeas Corpus* ("You Shall Have the Body")

It is the first day of Anatomy. Students await the arrival of their white-coated and gloved professor. Anxiety mounts as a stretcher covered in surgical drapes is wheeled in. This is the cadaver. Who will faint? *Will it be me?* For many students in the health professions, cadaver dissection is a cornerstone of their training. These students are following in a revered tradition that began 2300 years ago with the first examinations of the body after death by Greek royal physicians. The expression "a skeleton in your closet" dates from a later era when medical students had to procure bodies on their own for study (and keep them hidden in the closet). There is much to be learned from death. Cadaver dissections also reveal much about life. After working closely on a cadaver for months, students develop an attachment to "their" body, often naming it. The intimate revelations of the scalpel, the highly personal variations of human anatomy, the Rubik's cube of disease, and the stark reality of death combine to leave a deep intellectual and emotional mark on the student. Students and faculty may end the course with a ceremony to pay their respects to this human body and to this privileged experience.

is the examination of *tissues*—groups of specialized cells that work together to perform specific functions (Chapter 4). Tissues combine to form *organs*, such as the heart, kidney, liver, or brain, each with specific functions. Many organs are easy to examine without a microscope, so at the organ level we cross the boundary from microscopic anatomy to gross anatomy. As we proceed through the text, we will consider details at all levels, from microscopic to macroscopic.

Physiology

Human physiology is the study of the functions, or workings, of the human body. These functions are complex processes and much more difficult to examine than most anatomical structures. As a result, there are even more specialties in physiology than in anatomy. Examples include the following:

- *Cell physiology*, the study of the functions of cells, is the cornerstone of human physiology. Cell physiology looks at the chemistry of the cell. It includes both chemical processes within cells and chemical interactions among cells.
- *Organ physiology* is the study of the function of specific organs. An example is *cardiac physiology*, the study of heart function—how the heart works.
- *Systemic physiology* includes all aspects of the functioning of specific organ systems. Cardiovascular physiology, respiratory physiology, and reproductive physiology are examples.
- *Pathological physiology* is the study of the effects of diseases on organ functions or system functions. Modern medicine depends on an understanding of both normal physiology and pathological physiology.

Physicians normally use a combination of anatomical, physiological, chemical, and psychological information when they evaluate patients. When a patient presents with **signs** (an objective disease indication like a fever) and **symptoms** (a subjective disease indication, such as tiredness), the physician will look at the structures affected (gross anatomy), perhaps collect a fluid or tissue sample (microscopic anatomy) for analysis, and ask questions to find out what changes from normal functioning the patient is experiencing. Think back to your last trip to a doctor's office. Not only did the physician examine your body, noting any anatomical abnormalities, but he or she also evaluated your physiological processes by asking questions, observing your movements, listening to your body sounds, taking your temperature, and perhaps requesting chemical analyses of fluids such as blood or urine.

In evaluating all these observations to reach a diagnosis, physicians rely on a logical framework based on the scientific method. The **scientific method** is a system of advancing knowledge that begins by proposing a hypothesis to answer a question, and then testing that hypothesis with data collected through observation and experimentation. This method is at the core of all scientific thought, including medical diagnosis.

Checkpoint

3. Define *anatomy*.
4. Define *physiology*.
5. Describe how anatomy and physiology are closely related.
6. What is the difference between gross anatomy and microscopic anatomy?
7. Identify several specialties of physiology.
8. Why is it difficult to separate anatomy from physiology?

See the blue Answers tab at the back of the book.

-3 Levels of organization progress rom chemicals to a complete organism

earning Outcome Identify the major levels of organization in rganisms, from the simplest to the most complex, and identify ajor components of each organ system.

ur understanding of how the human body works is based n investigations of its different levels of organization. Higher vels of organization are more complex and more variable han lower levels. Chapters 2, 3, and 4 consider the chemi-al, cellular, and tissue levels of organization of the human ody. These levels are the foundations of more complex struc-ures and vital processes, as we describe in Chapters 5–29. The x levels of organization of the human body are shown in potlight Figure 1–2 and include:

- *The Chemical Level.* **Atoms** are the smallest stable units of matter. They can combine to form **molecules** with complex shapes. The atomic components and unique three-dimensional shape of a particular molecule determine its function. For example, complex protein molecules form filaments that produce the contractions of muscle cells in the heart. We explore this level of organization in Chapter 2.
- *The Cellular Level.* **Cells** are the smallest living units in the body. Complex molecules can form various types of larger structures called *organelles*. Each organelle has a specific function in a cell. Energy-producing organelles provide the energy needed for heart muscle cell contractions. We examine the cellular level of organization in Chapter 3.
- *The Tissue Level.* A **tissue** is a group of cells working together to perform one or more specific functions. Heart muscle cells, also called cardiac muscle cells (*cardium*, heart), interact with other types of cells and with materials outside the cell to form cardiac muscle tissue. We consider the tissue level of organization in Chapter 4.
- *The Organ Level.* **Organs** are made of two or more tissues working together to perform specific functions. Layers of cardiac muscle tissue, in combination with another type of tissue called connective tissue, form the bulk of the wall of the heart, which is a hollow, three-dimensional organ.
- *The Organ System Level.* A group of organs interacting to perform a particular function forms an **organ system**. Each time the heart contracts, for example, it pushes blood into a network of blood vessels. Together, the heart, blood, and blood vessels make up the cardiovascular system, one of 11 organ systems in the body. This system functions to distribute oxygen and nutrients throughout the body.
- *The Organism Level.* An individual life form is an **organism**. In our case, an individual human is the highest level of organization that we consider. All of the body's organ systems must work together to maintain the life and health of the organism.

The organization at each level determines not only the structural characteristics but also the functions of higher levels. For example, the arrangement of atoms and molecules at the chemical level creates the protein filaments and organelles at the cellular level that give individual cardiac muscle cells the ability to contract. At the tissue level, these cells are linked, forming cardiac muscle tissue. The structure of the tissue ensures that the contractions are coordinated, producing a powerful heartbeat. When that beat occurs, the internal anatomy of the heart, an organ, enables it to function as a pump. The heart is filled with blood and connected to the blood vessels, and its pumping action circulates blood through the vessels of the cardiovascular system. Through interactions with the respiratory, digestive, urinary, and other systems, the cardiovascular system performs a variety of functions essential to the survival of the organism.

Something that affects a system will ultimately affect each of the system's parts. For example, after massive blood loss, the heart cannot pump blood effectively. When the heart cannot pump and blood cannot flow, oxygen and nutrients cannot be distributed to the heart or around the body. Very soon, the cardiac muscle tissue begins to break down as individual muscle cells die from oxygen and nutrient starvation. These changes will not be restricted to the cardiovascular system. All cells, tissues, and organs in the body will be damaged. Spotlight Figure 1–2 illustrates the levels of organization and introduces the 11 interdependent, interconnected organ systems in the human body.

The cells, tissues, organs, and organ systems of the body coexist in a relatively small, shared environment, much like the residents of a large city. Just as city dwellers breathe the same air and drink the water supplied by the local water company, cells in the human body absorb oxygen and nutrients from the fluids that surround them. If a city is blanketed in smog or its water supply is contaminated, its inhabitants will become ill. Similarly, if the body fluid composition becomes abnormal, cells will be injured or destroyed. For example, suppose the temperature or salt content of the blood changes. The effect on the heart could range from the need for a minor adjustment (heart muscle tissue contracts more often, raising the heart rate) to a total disaster (the heart stops beating, so the individual dies).

✓ Checkpoint

9. **Identify the major levels of organization of the human body from the simplest to the most complex.**
10. **Identify the organ systems of the body and cite some major structures of each.**
11. **At which level of organization does a histologist investigate structures?**

See the blue Answers tab at the back of the book.

1-4 Medical terminology is important to understanding anatomy and physiology

Learning Outcome Describe the origins of anatomical and physiological terms, and explain the significance of *Terminologia Anatomica.*

Early anatomists faced serious problems when trying to communicate. Saying that a bump is "on the back," for example, does not give very precise information about its location. So anatomists created illustrated maps of the human body and gave each structure a specific name. They used prominent anatomical structures as landmarks, measured distances in centimeters or inches, and discussed these subjects in specialized directional terms. Modern anatomists continue and build on these practices. In effect, anatomy uses a special language that you must learn almost at the start of your study.

That special language, called **medical terminology**, involves using word roots, prefixes, suffixes, and combining forms to build terms related to the body in health and disease. Many of the anatomical and physiological terms you will encounter in this textbook are derived from Greek or Latin roots that originated more than 1500 years ago. In fact, the term *anatomy* is derived from Greek roots that mean "a cutting open"; the term *physiology* also comes from Greek. Learning the word parts used in medical terminology will greatly assist in your study of anatomy and physiology and in your preparation for any health-related career.

There are four basic building blocks—or word parts—of medical terms. *Word roots* are the basic, meaningful parts of a term that cannot be broken down into another term with another definition. *Prefixes* are word elements that are attached to the beginning of words to modify their meaning but cannot stand alone. *Suffixes* are similar to prefixes, except they are word elements or letters added to the end of a word or word part to form another term. *Combining forms* are independent words or word roots that are used in combination with words, prefixes, suffixes, or other combining forms to build a new term. As we introduce new terms, we will provide notes on pronunciation and relevant word parts. In addition, the table inside the back cover of your textbook lists many commonly used word roots, prefixes, suffixes, and combining forms.

To illustrate the building of medical terms, consider the word *pathology* (puh-THOL-ō-jē). Breaking this word into its basic parts reveals its meaning. The prefix *path-* refers to disease (the Greek term for "disease" is *pathos*). The suffix *-ology* means "study of." So pathology is the study of disease.

Latin and Greek terms are not the only ones that have been imported into the anatomical vocabulary over the centuries, and this vocabulary continues to expand. Many anatomical structures and clinical conditions were first named after either the discoverer or, in the case of diseases, the most famous victim. During the past 100 years, most of these commemorative names, or **eponyms** (EH-pō-nimz), have been replaced by more precise terms. Where appropriate, we will give both the eponym and the more precise term, because in clinical medicine, both terms may be used.

To avoid the miscommunication that plagued the early anatomists, it is important for scientists throughout the world to use the same name for each body structure. In 1998, two scientific organizations—the Federative Committee on Anatomical Terminology (FCAT) and the International Federation of Associations of Anatomists (IFAA)—published *Terminologia Anatomica* (*TA*). *Terminologia Anatomica* established the worldwide standard for human anatomical terminology. The successor of FCAT is the Federative International Programme on Anatomical Terminologies (FIPAT). In April 2011, FIPAT published *TA* online. Latin continues to be the language of anatomy, but this reference provides an English equivalent term for each anatomical structure. For example, the *tendo calcaneus* (Latin) is also called the calcaneal tendon (English). You may know the structure better by its eponym, the Achilles tendon. Eponyms are not found in *TA*. We have used *TA* as our standard in preparing this textbook.

√ Checkpoint

12. **Describe medical terminology.**
13. **Define *eponym*.**
14. **Name the book that serves as the international standard for anatomical terms.**

See the blue Answers tab at the back of the book.

1-5 Anatomical terms describe body regions, anatomical positions and directions, and body sections

Learning Outcome Use anatomical terms to describe body regions, body sections, and relative positions.

Anatomists use anatomical terms to describe body regions, relative positions and directions, and body sections, as well as major body cavities and their subdivisions. In the following sections we introduce the terms used in superficial anatomy and sectional anatomy.

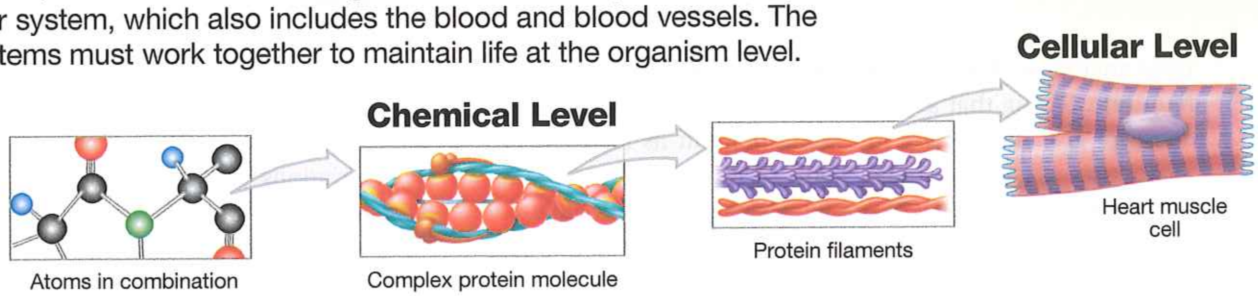
Surface Anatomy

Surface anatomy involves locating structures on or near the body surface. A familiarity with anatomical landmarks (structures that can be felt or palpated), anatomical regions (specific areas used for reference purposes), and terms for anatomical directions will make the material in subsequent chapters easier to understand.

SPOTLIGHT

Figure 1–2
Levels of Organization

Interacting atoms form molecules that combine to form the protein filaments of a heart muscle cell. Such cells interlock, forming heart muscle tissue, which makes up most of the walls of the heart, a three-dimensional organ. The heart is only one component of the cardiovascular system, which also includes the blood and blood vessels. The various organ systems must work together to maintain life at the organism level.



THE ORGAN SYSTEMS

Integumentary

Major Organs
- Skin
- Hair
- Sweat glands
- Nails

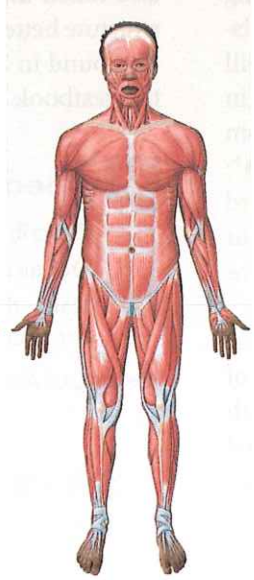
Functions
- Protects against environmental hazards
- Helps regulate body temperature
- Provides sensory information

Skeletal

Major Organs
- Bones
- Cartilages
- Associated ligaments
- Bone marrow

Functions
- Provides support and protection for other tissues
- Stores calcium and other minerals
- Forms blood cells

Muscular



Major Organs
- Skeletal muscles and associated tendons

Functions
- Provides movement
- Provides protection and support for other tissues
- Generates heat that maintains body temperature

Nervous

Major Organs
- Brain
- Spinal cord
- Peripheral nerves
- Sense organs

Functions
- Directs immediate responses to stimuli
- Coordinates or moderates activities of other organ systems
- Provides and interprets sensory information about external conditions

Endocrine

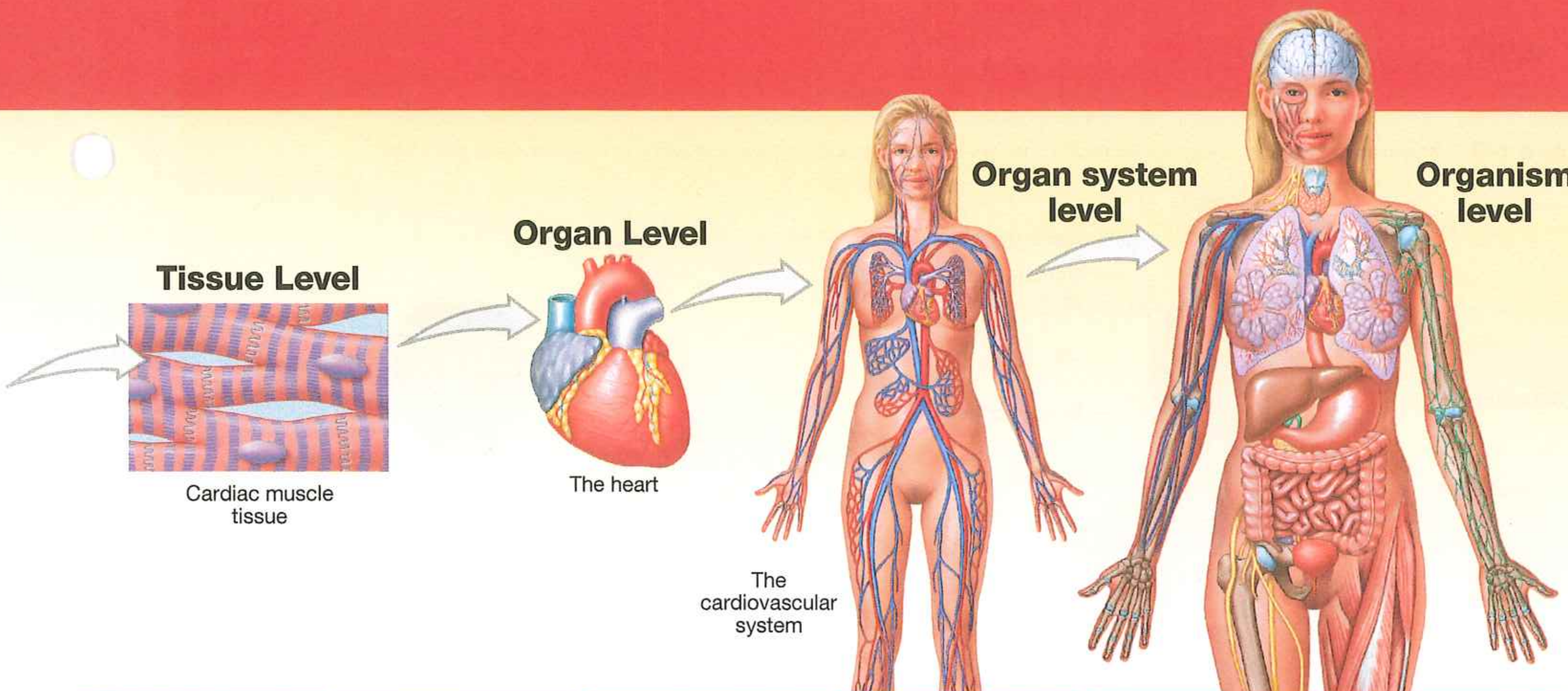
Major Organs
- Pituitary gland
- Thyroid gland
- Pancreas
- Adrenal glands
- Gonads
- Endocrine tissues in other systems

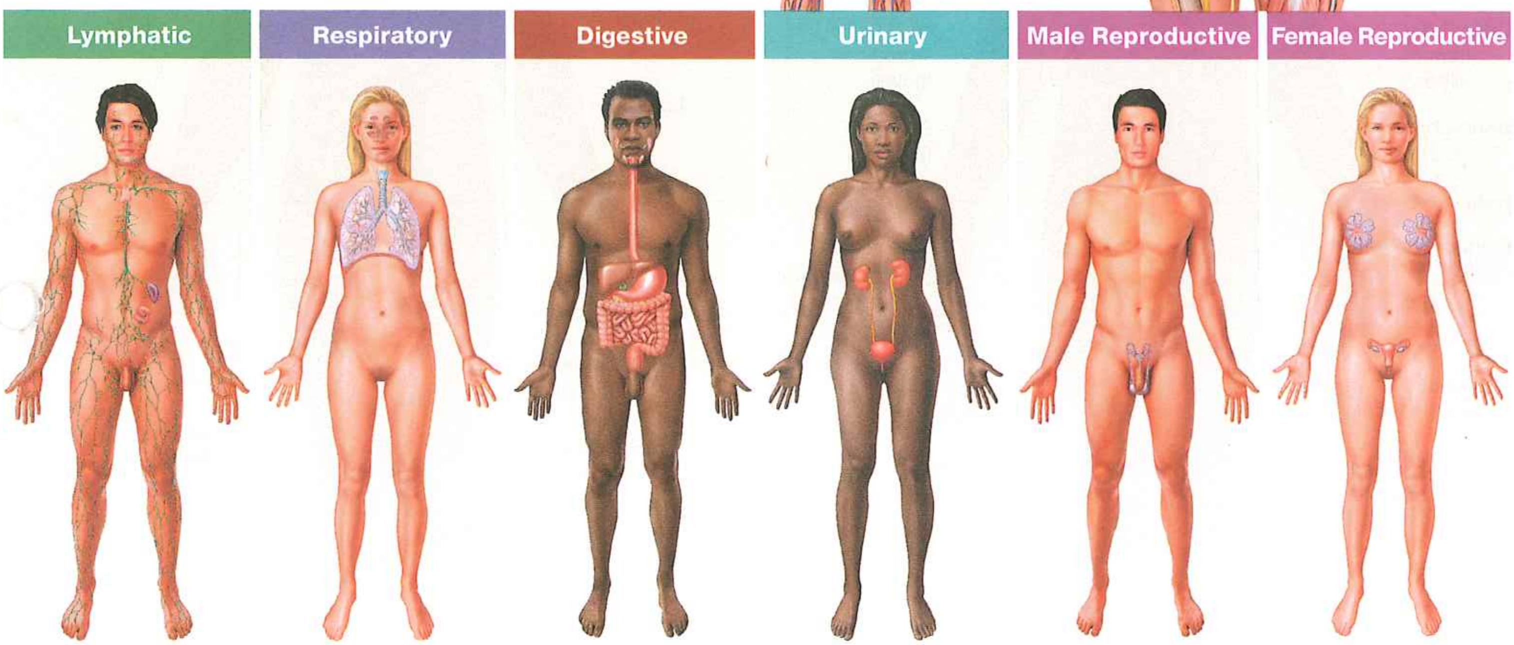
Functions
- Directs long-term changes in the activities of other organ systems
- Adjusts metabolic activity and energy use by the body
- Controls many structural and functional changes during development

Cardiovascular

Major Organs
- Heart
- Blood
- Blood vessels

Functions
- Distributes blood cells, water, and dissolved materials including nutrients, waste products, oxygen, and carbon dioxide
- Distributes heat and assists in control of body temperature





Lymphatic

Major Organs
- Spleen
- Thymus
- Lymphatic vessels
- Lymph nodes
- Tonsils

Functions
- Defends against infection and disease
- Returns tissue fluids to the bloodstream

Respiratory

Major Organs
- Nasal cavities
- Sinuses
- Larynx
- Trachea
- Bronchi
- Lungs
- Alveoli

Functions
- Delivers air to alveoli (sites in lungs where gas exchange occurs)
- Provides oxygen to bloodstream
- Removes carbon dioxide from bloodstream
- Produces sounds for communication

Digestive

Major Organs
- Teeth
- Tongue
- Pharynx
- Esophagus
- Stomach
- Small intestine
- Large intestine
- Liver
- Gallbladder
- Pancreas

Functions
- Processes and digests food
- Absorbs and conserves water
- Absorbs nutrients
- Stores energy reserves

Urinary

Major Organs
- Kidneys
- Ureters
- Urinary bladder
- Urethra

Functions
- Excretes waste products from the blood
- Controls water balance by regulating volume of urine produced
- Stores urine prior to voluntary elimination
- Regulates blood ion concentrations and pH

Male Reproductive

Major Organs
- Testes
- Epididymides
- Ductus deferentia
- Seminal vesicles
- Prostate gland
- Penis
- Scrotum

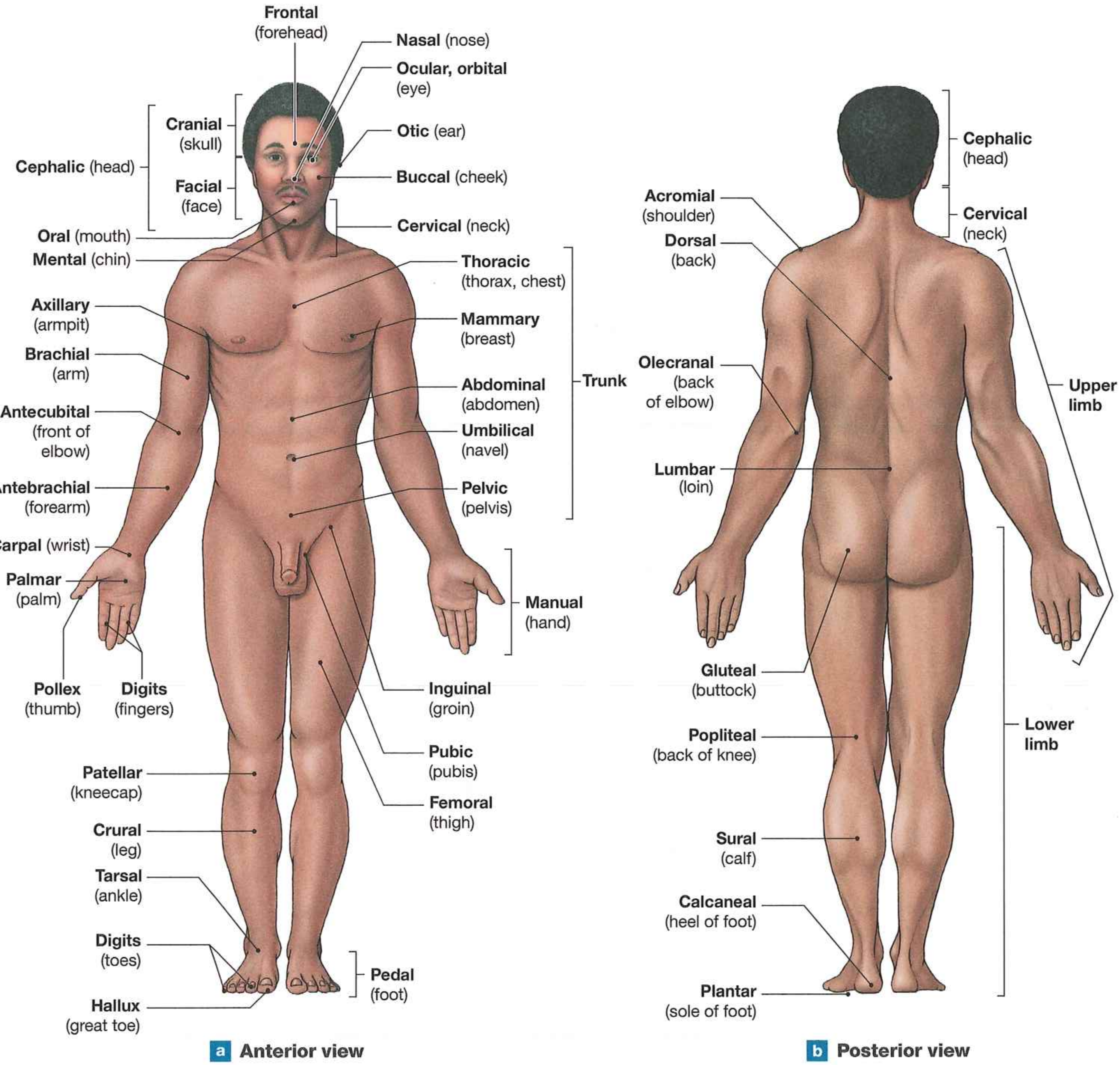
Functions
- Produces male sex cells (sperm), seminal fluids, and hormones
- Sexual intercourse

Female Reproductive

Major Organs
- Ovaries
- Uterine tubes
- Uterus
- Vagina
- Labia
- Clitoris
- Mammary glands

Functions
- Produces female sex cells (oocytes) and hormones
- Supports developing embryo from conception to delivery
- Provides milk to nourish newborn infant
- Sexual intercourse

igure 1–3 Anatomical Landmarks. Anatomical terms are shown in boldface type and common names are in plain type.



? Are the following anatomical landmarks visible from the anterior or posterior view: dorsal, gluteal, calcaneal?

natomical Landmarks

igure 1–3 presents important anatomical landmarks. Understand-ng the terms and their origins will help you remember both the ocation of a particular structure and its name. For example, *brachial* efers to the arm, and later we will consider the *brachialis muscle* and he *brachial artery*, which are in the arm, as their names suggest.

The standard anatomical reference for the human form is the **anatomical position**. This is also called the *anatomic position*. When the body is in this position, the hands are at the sides with the palms facing forward, and the feet are together. Figure 1–3a shows an individual in the anatomical position as seen from the front, called an *anterior view*. Figure 1–3b shows the body as seen from the back, called a *posterior view*. Unless otherwise noted, all descriptions in this text refer to the body in the anatomical position. A person lying down is said to be **supine** (sū-PĪN) when face up, and **prone** when face down.

Tips & Tools

Supine means "up." In order to carry a bowl of *soup*, your hand must be in the *supine* position.

Anatomical Regions

To describe a general area of interest or injury, clinicians and anatomists often need broader terms in addition to specific landmarks. They use two methods—dividing into quadrants and dividing into regions—to map the surface of the abdomen and pelvis.

Clinicians refer to four **abdominopelvic quadrants** (Figure 1–4a) formed by a pair of imaginary perpendicular lines that intersect at the umbilicus (navel). This simple method of dividing into quadrants provides useful references for describing the location of aches, pains, and injuries. Knowing the location can help the clinician determine the possible cause. For example, tenderness in the right lower quadrant (RLQ) is a symptom of appendicitis. Tenderness in the right upper quadrant (RUQ), however, may indicate gallbladder or liver problems.

Anatomists prefer more precise terms to describe the location and orientation of internal organs. They recognize nine **abdominopelvic regions** (Figure 1–4b). Figure 1–4c shows the relationships among quadrants, regions, and internal organs.

Tips & Tools

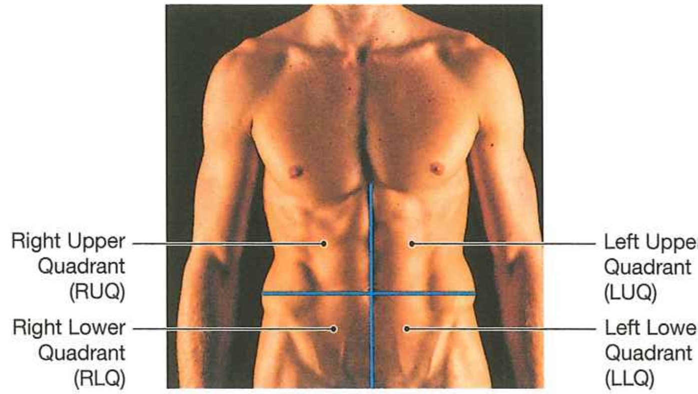
The imaginary lines dividing the abdominopelvic regions resemble a tic-tac-toe game.

Anatomical Directions

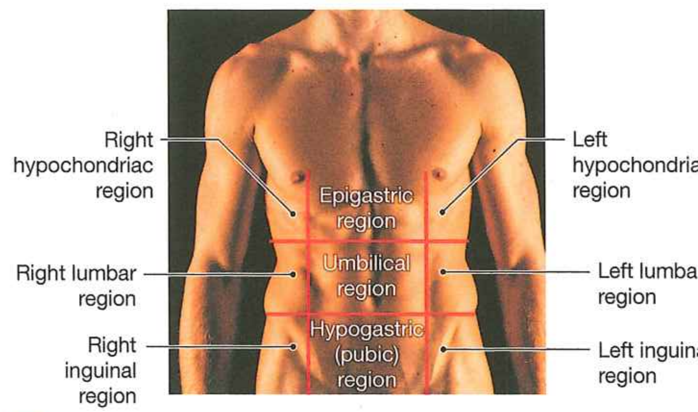
Figure 1–5 introduces the main directional terms and some examples of their use. There are many different terms, and some can be used interchangeably. For example, *anterior* refers to the front of the body when viewed in the anatomical position. In humans, this term is equivalent to *ventral*, which refers to the belly. *Posterior* refers to the back of the body; this term is equivalent to *dorsal*. When reading anatomical descriptions, remember that the terms *left* and *right* always refer to the left and right sides of the *subject*, not of the observer.

Before you read further, analyze the image in detail, and practice using the terms. We start using these terms in the rest of this chapter. If you are familiar with the basic vocabulary, the anatomical descriptions throughout this textbook will be easier to follow.

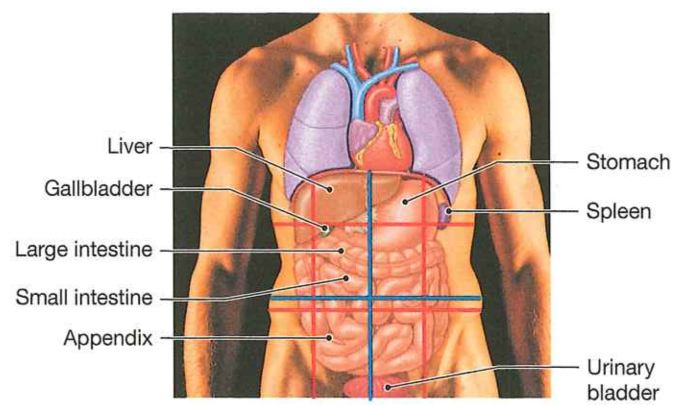
Figure 1–4 **Abdominopelvic Quadrants and Regions.**



a **Abdominopelvic quadrants**. The four abdominopelvic quadrants are formed by two perpendicular lines that intersect at the navel. The terms for these quadrants, or their abbreviations, are most often used in clinical discussions.



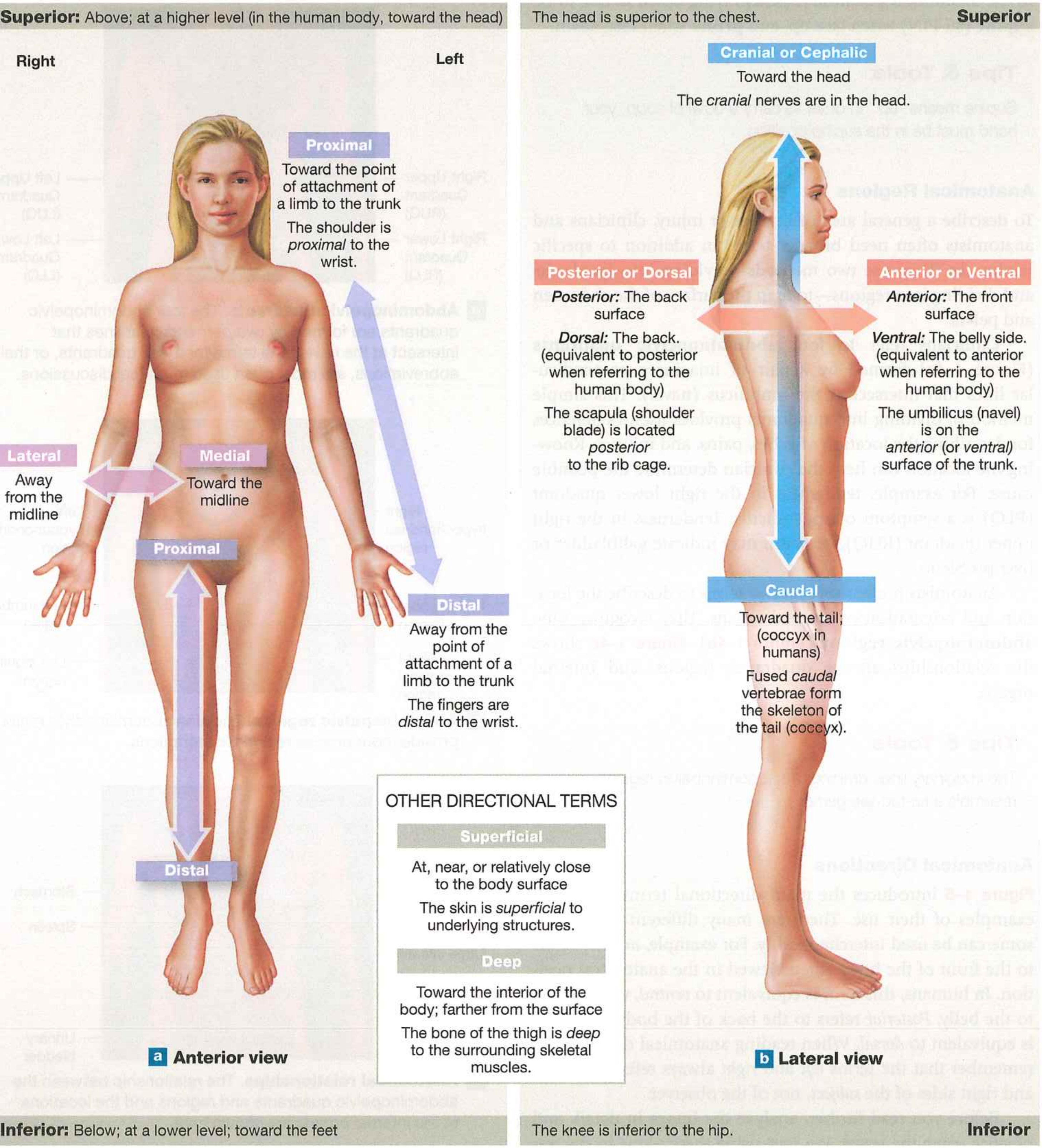
b **Abdominopelvic regions**. The nine abdominopelvic region provide more precise regional descriptions.



c **Anatomical relationships**. The relationship between the abdominopelvic quadrants and regions and the locations of the internal organs are shown here.

? In which abdominopelvic quadrant and region is the stomach predominantly found?

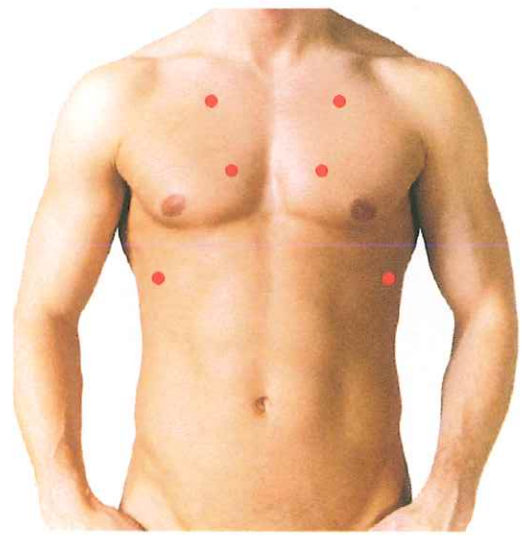
igure 1–5 Directional References.



? Using directional references for a person in the anatomical position, how would you describe the relationship of the hand compared to the elbow? To the groin?

Clinical Note The Sounds of the Body

We pay attention to the sounds of the body because they provide evidence of normal function. Midwives and doctors used to place their ears directly on the patient's body to listen. Then a piece of new-fangled technology, called the *stethoscope*, was invented in 1816 that gave the patient more privacy and the practitioner a better listen. *Auscultation* (aws-kul-TĀ-shun) is the practice of listening to the various sounds made by body organs with a stethoscope. After a surgical operation, the recovery room nurse auscultates the patient's abdomen to listen for bowel sounds (called by the imitative term *borborygmi* [bor-bō-RIG-mī]). These sounds confirm that the intestine is resuming its characteristic motility after anesthesia. When students get their college physicals, the practitioner auscultates the lungs over the dorsal surface of the body and superior to the clavicles (where the tips of the lungs lie). It is a thrilling moment when a pregnant woman hears her baby's heartbeat for the first time with the help of an ultrasound technician. A Doppler ultrasound device bounces sound waves off of a fetus's heart that are detected at the mother's skin surface in her pubic region (see Clinical Note: Diagnostic Imaging Techniques, pp. 16–17). The heartbeat is usually first heard when the fetus is about 12 weeks old. The sounds of an adult heart are heard at the general locations labeled on the anterior thoracic region of the body shown here. The heart sounds of "lubb-dupp" (which you will study in Chapter 20) tell us that heart valves are closing correctly during the heart's cycle. However, an unexpected "whoosh" can alert us to the possibility of a medical problem called a *heart murmur*.



Sectional Anatomy

Sometimes the only way to understand the relationships among the parts of a three-dimensional object is to slice through it and look at the internal organization. A slice through a three-dimensional object is called a *section*.

An understanding of sectional views is particularly important now that imaging techniques enable us to see inside the living body. These views are sometimes difficult to interpret, but it is worth spending the time required to understand what they show. Once you are able to interpret sectional views, you will have a good mental model for studying the anatomy and physiology of a particular region or system. Radiologists and other medical professionals responsible for interpreting medical scans spend much of their time analyzing sectional views of the body.

Any section through a three-dimensional object can be described in reference to a **sectional plane**, as indicated in Figure 1–6. A *plane* is a two-dimensional flat surface, and a section is a single view or slice along a plane. Common planes are frontal (coronal), sagittal, and transverse (horizontal).

- The **frontal (coronal) plane** is a vertical plane that divides the body or organ into anterior and posterior portions. A cut in this plane is called a **frontal section**, or *coronal section*.
- The **sagittal plane** is a vertical plane that divides the body into left and right portions. A cut in this plane is called a **sagittal section**. If the plane lies in the middle, it is called a **midsagittal plane**, and if it is offset from the middle, it is called a **parasagittal plane**.
- The **transverse plane** divides the body into *superior* and *inferior* portions. A cut in this plane is called a **transverse section**, or *cross section*. Unless otherwise noted, in this textbook all anatomical diagrams that present cross-sectional views of the body are oriented as though the subject were supine with you, the observer, standing at the subject's feet and looking toward the head.

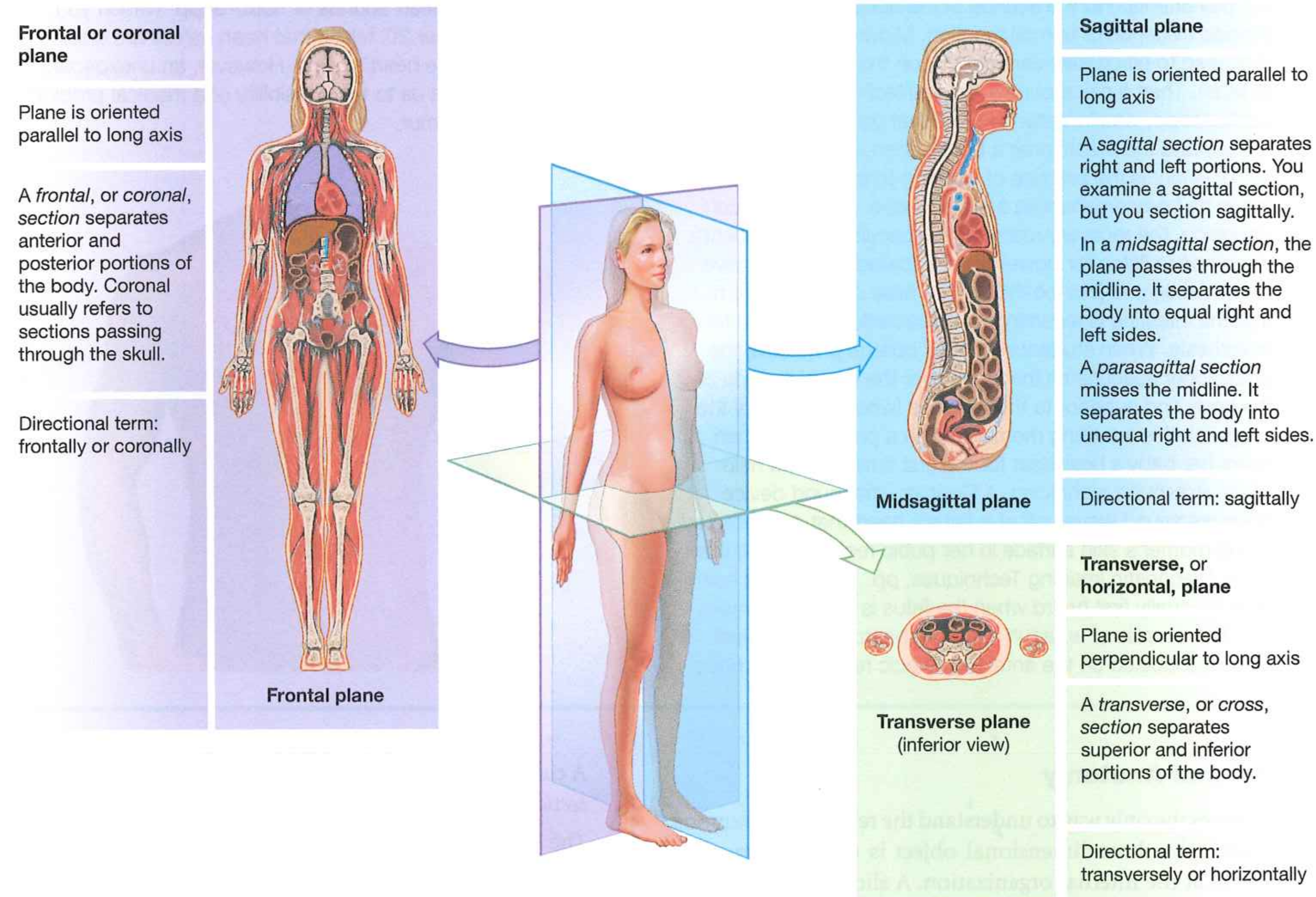
The atlas that accompanies this text contains images of sections taken through the body in various planes.

Checkpoint

15. **What is the purpose of anatomical terms?**
16. **For a body in the anatomical position, describe an anterior view and a posterior view.**

See the blue Answers tab at the back of the book.

Figure 1–6 Sectional Planes.



? Which plane separates the body into superior and inferior portions? Which plane separates the body into anterior and posterior portions?

1-6 Body cavities of the trunk protect internal organs and allow them to change shape

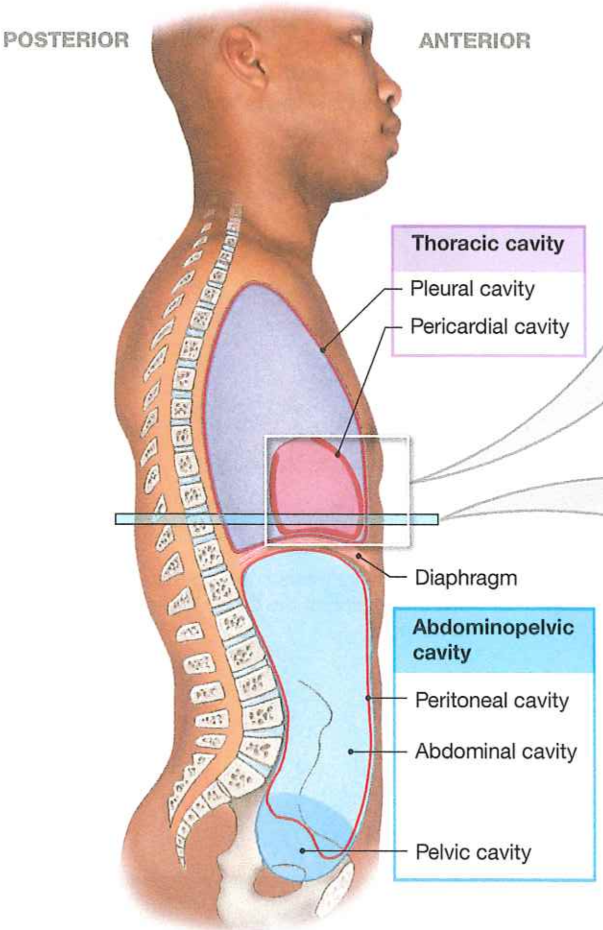
Learning Outcome Identify the major body cavities of the trunk and their subdivisions, and describe the functions of each.

The body's trunk is subdivided into three major regions established by the body wall: the thoracic, abdominal, and pelvic regions. Most of our vital organs are located within these regions of the trunk. The true **body cavities** are closed, fluid filled, and lined by a thin tissue layer called a *serous membrane*, or *serosa*. The vital organs of the trunk are suspended within these body cavities; they do not simply lie there. Early anatomists used the term *cavity* when referring to internal regions. For example, everything deep to the chest wall of the thoracic region is considered to be within the **thoracic cavity**, and all of the structures deep to the abdominal and pelvic walls are said to lie within the **abdominopelvic cavity**. Internally, the **diaphragm** (DĪ-uh-fram), a flat muscular sheet, separates these anatomical regions.

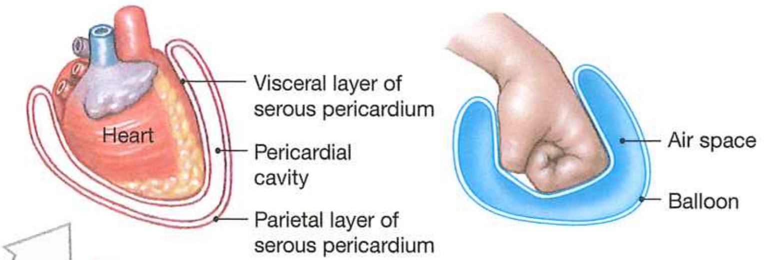
The boundaries of the true body cavities and the regional "cavities" are not identical. For example, the thoracic cavity contains two *pleural cavities* (each surrounding a lung), the *pericardial cavity* (surrounding the heart), and the *mediastinum* (a large tissue mass). The *peritoneal cavity* (surrounding abdominal organs) extends only partway into the pelvic cavity (surrounding pelvic organs). Figure 1–7 shows the boundaries between the subdivisions of the thoracic cavity and the abdominopelvic cavity.

The body cavities of the trunk have two essential functions: (1) They protect delicate organs from shocks and impacts, and (2) they permit significant changes in the size and shape of

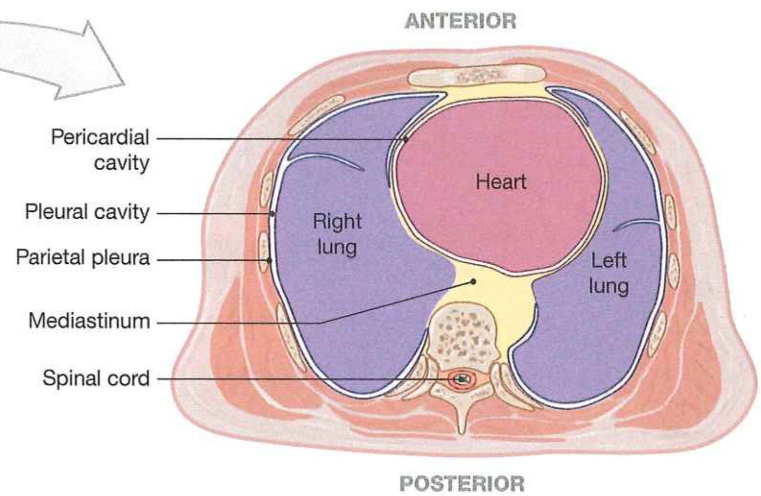
Figure 1–7 Relationships among the Subdivisions of the Body Cavities of the Trunk.



a A lateral view showing the body cavities of the trunk. The muscular diaphragm subdivides them into a superior thoracic cavity and an inferior abdominopelvic cavity. Three of the four adult true body cavities are shown and outlined in red; only one of the two pleural cavities can be shown in a sagittal section.



b The heart projects into the pericardial cavity like a fist pushed into a balloon. The attachment site, corresponding to the wrist of the hand, lies at the connection between the heart and major blood vessels. The width of the pericardial cavity is exaggerated here; normally the visceral and parietal layers are separated only by a thin layer of pericardial fluid.



c A transverse section through the thoracic cavity, showing the central location of the pericardial cavity. The mediastinum and pericardial cavity lie between the two pleural cavities. Note that this transverse or cross-sectional view is oriented as though you were standing at the feet of a supine person and looking toward that person's head. This inferior view of a transverse section is the standard presentation for clinical images. Unless otherwise noted, transverse or cross-sectional views in this text use this same orientation (*see Clinical Note: Diagnostic Imaging Techniques*).

internal organs. For example, the lungs, heart, stomach, intestines, urinary bladder, and many other organs can expand and contract without distorting surrounding tissues or disrupting the activities of nearby organs because they project into body cavities.

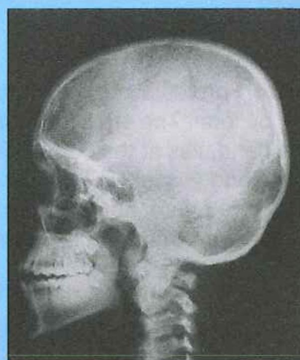
The internal organs that are enclosed by these cavities are known as **viscera** (VIS-e-ruh). A delicate serous membrane lines the walls of these internal cavities and covers the surfaces of the enclosed viscera. A watery fluid, called *serous fluid*, moistens serous membranes, coats opposing surfaces, and reduces friction. The portion of a serous membrane that directly covers a visceral organ is called the *visceral serosa*. The opposing layer that lines the inner surface of the body wall or chamber is called the *parietal serosa*. The parietal and visceral membranes are one membrane: The parietal serosa folds back onto itself, forming the visceral serosa. Because the moist parietal and visceral serosae are usually in close contact, the body cavities are called *potential spaces*. In some clinical conditions, however, excess fluid can accumulate within these potential spaces, increasing their volume and exerting pressure on the enclosed viscera.

The Thoracic Cavity

The thoracic cavity contains the lungs and heart; associated organs of the respiratory, cardiovascular, and lymphatic systems; the inferior portions of the esophagus; and the thymus (Figure 1–7a, c). The thoracic cavity is subdivided into the left and right **pleural cavities** (holding the lungs), separated by

During the past several decades, rapid progress has been made in discovering more accurate and more detailed ways to image the human body, both in health and disease.

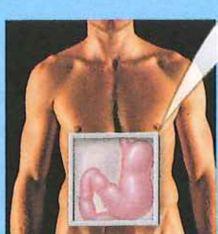
X-rays



An x-ray of the skull, taken from the left side

X-rays are the oldest and still the most common method of imaging. X-rays are a form of high-energy radiation that can penetrate living tissues. An x-ray beam travels through the body before striking a photographic plate. Not all of the projected x-rays arrive at the film. The body absorbs or deflects some of those x-rays. The ability to stop the passage of x-rays is referred to as **radiopacity**. When taking an x-ray, these areas that are impenetrable by x-rays appear light or white on the exposed film and are said to be **radiopaque**. In the body, air has the lowest radiopacity. Fat, liver, blood, muscle, and bone are increasingly radiopaque. As a result, radiopaque tissues look white, and less radiopaque tissues are in shades of gray to black.

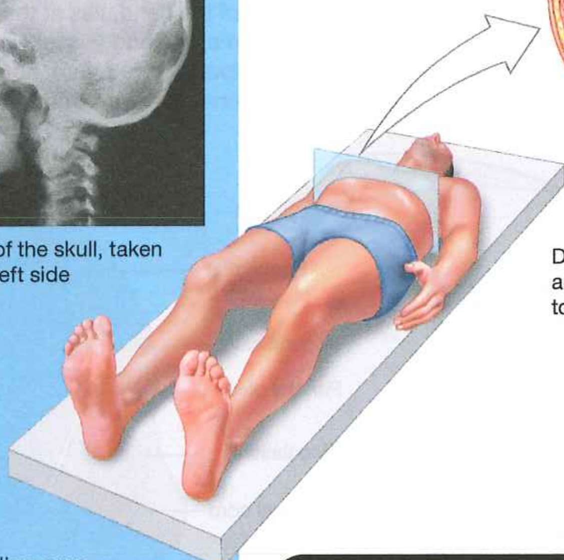
To use x-rays to visualize soft tissues, a very radiopaque substance must be introduced. To study the upper digestive tract, a radiopaque barium solution is ingested by the patient. The resulting x-ray shows the contours of the stomach and intestines.

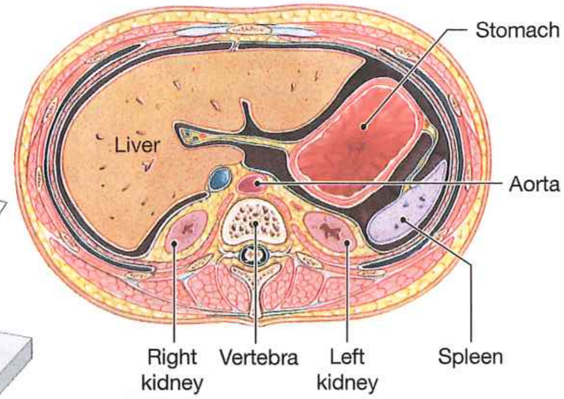


A **barium-contrast x-ray** of the upper digestive tract

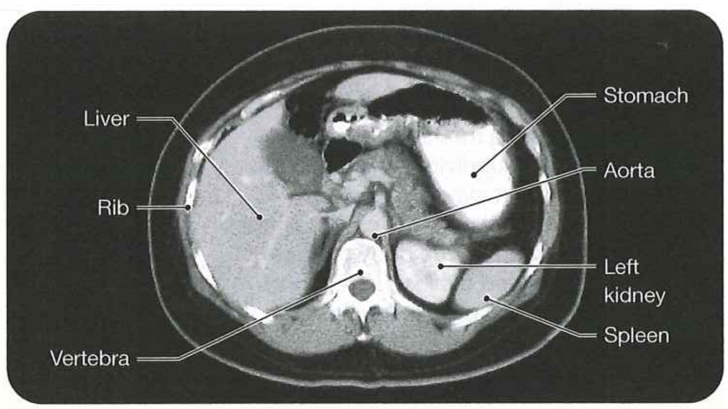
Standard Scanning Techniques

More recently, a variety of **scanning techniques** dependent on computers have been developed to show the less radiopaque, soft tissues of the body in much greater detail.





Diagrammatic views showing the relative position and orientation of the CT scan below and the MRI to the right.

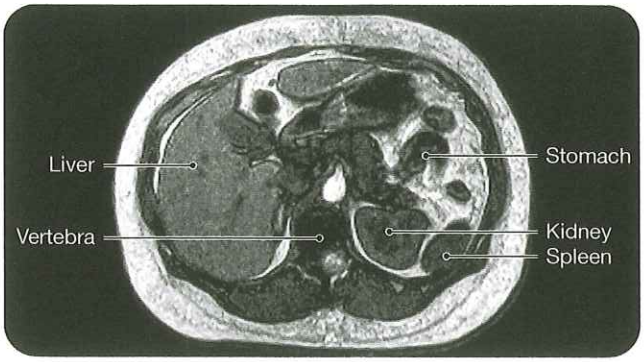


CT scan of the abdomen

CT (computed tomography) **scans** use computers to reconstruct sectional views. A single x-ray source rotates around the body, and the x-ray beam strikes a sensor monitored by the computer. The x-ray source completes one revolution around the body every few seconds. It then moves a short distance and repeats the process. The result is usually displayed as a sectional view in black and white, but it can be colorized for visual effect. CT scans show three-dimensional relationships and soft tissue structures more clearly than do standard x-rays.

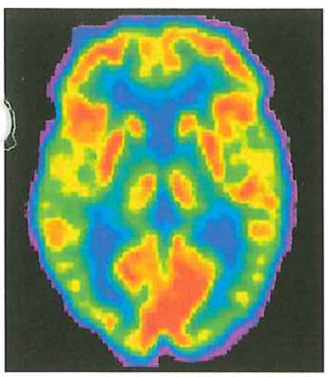
- Note that when anatomical diagrams or scans present cross-sectional views, the sections are presented from an inferior perspective, as though the observer were standing at the feet of a person in the supine position and looking toward the head of the subject.

Special Scanning Methods



MRI scan of the abdomen

An **MRI** of the same region (in this case, the abdomen) can show soft tissue structure in even greater detail than a CT scan. Magnetic resonance imaging surrounds part or all of the body with a magnetic field 3000 times as strong as that of Earth. This field causes particles within atoms throughout the body to line up in a uniform direction. Energy from pulses of radio waves are absorbed and released by the different atoms. The released energy is used to create a detailed image of the soft tissue structure.

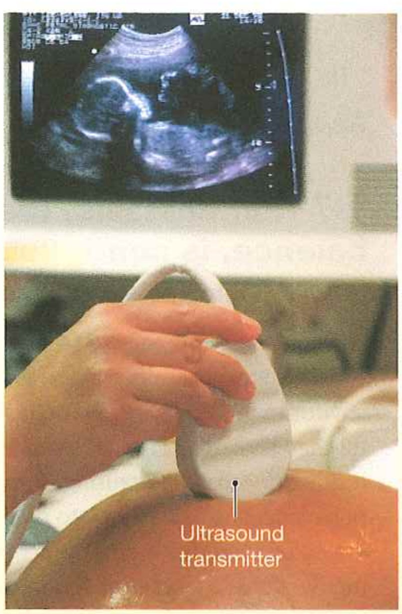


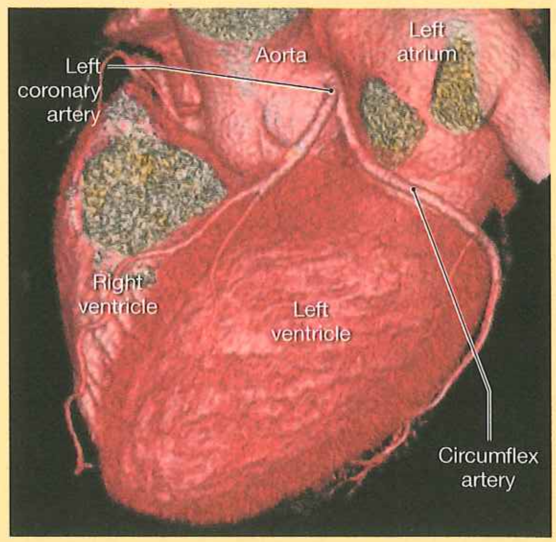
PET scan of the brain

Positron emission tomography (**PET**) is an imaging technique that assesses metabolic and physiological activity of a structure. A PET scan is an important tool in evaluating healthy and diseased brain function.

Ultrasound of the uterus

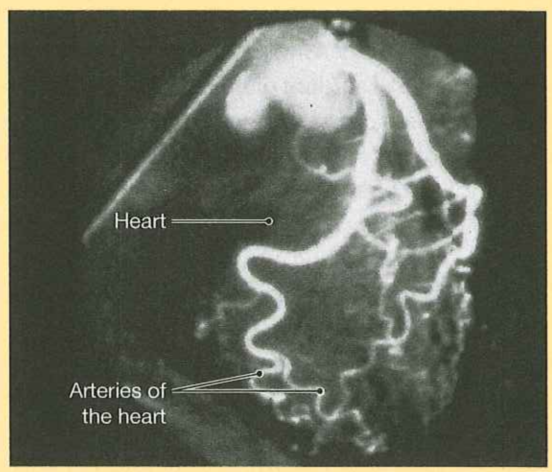
In **ultrasound** procedures, a small transmitter contacting the skin broadcasts a brief, narrow burst of high-frequency sound and then detects the echoes. The sound waves are reflected by internal structures, and a picture, or **echogram**, is assembled from the pattern of echoes. These images lack the clarity of other procedures, but no adverse effects have been reported, and fetal development can be monitored without a significant risk of birth defects. Special methods of transmission and processing permit analysis of the beating heart without the complications that can accompany dye injections.





Spiral scan of the heart

A **spiral CT scan** is a form of three-dimensional imaging technology that is becoming increasingly important in clinical settings. During a spiral CT scan, the patient is on a platform that advances at a steady pace through the scanner while the imaging source, usually x-rays, rotates continuously around the patient. Because the x-ray detector gathers data quickly and continuously, a higher quality image is generated, and the patient is exposed to less radiation as compared to a standard CT scanner, which collects data more slowly and only one slice of the body at a time.



Digital subtraction angiography of coronary arteries

Digital subtraction angiography (**DSA**) is used to monitor blood flow through specific organs, such as the brain, heart, lungs, and kidneys. X-rays are taken before and after radiopaque dye is administered, and a computer "subtracts" details common to both images. The result is a high-contrast image showing the distribution of the dye.

a mass of tissue called the **mediastinum** (mē-dē-a-STĪ-num). Each pleural cavity surrounds a lung and is lined by a slippery serous membrane that reduces friction as the lung expands and recoils during breathing. The serous membrane lining a pleural cavity is called a *pleura* (PLOOR-ah). The *visceral pleura* covers the outer surfaces of a lung, and the *parietal pleura* covers the mediastinal surface and the inner body wall.

The mediastinum consists of a mass of connective tissue that surrounds, stabilizes, and supports the esophagus, trachea, and thymus, as well as the major blood vessels that originate or end at the heart. The mediastinum also contains the **pericardial cavity**, a small chamber that surrounds the heart. The relationship between the heart and the pericardial cavity resembles that of a fist pushing into a balloon (Figure 1–7b). The wrist corresponds to the *base* (attached portion) of the heart, and the balloon corresponds to the serous membrane that lines the pericardial cavity. The serous membrane associated with the heart is called the *pericardium* (*peri-*, around + *cardium*, heart). The layer covering the heart is the *visceral layer of serous pericardium*, and the opposing surface is the *parietal layer of serous pericardium*. During each beat, the heart changes in size and shape. The pericardial cavity permits these changes, and the slippery pericardial serous membrane lining prevents friction between the heart and nearby structures in the thoracic cavity.

The Abdominopelvic Cavity

The abdominopelvic cavity extends from the diaphragm to the pelvis. It is subdivided into a superior *abdominal cavity* and an inferior *pelvic cavity* (Figure 1–7a). The abdominopelvic cavity contains the **peritoneal** (per-i-tō-NĒ-al) **cavity**, a potential space lined by a serous membrane known as the *peritoneum* (per-i-tō-NĒ-um). The *parietal peritoneum* lines the inner surface of the body wall. A narrow space containing a small amount of fluid separates the parietal peritoneum from the *visceral peritoneum*, which covers the enclosed organs. You are probably already aware of the movements of the organs in this cavity. Most of us have had at least one embarrassing moment when a digestive organ contracted, producing a movement of liquid or gas and a gurgling or rumbling sound. The peritoneum allows the organs of the digestive system to slide across one another without damage to themselves or the walls of the cavity.

The **abdominal cavity** extends from the inferior (toward the feet) surface of the diaphragm to the level of the superior (toward the head) margins of the pelvis. This cavity contains the liver, stomach, spleen, small intestine, and most of the large intestine. (Look back at Figure 1–4c that shows the positions of most of these organs.) The organs are partially or completely enclosed by the peritoneal cavity, much as the heart and lungs are enclosed by the pericardial and pleural cavities, respectively. A few organs, such as the kidneys and pancreas, lie between the peritoneal lining and the muscular wall of the abdominal cavity. Those organs are said to be *retroperitoneal* (*retro*, behind).

The **pelvic cavity** is inferior to the abdominal cavity. The bones of the pelvis form the walls of the pelvic cavity, and a layer of muscle forms its floor. The pelvic cavity contains the urinary bladder, various reproductive organs, and the distal (farthest) portion of the large intestine. In females, the pelvic cavity contains the ovaries, uterine tubes, and uterus. In males, it contains the prostate gland and seminal glands (seminal vesicles). The pelvic cavity also contains the inferior portion of the peritoneal cavity. The peritoneum covers the ovaries and the uterus in females, as well as the superior portion of the urinary bladder in both sexes. Organs such as the urinary bladder and the distal portions of the ureters and large intestine, which extend inferior to the peritoneal cavity, are said to be *infraperitoneal*.

The true body cavities of the trunk in the adult share a common embryological origin. The term "dorsal body cavity" is sometimes used to refer to the internal chamber of the skull (cranial cavity) and the space enclosed by the vertebrae (vertebral cavity). These chambers, which are defined by bony structures, are anatomically and embryonically distinct from true body cavities, and the term "dorsal body cavity" is not encountered in either clinical anatomy or comparative anatomy. For these reasons, we have avoided using that term in our discussion of body cavities.

A partial list of chambers, or spaces, within the body that are not true body cavities would include the cranial cavity, vertebral cavity, oral cavity, digestive cavity, orbits (eye sockets), tympanic cavity of each middle ear, nasal cavities, and paranasal sinuses (air-filled chambers within some cranial bones that are connected to the nasal cavities). These structures will be discussed in later chapters.

The Clinical Note: Diagnostic Imaging Techniques on pp. 16–17 highlights some clinical tests commonly used for viewing the interior of the body.

✓ Checkpoint

17. **Name two essential functions of the body cavities of the trunk.**
18. **Describe the various body cavities of the trunk.**

See the blue Answers tab at the back of the book.

1-7 Homeostasis, the state of internal balance, is continuously regulated

Learning Outcome Explain the concept of homeostasis.

Homeostasis (hō-mē-o-STĀ-sis; from the Greek *homeo*, similar + *stasis*, state of standing) refers to the existence of a stable internal environment. Various physiological processes act to prevent harmful changes in the composition of body fluids and the environment inside our cells. Maintaining homeostasis is absolutely vital to an organism's survival. Failure to maintain homeostasis soon leads to illness or even death. The principle of homeostasis is the central theme of this text and the foundation of all modern physiology.

Mechanisms of Homeostatic Regulation

Homeostatic regulation is the adjustment of physiological systems to preserve homeostasis. Physiological systems have evolved to maintain homeostasis in an environment that is often inconsistent, unpredictable, and potentially dangerous. An understanding of homeostatic regulation is crucial to making accurate predictions about the body's responses to both normal and abnormal conditions.

Homeostatic regulation involves two general mechanisms: autoregulation and extrinsic regulation.

1. **Autoregulation** is a process that occurs when a cell, tissue, organ, or organ system adjusts in response to some environmental change. For example, when the oxygen level decreases in a tissue, the cells release chemicals that widen, or dilate, blood vessels. This dilation increases the blood flow and provides more oxygen to the region.
2. **Extrinsic regulation** is a process that results from the activities of the nervous system or endocrine system. These organ systems detect an environmental change and send an electrical signal (nervous system) or chemical messenger (endocrine system) to control or adjust the activities of another or many other systems simultaneously. For example, when you exercise, your nervous system issues commands that increase your heart rate so that blood will circulate faster. Your nervous system also causes blood flow to be reduced to less active organs, such as the digestive tract. The oxygen in circulating blood is then available to the active muscles, which need it most.

In general, the nervous system directs rapid, short-term, and very specific responses. For example, if you accidentally set your hand on a hot stove, the heat would produce a painful, localized disturbance of homeostasis. Your nervous system would respond by ordering specific muscles to contract and pull your hand away from the stove. These contractions last only as long as the neural activity continues, usually a matter of seconds.

In contrast, the endocrine system releases chemical messengers called *hormones* into the bloodstream. These molecular messengers can affect tissues and organs throughout the body. The responses may not be immediately apparent, but they may persist for days or weeks. Examples of homeostatic regulation dependent on endocrine function include the long-term regulation of blood volume and composition, and the adjustment of organ system function during starvation.

An Overview of the Process of Homeostatic Regulation

Regardless of the system involved, homeostatic regulation always works to keep the internal environment within certain limits, or a range. A homeostatic regulatory mechanism consists of three parts: (1) a **receptor**, a sensor that is sensitive to a particular stimulus or environmental change; (2) a **control center**, which receives and processes the information supplied by the receptor and sends out commands; and (3) an **effector**, a cell or organ that responds to the commands of the control center and whose activity either opposes or enhances the stimulus. You are probably already familiar with similar mechanical regulatory mechanisms, such as the one involving the thermostat in your house or apartment (Figure 1–8a).

The thermostat is the control center. It receives information about room temperature from an internal or remote thermometer (a receptor). The setting on the thermostat establishes the **set point**, or desired value, which in this case is the temperature you select. (In our example, the set point is 22°C, or about 72°F.) The function of the thermostat is to keep room temperature within acceptable limits, usually within a degree or so of the set point. In summer, the thermostat performs this function by controlling an air conditioner (an effector). When the temperature at the thermometer rises above the set point, the thermostat turns on the air conditioner, which then cools the room. Then, when the temperature at the thermometer returns to the set point, the thermostat turns off the air conditioner. The control is not precise, especially if the room is large, and the thermostat is located on just one wall. Over time, the temperature in the center of the room fluctuates in a range above and below the set point (Figure 1–8b).

We can summarize the essential feature of temperature control by a thermostat very simply: A variation outside the set point triggers an automatic response that corrects the situation. In this way, variation in temperature is kept within an acceptable range. Now let's explore how the body uses a similar method of regulation called negative feedback.

✓ Checkpoint

19. **Define *homeostasis*.**
20. **Which general mechanism of homeostatic regulation always involves the nervous or endocrine system?**
21. **Why is homeostatic regulation important to an organism?**

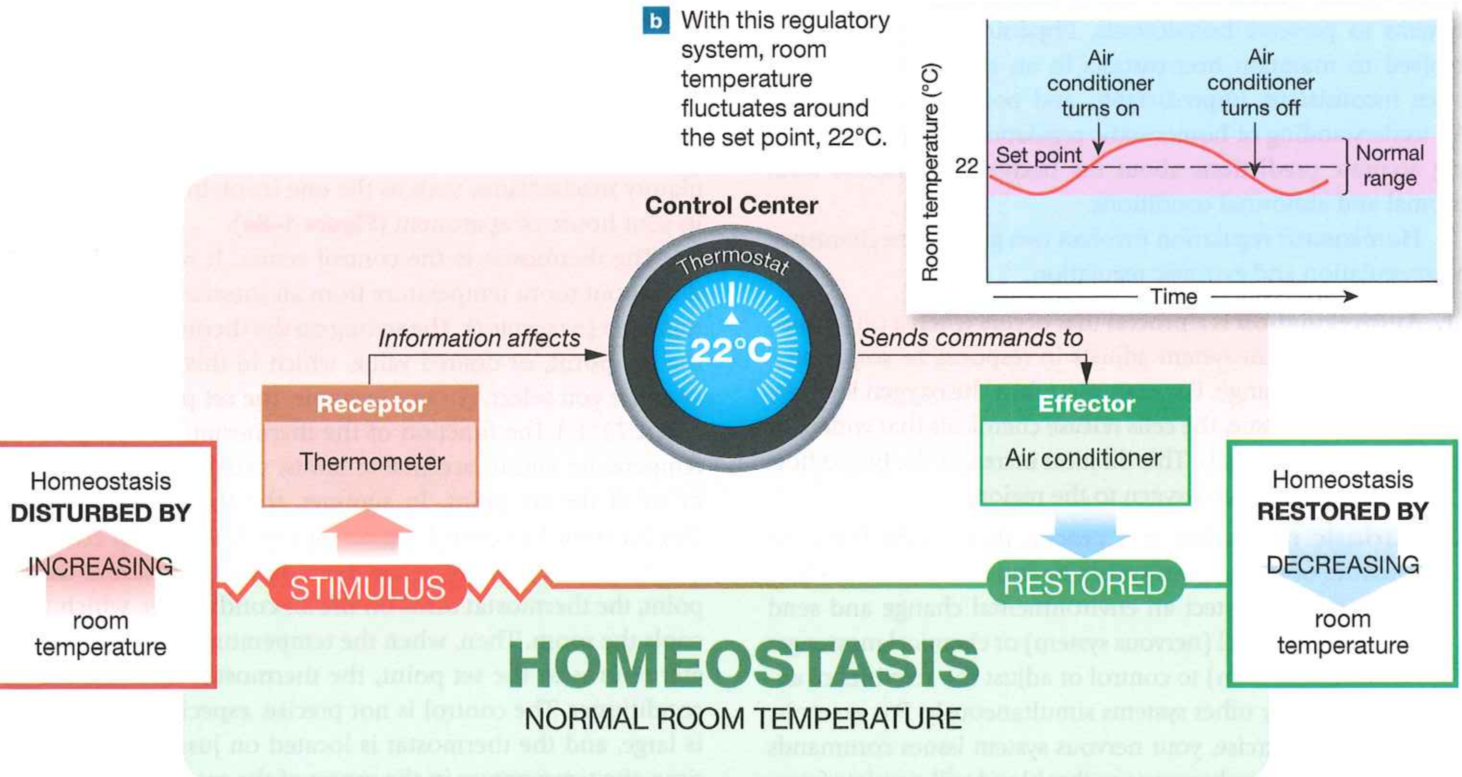
See the blue Answers tab at the back of the book.

1-8 Negative feedback opposes variations from normal, whereas positive feedback enhances them

Learning Outcome Describe how negative feedback and positive feedback are involved in homeostatic regulation.

To keep variation in key body systems within ranges that are compatible with our long-term survival, the body uses a method of homeostatic regulation called *negative feedback*. In this process, an effector activated by the control center opposes,

igure 1–8 The Control of Room Temperature.



In response to input from a receptor (a thermometer), a control center (a thermostat) triggers an effector response (either an air conditioner or a heater) that restores normal temperature. In this case, when room temperature rises above the set point, the thermostat turns on the air conditioner, and the temperature returns to normal.

r *negates,* the original stimulus. In this way, negative feedback ends to minimize change. The body also has another method f homeostatic regulation called *positive feedback,* which instead ends to enhance or *increase* the change that triggered it. However, most homeostatic regulatory mechanisms involve negative feedback. Let's examine the roles of negative and positive eedback in homeostasis before considering the roles of organ ystems in regulating homeostasis.

he Role of Negative Feedback n Homeostasis

n important example of **negative feedback**, a way of counteracting a change, is the control of body temperature, a process alled *thermoregulation*. In thermoregulation, the relationship etween heat loss, which takes place mainly at the body surface, nd heat production, which takes place in all active tissues, is ltered.

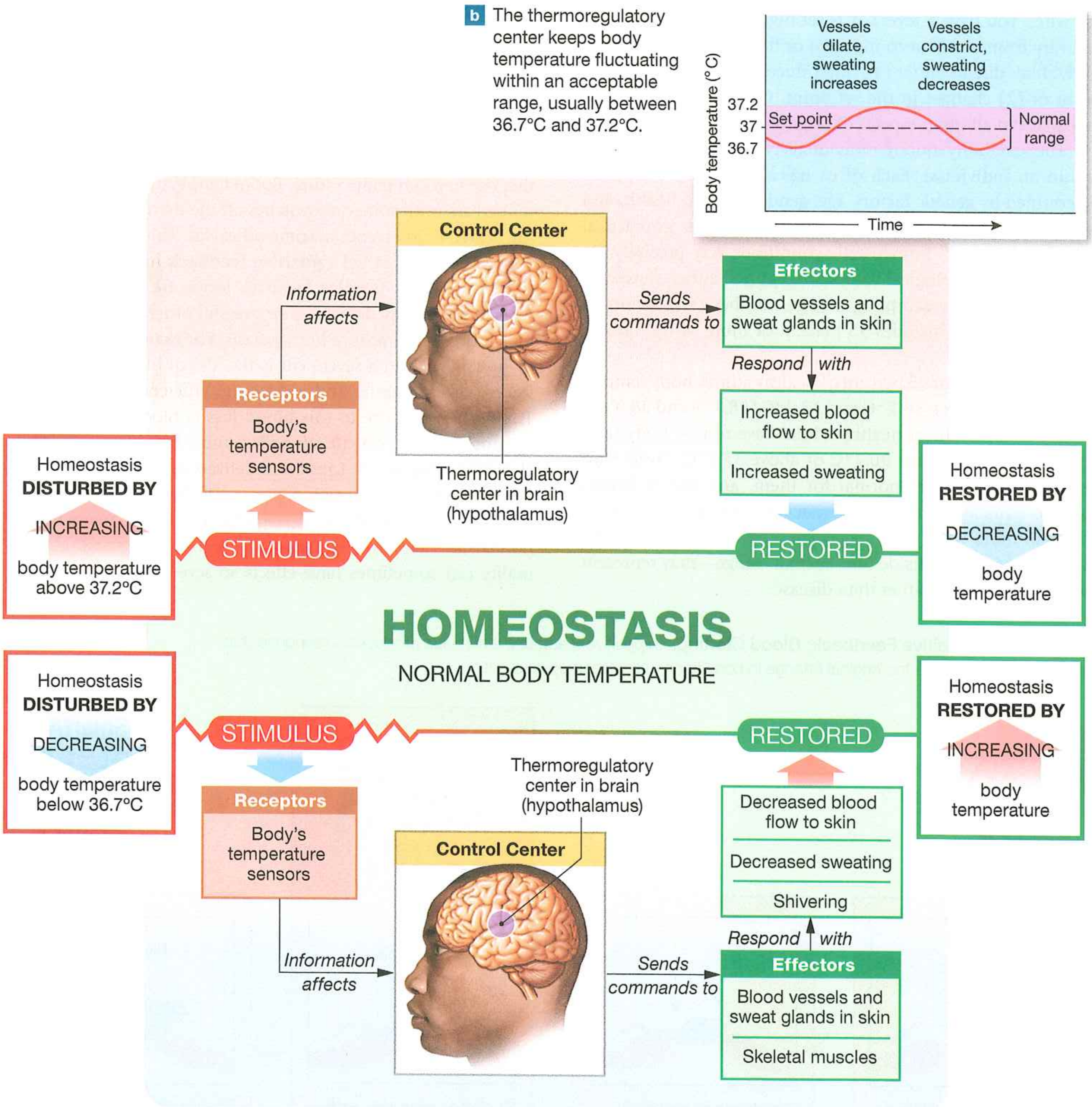
In the homeostatic control of body temperature igure 1–9a), the thermoregulatory control center is in the *ypothalamus,* a region of the brain. This control center receives nformation from two sets of temperature receptors, one in the kin and the other within the hypothalamus. At the normal set point, body temperature (as measured with an oral thermometer) is approximately 37°C (98.6°F).

If body temperature rises above 37.2°C, activity in the control center targets two effectors: (1) muscle tissue lining the walls of blood vessels supplying blood to the skin and (2) sweat glands. The muscle tissue relaxes so the blood vessels dilate (widen), increasing blood flow through vessels near the body surface, and the sweat glands speed up their secretion of sweat. The skin then acts like a radiator by losing heat to the environment, and the evaporation of sweat speeds the process.

As body temperature returns to normal, temperature in the hypothalamus decreases, and the thermoregulatory center becomes less active. Blood flow to the skin and sweat gland activity then decrease to previous levels. Body temperature drops below the set point as the secreted sweat evaporates.

Negative feedback is the primary mechanism of homeostatic regulation, and it provides long-term control over the body's internal conditions and systems. Homeostatic mechanisms using negative feedback normally ignore minor variations. They maintain a normal *range* rather than a fixed value. In our example, body temperature fluctuated around the set-point temperature (Figure 1–9b). The regulatory process itself

Figure 1–9 **Negative Feedback: Control of Body Temperature.** In negative feedback, a stimulus produces a response that opposes or negates the original stimulus.



a Events in the regulation of body temperature, which are comparable to those shown in *Figure 1–8*. A control center in the brain (the hypothalamus) functions as a thermostat with a set point of 37°C. If body temperature exceeds 37.2°C, heat loss is increased through increased blood flow to the skin and increased sweating.

? If a person's body temperature gets too high, the body will respond by decreasing its temperature to restore homeostasis. What are the homeostatic responses to an increase in body temperature?

dynamic. That is, it is constantly changing because the set oint may vary with changing environments or differing activ- y levels. For example, when you are asleep, your thermoregu- atory set point is lower. When you work outside on a hot day or when you have a fever), it is set higher. Body temperature an vary from moment to moment or from day to day for any ndividual, due to either (1) small fluctuations around the set oint or (2) changes in the set point. Comparable variations ake place in all other aspects of physiology.

The variability among individuals is even greater than that vithin an individual. Each of us has homeostatic set points etermined by genetic factors, age, gender, general health, and nvironmental conditions. For this reason, it is impractical o define "normal" homeostatic conditions very precisely. By onvention, physiological values are reported either as average alues obtained by sampling a large number of individuals, r as a range that includes 95 percent or more of the sample opulation.

For example, for 95 percent of healthy adults, body temper- ture ranges between 36.7°C and 37.2°C (98.1°F and 98.9°F). he other 5 percent of healthy adults have resting body tem- eratures that are below 36.7°C or above 37.2°C. These tem- eratures are perfectly normal for them, and the variations ave no clinical significance. Physicians must keep this vari- bility in mind when they review lab reports, because unusual alues—even those outside the "normal" range—may represent ndividual variation rather than disease.

The Role of Positive Feedback in Homeostasis

In **positive feedback**, an initial stimulus produces a response that amplifies or enhances the original change in conditions, rather than opposing it. You seldom encounter positive feedback in your daily life, simply because it tends to produce extreme responses. For example, suppose that the thermostat in Figure 1–8a was accidentally connected to a heater rather than to an air conditioner. Now when room temperature rises above the set point, the thermostat turns on the heater, causing a further rise in room temperature. Room temperature will continue to increase until someone switches off the thermostat, turns off the heater, or intervenes in some other way. This kind of escalating cycle is often called a **positive feedback loop**.

In the body, positive feedback loops are typically found when a potentially dangerous or stressful process must be completed quickly to restore homeostasis. For example, the immediate danger from a severe cut is the loss of blood, which can lower blood pressure and reduce the efficiency of the heart. The body's response to this blood loss is blood clotting, diagrammed in Figure 1–10. We will examine blood clotting more closely in Chapter 19. Labor and delivery are another example of positive feedback in action, as we will discuss in Chapter 29.

The human body is amazingly effective at maintaining homeostasis. Nevertheless, an infection, injury, or genetic abnormality can sometimes have effects so severe that homeostatic

igure 1–10 **Positive Feedback: Blood Clotting.** In positive feedback, a stimulus produces a response that ccelerates or enhances the original change in conditions, rather than opposing it.