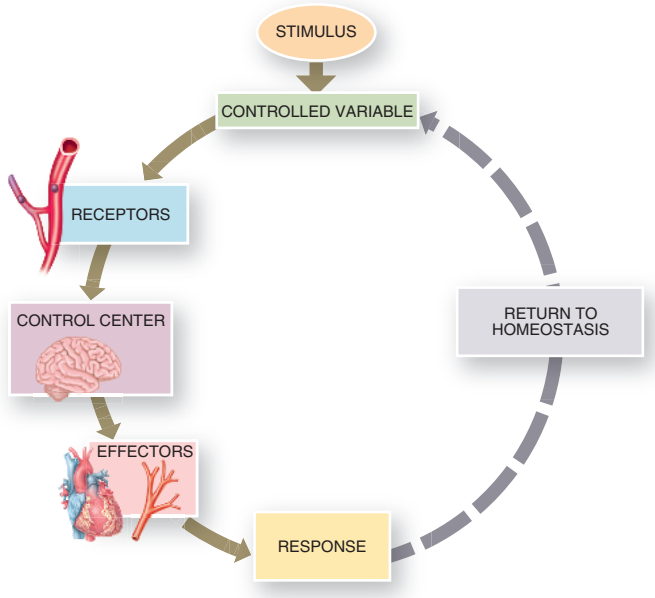
CHAPTER 1



An Introduction to Physiology

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The Human Body and Homeostasis

- Humans have many ways to maintain homeostasis, the state of relative stability of the body's internal environment. Disruptions to homeostasis often set in motion corrective cycles, called feedback systems, that help restore the conditions needed for health and life.

LOOKING BACK TO MOVE AHEAD...

- One of the fundamental principles of biology is the cell theory, which states that (1) the cell is basic unit of life; (2) all organisms are composed of one or more cells; and (3) cells arise from pre-existing cells.
- Organisms are classified into three domains: Bacteria, Archaea, and Eukarya; humans belong to domain Eukarya, kingdom Animalia, phylum Chordata, subphylum Vertebrata, and class Mammalia.
- All organisms have a binomial (a two-part Latin scientific name) that consists of a genus and species; the binomial for humans is *Homo sapiens*, which means "wise man" (*homo-* = *man; sapiens* = wise).
- Compared to other organisms, humans have several distinguishing features: erect posture; bipedal locomotion (ability to walk on two legs); and a large, well-developed brain that allows for analytical skills and complex thought.

Introduction

Your fascinating journey through the human body begins with an overview of the meaning of physiology, followed by a discussion of the organization of the human body and the properties that it shares with all living things. Next, you will discover how the body regulates its own internal environment through an unceasing process known as homeostasis. You will then explore physiology as a science—its historical background and the general methods of acquiring and organizing physiological information. The chapter concludes with a discussion of the key themes of physiology.

1.1 Physiology Defined

Objective

- Define physiology and identify several of its subdisciplines.

Physiology (fiz′-ē-OL-ō-jē) is the study of the functions of an organism and its constituent parts. This text focuses on *human physiology*—how the parts of the human body work. Human physiology considers topics such as the molecular mechanism responsible for muscle contraction; communication between cells using chemical messengers; the parts of the brain involved in language comprehension and expression; and the maintenance of blood pressure by the coordinated efforts of the heart, kidneys, brain, and glands. Because physiology has a broad scope, it is divided into many subdisciplines, several of which are described in **Table 1.1**.

Whereas physiology deals with body functions, *anatomy* is the study of body structure. However, the two cannot truly be separated: The function of a body part is a reflection of its structure. For example, the walls of the air sacs in the lungs are very thin, permitting rapid movement of inhaled oxygen into the blood. By contrast, the lining of the urinary bladder is much thicker to prevent the escape of urine into the pelvic cavity, yet its construction allows for considerable stretching as the urinary bladder fills with urine. Because structure and function are so closely related, as the function of a body part is discussed in the text, relevant information about its structure is provided to help clarify your understanding of the topic.

TABLE 1.1 Selected Subdisciplines of Physiology

Subdiscipline	Study of . . .
Molecular physiology	Functions of individual molecules, such as proteins.
Cell physiology	Functions of cells.
Neurophysiology	Functions of the nervous system.
Endocrinology	Hormones (chemical regulators in the blood) and how they control body functions.
Cardiovascular physiology	Functions of the heart, blood vessels, and blood.
Immunology	How the body defends itself against disease-causing agents.
Respiratory physiology	Functions of the air passageways and lungs.
Renal physiology	Functions of the kidneys.
Gastrointestinal physiology	Functions of the stomach and intestines.
Integrative physiology	How different parts of the body work together to accomplish a particular function.
Exercise physiology	Changes in cell and organ functions as a result of muscular activity.
Pathophysiology	Functional changes associated with disease and aging.

Checkpoint

1. Which subdiscipline of physiology would most likely explore how the kidneys and lungs work together to maintain the acid–base balance of your body fluids? (*Hint:* Refer to **Table 1.1**).

1.2 Levels of Organization in the Body

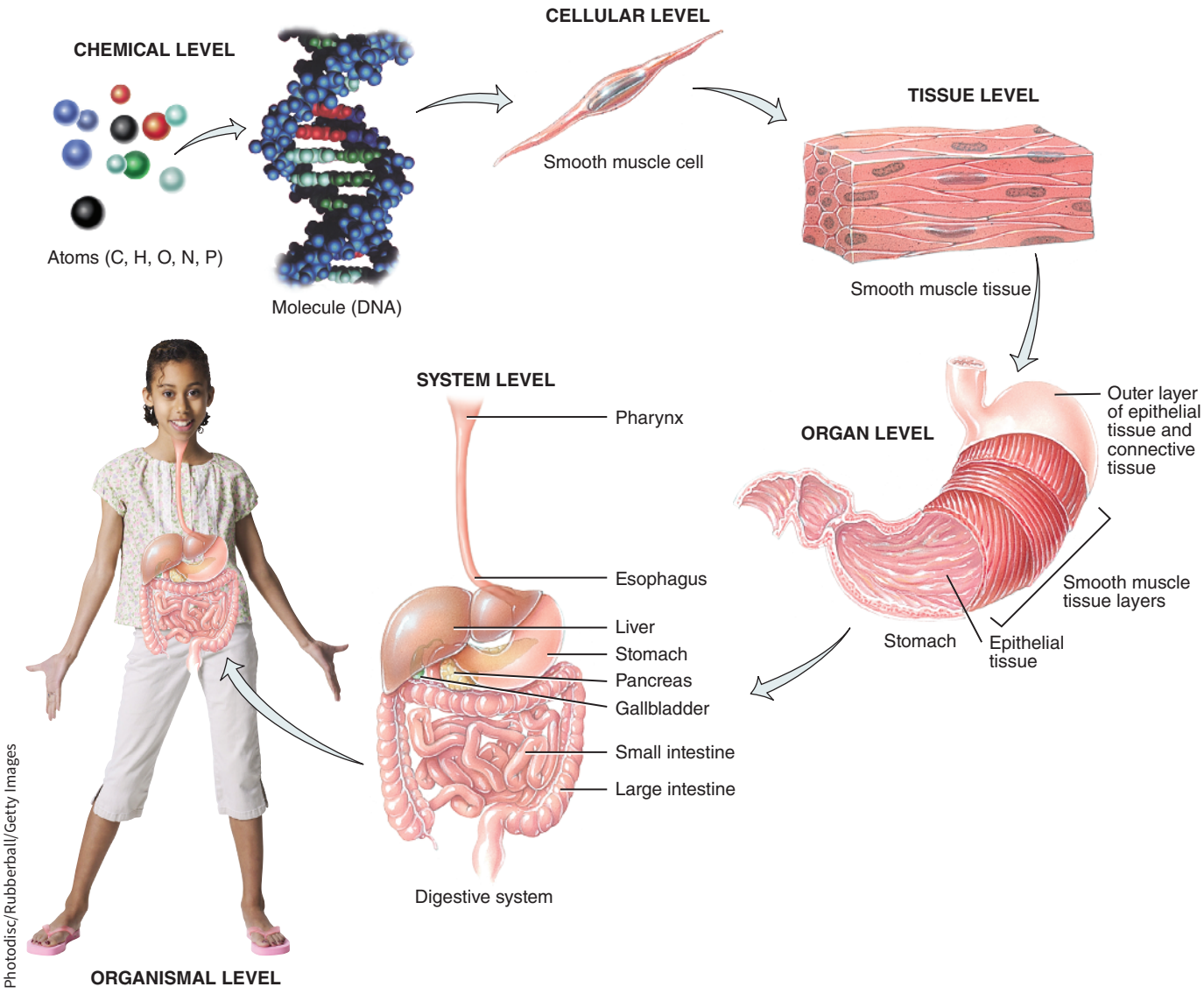
Objectives

- Describe the levels of organization that comprise the human body.
- Explain the functions of the twelve body systems.

As you study physiology, your exploration of the human body will extend from atoms and molecules to the whole person. From the smallest to the largest, six levels of organization will help you to understand how the body functions: the chemical, cellular, tissue, organ, system, and organismal levels of organization (**Figure 1.1**).

FIGURE 1.1 Levels of organization in the human body.

The levels of organization in the body are chemical, cellular, tissue, organ, system, and organismal.



Question

Which level of organization is composed of two or more different types of tissues that work together to perform a specific function?

- ***Chemical level.*** This very basic level includes **atoms**, the smallest units of matter that participate in chemical reactions, and **molecules**, two or more atoms joined together. Certain atoms, such as carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), calcium (Ca), and sulfur (S), are essential for maintaining life. Two familiar molecules found in the body are deoxyribonucleic acid (DNA), the genetic material passed from one generation to the next, and glucose, the main type of sugar in the bloodstream. Chapter 2 focuses on the chemical level of organization.
- ***Cellular level.*** Molecules combine to form **cells**, the basic structural and functional units of an organism. Cells are the smallest units capable of performing all life processes. Among the many kinds of cells in your body are epithelial cells, connective tissue cells, muscle cells, and neurons (nerve cells). **Figure 1.1** shows a smooth muscle cell, one of the three types of muscle cells in the body.
- ***Tissue level.*** A **tissue** is a group of similar cells that work together to perform a particular function. There are just four basic types of tissues in your body: epithelial tissue, connective tissue, muscle tissue, and nervous tissue. *Epithelial tissue* covers body surfaces, lines hollow organs and ducts, and forms glands. *Connective tissue* supports and protects body organs, stores energy reserves as fat, and helps

provide the body with immunity to disease-causing agents. *Muscle tissue* contracts to produce movement, maintain posture, and generate heat. *Nervous tissue* detects and responds to changes in the body's external or internal environment. Shown in **Figure 1.1** is smooth muscle tissue, which consists of tightly packed smooth muscle cells. The cellular and tissue levels of organization are described in Chapter 3.

- ***Organ level.*** An **organ** is a structure composed of two or more different types of tissues. It has a specific function and usually (but not always) has a recognizable shape. Examples of organs are the stomach, heart, liver, lungs, brain, and skin. **Figure 1.1** shows how several types of tissues comprise the stomach. The stomach's outer covering is a layer of epithelial tissue and connective tissue that reduces friction when the stomach moves and rubs against other organs. Underneath are smooth muscle tissue layers, which contract to churn and mix food and then push it into the next digestive organ, the small intestine. The innermost lining is an epithelial tissue layer that produces fluid and chemicals responsible for digestion.
- ***System level.*** A **system**, also known as an **organ system**, consists of related organs with a common function. An example of a system is the digestive system, which breaks down and absorbs food. Its organs include the mouth, salivary glands, pharynx (throat), esophagus, stomach, small intestine, large intestine, liver, gallbladder, and pancreas. Sometimes an organ is part of more than one system. The pancreas, for example, is part of both the digestive system and the hormone-producing endocrine system. **Table 1.2**

TABLE 1.2 The Twelve Systems of the Human Body

System	Components	Functions
Nervous	Brain, spinal cord, nerves, and special sense organs, such as the eyes and ears.	Generates action potentials to regulate body activities; detects changes in the body's external and internal environments, interprets the changes, and responds by causing muscular contractions or glandular secretions.
Muscular	Muscles composed of skeletal muscle tissue, so-called because it is usually attached to bones.	Produces body movements, such as walking; stabilizes body position (posture); generates heat.
Skeletal	Bones, joints, and associated cartilages.	Supports and protects the body; aids body movements; houses cells that produce blood cells.
Endocrine	Hormone-producing glands (pituitary gland, thyroid gland, parathyroid glands, adrenal glands, and pineal gland) and hormone-producing cells in several other organs and tissues.	Regulates body activities by releasing hormones, which are chemical messengers transported in blood from an endocrine gland or tissue to a target organ.
Cardiovascular	Heart, blood vessels, and blood.	The heart pumps blood through blood vessels; blood carries oxygen and nutrients to cells and carries carbon dioxide and other wastes away from cells.
Immune	Lymphocytes (white blood cells), lymph nodes, bone marrow, thymus, spleen, tonsils, and lymphoid tissue of the gut.	Defends body against microbes and other foreign substances.
Lymphatic	Lymphatic vessels, lymph, lymph nodes, bone marrow, thymus, spleen, tonsils, and lymphoid tissue of the gut.	Drains excess interstitial fluid; returns filtered plasma proteins back to the blood; carries out immune responses (part of the lymphatic system also functions as the immune system); transports dietary lipids.
Integumentary	Skin and associated structures, such as hair, nails, sweat glands, and oil glands.	Protects the body from the external environment; helps regulate body temperature; eliminates some wastes.
Respiratory	Nose, pharynx (throat), larynx (voice box), trachea (windpipe), bronchi, and lungs.	Transfers oxygen from inhaled air to blood and carbon dioxide from blood to exhaled air; helps regulate acid–base balance of body fluids.
Urinary	Kidneys, ureters, urinary bladder, and urethra.	Eliminates wastes and excess substances in urine; regulates volume and chemical composition of blood; helps regulate acid–base balance of body fluids.
Digestive	Mouth, pharynx (throat), esophagus, stomach, small and large intestines, salivary glands, liver, gallbladder, and pancreas.	Achieves physical and chemical breakdown of food; absorbs nutrients; eliminates solid wastes.
Reproductive	Gonads (testes in males and ovaries in females) and associated organs (epididymis, vas deferens, and penis in males; fallopian tubes, uterus, and vagina in females).	Gonads produce gametes (sperm or eggs) that unite to form a new organism; gonads also release hormones that regulate reproduction and other body processes; associated organs transport and store gametes.

introduces the components and functions of the twelve systems of the body.

- ***Organismal level.*** An **organism** is any living individual. All of the organ systems of the body collectively form the organism. In other words, the organism is the totality of all of its organ systems functioning together to maintain life.

In a complex hierarchy such as the body's organizational plan, as each level gives rise to the next highest level, new properties emerge that are not present at the levels below. These **emergent properties** are caused by the interactions of the simpler components of the lower levels of organization. For example, emotions, thoughts, memories, and intelligence are emergent properties of the brain (organ level) that are not present at lower levels of brain organization such as nervous tissue (tissue level) or individual neurons (cellular level). However, as the cells and tissues of the brain interact with each other in a variety of different ways, the brain's emergent properties arise. Because emergent properties depend on the interactions of lower-level components, they are not properties of any single one of these simpler components and cannot be predicted just by knowing that these components exist. The interaction of the components of the body to give rise to emergent properties is an example of integration. **Integration** is the process by which several components work together for a common, unified purpose. Thus, the body is much more than the sum of its parts: It is the result of integrated activities between components at essentially all levels of organization.

Checkpoint

2. Define the following terms: atom, molecule, cell, tissue, organ, system, and organism.
3. Refer to **Table 1.2**. Which body systems help eliminate wastes?
4. What is an emergent property?

1.3 Life Processes

Objective

- Identify the important life processes of the human body.

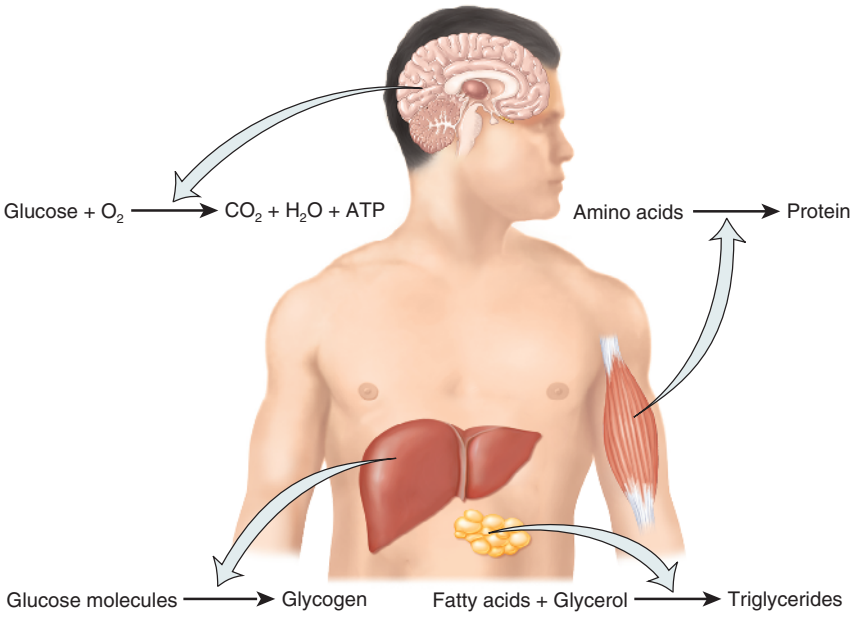
Certain processes distinguish organisms, or living things, from nonliving things. Following are the six most important life processes of the human body:

1. **Metabolism** is the sum of all of the chemical reactions that occur in the body (**Figure 1.2a**). One phase of metabolism is **catabolism**, the breakdown of complex chemical substances into simpler components. The other phase of metabolism is **anabolism**, the formation of complex chemical substances from smaller, simpler components. For example, digestive processes catabolize (break down) proteins in food into amino acids. These amino acids are then used to anabolize (build) new proteins that make up body structures such as muscles and bones.
2. **Responsiveness** is the body's ability to detect and respond to changes. For example, a decrease in body temperature represents a change in the internal environment (within the body), and lifting your foot off a sharp tack that you stepped on (**Figure 1.2b**) is a response to change in the external environment (outside the body). Different cells in the body respond to environmental changes in characteristic ways. Neurons respond by generating electrical signals known as *action potentials*. Muscle cells respond by contracting, which generates force to move body parts.
3. **Movement** includes motion of the whole body, individual organs, single cells, and even tiny structures inside cells. For example, the coordinated action of leg muscles moves your whole body from one place to another when you walk or run (**Figure 1.2c**). After you eat a meal that contains fats, your gallbladder contracts and squirts bile into the gastrointestinal tract to aid in the digestion of these fats. When a body tissue is damaged or infected, certain leukocytes (white blood cells) move from the blood into the affected tissue to help clean up and repair the area. Inside the cell, various parts move from one position to another to carry out their functions.
4. **Growth** is an increase in body size that results from an increase in the size of existing cells, an increase in the number of cells, or both. In addition, a tissue sometimes increases in size because the amount of material between cells increases. In a growing bone, for example, mineral deposits accumulate between bone cells, causing the bone to grow in length and width (**Figure 1.2d**).
5. **Differentiation** is the development of a cell from an unspecialized to a specialized state. Each type of cell in the body has a specialized structure and function that differs from that of its precursor (ancestor) cells. For example, erythrocytes (red blood cells) and several types of leukocytes all arise from the same unspecialized precursor cells in bone marrow (**Figure 1.2e**). Such precursor cells, which can divide and give rise to cells that undergo differentiation, are known as **stem cells**. Also through differentiation, a zygote (fertilized egg) develops into an embryo, and then into a fetus, an infant, a child, and finally an adult.
6. **Reproduction** refers either to (1) the formation of new cells for tissue growth, repair, or replacement, or (2) the production of a new individual. The formation of new cells occurs through cell division (**Figure 1.2f**). The production of a new individual occurs through the fertilization of an egg by a sperm cell to form a zygote, followed by repeated cell divisions and the differentiation of these cells.

When one or more life processes ceases to occur properly, the result is death of cells and tissues, which may lead to death of the organism. Clinically, loss of the heartbeat, absence of

FIGURE 1.2 Life processes of the human body.

The six most important life processes of the human body are metabolism, responsiveness, movement, growth, differentiation, and reproduction.



(a) Metabolism

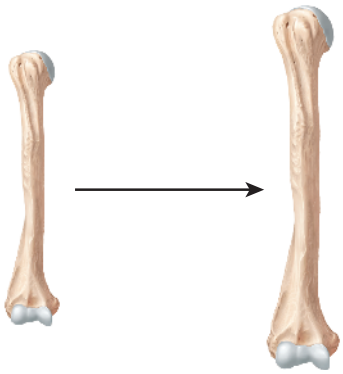


(b) Responsiveness

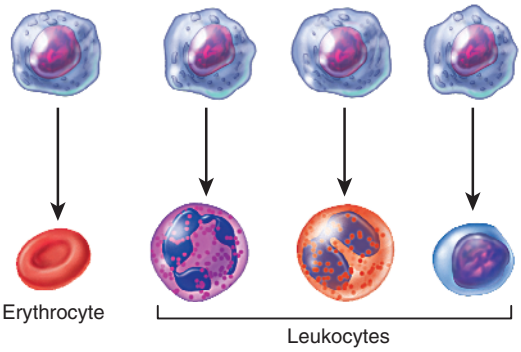


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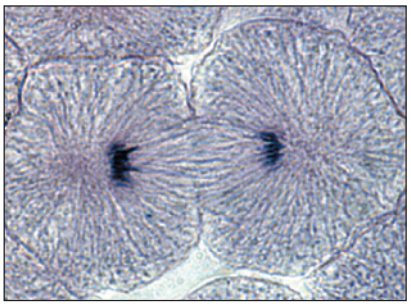
(c) Movement



(d) Growth



(e) Differentiation



Courtesy Michael Ross, University of Florida

(f) Reproduction

Question

Which life process would allow you to turn your head toward the sound of squealing brakes?

spontaneous breathing, and loss of brain functions indicate death in the human body.

Checkpoint

5. The formation of a muscle cell from a precursor cell is an example of which of the six life processes in the human body?

1.4 Homeostasis

Objectives

- Define homeostasis.
- Distinguish between the body's internal environment and external environment.
- Describe the components of a feedback system.
- Contrast the operation of negative and positive feedback systems.
- Explain feedforward control.

The cells that comprise the human body are able to thrive because they live in the relative constancy of the body's internal environment despite continual changes in the body's external environment. The maintenance of relatively stable conditions in the body's internal environment is known as **homeostasis** (hō′mē-ō-STĀ-sis; *homeo-* = sameness; *-stasis* = standing still). It occurs because of the ceaseless interplay of the body's many regulatory processes. Homeostasis is a dynamic steady state. The term *dynamic* is used to refer to homeostasis because each regulated parameter can change over a narrow range that is compatible with life. For example, the level of glucose is maintained between 70 and 110 milligrams of glucose per 100 milliliters of blood. It normally does not fall too low between meals or rise too high even after eating a high-glucose meal. The term *steady state* is used to refer to homeostasis because energy is needed to keep the regulated parameter at a relatively constant level. Steady state is not the same as equilibrium. In an *equilibrium*, conditions remain constant without the expenditure of energy. Each structure in the body, from the cellular level to the systemic level, contributes in some way to keeping the internal environment of the body within normal limits.

Maintenance of Body Fluid Volume and Composition Is Essential to Homeostasis

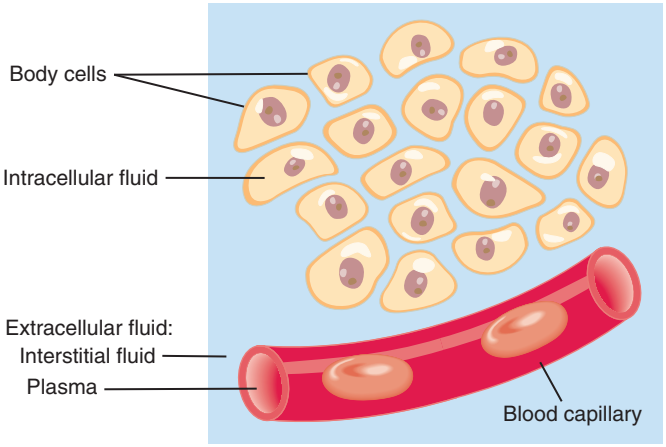
An important aspect of homeostasis is maintaining the volume and composition of **body fluids**, dilute, watery solutions containing dissolved chemicals that are found inside cells as well as surrounding them (**Figure 1.3**). In a lean adult, body fluids make up about 55–60% of total body mass; this percentage is lower in an individual with more adipose tissue (fat) because fat cells contain less water than skeletal muscle. About two-thirds of body fluid is **intracellular fluid (ICF)** (*intra-* = inside), the fluid within cells. The other one-third, called **extracellular fluid (ECF)** (*extra-* = outside), is fluid outside body cells. ECF consists of two components: (1) **interstitial fluid** (*inter-* = between), the fluid that fills the narrow spaces between cells, and (2) **plasma**, the fluid portion of blood. Interstitial fluid constitutes about 80% of the ECF, and plasma comprises the remaining 20%.

The proper functioning of body cells depends on precise regulation of the composition of their surrounding fluid. Because extracellular fluid surrounds the cells of the body, it serves as the body's **internal environment**. By contrast, the **external environment** of the body is the space that surrounds the entire body.

Figure 1.4 is a simplified view of the body that shows how a number of organ systems allow substances to be exchanged between the external environment, internal environment, and body cells in order to maintain homeostasis. Note that the integumentary system covers the outer surface of the body. Although this system does not play a major role in the exchange of materials, it protects the internal environment from damaging agents in the external environment. From the external environment, oxygen enters plasma through the respiratory system and nutrients enter plasma through the digestive system. After entering plasma, these substances are transported throughout the body by the cardiovascular system. Oxygen and nutrients

FIGURE 1.3 Body fluid compartments.

The fluid within cells is intracellular fluid; the fluid outside cells is extracellular fluid, which consists of interstitial fluid and plasma.

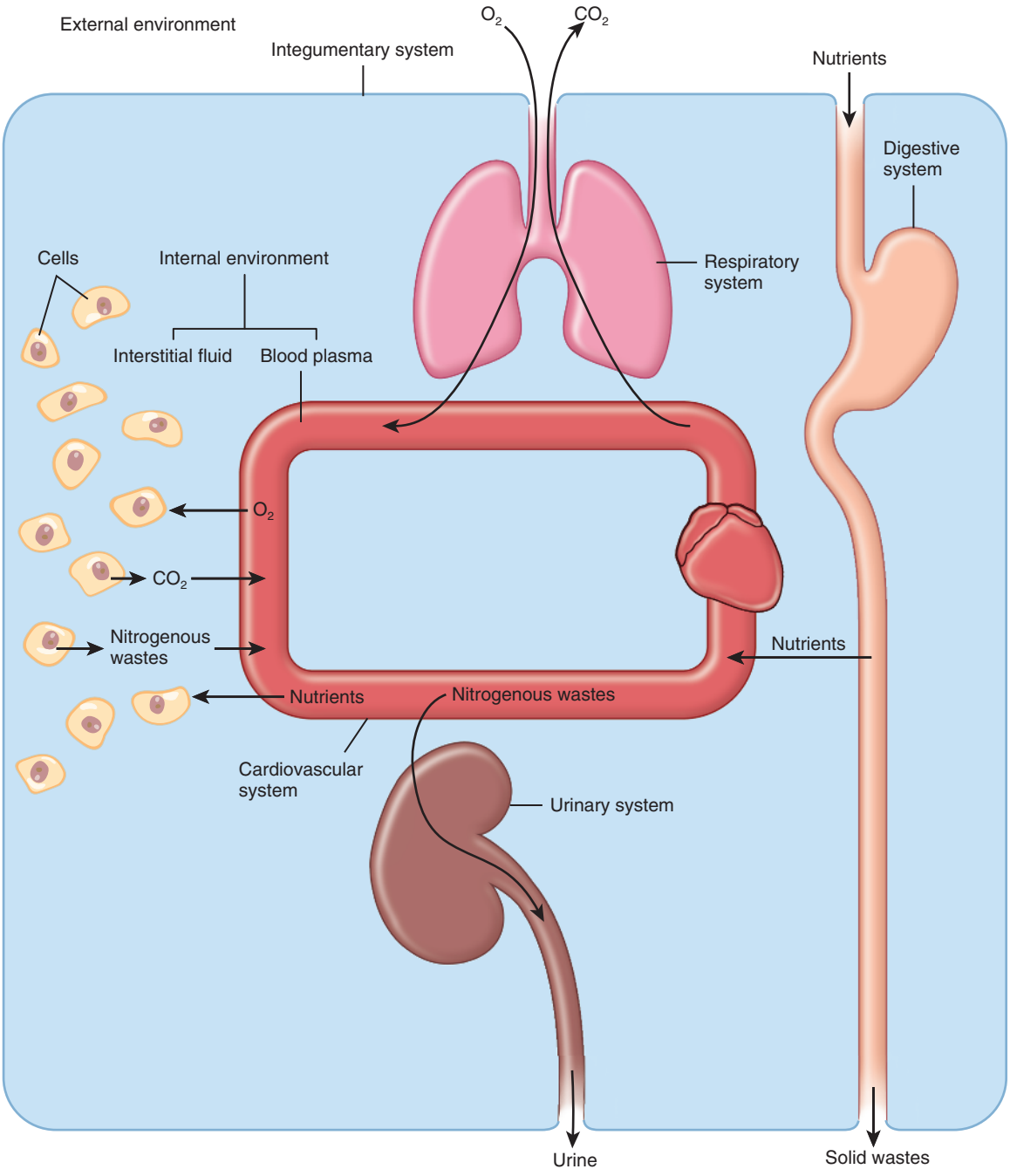


Question

What is the difference between interstitial fluid and plasma?

FIGURE 1.4 A simplified view of exchanges between the external and internal environments. Note that the linings of the respiratory, digestive, and urinary systems are continuous with the external environment.

The internal environment of the body refers to the extracellular fluid (interstitial fluid and plasma) that surrounds body cells.



Question

How does a nutrient in the external environment reach a body cell?

eventually leave plasma and enter interstitial fluid by crossing the walls of blood capillaries, the smallest blood vessels of the body. Blood capillaries are specialized to allow the transfer of material between plasma and interstitial fluid. From interstitial fluid, oxygen and nutrients are taken up by cells and metabolized for energy. During this process, the cells produce waste products, which enter interstitial fluid and then move across blood capillary walls into plasma. The cardiovascular system transports these wastes to the appropriate organs for elimination from the body into the external environment. The waste product CO_2 is

removed from the body by the respiratory system; nitrogen-containing wastes, such as urea and ammonia, are eliminated from the body by the urinary system.

Homeostasis Is Regulated via Feedback Systems and Feedforward Control

Homeostasis in the human body is continually being disturbed. Some disruptions come from the external environment in the form of physical insults such as the intense heat of a hot summer day or a lack of enough oxygen for that two-mile run. Other disruptions originate in the internal environment, such as a blood glucose level that falls too low when you skip breakfast. Homeostatic imbalances may also occur due to psychological stresses in our social environment—the demands of work and school, for example. In most cases the disruption of homeostasis is mild and temporary, and the responses of body cells quickly restore balance in the internal environment. However, in some cases the disruption of homeostasis may be intense and prolonged, as in poisoning, overexposure to temperature extremes, severe infection, or major surgery.

Fortunately, the body has many regulating systems that can usually bring the internal environment back into balance. Most often, the nervous system and the endocrine system, working together or independently, provide the needed corrective measures. The nervous system regulates homeostasis by sending action potentials (electrical signals) to organs that can counteract changes from the balanced state. The endocrine system includes many glands, organs, and tissues that secrete messenger molecules called *hormones* into the blood. Action potentials typically cause rapid changes, but hormones usually work more slowly. Both means of regulation, however, work toward the same end, usually through negative feedback systems.

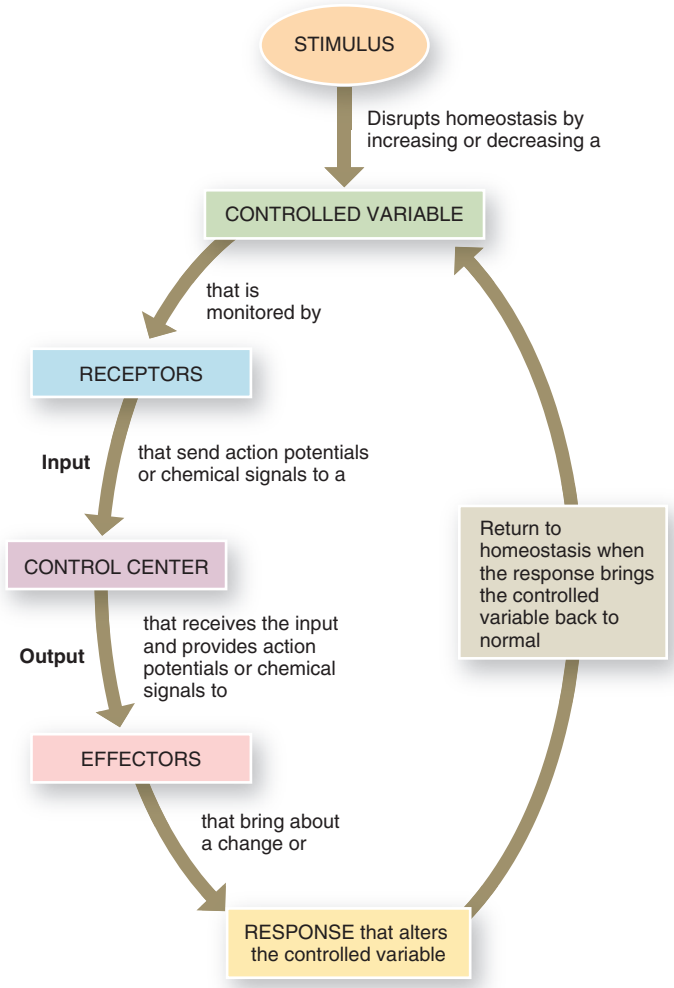
Feedback Systems

The body can regulate its internal environment through many feedback systems. A **feedback system** or *feedback loop* is a cycle of events in which a parameter of the internal environment is monitored, evaluated, changed, remonitored, reevaluated, and so on. Each monitored parameter is called a **controlled variable** or *controlled condition.* Examples of controlled variables include body temperature, blood pressure, blood glucose level, blood pH, and blood oxygen content. Any disruption that changes a controlled variable is called a *stimulus.* A feedback system includes three basic components—a receptor, a control center, and an effector (**Figure 1.5**).

1. A **receptor** is a body structure that monitors changes in a controlled variable and sends input to a control center. Typically, the *input* is in the form of action potentials or chemical signals. For example, certain nerve endings in the skin sense temperature and can detect changes, such as a dramatic drop in temperature.
2. A **control center** in the body determines the narrow range or **set point** within which a controlled variable should be maintained, evaluates the input it receives from receptors, and generates output commands when they are needed. *Output* from the control center typically occurs as action potentials, or hormones or other chemical signals. In the skin temperature example, the brain acts as the control center, receiving action potentials from the skin receptors and generating action potentials as output.
3. An **effector** is a body structure that receives output from the control center and produces a *response* or effect that changes the controlled variable. Nearly every organ or tissue in the body can behave as an effector; in many cases, the effector is a muscle or a gland. When your body temperature drops sharply, your brain (control center) sends action potentials (output) to your skeletal muscles (effectors). The result is shivering, which generates heat and raises your body temperature.

FIGURE 1.5 Operation of a feedback system. The solid return arrow symbolizes feedback.

The three basic components of a feedback system are the receptor, control center, and effector.



Question

What is the main difference between negative and positive feedback systems?

A group of receptors and effectors communicating with their control center forms a feedback system that can regulate a controlled variable in the body's internal environment. In a feedback system, the response of the system "feeds back" information to change the controlled variable in some way, either negating it (negative feedback) or enhancing it (positive feedback).

Negative Feedback Systems

A **negative feedback system** *reverses* a change in a controlled variable. Most controlled variables in the body, such as body temperature, blood pressure, and blood glucose level, are regulated by negative feedback systems. Consider the regulation of blood pressure. Blood pressure (BP) is the force exerted by blood as it presses against the walls of blood vessels. When the heart beats faster or harder, BP increases. If some internal or external stimulus causes blood pressure (controlled variable) to rise, the following sequence of events occurs (**Figure 1.6**). *Baroreceptors* (the receptors), pressure-sensitive neurons located in the walls of certain blood vessels, detect the higher pressure. These neurons send action potentials (input) to the brain (control center), which interprets the electrical signals and responds by sending action potentials (output) to the heart and blood vessels (the effectors). Heart rate decreases and blood vessels dilate (widen), which cause BP to decrease (response). This sequence of events quickly returns the controlled variable—blood pressure—to normal, and homeostasis is restored. Notice that the activity of the effector causes BP to drop, a result that negates the original stimulus (an increase in BP). This is why it is called a negative feedback system.

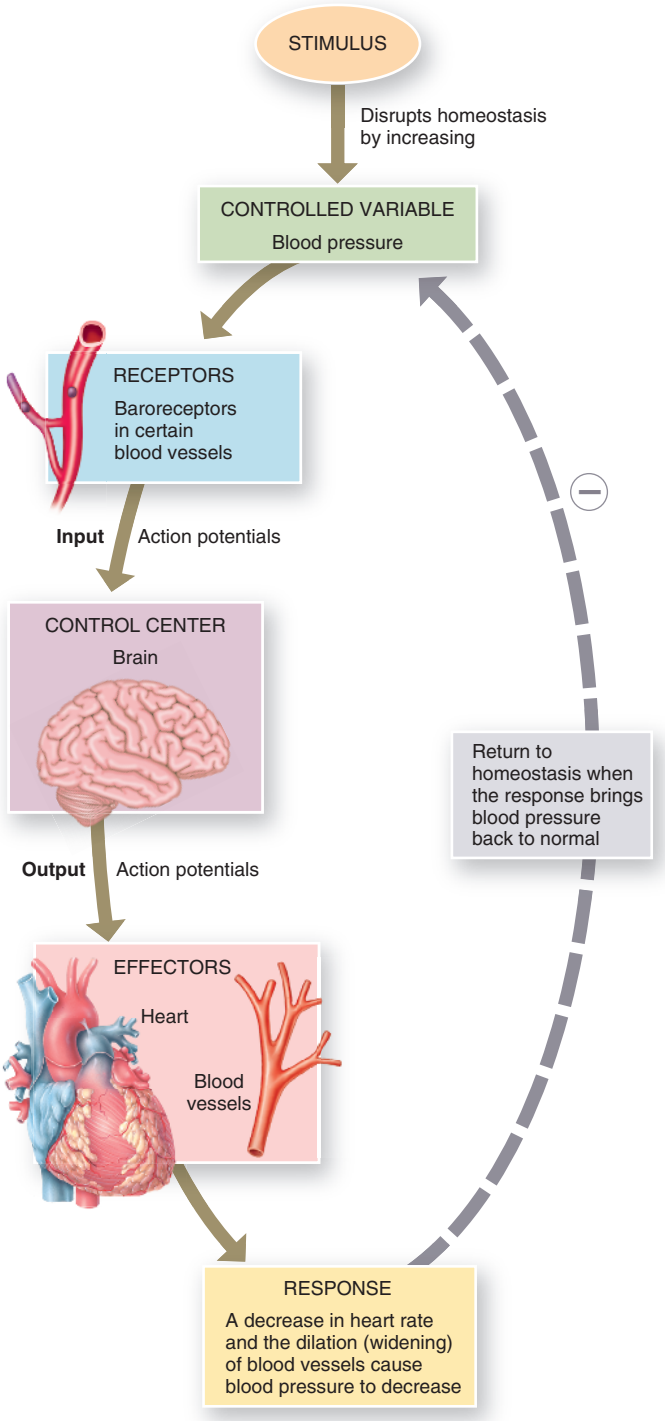
Positive Feedback Systems

A **positive feedback system** *strengthens* or *reinforces* a change in a controlled variable. A positive feedback system operates similarly to a negative feedback system except for the way the response affects the controlled variable. The control center still provides commands to an effector, but this time the effector produces a physiological response that adds to or *reinforces* the initial change in the controlled variable. The action of a positive feedback system continues until it is interrupted by some mechanism.

Normal childbirth provides a good example of a positive feedback system (**Figure 1.7**). The first contractions of labor (stimulus) push part of the fetus into the cervix, the lowest part of the uterus, which opens into the vagina. Stretch-sensitive neurons (receptors) monitor the amount of stretching of the cervix (controlled variable). As stretching increases, they send more action potentials (input) to the brain (control center), which in turn causes the pituitary gland to release the hormone oxytocin (output) into the blood. Oxytocin causes muscles in the wall of the uterus (effector) to contract even more forcefully. The contractions push the fetus farther down the uterus, which stretches the cervix even more. The cycle of stretching, hormone release, and ever-stronger contractions is interrupted only by the birth of the baby. Then stretching of the cervix ceases and oxytocin is no longer released.

FIGURE 1.6 Homeostatic regulation of blood pressure by a negative feedback system. The dashed return arrow with a negative sign surrounded by a circle symbolizes negative feedback.

If the response reverses the stimulus, a system is operating by negative feedback.

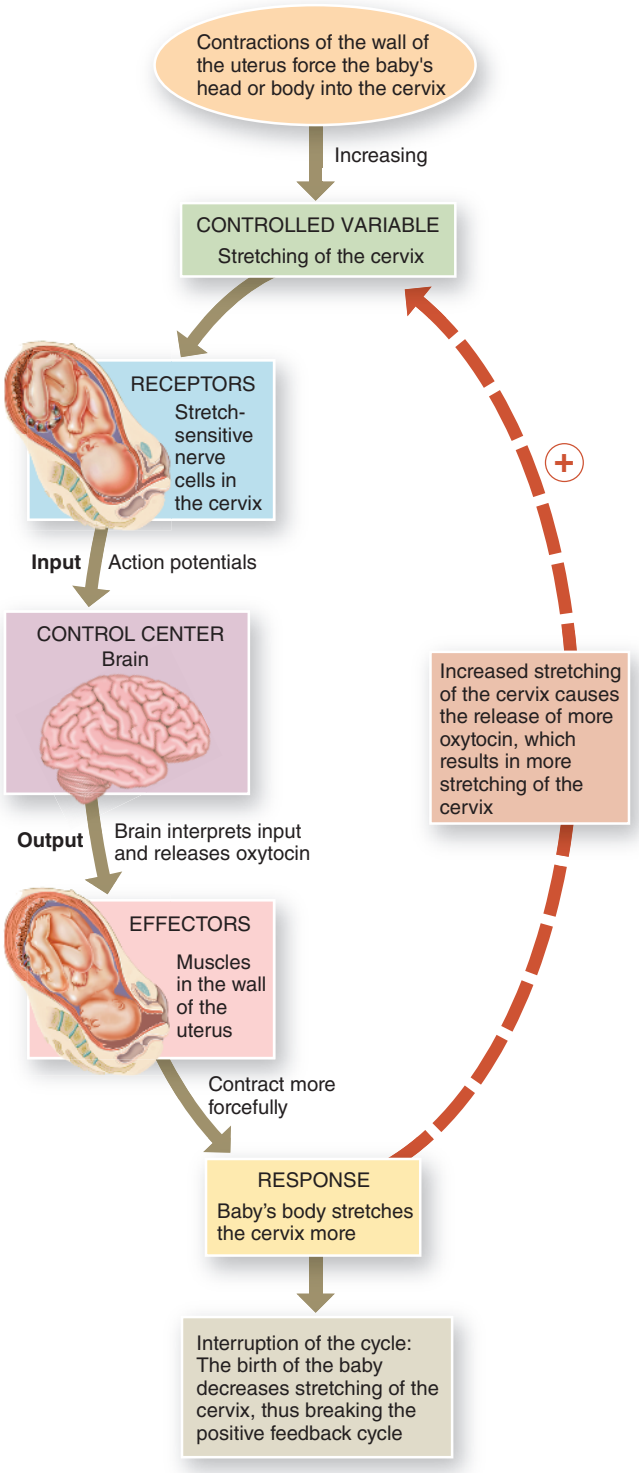


Question

What would happen to heart rate if some stimulus caused blood pressure to decrease? Would this occur by way of positive feedback or negative feedback?

FIGURE 1.7 Positive feedback control of labor contractions during birth of a baby. The dashed return arrow with a positive sign surrounded by a circle symbolizes positive feedback.

If the response enhances or intensifies the stimulus, a system is operating by positive feedback.



Question

Why do positive feedback systems that are part of a normal physiological response include some mechanism that terminates the system?

This example suggests some important differences between positive and negative feedback systems. Because a positive feedback system continually reinforces a change in a controlled variable, some event outside the system must shut it off. If the action of a positive feedback system is not stopped, it can "run away" and may even produce life-threatening conditions in the body. The action of a negative feedback system, by contrast, slows and then stops as the controlled variable returns to its normal state. Usually, positive feedback systems reinforce conditions that do not happen very often, and negative feedback systems regulate conditions in the body that remain fairly stable over long periods.

Feedforward Control

In a feedback system, events occur *in response to* a change in a controlled variable. In **feedforward control**, events occur *in anticipation of* a change in a controlled variable. To understand how feedforward control works, consider the following example. Suppose that the nutrient concentration in your internal environment becomes too low, which causes you to feel hungry. If you see, smell, or think about food during this time, a feedforward mechanism causes your mouth to salivate and your stomach to secrete gastric juice. This anticipatory response, which is part of the *cephalic phase* (*cephalic* = head) of digestion, prepares the digestive system for food that is about to be eaten, making it easier for the food to be digested and nutrients to enter the internal environment. You will learn more about the cephalic phase of digestion in Chapter 21 (see Section 21.8).

Clinical Connection

Diagnosis of Disease

Diagnosis (dī′-ag-NŌ-sis; *dia-* = through; *-gnosis* = knowledge) is the science and skill of distinguishing one disorder or disease from another. The patient's signs and symptoms, his or her medical history, a physical exam, and laboratory tests provide the basis for making a diagnosis. Taking a ***medical history*** consists of collecting information about events that might be related to a patient's illness. These include the chief complaint (primary reason for seeking medical attention), history of present illness, past medical problems, family medical problems, social history, and review of symptoms. A ***physical examination*** is an orderly evaluation of the body and its functions. This process includes **inspection** (the examiner observes the body for any changes that deviate from normal), **palpation** (the examiner feels body surfaces with the hands to detect enlarged or tender organs or abnormal masses), **auscultation** (the examiner listens to body sounds to evaluate the functioning of certain organs, often using a stethoscope to amplify the sounds), and **percussion** (the examiner taps on the body surface with the fingertips and listens to the resulting echo, which can provide information about the size, consistency, and position of an underlying structure). The physical examination also includes measurements of vital signs (temperature, pulse, respiratory rate, and blood pressure), and sometimes laboratory tests.

Critical Thinking

Working up a Sweat

Julie is the starting point guard for her college basketball team. On the day of one of her games, the gym is hot and crowded. The fans are cheering and excitement is in the air! As the game begins, Julie notices that her forehead is sweating. As the game continues, more areas of her body begin to sweat, and her palms leave wet prints on the ball. Eventually her entire jersey becomes drenched with perspiration. Once half-time is called, Julie is able to rest for a few minutes, cool down, and rehydrate.

Some Things to Keep in Mind

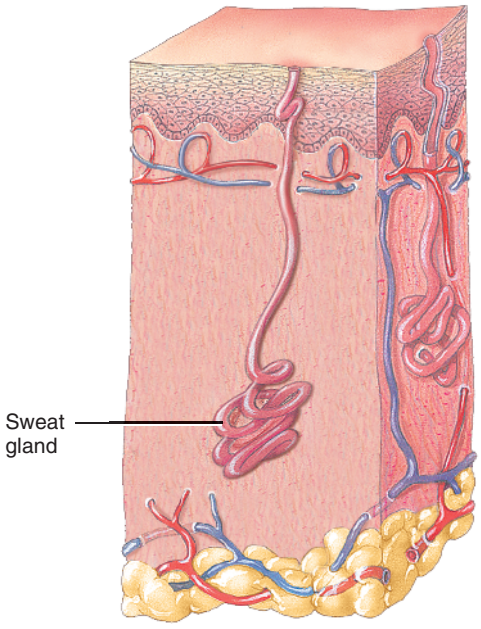
Various mechanisms are employed to keep our core body temperature in the normal range. Thermoregulation begins with thermoreceptors, which detect changes in body temperature. The thermoreceptors then relay that information to the thermoregulation center in the brain. This center in turn stimulates sweat glands in the skin to secrete sweat onto the skin surface. As the water in the sweat evaporates, large quantities of heat energy leave the skin surface and the body cools down.

Some Interesting Facts

Average number of sweat glands in the human body	3 million
Maximum amount of sweat produced in an hour	3 liters
Average amount of sweat lost daily under normal conditions	600 mL



Vico Collective/Alin Dragulin/Getty Images



What are the specific components of the feedback system involved in causing Julie to sweat when her body temperature becomes too high?

Why is this feedback system considered to be negative feedback?

Besides body temperature, what other controlled variables are regulated by a negative feedback system?

What would happen to Julie if her increased body temperature were regulated by a positive feedback system?

Why is thermoregulation so essential to maintaining homeostasis?

Homeostatic Imbalances Can Lead to Disorders, Diseases, or Even Death

As long as all of the body's controlled variables remain within certain narrow limits, homeostasis is maintained, body cells function efficiently, and the body stays healthy. However, should one or more components of the body lose their ability to contribute to homeostasis, the normal balance among all of the body's processes may be disturbed. If the homeostatic imbalance is moderate, a disorder or disease may occur; if it is severe, death may result.

A **disorder** is any abnormality of structure or function. **Disease** is a more specific term for an illness characterized by a recognizable set of signs and symptoms. **Signs** are *objective* changes that a clinician can observe and measure, such as swelling, fever, high blood pressure, or paralysis. **Symptoms** are *subjective* changes in body functions that are not apparent to an observer, such as headache, nausea, or anxiety. You will learn about specific disorders and diseases as the functions of the various parts of the body are discussed in the chapters to come.

Checkpoint

6. Why is extracellular fluid called the internal environment of the body?
7. What types of disturbances can act as stimuli that initiate a feedback system?
8. How are negative and positive feedback systems similar? How are they different?
9. What is the significance of feedforward control?

1.5 Physiology as a Science

Objectives

- Describe the history of physiology.
- Identify the steps of the scientific method.
- Explain the importance of scientific literature.
- Discuss the mechanistic approach to explaining body function.
- Define concept mapping.

The History of Physiology Spans Thousands of Years

The term *physiology*, which literally means "study of nature" (*physio-* = nature; *-logy* = study of), is derived from the Greek word *physiologoi* (fiz′-ē-OL-ō-goy), a name that refers to a group of ancient Greek philosophers of the sixth and fifth centuries B.C. who speculated about the existence and purpose of all things (living and nonliving) in the natural world. They searched for rational explanations about the phenomena that they observed around them and rejected traditional supernatural explanations. Prominent among the *physiologoi* were Thales, Anaximander, Pythagoras, and Democritus.

Over the next few centuries, the scope of physiology began to focus on how living things in nature function. The Greek physician Hippocrates (460–375 B.C.), considered the father of medicine, thought that the normal functioning of the body depended on the balance of four types of bodily fluids, or humors (blood, phlegm, yellow bile, and black bile) and that illness resulted when these humors were out of balance. This *humoral theory* influenced Western medicine for the next 2000 years and was eventually disproved in the 18th century. The Greek philosopher Aristotle (384–322 B.C.) proposed that every part of the body is formed for a specific purpose and that the function of a given body part can be deduced from its structure. The Greek physician Erasistratus (304–250 B.C.) accurately described the function of heart valves and distinguished between sensory nerves and motor nerves. Galen (A.D. 130–201), another Greek physician, correctly described functions of the kidneys and spinal nerves and demonstrated that arteries contain blood. However, Galen erroneously believed that air entering the body was transformed by the brain, liver, and heart into "souls" or "spirits" that governed the vital functions of the body. He also incorrectly described the movement of blood through the heart. Despite his errors, Galen became the undisputed authority on medicine in the Western world. His views went unchallenged for about 1400 years—that is, until the Renaissance.

The Renaissance was a cultural movement in Europe from the 14th to the 17th centuries characterized by a revival of classical influences on art and literature. It also marked the beginning of modern science: Experimentation in the physical and life sciences started to flourish; the way that science was performed began to change, with an emphasis on scientific procedure and reproducibility of results (the scientific method); and generally accepted scientific concepts passed down from the ancient Greeks were now being reexamined. This movement when science started to change to its modern form is known as the **Scientific Revolution**, which occurred during the 16th and 17th centuries. A major physiological discovery during the Scientific Revolution was made by the English physician William Harvey (1578–1657). Through dissection and experimentation, he was able to correctly explain the circulation of blood through the body: The heart pumps blood into arteries, arteries carry blood away from the heart, and veins return blood back to the heart. Harvey's discovery is considered to be the beginning of modern experimental physiology.

During the 18th and 19th centuries, there were many noteworthy contributions to physiology. The Italian physiologist Lazzaro Spallanzani (1729–1799) demonstrated that digestion of food in the stomach involves a chemical process. The English

physician William Hewson (1739–1774) determined that a substance now known as fibrinogen is necessary for blood clotting to occur. The German physiologist Carl Ludwig (1816–1895) invented the *kymograph*, an instrument designed to measure and record variations in fluid pressure. He was also the first to use isolated, perfused organs for experimentation. By the middle of the 19th century, the cell as the fundamental unit of life (the cell theory) was firmly established, so physiologists began to study cell function. The French physiologist Claude Bernard (1813–1878) first proposed that the cells of a multicellular organism flourish because they live in the relative constancy of *le milieu interieur*—the internal environment—despite continual changes in the organism's external environment. The American physiologist Walter B. Cannon (1871–1945) later coined the term *homeostasis* to describe this internal constancy.

Many advances in physiology were also achieved during the 20th century. In the early 1900s, the German physiologist Otto Frank (1865–1944) and the English physiologist Ernest Starling (1866–1927) described how the strength of the heart's contraction is affected by the degree of stretch of the heart wall—the so-called *Frank-Starling law of the heart*. In the 1950s, the English physiologists Alan Hodgkin (1914–1998) and Andrew Huxley (1917–2012) described the mechanism of the action potential in a giant squid axon. During that same decade, the English biologist Hugh Huxley (1929–2013) along with several others described the sliding filament mechanism of muscle contraction. In the 1970s and 1980s, the American pharmacologist Alfred Gilman (1941–present) and the American biochemist Martin Rodbell (1925–1998) described the function of G proteins in signal transduction pathways.

Today physiology is considered a mature discipline, as most of the functions at the organ and system levels have been elucidated. However, there is still more work to be done. Physiologists are currently focusing on functions at the cell and molecular levels. For example, in the last decade of the twentieth century, the genomes of humans, mice, fruit flies, and more than 50 microbes were sequenced. As a result, research in the field of **genomics**, the study of the relationships between the genome (all of the DNA of an organism) and the biological functions of an organism, has flourished. Another active area of research is **proteomics**, the study of the relationship between the proteome (all of the proteins of an organism) and the biological functions of that organism. Another key area of research during this millennium is integration: Twenty-first-century physiologists are seeking to understand how various parts of the body work together to accomplish a particular function.

The Scientific Method Is a Systematic Way of Acquiring Knowledge About the Natural World

The current knowledge that physiologists have about how the body functions has been obtained through observation and experimentation. The process of acquiring knowledge about some aspect of the natural world in a systematic way is known as the **scientific method**, which typically consists of four steps: (1) make an observation, (2) formulate a hypothesis, (3) design an experiment to test the hypothesis, and (4) interpret the data.

1. ***Make an observation.*** This observation may occur during experimentation or it may be gleaned from researching the scientific literature. For example, a physiologist who is interested in studying high-density lipoproteins (HDLs), also known as "good" cholesterol, might observe from reading a few scientific articles that athletes have higher levels of HDLs in their bloodstream than sedentary individuals.
2. ***Formulate a hypothesis.*** After making an observation, a hypothesis is formulated. A **hypothesis** is a tentative explanation for the observation. The hypothesis must be testable by experimentation and capable of being refuted. A logical hypothesis from the observation about HDLs given above is that exercise increases the HDL level in the bloodstream.
3. ***Design an experiment to test the hypothesis.*** A good experiment alters a single variable that the physiologist believes plays a critical role in the initial observation, while all other variables are kept constant. The variable that is altered is known as the **independent variable**. Any factor that varies in response to changes in the independent variable is known as the **dependent variable**. In the HDL hypothesis, exercise is the independent variable, and the HDL blood concentration is the dependent variable. To test the effect of exercise on the HDL level in the blood, the physiologist designs an experiment in which several groups of people exercise for varying amounts of time each day over a period of three months. One group does not exercise at all, another group exercises for 30 minutes a day, another group for 1 hour a day, and so on. Every week over the course of the experiment, the HDL blood concentration of each individual of each group is measured. A vital component of any experiment is the **control**, which is the part of the experiment in which the independent variable is not altered. Having a control allows the physiologist to know that the changes in the experimental group are due to a change in the independent variable and not some other factor. In the HDL experiment, the control is the group of people who do not exercise at all over the three-month period.

   In an experiment such as this one, many variables other than exercise might affect the outcome of the results. The physiologist tries to anticipate these issues and find ways to eliminate them. For example, some people in this experiment might be more physically fit than others. To eliminate this factor, the physiologist would include in the experiment only people who have the same approximate age, body weight, and overall degree of health. The physiologist would also check to make sure that the initial HDL levels in the bloodstream are about the same in all individuals participating in the study. Another possible source of variation is diet. Different foods can affect the cholesterol level in the bloodstream. So the physiologist would need to make sure that all participants in the study have the same type of diet

each day over the entire testing period. Still yet another possible source of variation is small population size. The smaller the number of people participating in this study, the more likely there will be errors or outliers in the data. Ideally the physiologist would involve thousands of individuals in this experiment, with each group consisting of hundreds of individuals. However, experiments with such a large number of people are often hard to manage, so limits might have to be set in terms of the number of people that can participate. It is important to point out that some variables might be out of the physiologist's control. A good example is genetics: Some people may be genetically prone to producing more or less HDLs and other types of cholesterol. If this is the case for some participants in this study, their results might not change significantly in response to exercise.

As the HDL experiment proceeds over the three-month period, the physiologist collects data. Scientific data may either be *quantitative* (involves numerical measurements) or *qualitative* (involves descriptions). In this experiment, the data obtained is quantitative because it involves measuring the HDL concentration in the blood.

A final point about the design of this experiment is that humans are used as the subjects because there is no threat to their well-being. However, in physiology experiments that are invasive, **animal models** such as rats or other mammals that resemble humans in structure are often used as the subjects. The results are then extrapolated to humans. Experiments that involve animal models have strict protocols to make sure that the animals are treated humanely.

4. ***Interpret the data.*** After the data is collected from the experiment, the results are interpreted. Data are often displayed on graphs and in tables. Interpretation of the data involves the use of *statistics* to make sure that the results obtained are not by chance but instead are real phenomena. In some experiments, the data may not support the hypothesis, and the physiologist will have to modify the hypothesis and design a new experiment to test that new hypothesis. In other cases, the data may support the hypothesis. Suppose that, for the HDL experiment, the physiologist finds that exercise does indeed increase the HDL level in the bloodstream. Although the data support the hypothesis, the physiologist should repeat the experiment several times to make sure that it is *reproducible.* An experiment must be reproducible to have merit in the scientific community. When a hypothesis is tested over and over again by independent scientists and the data support that hypothesis, the hypothesis becomes a **scientific theory**. Just because a hypothesis becomes a theory does not mean that it cannot ever be refuted. At some point in the future, new evidence may indicate that the theory is no longer true. So it is very possible that some physiological information that is currently accepted as fact by the scientific community may be disproved in years to come.

The scientific method is a way to investigate phenomena in the natural world using a fixed series of steps. However, in a more general process known as **scientific inquiry,** a scientist investigates a problem without a requisite order. The essence of scientific inquiry is essentially the same as the scientific method except that the physiologist is free to investigate the problem in any order that he or she wants. For example, the physiologist may perform an experiment and, based on what she finds, she may then develop a hypothesis.

Scientific Literature Helps Physiologists Conduct Research

A physiologist uses scientific literature as a research tool—to read about current studies in the field or as a means to publish the results of experiments that he or she has performed. The main sources of scientific information are journals, books, and the Internet.

- ***Journals.*** A journal is a collection of scientific articles, either original research articles or review articles, about a particular topic. Journals are usually **peer-reviewed**, meaning that a group of scientific experts makes sure that a given scientific article meets certain criteria before it is published. Examples of peer-reviewed journals include the *American Journal of Physiology, Nature*, and *Proceedings of the National Academy of Sciences*. Journal articles offer the most current scientific research that is available.
- ***Books.*** Books can also be a source of scientific information. A science textbook, such as this one, summarizes the main concepts in a particular scientific field. These concepts have been obtained over the years from numerous scientific experiments. Although books are wonderful sources of scientific information, they take longer to publish, so they are not as current as the latest edition of a journal.
- ***Internet.*** The Internet is another source of scientific information. However, information found on the Internet may not always be reliable. If you are searching for a particular scientific topic, use reputable websites that are written and maintained by scientific professionals. Examples of reputable scientific websites include www.nih.gov, www.mayoclinic.com, and www.webmd.com. Another reputable website is www.pubmed.com, a great search engine for finding journal articles about a particular topic. Many journals have websites that allow you to access scientific information online. For example, the website for the journal *Nature* is www.nature.com.

Physiologists Use the Mechanistic Approach to Explain How the Body Functions

At the core of physiology is the desire to explain the mechanisms responsible for the various functions of the body. This approach to explaining body function is called the **mechanistic approach**: It describes how a particular event in the body

occurs using cause-and-effect sequences. For example, consider the following question: "Why does the body sweat when its temperature becomes too hot?" The mechanistic approach to answering this question would be as follows: Thermoreceptors in the skin detect the hot temperature and then send signals to the brain, which in turn sends signals that activate sweat glands. Activation of sweat glands causes the body to sweat, and the body cools off as sweat evaporates from the skin surface.

Another approach to explaining body function is the **teleological approach**, which describes why a particular function occurs without mentioning the mechanism involved. In response to the question, "Why does the body sweat when its temperature becomes too hot?", the teleological approach to answering this question would simply be "To cool off the body." Because the teleological approach does not provide the mechanism of how the physiological event occurs, it is not the approach that physiologists prefer to use.

Concept Mapping Allows Physiologists to Illustrate the Relationships Between Ideas

As a physiologist studies body functions, the information that is learned often needs to be organized. This can be achieved through a process known as **concept mapping**, in which certain ideas or concepts are graphically displayed to illustrate their relationships to one another. A common type of concept map used in physiology is a **process map**, in which pieces of information about a particular process are connected by arrows to show cause-and-effect sequences. Because the information flows from one part of the map to the other, a process map is also known as a **flowchart**. Flowcharts are used throughout this text; examples include **Figure 13.21** and **Figure 18.16**. Some flowcharts are also called **feedback system** (*feedback loop*) **diagrams** if arrows are used to show that an initial change in a controlled variable causes a sequence of events that either reverses the change in the controlled variable (negative feedback) or enhances the change in the controlled variable (positive feedback). **Figures 1.5**, **1.6**, and **1.7** are examples of feedback system diagrams.

Checkpoint

10. What are the physiological contributions of Erasistratus? Galen? William Harvey? Claude Bernard?

11. What are the current areas of physiological research?

12. What is the difference between the scientific method and scientific inquiry?

13. What are some examples of reputable scientific websites?

14. How does the mechanistic approach to explaining body function differ from the teleological approach?

15. What is a flowchart?

1.6 Key Themes of Physiology

Objective

- Identify the key themes of physiology.

Four key themes of physiology appear throughout this book: homeostasis, integration, mechanism of action, and communication.

- ***Homeostasis.*** Earlier in this chapter you learned that homeostasis is the maintenance of relatively stable conditions in the body's internal environment. This occurs through the operation of feedback systems. Each feedback system consists of (1) a receptor that monitors a controlled variable, (2) a control center that determines the set point of the controlled variable and evaluates input from the receptor, and (3) an effector that receives output commands from the control center and produces a response that changes the controlled variable (see **Figure 1.5**). Because homeostasis is vital to the normal functioning of the body, it is the most important theme of physiology. Information relevant to homeostasis is presented in every chapter of this book. Furthermore, in certain chapters you will learn how controlled variables such as blood pressure, body temperature, blood glucose level, blood oxygen level, and blood pH are regulated to maintain homeostasis. For example, in Chapter 13 you will discover how the blood glucose concentration is regulated.
- ***Integration.*** Integration occurs when several components work together to accomplish a particular function. Essentially all of the components of the body—molecules, cells, tissues, organs, and organ systems—work together at various levels to keep the body alive. Because integration occurs throughout the body, it is a major theme of physiology. As you read the chapters of this book, you will encounter numerous examples of integration. For example, in Chapter 18 you will learn that breathing involves several organs of different systems—the lungs (respiratory system), brain (nervous system), and skeletal muscles (muscular system). Other examples of integration that you will explore in this text include control of movement (Chapter 12); growth of bone (Chapter 13); regulation of blood pressure (Chapter 15); acid–base balance (Chapter 20); and the so-called integrative functions of the brain: wakefulness and sleep, language, emotions, motivation, and learning and memory (Chapter 8).
- ***Mechanism of Action.*** Physiologists explain how the body works by indicating the mechanisms that are involved. This mechanistic approach describes how a physiological event occurs using cause-and-effect sequences. Because mechanism of action is the way that body function is explained, it is a prominent theme of physiology. As you read through

this book, you will learn the mechanisms of action of a large number of physiological events, ranging from the system level down to the molecular level. Because the current focus of physiology research is at the cell and molecular levels, this text emphasizes cell and molecular mechanisms of function. Beginning with Chapter 2, each chapter will have at least one physiological event described at the cell or molecular level. Some chapters will have multiple physiological events described in this manner. For example, in Chapter 9 you will learn about the cell and molecular mechanisms responsible for each of your sensations.

- ***Communication.*** Another key theme of physiology is communication. The cells of the body must communicate with one another in order for the body to function. Chapter 6 introduces the various ways that cells communicate with each other. For example, a main method of communication between cells is by the release of an *extracellular chemical messenger*. This messenger may be a *hormone* (a chemical that enters the blood to reach a distant target cell), a *neurotransmitter* (a chemical released at the junction between two neurons or between a neuron and a muscle cell), or a *local mediator* (a chemical that communicates with a nearby cell without entering the bloodstream). In several of the remaining chapters of this book, you will learn more details about how these chemical messengers function. For example, in Chapter 13 you will explore the roles of the different types of hormones in the body.

Checkpoint

16. Which of the four key themes of physiology is most important?

From Research to Reality

Diet and Blood Pressure

Reference

Appel, L. et al. (1997). A clinical trial of the effects of dietary patterns on blood pressure. *New England Journal of Medicine.* 336(16):1117–1124.

How much might your diet impact your blood pressure?

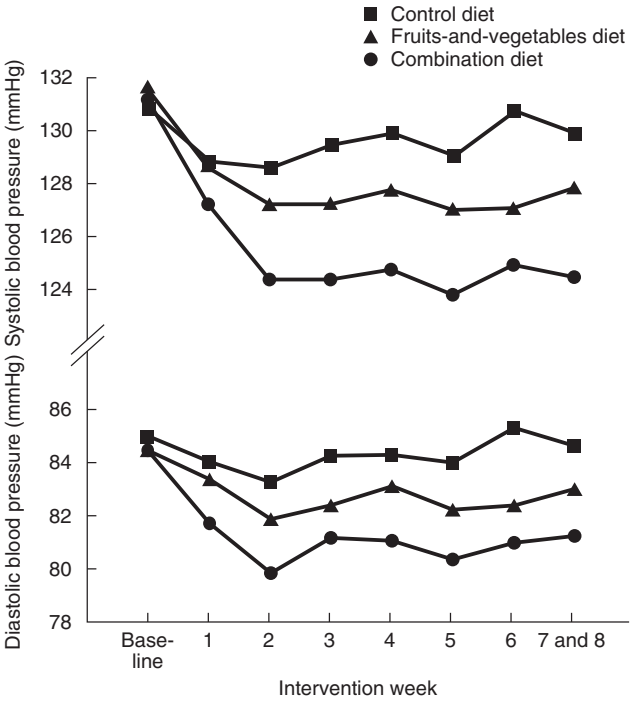


kivoart/Getty Images

The saying goes "You are what you eat." Is this true when you talk about blood pressure? Could a change in your diet change your blood pressure? Could diet be as effective as drugs at decreasing high blood pressure?

Article Description

Researchers gave 459 subjects a control diet for three weeks and then randomized those subjects into three diets: the control diet, a fruits-and-vegetables diet, or a combination diet. The control diet was reflective of the typical American diet; the fruits-and-vegetables diet was similar to the control diet but included more fruits and vegetables and fewer sweets and snacks; and the combination diet was rich in fruits and vegetables, but low in saturated fat, total fat, and cholesterol. The blood pressure of each subject was monitored for six weeks to see if diet could have any effect on blood pressure.



Go to WileyPLUS and use the data from this article to answer the questions posed there and to discover more about diet and blood pressure.

Chapter Review

1.1 Physiology Defined

1. Physiology is the study of the functions of an organism and its constituent parts.

2. Human physiology describes how the parts of the human body work.

1.2 Levels of Organization in the Body

1. The human body consists of six levels of organization: chemical, cellular, tissue, organ, system, and organismal.

2. Cells are the basic structural and functional units of an organism and the smallest living units in the human body.

3. Tissues are groups of cells and the materials surrounding them that work together to perform a particular function.

4. Organs are composed of two or more different types of tissues; they have specific functions and usually have recognizable shapes.

5. Systems consist of related organs that have a common function.

6. **Table 1.1** introduces the twelve systems of the human body: the endocrine, nervous, muscular, skeletal, cardiovascular, immune, lymphatic, integumentary, respiratory, urinary, digestive, and reproductive systems.

7. An organism is any living individual.

8. An emergent property is a new property that exists at a given level of organization and not at the levels below.

1.3 Life Processes

1. All organisms carry on certain processes that distinguish them from nonliving things.

2. The most important life processes of the human body are metabolism, responsiveness, movement, growth, differentiation, and reproduction.

1.4 Homeostasis

1. Homeostasis is the maintenance of relatively stable conditions in the body's internal environment.

2. Body fluids are dilute, watery solutions. Intracellular fluid (ICF) is fluid inside cells, and extracellular fluid (ECF) is fluid outside cells. Interstitial fluid is the ECF that fills spaces between cells; plasma is the ECF within blood vessels.

3. Because it surrounds all body cells, extracellular fluid is called the body's internal environment.

4. Disruptions of homeostasis come from external stimuli, internal stimuli, and psychological stresses.

5. When disruption of homeostasis is mild and temporary, responses of body cells quickly restore balance in the internal environment. If disruption is extreme, regulation of homeostasis may fail.

6. Most often, the nervous and endocrine systems, acting together or separately, regulate homeostasis. The nervous system detects body changes and sends action potentials to counteract the changes. The endocrine system regulates homeostasis by secreting hormones.

7. Feedback systems include three components: (1) Receptors monitor changes in a controlled variable and send input to a control center; (2) the control center determines the set point at which a controlled variable should be maintained, evaluates the input it receives from receptors, and generates output commands when they are needed; and (3) effectors receive output from the control center and produce a response (effect) that alters the controlled variable.

8. If a response reverses the original stimulus, the system is operating by negative feedback. One example of negative feedback is the regulation of blood pressure. If a response enhances the original stimulus, the system is operating by positive feedback. One example of positive feedback is uterine contractions during the birth of a baby.

9. In addition to feedback systems, homeostasis may also involve feedforward control. In feedforward control, events occur in anticipation of a change in a controlled variable. An example of feedback control occurs when the sight, smell, or thought of food causes your mouth to salivate and your stomach to produce gastric juice.

10. Disruptions of homeostasis—homeostatic imbalances—can lead to disorders, diseases, and even death.

1.5 Physiology as a Science

1. The term *physiology* is derived from the physiologoi, a group of ancient Greek philosophers who speculated about the existence and purpose of all things in nature.

2. Over time, the scope of physiology began to focus on how living things in nature function. Hippocrates, Aristotle, Erasistratus, and Galen (all Greek) were among the first to study body function.

3. During the Renaissance, old views about science began to change, resulting in a Scientific Revolution. William Harvey's discovery of the circulation of blood is considered to be the beginning of modern experimental physiology.

4. Over the next several centuries, there were many significant discoveries about body function. Currently, physiology is considered a mature science because most of the functions at the organ and systems levels have been elucidated. Physiologists are currently focusing on describing functions at the cell and molecular levels.

5. Because physiology is a science, knowledge about the body is obtained in a systematic way by using the scientific method. There are four steps to the scientific method: (1) make an observation, (2) formulate a hypothesis, (3) design an experiment to test the hypothesis, and (4) interpret the data.

6. As a physiologist studies body function, valuable information can be obtained by researching scientific literature. Sources of scientific information include journals, books, and the Internet.

7. The mechanistic approach to explaining body function describes how a particular event in the body occurs using cause-and-effect sequences.

8. Concept mapping is the process in which pieces of information are graphically displayed to illustrate their relationship to one another.

1.6 Key Themes of Physiology

1. Four key themes of physiology reoccur throughout this textbook: homeostasis, integration, mechanism of action, and communication.

2. Homeostasis is the maintenance of relatively stable conditions in the body's internal environment.

3. Integration is the process by which several components work together for a common purpose.

4. Mechanism of action refers to the cause-and-effect sequence that is used to describe a physiological event.

5. Communication is the process by which different parts of the body communicate with one another.

Ponder This

1. It is a cold day outside (50°F) and you have left for class without taking your jacket. Once you start walking across campus, the cold receptors in your skin start firing action potentials to the brain. The brain integrates the incoming information and sends an output signal to your skeletal muscles and the blood vessels in your skin. Your skeletal muscles start to produce rapid contractions causing you to shiver, while the blood vessels of your skin constrict, pulling blood away from the cold environmental air. These two compensation mechanisms reduce further loss of heat as well as help with the production of new heat. For this scenario, properly identify the stimulus, receptor, control center, effector, and response and explain what type of feedback mechanism this represents.

2. You are a prestigious scientist working in a lab with the hope to create a drug that will burn fat twice as fast when combined with exercise compared to exercise alone. You have gone through many research articles to investigate the effects that others have found on exercise and burning fat. You find that exercise is correlated with the amount of fat that can be burned, and decide to go ahead with your study. You design an experiment that includes 2 study groups, each with 100 subjects. Both groups are instructed to adhere to a strict diet and a daily exercise routine of 30 minutes on a treadmill, walking 3.0 mph. Group 1 receives a sugar pill while group 2 receives your new drug. Provide your hypothesis, independent and dependent variables, and the control for your study.

3. If you were to drink a gallon of salt water, assuming that all of this salt water is absorbed into the body, which fluid compartment would be first, and most directly, impacted by this fluid? Defend your answer.

Answers to Figure Questions

1.1 An organ (the organ level) is composed of two or more different types of tissues that work together to perform a specific function.

1.2 Responsiveness is the life process that allows you to turn your head in the direction of squealing brakes.

1.3 Interstitial fluid is the fluid between cells; plasma is the fluid portion of blood.

1.4 A nutrient moves from the external environment into plasma via the digestive system, then into the interstitial fluid, and then to a body cell.

1.5 In negative feedback systems, the response reverses the original stimulus, but in positive feedback systems, the response enhances the original stimulus.

1.6 When something causes blood pressure to decrease, heart rate increases because of operation of this negative feedback system.

1.7 Because positive feedback systems continually intensify or reinforce the original stimulus, some mechanism is needed to end the response.