SEEING THE BIG PICTURE

1 Organization of the Body, 4
2 The Chemical Basis of Life, 35
3 Anatomy of Cells, 69
4 Physiology of Cells, 91
5 Tissues, 123
The five chapters in Unit 1 “set the stage” for study of human anatomy and physiology. They provide the unifying information required to understand the “connectedness” of human structure and function and to understand how organized anatomical structures of a particular size, shape, form, or placement serve unique and specialized functions. Note that the illustration selected to introduce this unit shows the body not as an assemblage of isolated parts but as an integrated whole.

In Chapter 1 the concept of levels of organization in the body is presented, and the unifying theme of homeostasis is introduced to explain how interaction of structure and function at chemical, organelle, cellular, tissue, organ, and system levels is achieved and maintained by dynamic counterbalancing forces within the body. The material presented in Chapter 2—The Chemical Basis of Life—provides an understanding of the basic chemical interactions that influence the control, integration, and regulation of these counterbalancing forces in every organ system of the body.

Unit 1 concludes with information that builds on the organizational and biochemical information presented in the first two chapters. The structure and function of cells presented in Chapters 3 and 4 explain why physiologists often state that “all body functions are cellular functions.” Grouping similar cells into functioning tissues is accomplished in Chapter 5. Subsequent chapters of the text will focus on the remaining organ systems of the body.
Before reading this introduction, you probably spent a few minutes flipping through this book. Naturally, you are curious about your course in human anatomy and physiology, and you wanted to see what lay ahead. It is more than that. You are curious about the human body—about yourself, really. We all have that desire to learn more about how our bodies are put together and how all the parts work. Unlike many other people, though, you now have the opportunity to gain an understanding of the underlying scientific principles of human structure and function.

To truly understand the nature of the human body requires an ability to appreciate “the parts” and “the whole” at the same time. As you flipped through this book for the first time, you probably looked at many different body parts. Some were microscopic—like muscle cells—and some were very large—like arms and legs. In looking at these parts, however, you gained very little insight as to how they worked together to allow you to sit here, alive and breathing, and read and comprehend these words.

Think about it for a moment. What does it take to be able to read these words and understand them? You might begin by thinking about the eye. How do all of its many intricate parts work together to form an image? The eye is not the only organ you are using right now. What about the bones, joints, and muscles you are using to hold the book, to turn the pages, and to move your eyes as they scan this paragraph? Let’s not forget the nervous system. The brain, spinal cord, and nerves are receiving information from the eyes, evaluating it, and using it to coordinate the muscle movements. The squiggles we call letters are being interpreted near the top of the brain to form complex ideas. In short, you are thinking about what you are reading.

However, we still have not covered everything. How are you getting the energy to operate your eyes, muscles, brain, and nerves? Energetic chemical reactions inside each cell of these organs require oxygen and nutrients captured by the lungs and digestive tract and delivered by the heart and blood vessels. These chemical reactions produce wastes that are handled by the liver, kidneys, and other organs. All of these functions must be coordinated, a feat accomplished by regulation of body organs by hormones, nerves, and other mechanisms.

Learning to name the various body parts, to describe their detailed structure, and to explain the mechanisms underlying their functions is an essential step that leads to the goal of understanding the human body. To actually reach that goal, however, you must be able to draw together isolated facts and concepts. In other words, understanding the nature of individual body parts is meaningless if you do not understand how the parts work together in a living, whole person.

Many textbooks are written like reference books—encyclopedias, for example. They provide detailed descriptions of the structure and function of individual body parts, often in logical groupings, while rarely stopping to step back and look at the whole person. In this book, however, we have incorporated the “whole body” aspect into our discussion of every major topic. In chapter and unit introductions, in appropriate paragraphs within each section, and in specific sections near the end of each chapter, we have stepped back from the topic at hand and refocused attention to the broader view.

We are confident that our “whole body” approach will help you put each new fact or concept you learn into its proper place within a larger framework of understanding. You may also better appreciate why it is important to learn some detailed facts that may at first seem to have no practical value to you. When you have finished learning the many details covered in this course, however, you will have also gained a more complete understanding of the essential nature of the human body.
The Big Picture. What does it take for your body to sit and read these words? The coordination of your muscles, bones, and ligaments is needed to hold the book in your hands, to sit up without falling, and to hold your head and eyes in position. Your brain and nerves process the image of the words received by the eyes. Your digestive and other organs provide the nutrients— and thus the energy— needed by the muscles, bones, brain, and other organs. The urinary and respiratory systems remove the wastes produced by this conversion of food to energy. You can see that it takes a coordinated effort by nearly every small part of your body to simply read this book! This is the big picture—putting all your knowledge of bits and pieces into the larger picture of understanding how the body works as a whole.
CHAPTER 1
ORGANIZATION OF THE BODY

KEY TERMS

You have just begun the study of one of nature’s most wondrous structures—the human body. Anatomy (ah-NAT-o-me) and physiology (fiz-ee-OL-o-jee) are branches of biology that are concerned with the form and functions of the body. Anatomy is the study of body structure, whereas physiology deals with body function—that is, how the body parts work to support life. As you learn about the complex interdependence of structure and function in the human body, you become, in a very real sense, the subject of your own study.

Regardless of your field of study or your future career goals, acquiring and using information about your body structure and functions will enable you to live a more knowledgeable, involved, and healthy life in this science-conscious age. Your study of anatomy and physiology provides a unique and fascinating understanding of self, and this knowledge allows for more active and informed participation in your own personal health care decisions. If you are pursuing a health-related or athletic career, your study of anatomy and physiology takes on added significance. It provides the necessary concepts you will need in your professional courses and clinical experiences.

SCIENCE AND SOCIETY

Before we get to the details, we should emphasize that everything you will read in this book is in the context of a broad field of inquiry called science. Science is a style of inquiry that attempts to understand nature in a rational, logical manner. Using detailed observations and vigorous tests, or
science is a dynamic process of getting closer and closer to the truth about nature, including the nature of the human body. Science is definitely not the set of unchanging facts that many people in our culture often assume.

We should also take this opportunity to point out the social and cultural context of the science presented in this book. Scientists drive the process of science, but our culture drives the kinds of questions we ask about nature and how we attempt to answer them. For example, cutting apart human cadavers (dead bodies) has not always been an acceptable activity in all cultures. Today we are faced with a debate in our culture about the acceptability of using live animals in scientific experiments. Because our culture does not accept most experiments with living humans, we have until now often done our tests with animals that are similar to humans. In fact, most of the theories presented in this book are based on animal experimentation, but cultural influences are pulling scientists in experimental directions they otherwise may not have taken.

Similarly, science affects culture. Recent advances in understanding human genes and technological advances in our ability to use tissues from human embryos to treat devastating diseases have sparked new debates in how our culture defines what it means to be a human being. As you study the concepts presented in this book, keep in mind that they are not set in stone. Science is a rapidly changing set of ideas and processes that not only is influenced by our cultural biases but also affects our cultural awareness of who we are.

Before you move on in this chapter, take a moment to look at Appendix E at the end of this book. There you will find a table listing most of the Nobel Prizes awarded in the last century in the area the Nobel Committee calls “medicine or physiology.” How many women do you see? When they do appear on the list, are they nearer the beginning or the end of the list? Do you think this fact reflects a changing cultural framework for science? Look at the kinds of discoveries for which the prizes were awarded. Do you think these discoveries have affected our culture?

ANATOMY AND PHYSIOLOGY

ANATOMY

Anatomy is often defined as the study of the structure of an organism and the relationships of its parts. The word anatomy is derived from two Greek words (ana, “up,” and temos or tomos, “cutting”). Students of anatomy still learn about the structure of the human body by literally cutting it apart. This process, called dissection, remains a principal technique used to isolate and study the structural components or parts of the human body.

Biology is defined as the scientific study of life. Both anatomy and physiology are subdivisions of this very broad area of inquiry. Just as biology can be subdivided into specific areas for study, so can anatomy and physiology. For example, the term gross anatomy is used to describe the study of body parts visible to the naked eye. Before the discovery
of the microscope, anatomists had to study human structure using only the eye during dissection. These early anatomists could make only a gross, or whole, examination, as you can see in Figure 1-2. With the use of modern microscopes, many anatomists now specialize in microscopic anatomy, including the study of cells, called cytology (sye-TOL-o-jee), and tissues, called histology (his-TOL-o-gee). Other branches of anatomy include the study of human growth and development (developmental anatomy) or the study of diseased body structures (pathological anatomy). In the chapters that follow you will study the body by systems—a process called systemic anatomy. Systems are groups of organs that have a common function, such as the bones in the skeletal system and the muscles in the muscular system.

**PHYSIOLOGY**

Physiology is the science that treats the functions of the living organism and its parts. The term is a combination of two Greek words (physis, “nature,” and logos, “science or study”). Simply stated, it is the study of physiology that helps us understand how the body works. Physiologists attempt to discover and understand the intricate control systems that permit the body to operate and survive, in an often hostile environment. As a scientific discipline, physiology can be subdivided according to (1) the type of organism involved, such as human physiology or plant physiology; (2) the organizational level studied, such as molecular or cellular physiology; or (3) a specific or systemic function being studied, such as neurophysiology, respiratory physiology, or cardiovascular physiology.

In the chapters that follow, both anatomy and physiology are studied by specific organ systems. This unit begins with an overview of the body as a whole. In subsequent chapters the body is dissected and studied, both structurally (anatomy) and functionally (physiology), into “levels of organization” so that its component parts can be more easily understood and then “fit together” into a living and integrated whole. It is knowledge of anatomy and physiology that allows us to understand how nerve impulses travel from one part of the body to another; how muscles contract; how light energy can be transformed into visual images; how we breathe, digest food, reproduce, excrete wastes, and sense changes in our environment; and even how we think and reason.

**CHARACTERISTICS OF LIFE**

Anatomy and physiology are important disciplines in biology—the study of life. But what is life? What is the quality that distinguishes a vital and functional being from a dead body? We know that a living organism is endowed with certain characteristics not associated with inorganic matter. However, there is no short and very specific definition of life because no single criterion adequately describes life. One could say that living organisms are self-organizing or self-maintaining and nonliving structures are not. Another idea, called the cell theory, states that any independent structure made up of one or more microscopic units called cells is a living organism. Instead of trying to find a single difference that separates living and nonliving things, scientists sometimes define life by listing what are often called characteristics of life.

Lists of characteristics of life may differ from one physiologist to the next, depending on the type of organism being studied and the way in which life functions are grouped and defined. Attributes that characterize life in bacteria, plants, or animals may vary. Those that are considered most important in humans are described as follows:

1. **Responsiveness.** Responsiveness or irritability is that characteristic of life that permits an organism to sense, monitor, and respond to changes in its external environment. Withdrawing from a painful stimulus, such as a pinprick, is an example of responsiveness.


**Conductivity.** Conductivity refers to the capacity of living cells and tissues to selectively transmit or propagate a wave of excitation from one point to another within the body. Responsiveness and conductivity are highly developed in nerve and muscle cells in living organisms.

**Growth.** Growth occurs as a result of a normal increase in size or number of cells. In most instances, it produces an increase in size of the individual, or of a particular organ or part, but little change in the shape of the organism as a whole or of the part affected.

**Respiration.** Respiration involves processes that result in the absorption, transport, utilization, or exchange of respiratory gases (oxygen and carbon dioxide) between an organism and its environment. The exchange of gases may occur between the blood and individual body cells (internal respiration) as the cells use nutrients to produce energy or between the blood and air in the lungs (external respiration).

**Digestion.** Digestion is the process by which complex food products are broken down into simpler substances that can be absorbed and used by individual body cells.

**Absorption.** Absorption refers to the movement of digested nutrients through the wall of the digestive tube and into the body fluids for transport to cells for use.

**Secretion.** Secretion is the production and delivery of specialized substances, such as digestive juices and hormones, for diverse body functions.

**Excretion.** Excretion refers to removal of waste products produced during many body functions, including the breakdown and use of nutrients in the cell. Carbon dioxide is a gaseous waste that is excreted during respiration.

**Circulation.** Circulation refers to the movement of body fluids and many other substances, such as nutrients, hormones, and waste products, from one body area to another.

**Reproduction.** Reproduction involves the formation of a new individual and also the formation of new cells (through cell division) in the body to permit growth, wound repair, and replacement of dead or aging cells on a regular basis.

Each characteristic of life is related to the sum total of all the physical and chemical reactions occurring in the body. The term **metabolism** is used to describe these various processes. They include the steps involved in the breakdown of nutrient materials to produce energy and the transformation of one material into another. For example, if we eat and absorb more sugar than needed for the body’s immediate energy requirements, it is converted into an alternate form, such as fat, that can be stored in the body. Metabolic reactions are also required for making complex compounds out of simpler ones, as in tissue growth, wound repair, or manufacture of body secretions.

Each characteristic of life—its functional manifestation in the body, its integration with other body functions and structures, and its mechanism of control—is the subject of study in subsequent chapters of the text.

---

**LEVELS OF ORGANIZATION**

Before you begin the study of the structure and function of the human body and its many parts, it is important to think about how the parts are organized and how they might logically fit together and function effectively. The differing levels of organization that influence body structure and function are illustrated in Figure 1-3.

**CHEMICAL LEVEL—BASIS FOR LIFE**

Note that organization of the body begins at the chemical level (see Figure 1-3). There are more than 100 different chemical building blocks of nature, called **atoms**—tiny spheres of matter so small they are invisible. Every material thing in our universe, including the human body, is composed of atoms. Combinations of atoms form larger chemical groupings, called **molecules**. Molecules, in turn, often combine with other atoms and molecules to form larger and more complex chemicals, called **macromolecules**.

The unique and complex relationships that exist between atoms, molecules, and macromolecules in living material form a gel-like material made of fluids, particles, and membranes called **cytoplasm** (SYE-toe-plazm)—the essential material of human life. Unless proper relationships between chemical elements are maintained, death results. Maintaining the type of chemical organization in cytoplasm required for life requires the expenditure of energy. In Chapter 2, important information related to the chemistry of life is discussed in more detail.

**ORGANELLE LEVEL**

Chemical structures may be organized within larger units called **cells** to form various structures called **organelles** (or-gan-ELZ), the next level of organization (see Figure 1-3). An organelle may be defined as a structure made of molecules organized in such a way that it can perform a specific function. Organelles are the “tiny organs” that allow each cell to live. Organelles cannot survive outside the cell, but without organelles a cell could not survive either.

Dozens of different kinds of organelles have been identified. A few examples include **mitochondria** (my-to-KON-dree-ah), the “power houses” of cells, which provide the energy needed by the cell to carry on day-to-day functioning, growth, and repair; **Golgi** (GOL-je) **apparatus**, which provides a “packaging” service to the cell by storing material for future internal use or for export from the cell; and **endoplasmic reticulum**, the network of transport channels within the cell, which act as “highways” for the movement of chemicals. Chapter 3 contains a complete discussion of organelles and their functions.
The smallest parts of the body are the atoms that make up the chemicals, or molecules, of the body. Molecules, in turn, make up microscopic parts called **organelles** that fit together to form each cell of the body. Groups of similar cells are called **tissues**, which combine with other tissues to form individual organs. Groups of organs that work together are called **systems**. All the systems of the body together make up an individual organism. Knowledge of the different levels of organization will help you understand the basic concepts of human anatomy and physiology.
CELLULAR LEVEL

The characteristics of life ultimately result from a hierarchy of structure and function that begins with the organization of atoms, molecules, and macromolecules. Continued organization resulting in organelles is the next step. However, in the view of the anatomist, the most important function of the chemical and organelle levels of organization is to furnish the basic building blocks and specialized structures required for the next higher level of body structure—*the cellular level*. **Cells** are the smallest and most numerous structural units that possess and exhibit the basic characteristics of living matter. How many cells are there in the body? One estimate places the number of cells in a 150-pound adult human body at 100,000,000,000,000. In case you cannot translate this number—1 with 14 zeroes after it—it is 100 trillion! or 100,000 billion! or 100 million million!

Each cell is surrounded by a membrane and is characterized by a single nucleus surrounded by cytoplasm that includes the numerous organelles required for specialized activity. Although all cells have certain features in common, they specialize or **differentiate** to perform unique functions. Fat cells, for example, are structurally modified to permit the storage of fats, whereas other cells, such as cardiac muscle cells, are specialized to contract (see Figure 1-3). Muscle, bone, nerve, and blood cells are other examples of structurally and functionally specialized cells.

TISSUE LEVEL

The next higher level of organization beyond the cell is the **tissue level** (see Figure 1-3). Tissues represent another step in the progressive organization of living matter. By definition, a **tissue** is a group of a great many similar cells that all developed together from the same part of the embryo and are all specialized to perform a certain function. Tissue cells are surrounded by varying amounts and kinds of nonliving, intercellular substances, or the matrix. Tissues are the “fabric” of the body.

There are four major or principal tissue types: **epithelial, connective, muscle, and nervous**. Considering the complex nature of the human body, this is a surprisingly short list of major tissues. Each of the four major tissues, however, can be subdivided into several specialized subtypes. Together the body tissues are able to meet all of the structural and functional needs of the body.

The tissue used as an example in Figure 1-3 is a specialized type of muscle called **cardiac** muscle. Note how the cells are branching and interconnected. The details of tissue structure and function are covered in Chapter 5.

ORGAN LEVEL

**Organs** are more complex units than tissues. An **organ** is defined as a structure made up of several different kinds of tissues so arranged that, together, they can perform a special function. If tissues are the “fabric” of the body, then an organ is like an item of clothing with a specific function made up of different fabrics. The heart is an example of the **organ level**: muscle and specialized connective tissues give it shape, specialized epithelial tissues line the cavities, or chambers, and nervous tissues permit control of muscular contraction.

Tissues seldom exist in isolation. Instead, joined together, they form organs that represent discrete but functionally complex operational units. Each organ has a unique shape, size, appearance, and placement in the body, and each can be identified by the pattern of tissues that forms it. The lungs, heart, brain, kidneys, liver, and spleen are all examples of organs.

SYSTEM LEVEL

**Systems** are the most complex of the organizational units of the body. The **system** level of organization involves varying numbers and kinds of organs so arranged that, together, they can perform complex functions for the body. Eleven major systems compose the human body: integumentary, skeletal, muscular, nervous, endocrine, circulatory, lymphatic/ immune, respiratory, digestive, urinary, and reproductive. Systems that work together to accomplish the general needs of the body are summarized in Table 1-1.

Take a few minutes to read through Table 1-1. The left column points out that several different systems often work together to accomplish some overall goal. For example, the first three systems listed (integumentary, skeletal, muscular) make up the framework of the body and therefore provide support and movement. Notice also that this table corresponds to the organization of this book. Once we get to the system level of organization, we will study each system one by one; chapter by chapter. To help you navigate through the book, we have organized the chapters into units of several systems each—units that group the systems by common or overlapping functions.

You are probably aware that some systems can be grouped together or split apart if you find that more useful to you. For example, because both the skeletal and muscular systems work together to produce athletic movements, an athletic trainer may study them together as the “skeletomuscular system.” A physical therapist may also include concepts of nervous control of movement and study the “neuroskeletomuscular system.” On the other hand, a neurologist may find it useful to keep in mind a distinction between the sensory nervous system and the motor nervous system. In any case the idea of levels of organization is universal, and once you know how it works, you can adapt it to suit your own changing needs. The plan of 11 major systems is widely used among biologists, so we will use it as the basis of our study, too.

ORGANISM LEVEL

The living human **organism** is certainly more than the sum of its parts. It is a marvelously integrated assemblage of interactive structures that is able to survive and flourish in an often hostile environment. The human body can not only reproduce itself (and its genetic information) and maintain ongoing repair and replacement of worn or damaged parts, but it can also maintain—in a constant and predictable way—an incredible number of variables required to lead healthy, productive lives.

We are able to maintain a “normal” body temperature and fluid balance under widely varying environmental extremes; we maintain constant blood levels of many important chemicals and nutrients; we experience effective protection against
disease, elimination of waste products, and coordinated movement; and we correctly and quickly interpret sound, visual images, and other external stimuli with great regularity. These are a few examples of how the different levels of organization in the human organism permit the expression of the characteristics associated with life.

As you study the structure and function of the human body, it is too easy to think of each part or function in isolation from the body as a whole. Always remember that you are ultimately dealing with information related to the entire human organism—not information limited to an understanding of the structure and function of a single organelle, cell, tissue, organ, or organ system. Do not limit your learning to the memorization of facts. Instead, integrate and conceptualize factual information so that your understanding of human structure and function is related not to a part of the body but to the body as a whole.

**ANATOMICAL POSITION**

Discussions about the body, how it moves, its posture, or the relationship of one area to another, assume that the body as a whole is in a specific position called the anatomical position. In this reference position the body is in an erect, or standing, posture with the arms at the sides and palms turned forward (Figure 1-4). The head and feet are also pointing forward. The anatomical position is a reference position that gives meaning to the directional terms used to describe the body parts and regions.

<table>
<thead>
<tr>
<th>Functional Category</th>
<th>System</th>
<th>Principal Organs</th>
<th>Primary Function(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support and movement (Unit 1)</td>
<td>Integumentary (Chapter 6)</td>
<td>Skin</td>
<td>Protection, temperature regulation, sensation</td>
</tr>
<tr>
<td></td>
<td>Skeletal (Chapters 7-9)</td>
<td>Bones, ligaments</td>
<td>Support, protection, movement, mineral and fat storage, blood production</td>
</tr>
<tr>
<td></td>
<td>Muscular (Chapters 10-11)</td>
<td>Skeletal muscles, tendons</td>
<td>Movement, posture, heat production</td>
</tr>
<tr>
<td>Communication, control, and integration (Unit 2)</td>
<td>Nervous (Chapters 12-15)</td>
<td>Brain, spinal cord, nerves, sensory organs</td>
<td>Control, regulation, and coordination of other systems, sensation, memory</td>
</tr>
<tr>
<td></td>
<td>Endocrine (Chapter 16)</td>
<td>Pituitary gland, adrenals, pancreas, thyroid, parathyroids, and other glands</td>
<td>Control and regulation of other systems</td>
</tr>
<tr>
<td>Transportation and defense (Unit 3)</td>
<td>Cardiovascular (Chapters 17-19)</td>
<td>Heart, arteries, veins, capillaries</td>
<td>Exchange and transport of materials</td>
</tr>
<tr>
<td></td>
<td>Lymphatic (Chapters 20-22)</td>
<td>Lymph nodes, lymphatic vessels, spleen, thymus, tonsils</td>
<td>Immunity, fluid balance</td>
</tr>
<tr>
<td>Respiration, nutrition, and excretion (Unit 4)</td>
<td>Respiratory (Chapters 23-24)</td>
<td>Lungs, bronchial tree, trachea, larynx, nasal cavity</td>
<td>Gas exchange, acid-base balance</td>
</tr>
<tr>
<td></td>
<td>Digestive (Chapters 25-27)</td>
<td>Stomach, small and large intestines, esophagus, liver, mouth, pancreas</td>
<td>Breakdown and absorption of nutrients, elimination of waste</td>
</tr>
<tr>
<td></td>
<td>Urinary (Chapters 28-30)</td>
<td>Kidneys, ureters, bladder, urethra</td>
<td>Excretion of waste, fluid and electrolyte balance, acid-base balance</td>
</tr>
<tr>
<td>Reproduction and development (Unit 5)</td>
<td>Reproductive (Chapters 31-34)</td>
<td>Male: Testes, vas deferens, prostate, seminal vesicles, penis Female: Ovaries, fallopian tubes, uterus, vagina, breasts</td>
<td>Reproduction, continuity of genetic information, nurturing of offspring</td>
</tr>
</tbody>
</table>
Bilateral symmetry is one of the most obvious of the external organizational features in humans. The figure shown in Figure 1-4 is divided by a line into bilaterally symmetrical sides. To say that humans are bilaterally symmetrical simply means that the right and left sides of the body are mirror images of each other, and only one plane can divide the body into left and right sides. One of the most important features of bilateral symmetry is balanced proportions. There is a remarkable correspondence in size and shape when comparing similar anatomical parts or external areas on opposite sides of the body.

The terms ipsilateral and contralateral are often used to identify placement of one body part with respect to another on the same or opposite side of the body. These terms are used most frequently in describing injury to an extremity. Ipsilateral simply means “on the same side,” and contralateral means “on the opposite side.” Injuries to an arm or leg require careful comparison of the injured with the noninjured side. Minimal swelling or deformity on one side of the body is often apparent only to the trained observer who compares a suspected area of injury with its corresponding part on the opposite side of the body. If the right knee were injured, for example, the left knee would be designated as the contralateral knee.

**BODY CAVITIES**

The body, contrary to its external appearance, is not a solid structure. It contains two major cavities that are, in turn, subdivided and contain compact, well-ordered arrangements of internal organs. The two major cavities are called the ventral and dorsal body cavities. The location and outlines of the body cavities are illustrated in Figure 1-5.

The ventral cavity consists of the thoracic or chest cavity and the abdominopelvic cavity. The thoracic cavity consists of a right and a left pleural cavity and a midportion called the mediastinum (me-de-uh-STI-num). Fibrous tissue forms a wall around the mediastinum, completely separating it from the right pleural cavity, in which the right lung lies, and from the left pleural cavity, in which the left lung lies. Thus the only organs in the thoracic cavity that are not located in the mediastinum are the lungs. Organs that are located in the mediastinum are the following: the heart (enclosed in its pericardial cavity), the trachea and right and left bronchi, the esophagus, the thymus, various blood vessels (e.g., thoracic aorta, superior vena cava), the thoracic duct and other lymphatic vessels, various lymph nodes, and nerves (such as the phrenic and vagus nerves). The abdominopelvic cavity consists of an upper portion, the abdominal cavity, and a lower...
portion, the pelvic cavity. The abdominal cavity contains the liver, gallbladder, stomach, pancreas, intestines, spleen, kidneys, and ureters. The bladder, certain reproductive organs (uterus, uterine tubes, and ovaries in the female; prostate gland, seminal vesicles, and part of the vas deferens in the male), and part of the large intestine (namely, the sigmoid colon and rectum) lie in the pelvic cavity (Table 1-2).

The dorsal cavity consists of the cranial and spinal cavities. The cranial cavity lies in the skull and houses the brain. The spinal cavity lies in the spinal column and houses the spinal cord (see Figure 1-5).

The thin filmy membranes that line body cavities or cover the surfaces of organs within body cavities also have special names. The term parietal refers to the actual wall of a body cavity or the lining membrane that covers its surface. Visceral refers not to the wall or lining of a body cavity but to the thin membrane that covers the organs, or viscera, within a cavity.

The membrane lining the inside of the abdominal cavity, for example, is called the parietal peritoneum. The membrane that covers the organs within the abdominal cavity is called the visceral peritoneum. You can see in Figure 1-6 that there is a space or opening between the two membranes in the abdomen. This is called the peritoneal cavity. Body membranes are discussed in greater detail in Chapter 5.

**BODY REGIONS**

Identification of an object begins with overall recognition of its structure and form. Initially, it is in this way that the human form can be distinguished from other creatures or objects. Recognition occurs as soon as you can identify overall shape and basic outline. For more specific identification to occur, details of size, shape, and appearance of individual body areas must be described. Individuals differ in overall appearance because specific body areas such as the face or torso have unique identifying characteristics. Detailed descriptions of the human form require that specific regions be identified and appropriate terms be used to describe them (Figure 1-6 and Table 1-3).

The body as a whole can be subdivided into two major portions or components: axial and appendicular. The axial portion of the body consists of the head, neck, and torso; the appendicular portion consists of the upper and lower extremities and their connections to the axial portion. Each major area is subdivided as shown in Figure 1-6. Note, for example, that the torso is composed of thoracic, abdominal, and pelvic areas, and the upper extremity is divided into arm, forearm, wrist, and hand components. Although most terms used to describe gross body regions are familiar, misuse is common. The term leg is a good example. To an anatomist, “leg” refers to the area of the lower extremity between the knee and ankle and not to the entire lower extremity.

**ABDOMINAL REGIONS**

For convenience in locating abdominal organs, anatomists divide the abdomen like a tic-tac-toe grid into nine imaginary regions. The following is a list of the nine regions (Figure 1-7) identified from right to left and from top to bottom:

1. Right hypochondriac region
2. Epigastric region
3. Left hypochondriac region
4. Right lumbar region
5. Umbilical region
6. Left lumbar region
7. Right iliac (inguinal) region
8. Hypogastric region
9. Left iliac (inguinal) region

The most superficial organs located in each of the nine abdominal regions are shown in Figure 1-7. In the right hypochondriac region the right lobe of the liver and the gallbladder are visible. In the epigastric area, parts of the right and left lobes of the liver and a large portion of the stomach can be seen. Viewed superficially, only a small portion of the stomach and large intestine is visible in the left hypochondriac area. Note that the right lumbar region includes parts

---

**Table 1-2 Organs in Ventral Body Cavities**

<table>
<thead>
<tr>
<th>Areas</th>
<th>Organs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thoracic Cavity</strong></td>
<td></td>
</tr>
<tr>
<td>Right pleural cavity</td>
<td>Right lung (in pleural cavity)</td>
</tr>
<tr>
<td>Mediastinum</td>
<td>Heart (in pericardial cavity)</td>
</tr>
<tr>
<td></td>
<td>Trachea</td>
</tr>
<tr>
<td></td>
<td>Right and left bronchi</td>
</tr>
<tr>
<td></td>
<td>Esophagus</td>
</tr>
<tr>
<td></td>
<td>Thymus gland</td>
</tr>
<tr>
<td></td>
<td>Aortic arch and thoracic aorta</td>
</tr>
<tr>
<td></td>
<td>Vena cava</td>
</tr>
<tr>
<td></td>
<td>Various lymph nodes and nerves</td>
</tr>
<tr>
<td></td>
<td>Thoracic duct</td>
</tr>
<tr>
<td>Left pleural cavity</td>
<td>Left lung (in pleural cavity)</td>
</tr>
<tr>
<td><strong>Abdominopelvic Cavity</strong></td>
<td></td>
</tr>
<tr>
<td>Abdominal cavity</td>
<td>Liver</td>
</tr>
<tr>
<td></td>
<td>Gallbladder</td>
</tr>
<tr>
<td></td>
<td>Stomach</td>
</tr>
<tr>
<td></td>
<td>Pancreas</td>
</tr>
<tr>
<td></td>
<td>Intestines</td>
</tr>
<tr>
<td></td>
<td>Spleen</td>
</tr>
<tr>
<td></td>
<td>Kidneys</td>
</tr>
<tr>
<td></td>
<td>Ureters</td>
</tr>
<tr>
<td>Pelvic cavity</td>
<td>Urinary bladder</td>
</tr>
<tr>
<td></td>
<td>Female reproductive organs</td>
</tr>
<tr>
<td></td>
<td>Uterus</td>
</tr>
<tr>
<td></td>
<td>Uterine tubes</td>
</tr>
<tr>
<td></td>
<td>Ovaries</td>
</tr>
<tr>
<td></td>
<td>Male reproductive organs</td>
</tr>
<tr>
<td></td>
<td>Prostate gland</td>
</tr>
<tr>
<td></td>
<td>Seminal vesicles</td>
</tr>
<tr>
<td></td>
<td>Parts of vas deferens</td>
</tr>
<tr>
<td></td>
<td>Part of large intestine, namely,</td>
</tr>
<tr>
<td></td>
<td>sigmoid colon and rectum</td>
</tr>
</tbody>
</table>

---
of the large and small intestine (see Figure 1-7). The superficial organs seen in the umbilical region include a portion of the transverse colon and loops of the small intestine. Additional loops of the small intestine and a part of the colon can be seen in the left lumbar region. The right iliac region contains the cecum and parts of the small intestine. Only loops of the small intestine, the urinary bladder, and the appendix are seen in the hypogastric region. The left iliac region shows portions of the colon and the small intestine.

**ABDOMINOPELVIC QUADRANTS**

Physicians and other health professionals frequently divide the abdomen into four quadrants to describe the site of abdominopelvic pain or locate some type of internal pathology such as a tumor or abscess (Figure 1-8). A horizontal and vertical line passing through the umbilicus (navel) divides the abdomen into right and left upper quadrants and right and left lower quadrants (see Figure 1-8).

1. Define the term **anatomical position** and explain its importance.
2. Name the two major subdivisions of the body as a whole.
3. Identify the two major body cavities and the subdivisions of each.
4. List the nine abdominal regions and four abdominopelvic quadrants.
### Table 1-3  Descriptive Terms for Body Regions

<table>
<thead>
<tr>
<th>Body Region</th>
<th>Area or Example</th>
<th>Body Region</th>
<th>Area or Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdominal</td>
<td>Anterior torso below</td>
<td>Gluteal</td>
<td>Buttock</td>
</tr>
<tr>
<td>Acromial</td>
<td>Shoulder</td>
<td>Hallux</td>
<td>Great toe</td>
</tr>
<tr>
<td>Antebrachial</td>
<td>Forearm</td>
<td>Inguinal</td>
<td>Groin</td>
</tr>
<tr>
<td>Antecubital</td>
<td>Depressed area just in</td>
<td>Lumbar</td>
<td>Lower back between ribs</td>
</tr>
<tr>
<td>Axillary</td>
<td>Armpit</td>
<td>Mammary</td>
<td>Breast</td>
</tr>
<tr>
<td>Brachial</td>
<td>Upper arm</td>
<td>Manual</td>
<td>Hand</td>
</tr>
<tr>
<td>Calcaneal</td>
<td>Heel of foot</td>
<td>Mental</td>
<td>Chin</td>
</tr>
<tr>
<td>Carpal</td>
<td>Wrist</td>
<td>Navel</td>
<td>Area around navel, or</td>
</tr>
<tr>
<td>Cephalic</td>
<td>Head</td>
<td>Occipital</td>
<td>Back of lower skull</td>
</tr>
<tr>
<td>Cervical</td>
<td>Neck</td>
<td>Olecranal</td>
<td>Back of elbow</td>
</tr>
<tr>
<td>Coxal</td>
<td>Hip</td>
<td>Palmar</td>
<td>Palm of hand</td>
</tr>
<tr>
<td>Cranial</td>
<td>Skull</td>
<td>Patellar</td>
<td>Front of knee</td>
</tr>
<tr>
<td>Crural</td>
<td>Leg</td>
<td>Pedal</td>
<td>Foot</td>
</tr>
<tr>
<td>Cubital</td>
<td>Elbow</td>
<td>Pelvic</td>
<td>Lower portion of torso</td>
</tr>
<tr>
<td>Cutaneous</td>
<td>Skin (or body surface)</td>
<td>Perineal</td>
<td>Area (perineum) between</td>
</tr>
<tr>
<td>Digital</td>
<td>Fingers or toes</td>
<td>Plantar</td>
<td>anus and genitals</td>
</tr>
<tr>
<td>Dorsal</td>
<td>Back or top</td>
<td>Pollex</td>
<td>Thumb</td>
</tr>
<tr>
<td>Facial</td>
<td>Face</td>
<td>Popliteal</td>
<td>Area behind knee</td>
</tr>
<tr>
<td>Buccal</td>
<td>Cheek (inside)</td>
<td>Pubic</td>
<td>Pubis</td>
</tr>
<tr>
<td>Frontal</td>
<td>Forehead</td>
<td>Supracleavicular</td>
<td>Area above clavicle</td>
</tr>
<tr>
<td>Nasal</td>
<td>Nose</td>
<td>Sural</td>
<td>Calf</td>
</tr>
<tr>
<td>Oral</td>
<td>Mouth</td>
<td>Tarsal</td>
<td>Ankle</td>
</tr>
<tr>
<td>Orbital or</td>
<td>Eyes</td>
<td>Temporal</td>
<td>Side of skull</td>
</tr>
<tr>
<td>Otic</td>
<td>Ear</td>
<td>Thoracic</td>
<td>Chest</td>
</tr>
<tr>
<td>Femoral</td>
<td>Thigh</td>
<td>Zygomatic</td>
<td>Cheek</td>
</tr>
</tbody>
</table>

**TERMS USED IN DESCRIBING BODY STRUCTURE**

**DIRECTIONAL TERMS**

To minimize confusion when discussing the relationship between body areas or the location of a particular anatomical structure, specific terms must be used. When the body is in the anatomical position, the following directional terms can be used to describe the location of one body part with respect to another (Figure 1-9).

Superior and inferior. Superior means “toward the head,” and inferior means “toward the feet.” Superior also means “upper” or “above,” and inferior means “lower” or “below.” For example, the lungs are located superior to the diaphragm, whereas the stomach is located inferior to it.

Anterior and posterior. Anterior means “front” or “in front of”; posterior means “back” or “in back of.” In humans—who walk in an upright position—ventral (toward the belly) can be used in place of anterior, and dorsal (toward the back) can be used for posterior. For example, the nose is on the anterior.
Figure 1-7 Nine regions of the abdominopelvic cavity. The nine regions of the abdominopelvic cavity showing the most superficial organs. 1, Right hypochondriac region. 2, Epigastric region. 3, Left hypochondriac region. 4, Right lumbar region. 5, Umbilical region. 6, Left lumbar region. 7, Right iliac region. 8, Hypogastric region. 9, Left iliac region.

Figure 1-8 Division of the abdomen into four quadrants. Diagram shows relationship of internal organs to the four abdominopelvic quadrants: 1, Right upper quadrant (RUQ); 2, left upper quadrant (LUQ); 3, right lower quadrant (RLQ); 4, left lower quadrant (LLQ).

Figure 1-9 Directions and planes of the body.
surface of the body, and the shoulder blades are on its posterior surface.

Medial and lateral. Medial means “toward the midline of the body”; lateral means “toward the side of the body, or away from its midline.” For example, the great toe is at the medial side of the foot, and the little toe is at its lateral side. The heart lies medial to the lungs, and the lungs lie lateral to the heart.

Proximal and distal. Proximal means “toward or nearest the trunk of the body, or nearest the point of origin of one of its parts”; distal means “away from or farthest from the trunk or the point of origin of a body part.” For example, the elbow lies at the proximal end of the lower arm, whereas the hand lies at its distal end.

Superficial and deep. Superficial means “nearer the surface”; deep means “farther away from the body surface.” For example, the skin of the arm is superficial to the muscles below it, and the bone of the upper arm is deep to the muscles that surround and cover it. Refer often to the table of anatomical directions on the inside front cover. It is intended to serve as a useful and ready reference for review.

BODY PLANES AND SECTIONS

The transparent glasslike plates in Figure 1-9 dividing the body into parts represent cuts or sections that can be made along a particular axis, or line of orientation, called a plane. There are three major body planes that lie at right angles to each other. They are called the sagittal (SA-jih-tul), coronal (kuh-RO-nul), and transverse (or horizontal) planes. Literally hundreds of sections can be made in each plane, and each section made is named after the particular plane along which it occurs. For example, the transverse plane in Figure 1-9 is shown dividing the individual into upper and lower parts at about the level of the umbilicus. Many other transverse sections are possible in parallel transverse planes. A transverse section through the knee would amputate the lower extremity at that joint, and a transverse section through the neck would result in decapitation. Box 1-1 shows how these planes are sometimes used in medical imaging.

Read the following definitions and identify each term in Figure 1-9:

Sagittal. A lengthwise plane running from front to back is called a sagittal plane. Such a plane divides the body or any of its parts into right and left sides. If a sagittal section is made in the exact midline, resulting in equal and symmetrical right and left halves, the plane is called a midsagittal plane (see Figure 1-9).

Coronal. A lengthwise plane running from side to side; divides the body or any of its parts into anterior and posterior portions; also called a frontal plane.

Transverse. A crosswise plane; divides the body or any of its parts into upper and lower parts; also called a horizontal plane.

Figure 1-10 shows the organs of the abdominal cavity as they would appear in the transverse, or horizontal, plane or “cut” through the abdomen represented in Figure 1-9. In addition to the actual photograph a simplified line diagram helps in identifying the primary organs. Note that organs near the bottom of the photo or line drawing are in a posterior position. The cut vertebra of the spine, for example, can be identified in its position behind, or posterior, to the stomach. The kidneys are located on either side of the vertebra—they are lateral and the vertebra is medial. To make the reading of anatomical figures a little easier, an anatomical rosette is used throughout this book. On many figures, you will notice a small compass rosette similar to those on geographical maps. Rather than being labeled N, S, E, and W, the anatomical rosette is labeled with abbreviated anatomical directions:

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Anterior</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Distal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Inferior</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L (opposite M)</td>
<td>Lateral</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L (opposite R)</td>
<td>Left</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>Medial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P (opposite A)</td>
<td>Posterior</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P (opposite D)</td>
<td>Proximal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>Right</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>Superior</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For your convenience, the compass rosette, its possible directions, a helpful diagram of the planes and directions of the body, and a summary table are found on the inside front cover of this book. Refer to it frequently until you are familiar enough with anatomy to do without it.

INTERACTION OF STRUCTURE AND FUNCTION

One of the most unifying and important concepts of the study of anatomy and physiology is the principle of complementarity of structure and function. In the chapters that follow, you will note again and again that anatomical structures seem “designed” to perform specific functions. Each structure has a particular size, shape, form, or placement in the body that makes it especially efficient at performing a unique and specialized activity.

The relationships between the levels of structural organization will take on added meaning as you study the various organ systems in the chapters that follow. For example, as you study the respiratory system in Chapter 24, you will learn about a special chemical substance secreted by cells in the lungs that help to keep tiny air sacs in these organs from collapsing during respiration. Hereditary material called DNA (a macromolecule) “directs” the differentiation of specialized cells in the lungs during development so that they can effectively contribute to respiratory function. As a result of DNA activity, special chemicals are produced, cells are modified, and tissues appear that are uniquely suited to this organ system. The cilia (organelles), which cover the exposed surface of cells that form the tissues that line the respiratory passageways, help trap and eliminate inhaled contaminants such as dust. The structures of the respiratory
Box 1-1 DIAGNOSTIC STUDY

Medical Imaging of the Body

Cadavers (preserved human bodies used for scientific study) can be cut into sagittal, frontal, or transverse sections for easy viewing of internal structures but living bodies, of course, cannot. This fact has been troublesome for medical professionals who must determine whether internal organs are injured or diseased. In some cases the only sure way to detect a lesion or variation from normal is extensive exploratory surgery. Fortunately, recent advances in medical imaging allow physicians to visualize internal structures of the body without risking the trauma or other complications associated with extensive surgery. Some of the more widely used techniques are briefly described here.

Radiography

Radiography, or x-ray photography, is the oldest and still most widely used method of noninvasive imaging of internal body structures. In this method, energy in the x band of the radiation spectrum is beamed through the body to photographic film (part A of the figure). The x-ray photograph shows the outlines of bones and other dense structures that partially absorb the x rays. In fluoroscopy, a phosphorescent screen sensitive to x rays is used instead of photographic film. A visible image is formed on the screen as x rays passing through the subject cause the screen to glow. Fluoroscopy allows a medical professional to view the internal structures of the subject’s body as it moves. One way to make soft, hollow structures such as blood vessels or digestive organs more visible is to use radiopaque contrast media. Substances such as barium sulfate that absorb x-rays are injected or swallowed to fill the hollow organ of interest. As the screen in part A of the figure shows, the hollow organ shows up as distinctly as a dense bone.
tubes and of the lungs assist in the efficient and rapid movement of air and also make possible the exchange of critical respiratory gases such as oxygen and carbon dioxide between the air in the lungs and the blood. Working together as the respiratory system, specialized chemicals, organelles, cells, tissues, and organs supply every cell of our body with necessary oxygen and constantly remove carbon dioxide.

Structure determines function, and function influences the actual anatomy of an organism over time. Understanding this fact helps students better understand the mechanisms of disease and the structural abnormalities often associated with pathology. Current research in the study of human biology is now focused in large part on integration, interaction, development, modification, and control of functioning body structures.

By applying the principle of complementarity of structure and function as you study the structural and functional levels of the body’s organization in each organ system, you will be able to integrate otherwise isolated factual information into a cohesive and understandable whole. A memorized set of individual and isolated facts is soon forgotten—the parts of an anatomical structure that can be related to its function are not.

**Box 1-1 DIAGNOSTIC STUDY**

**Medical Imaging of the Body—cont’d**

**Computed Tomography**

A newer variation of traditional x-ray photography is called computed tomography (CT), or computed axial tomography (CAT) scanning. In this method, a device with an x-ray source on one side of the body and an x-ray detector on the other side is rotated around the central axis of the subject’s body (see part B of the figure). Information from the x-ray detectors is interpreted by a computer, which generates a video image of the body as if it were cut into anatomical sections. The term computed tomography literally means “picturing a cut using a computer.” Because CT scanning and other recent advances in diagnostic imaging produce images of the body as if it were actually cut into sections, it has become especially important for students of the health sciences to be familiar with sectional anatomy. Sectional anatomy is the study of the structural relationships visible in anatomical sections.

**Magnetic Resonance Imaging**

*Magnetic resonance imaging (MRI)* is a type of scanning that uses a magnetic field to induce tissues to emit radio frequency (RF) waves. An RF detector coil senses the waves and sends the information to a computer that constructs sectional images similar to those produced in CT scanning (part C of the figure). Different tissues can be distinguished because each emits different radio signals. MRI, also called nuclear magnetic resonance (NMR) imaging, avoids the use of potentially harmful x-radiation and often produces sharper images of soft tissues than other imaging methods.

**Ultrasoundography**

In ultrasoundography, high-frequency (ultrasonic) waves are reflected off internal tissues to produce an image called a sonogram (part D of the figure). Because it does not involve x-radiation, and because it is relatively inexpensive and easy to use, ultrasoundography has been used extensively—especially in studying maternal or fetal structures in pregnant women. However, the image produced is not nearly as clear or sharp as in MRI, CT scanning, or traditional radiography.

Variations of these and other technological advances that have improved the ability to study the structure and functions of the human body are discussed in later chapters.

**BODY TYPE AND DISEASE**

A good example of how structure and function are interrelated is in applying the concept of body types. The term somatotype is used to describe a particular category of body build, or physique. Although the human body comes in many sizes and shapes, every individual can be classified as belonging to one of three basic body types, or somatotypes.

The names used to describe these body types are

*Endomorph:* heavy, rounded physique characterized by large accumulations of fat in the trunk and thighs

*Mesomorph:* muscular physique

*Ectomorph:* thin, fragile physique characterized by little body fat accumulation.

Figure 1-11 shows extreme examples of the three somatypes. By carefully studying the body build of numerous individuals, scientists have found that the basic components that determine the different categories of physique occur in varying degrees in every person—both men and women. Only in very rare instances does an individual show almost total dominance by a single somatotype component.

Until recently the concept of somatotype was considered largely “historical” and of relatively little practical importance. However, new research findings have rekindled interest in this area. We now know, for example, that knowledge of physique can provide health care professionals and educators with vital information useful in such areas as disease screening procedures, programs designed to identify individuals who may be at risk for developing certain diseases, and for predicting performance capability in selected physical education programs.

1. Define complementarity of structure and function.
2. Give an example of how the chemical macromolecule, DNA, can have an influence on body structure.
3. Discuss how structure relates to function at the tissue level of organization in the respiratory system.
Researchers have discovered that individuals (especially endomorphs) who have large waistlines and are "apple-shaped," or fattest in the abdomen, have a greater risk for heart disease, stroke, high blood pressure, and diabetes than individuals with a lower "pear-shaped" distribution pattern of fat in the hips, thighs, and buttocks. Breast cancer in postmenopausal women is also associated with the storage of fat in the abdomen and upper body area (apple shape). In both sexes, endomorphic individuals of the same height and weight but with a lower, or pear-shaped, body fat distribution pattern developed these diseases in larger numbers than mesomorphs and ectomorphs but less frequently than endomorphs with an apple-shaped, or high body fat distribution pattern.

The waist-to-hip ratio is used to assess apple- or pear-shaped body fat distribution patterns and is considered a

Figure 1-10  Transverse section of the abdomen. A, Transverse, or horizontal, plane through the abdomen shows the position of various organs within the cavity. B, Drawing of the photograph helps clarify the photo.
valuable clinical tool to assist health care professionals in evaluating the risk of individuals developing many diseases. To obtain the ratio, simply divide the waist measurement by the hip size. A ratio greater than 1.0 for men and 0.9 for women places the person at high risk for diseases associated with a high body, or apple-shaped, fat distribution pattern.

The graph illustrates the increasing health risks for both men and women who develop an apple shape as the waist-to-hip ratio increases. This is especially true if the individual is not physically fit and leads a sedentary lifestyle.

1. Contrast each term in these pairs: superior/inferior, anterior/posterior, medial/lateral, dorsal/ventral.
2. How is anatomical left different from your left?
3. List and define the three major planes that are used to divide the body into parts.
4. Explain how an anatomical rosette is used in anatomical illustrations.
5. How might a person’s body type influence their health risks?

**HOMEOSTASIS**

More than a century ago a great French physiologist, Claude Bernard (1813–1878), made a remarkable observation. He noted that body cells survived in a healthy condition only when the temperature, pressure, and chemical composition of their fluid environment remained relatively constant. He called the environment of cells the internal environment, or milieu intérieur. Bernard realized that although many elements of the external environment in which we live are in a constant state of change, important elements of the internal environment, such as body temperature, remain remarkably stable. For example, Bernard’s neighbor, who travels from his fireplace in Paris to the snowy slopes of the Alps in January, is exposed to dramatic changes in air temperature within a few hours. Fortunately, in a healthy individual, body temperature will remain at or very near normal regardless of temperature changes that may occur in the external environment. Just as the external environment surrounding the body as a whole is subject to change, so too is the fluid environment surrounding each body cell. The remarkable fluid that bathes each cell contains literally dozens of different substances. Good health, indeed life itself, depends on the correct and constant amount of each substance in the blood and other body fluids. The precise and constant chemical composition of the internal environment must be maintained within very narrow limits (“normal ranges”), or sickness and death will result.

In 1932 a famous American physiologist, Walter B. Cannon, suggested the name homeostasis (ho-me-o-STA-sis) for the relatively constant states maintained by the body. Homeostasis is a key word in modern physiology. It comes from two Greek words (homoios, “the same,” and stasis, “standing”). “Standing or staying the same,” then, is the literal meaning of homeostasis. In his classic publication entitled The Wisdom of the Body, Cannon advanced one of the most unifying and important themes of physiology. He suggested that every regulatory mechanism of the body existed to maintain homeostasis or constancy, of the body’s internal fluid environment. However, as Cannon emphasized,
homeostasis does not mean something set and immobile that stays exactly the same all the time. In his words, homeostasis “means a condition that may vary, but which is relatively constant.” It is the maintenance of relatively constant internal conditions despite changes in either the internal or the external environment that characterizes homeostasis. For example, even if external temperatures vary, homeostasis of body temperature means that it remains relatively constant at about 37° C (98.6° F), although it may vary slightly above or below that point and still be “normal.” The fasting concentration of blood glucose, an important nutrient, can also vary somewhat and still remain within normal limits (Figure 1-12). This normal reading or range of normal is called the set point or set point range. A value between 80 and 100 mg of glucose per milliliter of blood, depending on dietary intake and timing of meals, is typical. Although levels of the important gases, oxygen and carbon dioxide, also vary with respiratory rate, these substances, like body temperature and blood glucose levels, must be maintained within very narrow limits.

Specific regulatory mechanisms are responsible for adjusting body systems to maintain homeostasis. This ability of the body to “self-regulate,” or “return to normal” to maintain homeostasis, is a critically important concept in modern physiology and also serves as a basis for understanding mechanisms of disease. Each cell of the body, each tissue, and each organ system plays an important role in homeostasis. Each of the diverse regulatory systems described in subsequent chapters of the text is explained as a function of homeostasis. You will learn how specific regulatory activities such as temperature control or carbon dioxide elimination are accomplished. In addition, an understanding of the relationship of homeostasis to healthy survival helps explain why such mechanisms are necessary.

Take a moment to study Figure 1-13. This diagram is a classic way of envisioning the idea of the body as “bag of fluid.” The fluid inside the bag is our internal environment and it is this fluid that must be kept at a relatively constant temperature, glucose level, and so on, if the cells that make up the body are to survive. It is like a big, walking fish bowl, and our cells are the fish. All of the little tubes and gizmos you see in Figure 1-13 are the systems that keep the “water in the fishbowl”—your internal fluid environment—stable. For example, the tube representing the digestive tract is a way for food in the external environment to be absorbed into the internal environment. So, just as you feed your goldfish every day, keeping the nutrient level in the fishbowl relatively constant over the years, your digestive tract keeps your body’s nutrient levels relatively constant over the years. All of the other “accessories” in the diagram are like the accessories you may use on your fishbowl. The urinary system is like a filter, keeping waste levels constantly low. The respiratory system is like an aquarium’s air pump, getting oxygen deep in the body to keep oxygen levels high for your cells. Throughout the book, we will be regularly referring back to this diagram and the idea it represents—because this idea represents the foundation for understanding all of physiology. If you know that everything functions to keep your “fishbowl” of a body constant so that your “fish” or cells will stay alive, then you can understand the basic function of every organ of every system!

**HOMEOSTATIC CONTROL MECHANISMS**

Maintaining homeostasis means that the cells of the body are in an environment that meets their needs and permits them to function normally under changing external conditions. Processes for maintaining or restoring homeostasis are known as homeostatic control mechanisms. They involve virtually all of the body’s organs and systems. If circumstances occur that require changes or more active regulation in some aspect of the internal environment, the body must have appropriate control mechanisms available that respond to these changing needs and then restore and maintain a healthy internal environment. For example, exercise increases the need for oxygen and results in accumulation of the waste product carbon dioxide. By increasing our breathing rate above its average of about 17 breaths per minute, we can maintain an adequate blood oxygen level and also increase the elimination of carbon dioxide. When exercise stops, the need for an increased respiratory rate no longer exists and the frequency of breathing returns to normal.

To accomplish this self-regulation, a highly complex and integrated communication control system or network is required. This type of network is called a feedback control loop. Different networks in the body control such diverse functions as blood carbon dioxide levels, temperature, heart rate, sleep cycles, and thirst. Information may be transmitted in these control loops by nervous impulses or by specific chemical messengers called hormones, which are secreted into the blood. Regardless of the body function being regulated or the mechanism of information transfer (nerve impulse or hormone secretion), these feedback control loops have the same basic components and work in the same way.
The human body is like a bag of fluid separated from the external environment. Tubes, such as the digestive tract and respiratory tract, bring the external environment to deeper parts of the bag where substances may be absorbed into the internal fluid environment or excreted into the external environment. All of the ‘accessories’ somehow help maintain a constant environment inside the bag, allowing the cells that live there to survive.
BASIC COMPONENTS OF CONTROL MECHANISMS

There is a minimum of four basic components in every feedback control loop:

1. Sensor mechanism
2. Integrating, or control, center
3. Effector mechanism
4. Feedback

The terms *afferent* and *efferent* are important directional terms frequently used in physiology. They are used to describe movement of a signal from a sensor mechanism to a particular integrating or control center and, in turn, movement of a signal from that center to some type of effector mechanism. *Afferent* means that a signal is traveling toward a particular center or point of reference, and *efferent* means that the signal is moving away from a center or other point of reference. These terms are of particular importance in the study of the nervous and endocrine systems in Unit 3.

The process of regulation and the concept of return to normal require that the body be able to “sense” or identify the variable being controlled. Sensory nerve cells or hormone-producing (endocrine) glands frequently act as homeostatic sensors. To function in this way a specialized sensor must be able to identify the element being controlled. It must also be able to respond to any changes that may occur from the normal set point range. If deviations from the normal set point range occur, the sensor generates an afferent signal (nerve impulse or hormone) to transmit that information to the second component of the feedback loop—the integration or control center (Box 1-2).

When the integration or control center of the feedback loop (often a discrete area of the brain) receives input from a homeostatic sensor, that information is analyzed and integrated with input from other sensors, and then an efferent signal travels from the center to some type of effector mechanism, where a specific action is initiated, if necessary, to maintain homeostasis. First, the level or magnitude of the

---

**Box 1-2 FYI**

**Changing the Set Point**

Like the set point on a furnace, the physiological set points in your body can be changed. Your body’s set point temperature is a good example. First, not everyone’s set point, or “normal,” body temperature is the same. The figure at right shows the difference in body temperatures observed in a group of healthy students. You can see that temperatures varied widely. This explains why some people are comfortable at a temperature that is too cold for others around them—their temperature set point must be lower. However, your set point can also change under varying circumstances. For example, we know a fellow who once turned up the thermostat in his house to get the temperature warm enough to get some unwelcome visitors to leave. Likewise, during a bacterial infection your immune system sends chemicals to signal the brain’s hypothalamus to “turn up the set point temperature.” Your body shivers, and you may ask for a blanket as your body tries to reach this new higher set point. You now have a fever. The bacteria that have invaded your body did so because they liked the temperature of your body. During a fever your body becomes uncomfortably warm for the bacteria, and they slow down their reproductive rate, which slows the infection. At the same time, the warmer temperature helps improve the immune system’s function in dealing with the bacteria. After the infection is over, the hypothalamus returns to its usual set point and your fever goes away.

---

Range of normal body temperatures. In a well-controlled experiment, a group of healthy students shows a wide range of normal rectal temperatures. The average (mean) temperature of the group is 37.1º C (98.8º F).
The variable being measured by the sensor is compared with the normal set point level that must be maintained for homeostasis. If significant deviation from that predetermined level exists, the integration/control center sends its own specialized signal to the third component of the control loop—the effector mechanism.

Effectors are organs, such as muscles or glands, that directly influence controlled physiological variables. For example, it is effector action that increases or decreases variables such as body temperature, heart rate, blood pressure, or blood sugar concentration, to keep them within their normal range. The activity of effectors is ultimately regulated by feedback of information regarding their own effects on a controlled variable.

Many instructors use the example of a furnace controlled by a thermostat to explain how feedback control systems work. This analogy is a good one because it parallels the homeostatic mechanism used to control body temperature. Note that changes in room temperature (the controlled variable) are detected by a thermometer (sensor) attached to the thermostat (integrator) (Figure 1-14, A). The thermostat contains a switch that controls the furnace (effector). When cold weather causes a decrease in room temperature, the change is detected by the thermometer and relayed to the thermostat. The thermostat compares the actual room temperature with the set point temperature. After the integrator determines that the actual temperature is too low, it sends a “correction” signal by switching on the furnace. The furnace produces heat and thus increases room temperature back toward normal. As the room temperature increases above normal, feedback information from the thermometer causes the thermostat to switch off the furnace. Thus by intermittently switching the furnace off and on, a relatively constant room temperature can be maintained.

Figure 1-14 Basic components of homeostatic control mechanisms. A, Heat regulation by a furnace controlled by a thermostat. B, Homeostasis of body temperature. Note that in both examples A and B a stimulus (drop in temperature) activates a sensor mechanism (thermostat or body temperature receptor) that sends input to an integrating, or control, center (on-off switch or hypothalamus), which then sends input to an effector mechanism (furnace or contracting muscle). The resulting heat that is produced maintains the temperature in a ‘normal range.’ Feedback of effector activity to the sensor mechanism completes the control loop.
Negative Feedback Control Systems

The example of temperature regulation by action of a thermostatically regulated furnace is a classic example of negative feedback. Negative feedback control systems are inhibitory. They oppose a change (such as a drop in temperature) by creating a response (production of heat) that is opposite in direction to the initial disturbance (fall in temperature below a normal set point). All negative feedback mechanisms in the body respond in this way regardless of the variable being controlled. They produce an action that is opposite to the change that activated the system. It is important to emphasize that negative feedback control systems stabilize physiological variables. They keep variables from straying too far outside of their normal ranges. Negative feedback systems are responsible for maintaining a constant internal environment.

Positive Feedback Control Systems

Positive feedback is also possible in control systems. However, because positive feedback does not operate to help the body maintain a stable, or homeostatic, condition it is often harmful, even disastrous, to survival. Positive feedback control systems are stimulatory. Instead of opposing a change in the internal environment and causing a return to normal, positive feedback tends to amplify or reinforce the change that is occurring. In the example of the furnace controlled by a thermostat, a positive feedback loop continues to increase the temperature. It does so by stimulating the furnace to produce more and more heat. Each increase in heat production is followed by a positive stimulation to increase the temperature even more. Typically, such responses result in instability and disrupt homeostasis because the variable in question continues to deviate further and further away from its normal range.

Only a few examples of positive feedback operate in the body under normal conditions. In each case, positive feedback accelerates the process in question. The feedback causes an ever-increasing rate of events to occur until something stops the process. In other words, positive feedback loops tend to amplify or accelerate a change—in contrast to negative feedback loops that reverse a change. Although positive feedback is not the usual type of feedback in the body, it is no less important (Box 1-3).

Events that lead to a simple sneeze, the birth of a baby, an immune response to an infection, or the formation of a blood clot are all examples of positive feedback.

Feed-Forward in Control Systems

As you study the complexity of control systems throughout the body, you will no doubt run into cases of feed-forward in control systems. Feed-forward is the concept that information may flow ahead to another process to trigger a change in anticipation of an event that will follow. For example, when you eat a meal, the stomach stretches and this triggers stretch sensors in the stomach wall. At the same time, the stretch stimulus has leaped ahead to the next logical feedback loop (in the intestines), getting the second loop ready ahead of time. Feed-forward causes a feedback loop to anticipate a stimulus (in this case, stretch of the intestinal wall caused by food moving down from the stomach) before it actually happens.

In summary, many homeostatic mechanisms operate on the negative feedback principle. They are activated, or turned on, by changes in the environment that surround
every body cell. Negative feedback systems are inhibitory. They reverse the change that initially activated the homeostatic mechanism. By reversing the initial change, a homeostatic mechanism tends to maintain or restore internal constancy. Occasionally, a positive (stimulatory) feedback mechanism helps to promote survival. Such positive or stimulatory feedback systems may be required to bring specific body functions to swift completion (see Box 1-3). Feed-forward occurs when sensory information “jumps ahead” to a feedback loop to get it started before the stimulus actually changes the controlled physiological variable.

1. Define the term homeostasis.
2. List the three basic components of every feedback control system.
3. Explain the mechanism of action of negative and positive feedback control systems.

A n important generalization about body structure is that every organ, regardless of location or function, undergoes change over the years. In general the body performs its functions least well at both ends of life—in infancy and in old age. Organs develop and grow during the years before maturity, and body functions gradually become more and more efficient and effective. In the healthy young adult all body systems are mature and fully operational. Homeostatic mechanisms tend to function most effectively during this period of life to maintain the constancy of one's internal environment. After maturity, effective repair and replacement of the body's structural components often decrease. The term atrophy is used to describe the wasting effects of advancing age. In addition to structural atrophy, the functioning of many physiological control mechanisms also decreases and becomes less precise with advancing age. The changes in functions that occur during the early years are called developmental processes. Those that occur during the late years are called aging processes. The study of aging processes and other changes that occur in our lives as we get older is called gerontology. Many specific age changes are noted in the chapters that follow.

THE BIG PICTURE
Organization of the Body

Ultimately, your success in the study of anatomy and physiology, your ability to see the Big Picture, will require understanding, synthesis, and integration of structural information and functional concepts. After you have completed your study of the individual organ systems of the body presented in the chapters that follow, you must be able to reassemble the parts and view the body in a holistic, integrated way.

The body is truly more than the sum of the parts, and understanding the connectedness of human structure and function is the real challenge—and the greatest reward—in the study of anatomy and physiology. Your ability to integrate otherwise isolated factual information about bones, muscles, nerves, and blood vessels, for example, will allow you to view anatomical components of the body and their specialized functions in a more cohesive and understandable way. This chapter introduces the principle of homeostasis as the glue that integrates and explains how the normal interaction of structure and function is achieved and maintained and how a breakdown of this integration results in disease. Furthermore, it provides the basis for understanding and integrating the body of knowledge, both factual and conceptual, that anatomy and physiology encompass.

Mastery of any academic discipline or achieving success in any health care–related work environment requires the ability to communicate effectively. The ability to understand and appropriately use the vocabulary of anatomy and physiology allows you to accurately describe the body itself, the orientation of the body in its surrounding environment, and the relationships that exist between its component parts in both health and disease. This chapter provides you with information necessary to be successful in seeing the Big Picture, as you master the details of each organ system, which, although presented separately in subsequent chapters of the text, are in reality part of a marvelously integrated whole.
everyone is interested in pathology—the study of disease. Researchers want to know the scientific basis of abnormal conditions. Health practitioners want to know how to prevent and treat various diseases. Every one of us, when we suffer from the inevitable head cold or something more serious, want to know what is going on and how best to deal with it. Pathology has its own terminology, as in any specialized field. Most of these terms are derived from Latin and Greek word parts. For example, patho—comes from the Greek word for disease (pathos) and is used in many terms, including ‘pathology’ itself.

Disease conditions are usually diagnosed or identified by signs and symptoms. Signs are objective abnormalities that can be seen or measured by someone other than the patient, whereas symptoms are the subjective abnormalities that are felt only by the patient. Although sign and symptom are distinct terms, we often use them interchangeably. A syndrome is a collection of different signs and symptoms that occur together. When signs and symptoms appear suddenly, persist for a short time, then disappear, we say that the disease is acute. On the other hand, diseases that develop slowly and last for a long time (perhaps for life) are labeled chronic diseases. The term subacute refers to diseases with characteristics somewhere between acute and chronic.

The study of all the factors involved in causing a disease is its etiology. The etiology of a skin infection often involves a cut or abrasion and subsequent invasion and growth of a bacterial colony. Diseases with undetermined causes are said to be idiopathic. Communicable diseases are those that can be transmitted from one person to another.

The term etiology refers to the theory of a disease’s cause, but the actual pattern of a disease’s development is called its pathogenesis. The common cold, for example, begins with a latent or “hidden” stage during which the cold virus establishes itself in the patient. No signs of the cold are yet evident. In infectious diseases, the latent stage is also called incubation. The cold may then manifest itself as a mild nasal drip, triggering a few sneezes. It then progresses to its full fury and continues for a few days. After the cold infection has run its course, a period of convalescence, or recovery, occurs. During this stage, body functions return to normal. Some chronic diseases, such as cancer, exhibit a temporary reversal that seems to be a recovery. Such reversal of a chronic disease is called a remission. If a remission is permanent, we say that the person is “cured.”

Epidemiology is the study of the occurrence, distribution, and transmission of diseases in human populations. A disease that is native to a local region is called an endemic disease. If the disease spreads to many individuals at the same time, the situation is called an epidemic. Pandemics are epidemics that affect large geographic regions, perhaps spreading worldwide. Because of the speed and availability of modern air travel, pandemics are more common than they once were. Almost every flu season, we see a new strain of influenza virus quickly spreading from continent to continent.

Risk Factors
Other than direct causes or disease mechanisms, certain predisposing conditions may exist that make the development of a disease more likely to occur. Usually called risk factors, they often do not actually cause a disease but just put one ‘at risk’ for developing it. Risk factors can combine, increasing a person’s chances of developing a specific disease even more. Some of the major types of risk factors are listed below:

1. Genetic factors. There are several types of genetic risk factors. Sometimes an inherited trait puts one at a greater-than-normal risk for developing a specific disease. For example, light-skinned people are more at risk for developing certain forms of skin cancer than dark-skinned people. This occurs because light-skinned people have less pigment in their skin to protect them from cancer-causing ultraviolet radiation (see Chapter 5). Membership in a certain ethnic group, or gene pool, involves the ‘risk’ of inheriting a disease-causing gene that is common in that gene pool. For example, certain Africans and their descendants are at a greater-than-average risk of inheriting sickle-cell anemia—a deadly blood disorder.

2. Age. Biological and behavioral variations during different phases of the human life cycle put us at greater risk for developing certain diseases at certain times in our life. For example, middle ear infections are more common in infants than in adults because of the difference in ear structure at different ages.

3. Lifestyle. The way we live and work can put us at risk for some diseases. People whose work or personal activity puts them in direct sunlight for long periods have a greater chance of developing skin cancer because this puts them in more frequent contact with ultraviolet radiation from the sun. Some researchers believe that the high-fat, low-fiber diet common among people in the ‘developed’ nations increases the risk of developing cancer.

4. Stress. Physical, psychological, or emotional stress can put one at risk of developing problems such as chronic high blood pressure (hypertension), peptic ulcers, and headaches. Conditions caused by psychological factors are sometimes called psychogenic (mind-caused) disorders. Chapter 22 discusses the concept of stress and its effect on health.

5. Environmental factors. Although environmental factors such as climate and pollution can actually cause injury or disease, some environmental situations simply put us at greater risk for getting certain diseases. For example, because some parasites survive only in tropical environments, we are not at risk if we live in a temperate climate.

6. Microorganisms. Different types of pathological organisms, such as viruses and bacteria, are now suspected of being ‘infectious cofactors’ in the development of certain

Continued
Box 1-4 HEALTH MATTERS

Disease Terminology—cont’d

7. Preexisting conditions. A preexisting condition can adversely affect our capacity to defend ourselves against an entirely different condition or disease. Thus the primary (pre-existing) condition can put a person at risk of developing a secondary condition. For example, in individuals with AIDS the primary condition is characterized by a suppressed immune system. As a result, secondary or ‘opportunistic’ infections such as pneumonia often develop.

Some General Considerations

Clearer understanding of the normal function of the body often comes from our study of disease (Box 1-4). Pathophysiology is the organized study of the underlying physiological processes associated with disease. Pathophysiologists attempt to understand the mechanisms of a disease and its course of development, or pathogenesis. Near the end of each chapter of this book we briefly describe some important disease mechanisms that illustrate the normal functions described in that chapter.

Many diseases are best understood as disturbances to homeostasis, the relative constancy of the body’s internal environment. If homeostasis is disturbed, various negative feedback mechanisms usually return the body to normal. When a disturbance goes beyond the normal fluctuation of everyday life, we can say that a disease condition exists. In acute conditions the body recovers its homeostatic balance quickly. In chronic diseases a normal state of balance may never be restored. If the disturbance keeps the body’s internal environment too far from normal for too long, death may result.

Basic Mechanisms of Disease

Disturbances to homeostasis and the body’s responses are the basic mechanisms of disease. Because of their variety, disease mechanisms can be categorized for easier study:

1. Genetic mechanisms. Altered, or mutated, genes can cause abnormal proteins to be made. These abnormal proteins often do not perform their intended function—resulting in the absence of an essential function. On the other hand, such proteins may actually perform an abnormal, disruptive function. Either case poses a potential threat to the constancy of the body’s internal environment. The action of genes is first discussed in Chapter 3, and the mechanisms by which genes are inherited are discussed in Chapter 34.

2. Pathogenic organisms. Many important disorders are caused by pathogenic (disease-causing) organisms or particles that damage the body in some way (Figure 1-15). Any organism that lives in or on another organism to obtain its nutrients is called a parasite. The presence of microscopic or larger parasites may interfere with normal body functions of the host, causing disease. Besides parasites, there are organisms that poison or otherwise damage the human body to cause disease. Some of the major pathogenic organisms and particles include the following:
   - Prions (proteinaceous infectious particles) are proteins that convert normal proteins of the nervous system into abnormal proteins, causing loss of nervous system function. The abnormal form of the protein may also be inherited. A newly discovered type of pathogen, not much is known about how the prion works to cause such diseases as bovine spongiform encephalopathy (BSE; “mad cow disease”) or Creutzfeldt-Jakob disease (CJD).
   - Viruses are intracellular parasites that consist of a DNA or RNA core surrounded by a protein coat and, sometimes, a lipoprotein envelope. They are particles that invade human cells and cause them to produce viral components.
   - Bacteria are tiny, primitive cells that lack nuclei. They cause infection by parasitizing tissues or otherwise disrupting normal function (Box 1-5).
   - Fungi are simple organisms similar to plants but lack the chlorophyll pigments that allow plants to make their own food. Because they cannot make their own food, fungi must parasitize other tissues, including those of the human body.
   - Protozoa are protozoan parasites of a DNA or RNA core surrounded by a protein coat and, sometimes, a lipoprotein envelope. They are particles that invade human cells and cause them to produce viral components.
   - Pathogenic animals are large, multicellular organisms such as insects and worms. Such animals can parasitize
Figure 1-15  A, Prion (cause of Creutzfeldt-Jakob disease).  B, Viruses (the human immunodeficiency virus [HIV] that causes AIDS).  C, Bacteria (Streptococcus bacteria that cause strep throat and other infections).  D, Fungi (yeast cells that commonly infect the urinary and reproductive tracts).  E, Fungi (the mold that causes aspergillosis).  F, Protozoans (the flagellated cells that cause traveler’s diarrhea).  G, Pathogenic animals (the parasitic worms that cause snail fever).
Recent world events have shown us that the intentional transmission of disease can be used as a weapon of terror. Anthrax, a bacterial infection caused by *Bacillus anthracis*, is an example of a pathogen that has been intentionally distributed to otherwise healthy victims in acts of bioterrorism. This particular bacterium ordinarily affects plant-eating animals such as sheep, cattle, and goats, often killing them.

The anthrax bacterium can assume the form of a spore that is resistant to heat, drying, and chemicals but later becomes active to cause infection. Rarely, humans inhale some anthrax spores or get the spores in an open cut when handling infected animals or their hides. The inhaled form may be fatal if not treated quickly with antibiotics. The cutaneous (skin) form is less serious, characterized by a reddish-brown patch on the skin that ulcerates and forms a dark, nearly black scab (see the figure) followed by muscle pain, internal hemorrhage (bleeding), headache, fever, nausea, and vomiting. Anthrax causes disease by releasing a toxin that latches onto receptors on the cells of the host, punches a hole in the cell's membrane, and inserts a portion of the toxin called “lethal factor” that destroys proteins in the cell and kills it.

If the infection is discovered before the anthrax bacteria have time to make large amounts of toxin, antibiotics such as doxycycline and ciprofloxacin can cure anthrax. Scientists are also working to perfect drugs that imitate the cell's receptors and thus 'gum up' the toxin with fake receptors before it can attack cells. Vaccines are available, but they must be given long before possible exposure to the spores.

Anthrax spores have been refined for military purposes, even though this is now outlawed by various treaties, and have been used by terrorists to cause panic among civilian populations. Other bacteria such as *Yersinia pestis* (plague), viruses such as smallpox, and a variety of genetically engineered forms of known pathogens may also be added to the arsenal of the terrorist.
Mr. Sam Rider, age 46 years, came to the clinic complaining of pain in his right lower leg, below his knee, on the inside of his leg. He says he “fell about an hour ago while stepping off a curb” and that he is “afraid he broke his leg.” He is unable to place any pressure on this leg without the pain becoming worse. Past medical history is negative for previous injury. Mr. Rider has a history of high blood pressure (hypertension) and has taken medication for this until about 5 months ago, when he stopped taking his medication because he felt “well.” Mr. Rider works as an auto mechanic, has no regular exercise pattern, and follows no specific diet. He smokes half pack of cigarettes per day and drinks three cups of coffee a day. Family history is significant in that his father died of a heart attack at the age of 64 years and his mother is alive at age 72 years, with type 2 diabetes. Physical examination reflects an obese gentleman measuring 5 foot 9 inches in height with a weight of 235 pounds. Current blood pressure is elevated at 180/90, pulse rate is normal at 80, and respirations are normal at 20.

1. Which of the following correctly describes the location of Mr. Rider’s injury?
   A. Right medial leg pain, distal to patella
   B. Right lateral leg pain, proximal to patella
   C. Right anterior leg pain, distal to patella
   D. Right inferior, lateral leg pain proximal to patella

2. Based on the description provided for Mr. Rider, you would expect him to have what type of body build or physique?
   A. Endomorph
   B. Mesomorph
   C. Ectomorph
   D. Hypothalamic

3. Which of the following diagnostic tests would provide the BEST information to rule out the possibility of fracture?
   A. MRI
   B. CAT scan
   C. Ultrasound
   D. X-ray

4. You have assessed Mr. Rider’s risk factors for cardiovascular disease and have decided to develop a teaching plan to help him lower or alter these factors. Which of the following would be MOST important to include in this teaching plan?
   A. Patient’s occupation, caffeine intake, lack of exercise program, sex of patient
   B. Family history of heart disease, patient’s age, obesity
   C. Cigarette smoking, failure to control hypertension, failure to follow specific diet and exercise plan
   D. Patient’s sex, age, occupation, cigarette smoking, and uncontrolled high blood pressure

---

**Science and Society**

A. Science involves logical inquiry based on experimentation (Figure 1-1)
   1. Hypothesis—idea or principle to be tested in experiments
   2. Experiment—series of tests of a hypothesis; a controlled experiment eliminates biases or outside influences
   3. Theory—a hypothesis that has been proven by experiments to have a high degree of confidence
   4. Law—a theory that has an unusually high level of confidence
   5. The process of science is active and changing as new experiments add new knowledge

B. Science is affected by culture and culture is affected by society

**Anatomy and Physiology**

A. Anatomy and physiology are branches of biology concerned with the form and functions of the body

B. Anatomy—science of the structure of an organism and the relationship of its parts
   1. Gross anatomy—study of the body and its parts using only the naked eye (Figure 1-2)
   2. Microscopic anatomy—study of body parts using a microscope
      a. Cytology—study of cells
      b. Histology—study of tissues
   3. Developmental anatomy—study of human growth and development
   4. Pathological anatomy—study of diseased body structures
   5. Systemic anatomy—study of the body by systems

C. Physiology—science of the functions of organisms; subdivisions named according to:
   1. Organism involved—human or plant physiology
   2. Organizational level—molecular or cellular physiology
   3. Systemic function—respiratory, neuro-, or cardiovascular physiology
CHARACTERISTICS OF LIFE
A. A single criterion is often not adequate to describe life, for example:
   1. Living organisms are self-organized
   2. Cell theory—if it is made of one or more cells, it is alive
B. Characteristics of life considered most important in humans:
   1. Responsiveness
   2. Conductivity
   3. Growth
   4. Respiration
   5. Digestion
   6. Absorption
   7. Secretion
   8. Excretion
   9. Circulation
   10. Reproduction
C. Metabolism—sum total of all physical and chemical reactions occurring in the living body

LEVELS OF ORGANIZATION (Figure 1-3)
A. Chemical level—basis for life
   1. Organization of chemical structures separates living material from nonliving material
   2. Organization of atoms, molecules, and macromolecules results in living matter—a gel called cytoplasm
B. Organelle level
   1. Chemical structures organized to form organelles that perform individual functions
   2. It is the functions of the organelles that allow the cell to live
   3. Dozens of organelles have been identified, including:
      a. Mitochondria
      b. Golgi apparatus
      c. Endoplasmic reticulum
C. Cellular level
   1. Cells—smallest and most numerous units that possess and exhibit characteristics of life
   2. Cell—nucleus surrounded by cytoplasm within a limiting membrane
   3. Cells differentiate to perform unique functions
D. Tissue level
   1. Tissue—an organization of similar cells specialized to perform a certain function
   2. Tissue cells surrounded by nonliving matrix
   3. Four major tissue types
      a. Epithelial tissue
      b. Connective tissue
      c. Muscle tissue
      d. Nervous tissue
E. Organ level
   1. Organ—organization of several different kinds of tissues to perform a special function
   2. Organs represent discrete and functionally complex operational units
   3. Each organ has a unique size, shape, appearance, and placement in the body
F. System level
   1. Systems—most complex organizational units of the body
   2. System level involves varying numbers and kinds of organs arranged to perform complex functions (Table 1-1):
      a. Support and movement
      b. Communication, control, and integration
      c. Transportation and defense
      d. Respiration, nutrition, and excretion
      e. Reproduction and development
G. Organism level
   1. The living human organism is greater than the sum of its parts
   2. All of the components interact to allow the human to survive and flourish

ANATOMICAL POSITION (Figure 1-4)
A. Reference position
B. Body erect with arms at sides and palms forward
C. Head and feet pointing forward
D. Bilateral symmetry is a term meaning that right and left sides of body are mirror images
   1. Bilateral symmetry confers balanced proportions
   2. Remarkable correspondence of size and shape between body parts on opposite sides of the body
   3. Ipsilateral structures are on the same side of the body in anatomical position
   4. Contralateral structures are on opposite sides of the body in anatomical position

BODY CAVITIES (Figure 1-5; Table 1-2)
A. Ventral body cavity
   1. Thoracic cavity
      a. Right and left pleural cavities
      b. Mediastinum
   2. Abdominopelvic cavity
      a. Abdominal cavity
      b. Pelvic cavity
B. Dorsal body cavity
   1. Cranial cavity
   2. Spinal cavity

BODY REGIONS (Figure 1-6; Table 1-3)
A. Axial subdivision
   1. Head
   2. Neck
   3. Torso, or trunk, and its subdivisions
B. Appendicular subdivision
   1. Upper extremity and subdivisions
   2. Lower extremity and subdivisions
C. Abdominal regions (Figure 1-7)
   1. Right hypochondriac region
   2. Epigastric region
   3. Left hypochondriac region
4. Right lumbar region
5. Umbilical region
6. Left lumbar region
7. Right iliac (inguinal) region
8. Hypogastric region
9. Left iliac (inguinal) region
D. Abdominopelvic quadrants (Figure 1-8)
   1. Right upper quadrant
   2. Left upper quadrant
   3. Right lower quadrant
   4. Left lower quadrant

TERMS USED IN DESCRIBING BODY STRUCTURE
A. Directional terms (Figure 1-9)
   1. Superior
   2. Inferior
   3. Anterior (ventral)
   4. Posterior (dorsal)
   5. Medial
   6. Lateral
   7. Proximal
   8. Distal
   9. Superficial
   10. Deep

BODY PLANES AND SECTIONS
(Figures 1-9 and 1-10)
A. Planes are lines of orientation along which cuts or sections can be made to divide the body, or a body part, into smaller pieces
B. There are three major planes, which lie at right angles to each other:
   1. Sagittal plane front to back so that sections through this plane divide body (or body part) into right and left sides
      a. If section divides body (or part) into symmetrical right and left halves, the plane is called midsagittal or median sagittal
   2. Frontal (coronal) plane runs lengthwise (side to side) and divides body (or part) into anterior and posterior portions
   3. Transverse (horizontal) plane is a “crosswise” plane—it divides body (or part) into upper and lower parts

INTERACTION OF STRUCTURE AND FUNCTION
A. Complementarity of structure and function is an important and unifying concept in the study of anatomy and physiology
B. Anatomical structures often seem “designed” to perform specific functions because of their unique size, shape, form, or body location
C. Understanding the interaction of structure and function assists in integration of otherwise isolated factual information

BODY TYPE AND DISEASE (Figure 1-11)
A. Somatotype—category of body build or physique
B. Endomorph—heavy, rounded physique with accumulation of fat
   a. “Apple-shaped” endomorph has more accumulation of fat in the waist than hip
      (1) Waist-to-hip ratio higher than >0.9 for women and >1.0 for men
      (2) Higher risk for health problems than “pear shape”
   b. “Pear-shaped” endomorph has more accumulation of fat in hips than in waist
C. Mesomorph—muscular physique
D. Ectomorph—thin, often fragile physique with little fat

HOMEOSTASIS (Figure 1-14)
A. Term homeostasis coined by American physiologist, Walter B. Cannon
B. Homeostasis is the term used to describe the relatively constant states maintained by the body—internal environment around body cells remains constant
C. Body adjusts important variables from a normal “set point” in an acceptable or normal range
D. Examples of homeostasis
   1. Temperature regulation
   2. Regulation of blood carbon dioxide level
   3. Regulation of blood glucose level

HOMEOSTATIC CONTROL MECHANISMS
A. Devices for maintaining or restoring homeostasis by self-regulation through feedback control loops
B. Basic components of control mechanisms
   1. Sensor mechanism—specific sensors detect and react to any changes from normal
   2. Integrating, or control, center—information is analyzed and integrated, and then, if needed, a specific action is initiated
   3. Effector mechanism—effectors directly influence controlled physiological variables
   4. Feedback—process of information about a variable constantly flowing back from the sensor to the integrator
C. Negative feedback control systems
   1. Are inhibitory
   2. Stabilize physiological variables
   3. Produce an action that is opposite to the change that activated the system
   4. Are responsible for maintaining homeostasis
   5. Are much more common than positive feedback control systems
D. Positive feedback control systems
   1. Are stimulatory
   2. Amplify or reinforce the change that is occurring
   3. Tend to produce destabilizing effects and disrupt homeostasis
   4. Bring specific body functions to swift completion
E. Feed-forward occurs when information flows ahead to another process or feedback loop to trigger a change in anticipation of an event that will follow.

CYCLE OF LIFE: LIFE SPAN CONSIDERATIONS
A. Structure and function of body undergo changes over the early years (developmental processes) and late years (aging processes)
B. Infancy and old age are periods of time when the body functions least well
C. Young adulthood is period of greatest homeostatic efficiency
D. Atrophy—term to describe the wasting effects of advancing age

REVIEW QUESTIONS
1. Define the terms anatomy and physiology.
2. List and briefly describe the levels of organization that relate the structure of an organism to its function. Give examples characteristic of each level.
3. Give examples of each system level of organization in the body and briefly discuss the function of each.
4. What is meant by the term anatomical position? How do the specific anatomical terms of position or direction relate to this body orientation?
5. What is bilateral symmetry? What terms are used to identify placement of one body part with respect to another on the same or opposite sides of the body?
6. What does the term somatotype mean? Name the three major somatotype categories and briefly describe the general characteristics of each.
7. Define briefly each of the following terms: anterior, distal, sagittal plane, medial, dorsal, coronal plane, organ, parietal peritoneum, superior, tissue.
8. Locate the mediastinum.
9. What does the term homeostasis mean? Illustrate some generalizations about body function using homeostatic mechanisms as examples.
10. Define homeostatic control mechanisms and feedback control loops.
11. Identify the three basic components of a control loop.
12. Discuss in general terms the principle of complementarity of structure and function.
13. Briefly describe medical imaging techniques that allow physicians to examine internal structures in a noninvasive manner.
14. List the major types of risk factors that may increase a person's chances of developing a specific disease.

CRITICAL THINKING QUESTIONS
1. Each characteristic of life is related to body metabolism. Explain how digestion, circulation, and growth are metabolically related.
2. What diseases may result with a patient with an endomorph somatotype and a waist-to-hip ratio of 1:2?
3. An x-ray technician has been asked to take x-rays of the entire large intestine (colon), including the appendix. Which of the nine abdominopelvic regions must be included in the x-ray?
4. Body cavities can be subdivided into smaller and smaller sections. Identify, from largest to smallest, the cavities in which the urinary bladder can be placed.
5. When driving in traffic, it is important to stay in your own lane. If you see that you are drifting out of your lane, your brain tells your arms and hands to move in such a way that you get back in your lane. Identify the three components of a control loop in this example. Explain why this would be a negative feedback loop.