An Introduction to Structure and Function

The human body is a marvel of structure and function made from billions and billions of cells. These cells combine to form tissues, such as muscle and connective tissue. Tissues, in turn, combine to form organs. Organs perform specific functions like respiration or food digestion. Organs that perform related functions form the organ systems of the body.

Body Tissues

The human body consists of four tissue types: (1) epithelial, (2) connective, (3) muscle, and (4) nervous. These are called the **primary tissues**. Each primary tissue consists of two or three subtypes. Muscle tissue, for instance, comes in three varieties discussed shortly.

The primary tissues exist in all organs in varying amounts. The wall of the stomach, for example, consists of a single layer of epithelial (e-peh-THEE-lee-il) cells forming the inner lining that provides a protective coating (**FIGURE 1-1**). Just beneath the epithelial lining is a layer of connective tissue that joins or connects the epithelial layer to the next layer, a thick sheet of smooth muscle cells. It forms the bulk of the stomach wall. Nerves enter with the blood vessels and control the flow of blood in the stomach. With this overview, let's take a look at each primary tissue.

Epithelium. Most epithelial tissues form internal and external linings of the organs of the body. However, some epithelial tissue forms vital glands. The epithelium forming linings or coverings typically consist of one or more layers of cells (**FIGURE 1-2**). The number of layers often reflects their function. The epithelial lining of the intestine, for example, consists of a single layer of cells, ideal for absorbing food molecules. In contrast, skin consists of many layers, providing much-needed protection.

As just noted, some epithelial cells form glands of the body during embryonic development. Some of these glands remain connected by hollow ducts to the epithelial layer from which they were formed. The glands release their products into the ducts that deliver them to the proper location. In humans, sweat glands are formed this way. These glands produce a clear, watery fluid that is released onto the surface of the skin through ducts. This fluid evaporates from the skin, cooling us off on a hot summer day.

Some glands break off completely during embryonic development. Their products, called hormones, are released into blood vessels inside the gland and then transported throughout

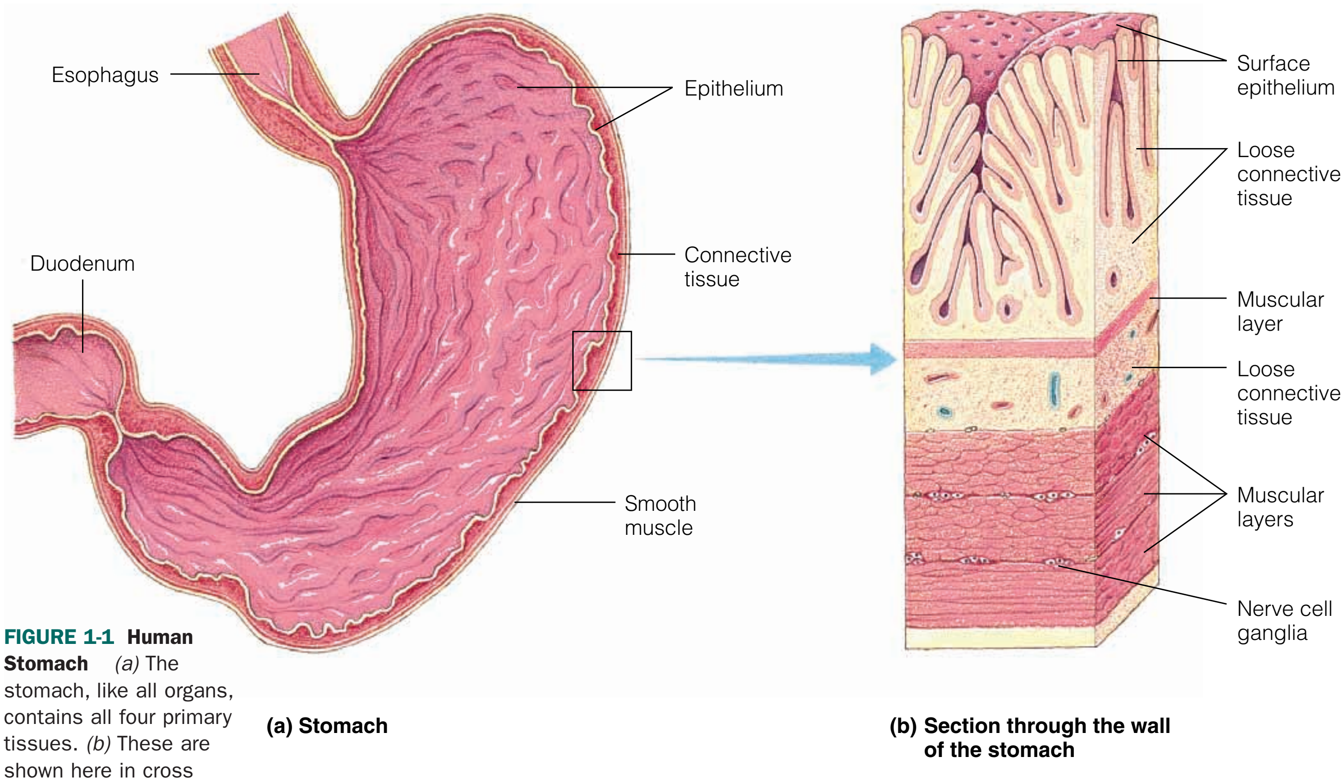


FIGURE 1-1 Human Stomach *(a)* The stomach, like all organs, contains all four primary tissues. *(b)* These are shown here in cross section.

the body in the bloodstream. These are known as endocrine glands. A good example is the thyroid gland in the neck. It produces hormones that stimulate metabolism.

Connective Tissue. As the name implies, connective tissue binds cells and other tissues together. Present in all organs in varying amounts, connective tissue consists of two basic components: cells and varying amounts of extracellular material, such as fibers.

The body contains several types of connective tissue, each with specific functions (**FIGURE 1-3**). Some connective tissue consists of a loosely knit mesh of fibers and cells and is known as *loose connective tissue*. It serves as a packing material around cells. Fat cells are often located in this type of connective tissue.

Fat cells often contain huge fat globules that press the cytoplasm and the nucleus of the cells to the outside (Figure 1-3). Fat cells occur alone or in groups of varying size. When a loose connective tissue contains many fat cells it is called fat or **adipose tissue**. Fat tissue is an important storage depot for energy and also provides insulation against cold.

Also located in loose connective tissue is a group of cells that help guard us against bacterial infections. They are known as macrophages, a fancy name for "big eaters." These cells get this name because they can gobble up bacteria that enter tissues from the blood stream or directly when a tissue is damaged, and thus provide protection from infection.

Other connective tissue consists primarily of densely packed fibers. Known as *dense fibrous connective tissue*, it is found in tendons and ligaments. **Ligaments** are one type of dense connective tissue. Ligaments are structures that reinforce joints. They join bones to bones at joints. Tendons are another type of dense connective tissue. They connect muscles to the bones of the body. When a muscle contracts, its tendon pulls on the bone, causing movement.

Specialized Connective Tissues. The human body also contains three types of specialized connective tissue: cartilage, bone, and blood.

Cartilage is found in many parts of the body—for example, the tip of the nose, the ears, the ends of the long bones, and between the bones of the spine. Cartilage has no blood vessels and must be nourished by nutrients that come from blood vessels surrounding this tissue. For this reason, cartilage heals very slowly, if at all, when damaged.

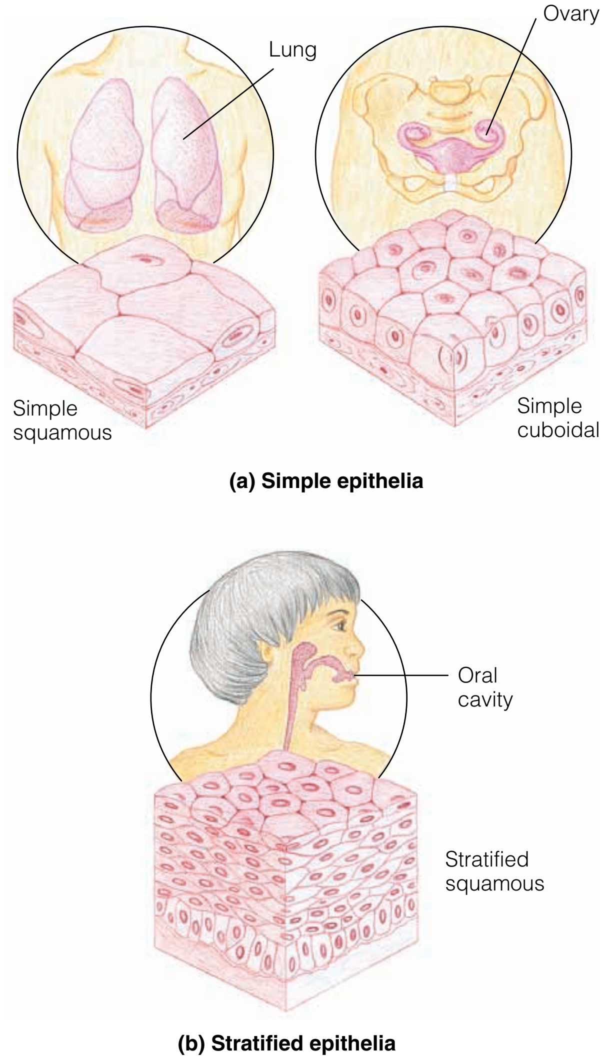


FIGURE 1-2 Membranous Epithelia *(a)* Single-celled (simple) epithelia and *(b)* stratified epithelia exist in different parts of the body.

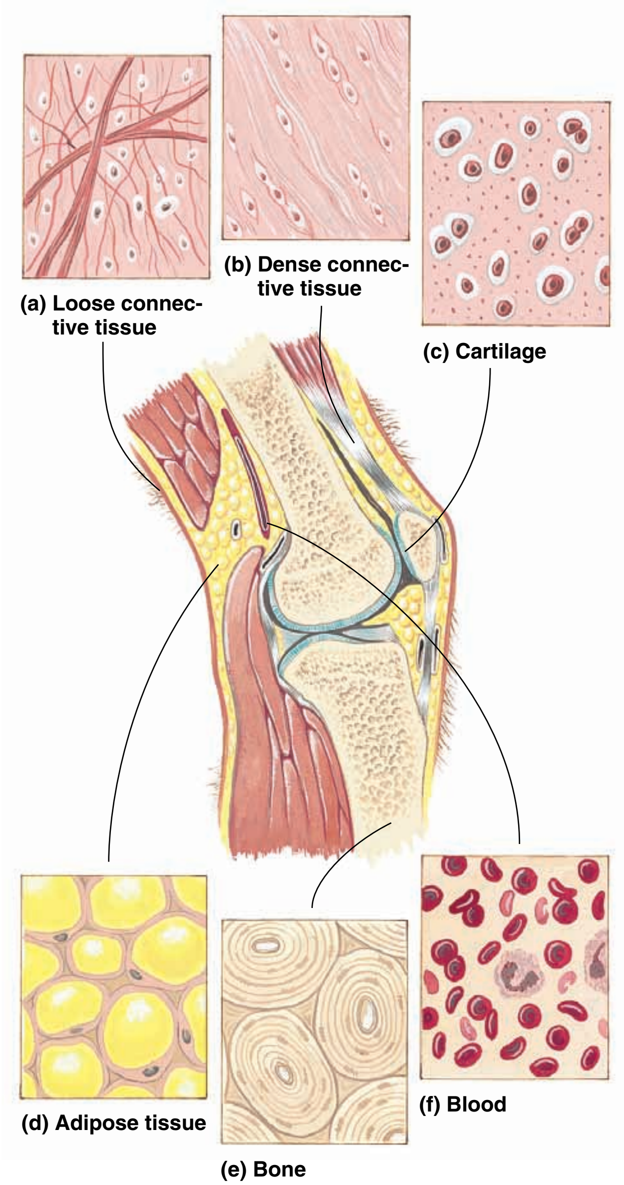


FIGURE 1-3 Connective Tissue Connective tissue consists of many diverse subtypes, shown here.

Bone is dynamic, living tissue that forms the internal framework of our bodies—our skeleton. Some bones provide protection to internal organs, such as the brain, heart, and lungs. Besides providing support and protecting organs, bone acts as a calcium reserve that helps us maintain proper blood calcium levels in the bloodstream. Calcium is required for many body functions, such as muscle contraction, nerve functioning, and blood clotting.

Blood. Blood consists of two types of cells: red blood cells and white blood cells. Blood also contains cell fragments called *platelets*. The cells and platelets are suspended in a fluid called plasma.

Red blood cells transport oxygen to the cells of the body from the lungs and transport waste carbon dioxide to the lungs for removal. **White blood cells** are involved in fighting infections and cancer. **Platelets** play a key role in blood clotting.

Muscle. Muscle gets its name from the Latin word for "mouse" (mus). Early observers likened the contracting muscle of the biceps to a mouse moving under a carpet.

When muscle contracts, it causes body parts like the arms and fingers to move. Working in large numbers, muscle cells can create enormous forces. Muscles of the jaw, for instance, create a pressure of 200 pounds per square inch, forceful enough to

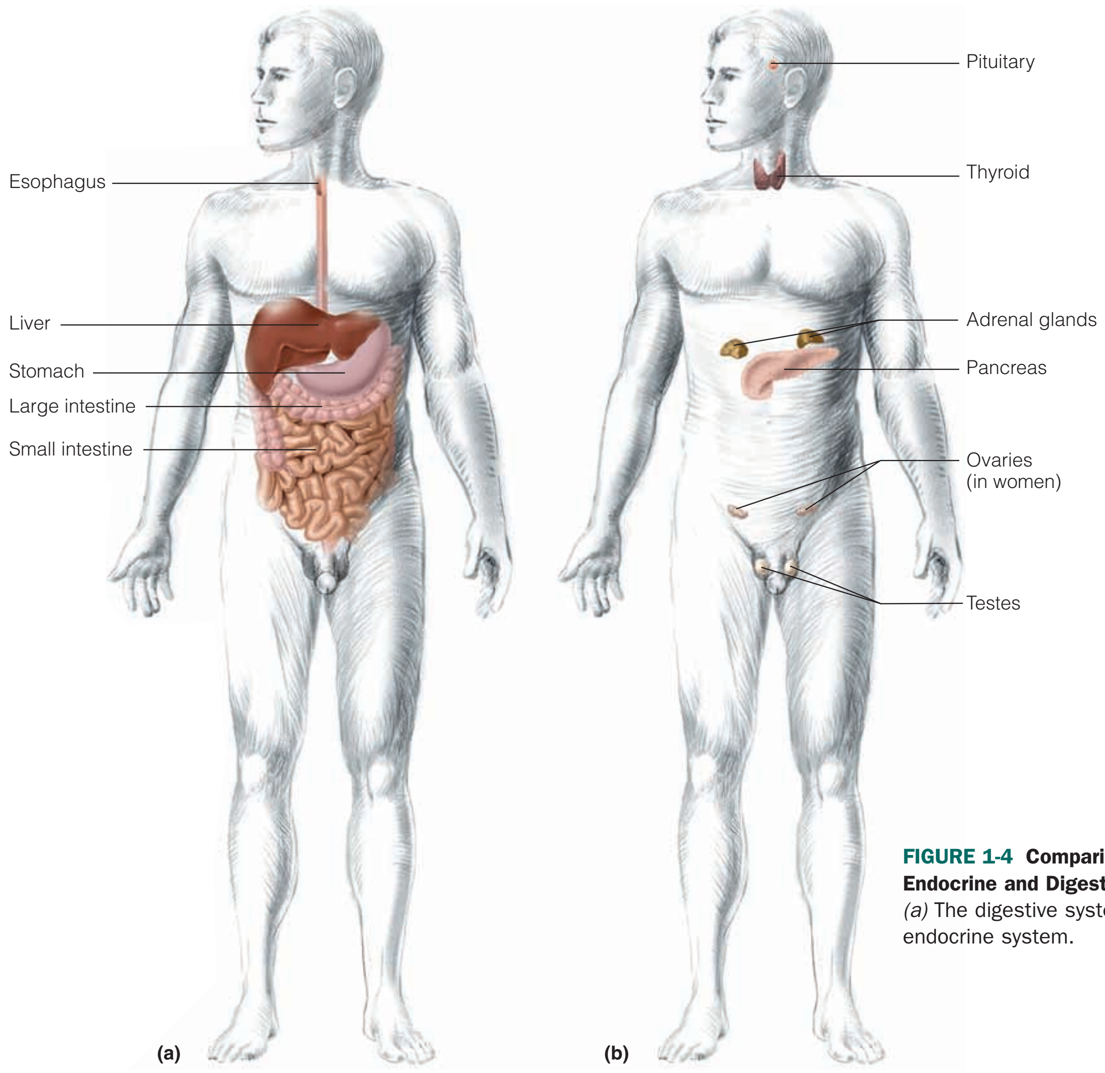


FIGURE 1-4 Comparison of the Endocrine and Digestive Systems *(a)* The digestive system. *(b)* The endocrine system.

snap off a finger. (Don't try this at home.) Muscle also propels food along the digestive tract and expels the fetus from the uterus during birth. Heart muscle contracts and pumps blood through the 50,000 miles of blood vessels in the body. Acting in smaller numbers, muscle cells are responsible for intricate movements, such as those required to play the piano or move the eyes.

As mentioned earlier, three types of muscle are found in humans: skeletal, cardiac, and smooth. The majority of the body's muscle is called **skeletal muscle**—so named because it is usually attached to the skeleton. Most skeletal muscle in the body is under voluntary control.

Cardiac muscle looks a bit like skeletal muscle, but is involuntary—that is, it contracts without conscious control. It is found only in the walls of the heart.

Smooth muscle occurs alone or in small groups. Smooth muscle cells are most often arranged in sheets in the walls of organs, such as the stomach and intestines (Figure 1-1). Smooth muscle cells in the wall of the stomach churn the food, mixing the stomach contents, and force the liquefied food into the small intestine. Smooth muscle contractions also propel the food along the intestinal tract. Smooth muscle cells are associated with many blood vessels. Small rings of smooth muscle cells, for example, surround tiny blood vessels in tissues. When these cells contract, they shut off or reduce the supply of blood to tissues.

Nervous Tissue. Last but not least of the primary tissues is nervous tissue. Nervous tissue consists of nerve cells, or **neurons**, that respond to stimuli, such as pain or temperature. Stimulation of these cells results in tiny bioelectric impulses. Neurons transmit these impulses from one region of the body to another, helping control movements and other functions.

The other type of cell found in nervous tissue is a kind of nervous system connective tissue. These cells are incapable of conducting impulses, but they perform other important functions. For example, they transport nutrients from blood vessels to neurons and form a barrier to many potentially harmful substances. Together, the neurons and their supporting cells form the brain, spinal cord, and nerves of the nervous system.

Organs and Organ Systems

Organs are structures in the body that perform specific functions. Organs with similar function, like the heart and blood vessels, form **organ systems**.

As you will see in upcoming modules, components of an organ system are sometimes physically connected—as in the digestive system. In other cases, they are dispersed throughout the body—as in the endocrine system, the system that produces hormones (**FIGURE 1-4**). Some organs belong to more than one system. The pancreas, for instance, makes hormones, so is part of the endocrine system. It also produces digestive enzymes, so it is also part of the digestive system.

Later modules describe the major organ systems and the functions each performs, paying special attention to their role in *homeostasis* (hoe-mee-oh-stay-siss), described next.

Principles of Homeostasis

The body's many systems perform specific functions that help us move about in our environment, perform work or play, and survive. Many of these systems also contribute to homeostasis. This process, as you will soon see, is essential for maintaining internal conditions vital to the survival of cells, tissues, and organs—and to our own survival as well.

Homeostasis is a state of relative internal constancy. Homeostasis is maintained by a process called negative feedback. **Negative feedback** is best illustrated by studying how a home heating system operates.

In the winter, the furnace of a house maintains a constant internal temperature, even though the

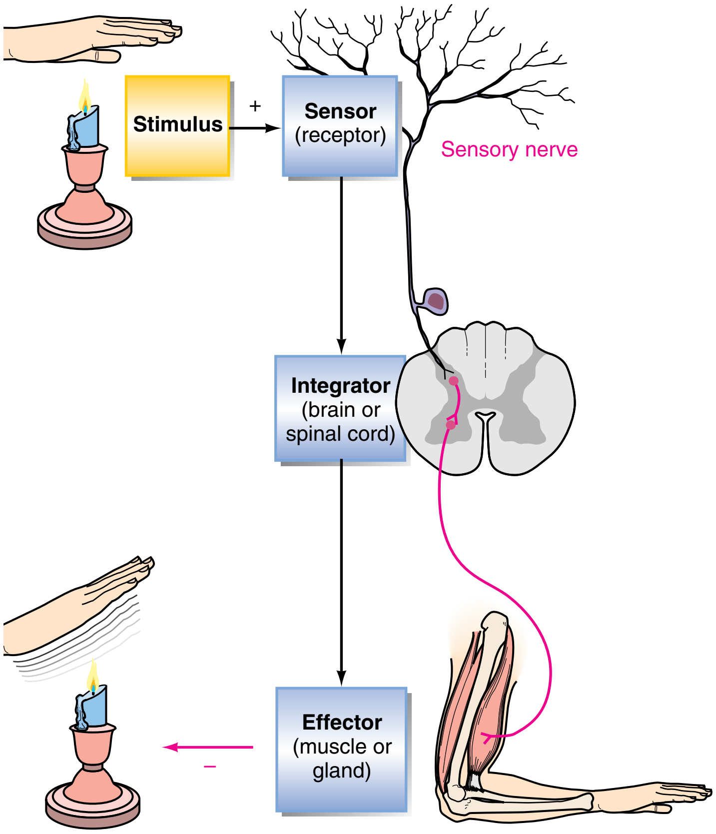


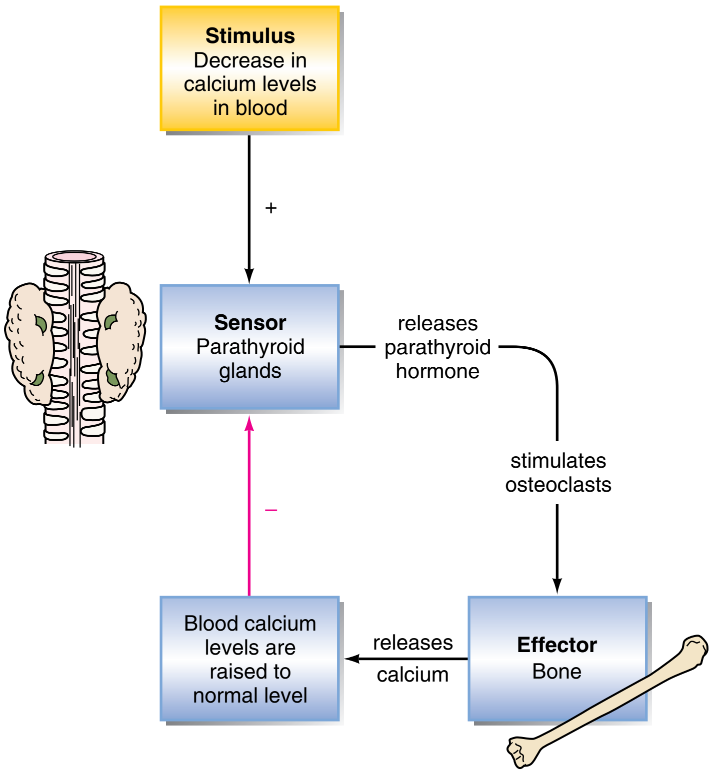
FIGURE 1-5 Nervous System Reflex Reflexes involve some kind of stimulus, a sensor, an integrator, and an effector. The sensor detects a change and sends a signal to the integrator, the brain or spinal cord, which then elicits a response in the effector organs. Negative feedback from the effector eliminates the stimulus.

outside temperature fluctuates dramatically. The furnace is controlled by a thermostat, which monitors room temperature. When the indoor temperature falls below the desired setting, the thermostat sends an electric signal to the furnace, turning it on. Heat is generated by the furnace and is then distributed throughout the house, raising the room temperature. When the room temperature reaches the desired setting, the thermostat shuts the furnace off. This is a negative feedback mechanism.

Systems in the human body that maintain homeostasis operate similarly, but like the furnace they do not maintain absolute constancy. Rather, they maintain conditions such as body temperature within a given range around a set point.

As you will see in later modules, our bodies maintain fairly constant levels of a great many chemicals, such as hormones and nutrients. They

FIGURE 1-6 Endocrine Reflex Not Involving the Nervous System This reflex operates through the bloodstream. A decrease in calcium in the blood stimulates a series of reactions that restores normal blood calcium levels. A plus sign indicates that the stimulus increases parathyroid gland activity; a minus sign indicates the opposite effect.



also maintain relatively constant physical conditions, such as body temperature and blood pressure. All of this is done automatically.

Homeostasis in the human body requires **sensors** that detect changes in internal and external conditions and **effectors** that make adjustments for these conditions. In your home, the thermostat is the sensor, and the furnace is the effector.

The human body contains many sensors. Specially modified nerve cell endings in the skin, for instance, detect temperature in the environment. The nerves send signals to the brain, alerting it to changes. The brain then sends signals to the body to correct matters—in this instance, to increase heat production.

Most homeostatic mechanisms are **reflexes**—that is, automatic responses triggered by internal and external stimuli. Two types of reflexes exist: nervous system and hormonal.

Homeostatic systems controlled by the nervous system are fairly straightforward. As shown in **FIGURE 1-5**, heat from a candle is detected by sensors in the skin. These receptors send nerve impulses to the spinal cord via sensory nerves. The spinal cord, in turn, sends a signal to pull the hand away from the flame. That's a nervous system reflex.

Hormones are chemical substances produced by certain glands in the body, known as *endocrine glands*. Released into the blood, hormones travel to distant sites where they cause some kind of change. Hormones don't just pour out of endocrine glands in a constant stream, however. They are released only under certain circumstances, usually as part of a chemical reflex. When calcium levels in the blood fall below a certain concentration, for example, tiny glands in the neck, known as the *parathyroid glands* (pair-ah-THIGH-roid), release a hormone (parathyroid hormone). It travels in the blood to the bone (**FIGURE 1-6**). Here it stimulates certain cells that literally digest small amounts of bone, releasing calcium stored in the bone into the bloodstream. This, in turn, raises the calcium level of the blood. Calcium levels return to normal.

Health and Homeostasis

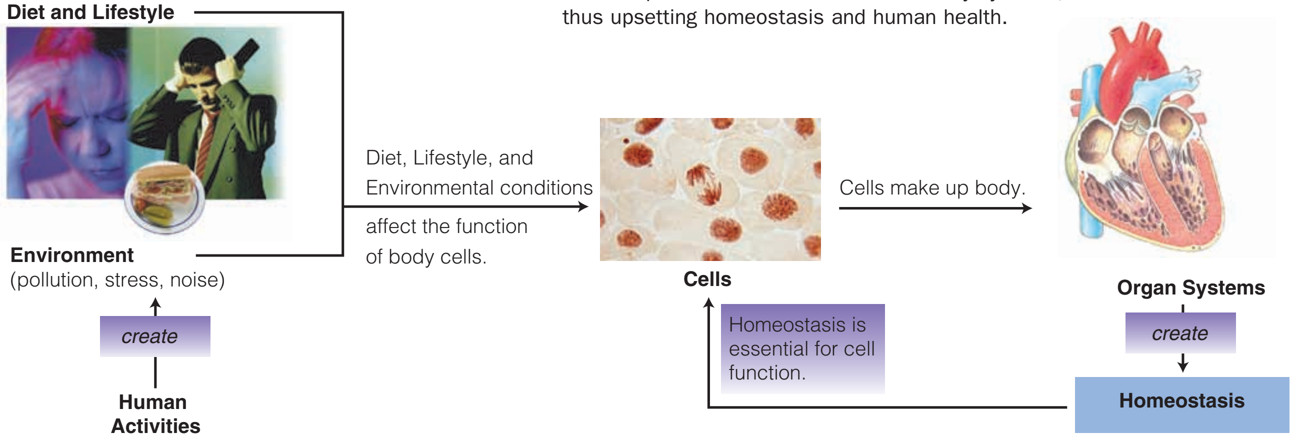
Human health is dependent on homeostasis. When homeostasis is altered, we become sick, and can even die. Homeostasis, in turn, requires a healthy, clean environment.

The relationship between homeostasis and health is shown in **FIGURE 1-7**. Take a moment to study this diagram. Notice that the body systems (right side of diagram) maintain homeostasis. Homeostasis, in turn, is essential for proper cell function. Because cells make up organs of the body, which are vital to survival, the health of all cells is essential to our well-being and survival. As the diagram shows, environmental factors, such as pollution, affect the function of cells and organ systems in ways that can upset the internal balance, harming human health, even causing death.

Biological Rhythms

The previous discussion may have given you the impression that homeostasis establishes an unwavering condition of stability that remains more or less the same, day after day, year after year. In truth, many body processes undergo daily or monthly changes. Body temperature, for example,

FIGURE 1-7 Health, Homeostasis, and the Environment Human health is dependent on maintaining homeostasis. Homeostasis, however, is affected by the condition of our environment. Stress, pollution, noise, and other environmental factors upset the function of cells and body systems, thus upsetting homeostasis and human health.



varies during a 24-hour period by as much as a half degree Celsius. Blood pressure may change by as much as 20%, and the number of white blood cells, which fight infection, can vary by 50% during the day. Alertness also varies considerably. About 1:00 P.M. each day, for instance, most people go through a slump. For most of us, activity and alertness peak early in the evening, which, by the way, makes this an excellent time to study. Daily cycles are natural body rhythms linked to the 24-hour day-night cycle.

Many hormones follow daily cycles. The male sex hormone testosterone, for example, is released in a 24-hour cycle. The highest levels occur in the night, particularly during dream sleep, also known as **REM sleep**. Dream sleep occurs primarily in the early morning hours.

Not all cycles occur over 24 hours, however. Some can be much longer. The menstrual cycle, for instance, is a recurring series of events in the reproductive systems of women. It lasts, on average, 28 days. During the menstrual cycle, levels of the female sex hormone estrogen undergo dramatic shifts. Estrogen concentrations in the blood are low at the beginning of each cycle and peak on day 14, when ovulation (release of the egg) normally occurs. Throughout the remaining 14 days, estrogen levels are rather high. They drop off again when a new cycle begins. Estrogen levels follow this cycle month after month in women of reproductive age.

The important point here is that the body is not static. Although many chemical substances are held within a fairly narrow range by homeostatic mechanisms, others fluctuate widely as part of normal body cycles. Over the long run, these changes are quite predictable.

Internal biological rhythms are controlled by the brain. Just how the body controls its many internal rhythms remains a mystery. Research suggests a clump of nerve cells in the base of the brain in a region called the *hypothalamus*. It may regulate other control centers and is often referred to as the "master clock."

Ultimate control of the master clock is thought to occur in a gland in the brain known as the *pineal gland* (PIE-nee-al). It secretes a hormone thought to keep the master clock in sync with the 24-hour day-night cycle.

The study of biological rhythms is a fascinating field that has yielded some important insights. One practical application is a better understanding of jet lag—that drowsy, uncomfortable feeling people get from the disruption of sleep patterns caused by long-distance jet travel. Studies suggest that jet lag occurs when the body's biological clock is thrown out of sync with the day-night cycle of a traveler's new surroundings. A business woman who travels from Los Angeles to New York, for instance, may be wide awake at 11:00 P.M. New York time because her body is still on Los Angeles time—3 hours earlier. When the alarm goes off at 6:00 A.M., our weary traveler crawls out of bed exhausted. As far as her body is concerned, it is 3:00 A.M. Los Angeles time.

Probably the greatest disrupter of our natural body rhythms is the variable work schedule, which is surprisingly common among industrialized nations. It is used to keep factories running 24 hours a day to maximize profits and keep up with production. Workers on alternating shifts suffer from a higher incidence of ulcers, insomnia, irritability, depression, and tension than workers on regular shifts. Making matters worse, tired, irritable workers may suffer from impaired judgment, posing a threat not only to themselves but also to society. Fortunately, researchers are finding ways to reset the biological clock, which could reduce the problems shift workers face and thereby increase work performance, particularly of those on the graveyard (overnight) shift.