4.2 Adaptations for Homeostasis

4.2 VOCABULARY			
AIDS	cancer	guard cells	positive feedback
antibodies	contagious diseases	negative feedback	stimulus
antigens	dynamic equilibrium	pathogens	tumor

Living organisms are always dealing with change. Waste products build up as a result of cell metabolism, disease organisms enter the body, and the environmental temperature falls quickly—all possible ways that things can begin to get out of control.

From bacteria and protozoans to plants and animals, all organisms must respond to such changes on a regular basis. If things don't function properly and the organism does not respond appropriately, it may be unable to survive.

Sensing and Responding to Change

Because an organism's external and internal environment is constantly changing, its homeostasis is constantly threatened. As a result, living things must monitor and respond to changes in the environment. A change in an organism's environment is called a **stimulus**. Failure to detect critical stimuli, either within the organism or in the external environment, could be fatal.

Single-celled organisms are able to detect changes that signal the presence of food or danger. They are sensitive to chemical changes in their environment, such an increase in salt concentration that may be harmful. Some use cilia and others use flagella to move away from the potential danger.

Some protozoans are capable of photosynthesis. One, the euglena, even has an "eye spot" in the cell that is able to detect the presence of light. When it senses light, it uses its flagellum to move toward the light. Freshwater protozoans can also detect when too much water has entered the cell from the surrounding environment and activate their contractile vacuoles to deal with it.

Plants do not have nervous systems, but they are capable of many responses to changes in their environment. Many produce hormones that circulate through the vascular system or pass from cell to cell to regulate activity. The light plants normally receive comes from above the plant. If a plant is given light from one side, as shown in Figure 4-10, plant growth hormones will cause cells on the darker side of the stem to grow longer than those on the lighted side, which results in the stem bending toward the source of light.

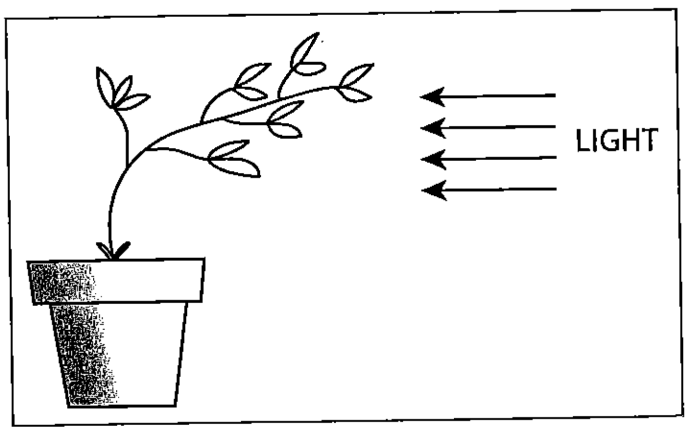

Figure 4-10. Plant hormones influence growth toward light.

Plants and some animals can also sense changes in the length of daylight. As seasons change, days get longer or shorter. Detecting these changes is important for animals that migrate or hibernate, for plants that lose their leaves for the winter, and plants that flower at the best time of year for reproductive success.

Multicellular organisms can detect and respond to change at both the cellular and the organismal level. In animals, one such adaptation is a nervous system. Animals exhibit a variety of

Table 4-2: Responses to Environmental Change		
Organism	**Change (stimulus)**	**Response**
A bacterial species	Temperature falls below a certain point	The bacteria produce a chemical that acts like antifreeze.
Many plants	Air is hot and dry	Stomates in leaves close to conserve water.
Monarch butterflies	Detect bright colors	The butterflies fly toward nearby flowers.
Rabbits	Hear a loud noise	Hormones are released that increase alertness and speed up heart rate in case the rabbit must flee from danger.
Some plants	Feeding by insects	Plants release chemicals with bad taste to repel insect.

different types of nervous systems, ranging from simple to complex. A jellyfish has a very simple net-like system, yet it can sense that an object in the environment is touching it.

DID YOU KNOW?

Jellyfish also have a chemical sense to determine whether the object that touched it is food or not. If the object appears to be food, the jellyfish may fire specialized stinging cells in response and capture the prey. If the organism touching it is too large to be food, the stinging cell response serves as a defense mechanism.

Many animals have sensory organs as part of their nervous system. Eyes, ears, and antennae are all sense organs that have evolved over time. The nervous system of insects allows them to use the senses of sight and smell to find food. The nervous system also coordinates the beating of their wings as they fly toward the food. Many animals can detect changes in temperature, allowing them to respond by shivering, panting, sweating, or other means of keeping their body temperature within normal limits.

The endocrine system is another adaptation for responding to environmental changes—both internal and external. The endocrine system in some complex animals is made of several glands that produce hormones. Hormones are often released into the circulatory system in response to a stimulus detected by the nervous system. In some animals, environmental stimuli trigger the flow of sex hormones. These hormones may stimulate physical or behavioral changes in the animal associated with the breeding season.

Some additional examples of responses organisms have to changes they encounter are shown in Table 4-2.

Dynamic Equilibrium

Organisms have a variety of mechanisms that maintain the physical and chemical aspects of the internal environment within the narrow limits that are favorable for cell activities. Homeostasis is a result of these responses. Homeostasis is not always a steady, unchanging condition. It often involves constant small corrections around a normal level.

Dynamic equilibrium is the term used to describe the small corrections that keep the internal environment within the limits needed for survival. In Figure 4-11, on the following page, notice how these small corrections include a narrow range of variations. Certain microorganisms or diseases can interfere with dynamic equilibrium and therefore with homeostasis. Organisms have mechanisms to deal with such interference and restore the normal state. Homeostatic adjustments have their limits. They can operate only within certain set ranges.

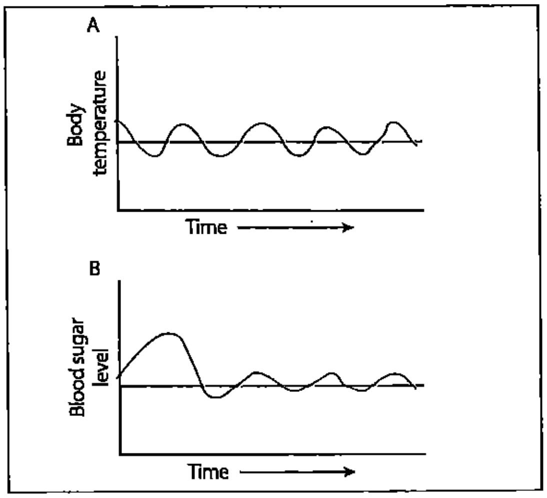

Figure 4-11. Dynamic equilibrium: (A) Temperature: The body temperature of many mammals and birds shows a regular pattern of slight changes around a "normal" temperature for the organism. The graph represents the slight differences in temperature that are part of a daily cycle. Mechanisms such as shivering, panting, or sweating may help maintain this range.
(B) Blood sugar: Normal blood sugar levels show a rise in blood sugar after a meal, but blood sugar level is quickly restored to equilibrium as the hormone insulin prompts glucose to move from the blood to body cells.

Feedback Mechanisms

A feedback mechanism involves a cycle in which the output of a system "feeds back" to either modify or reinforce the action taken by the system. A variety of feedback mechanisms have evolved for helping organisms detect and respond to stimuli. Multi-celled organisms detect and respond to change both at the cellular level and at the organismal level. Their systems detect departures from the normal state and take action to restore homeostasis.

Feedback responses can be simple or complex. A simple feedback response might involve a hormone that regulates a particular chemical process in a cell. A complex feedback response might be an elaborate learned behavior.

POSITIVE FEEDBACK Feedback mechanisms can also be either positive or negative. In systems involving **positive feedback**, a change prompts a response, which leads to a greater change and a greater response.

An early stage of childbirth is a positive feedback system. The first contractions push the baby's head against the base of the uterus, which causes stronger contractions in the muscles surrounding the uterus, which increases the pressure of the baby's head against the base of the uterus, which causes stronger contractions and so on. Eventually the baby is born, and the feedback cycle ends.

NEGATIVE FEEDBACK Negative feedback systems are the most common. In systems involving **negative feedback**, a change prompts a response, which then cancels or reduces the original response. In this case, a change in the environment can prompt system 1 to send a message, often a hormone, to system 2, which responds by attempting to restore homeostasis. When system 1 detects that system 2 has acted, it stops signaling for further action.

A typical house heating system is an example of negative feedback. The furnace has a thermostat that is set to a specific temperature called the set point. When the room cools below the set point, the thermostat sends a message to turn on the furnace. When the room temperature rises above the set point, the thermostat stops sending the message, and the furnace shuts down. (See Figure 4-12.)

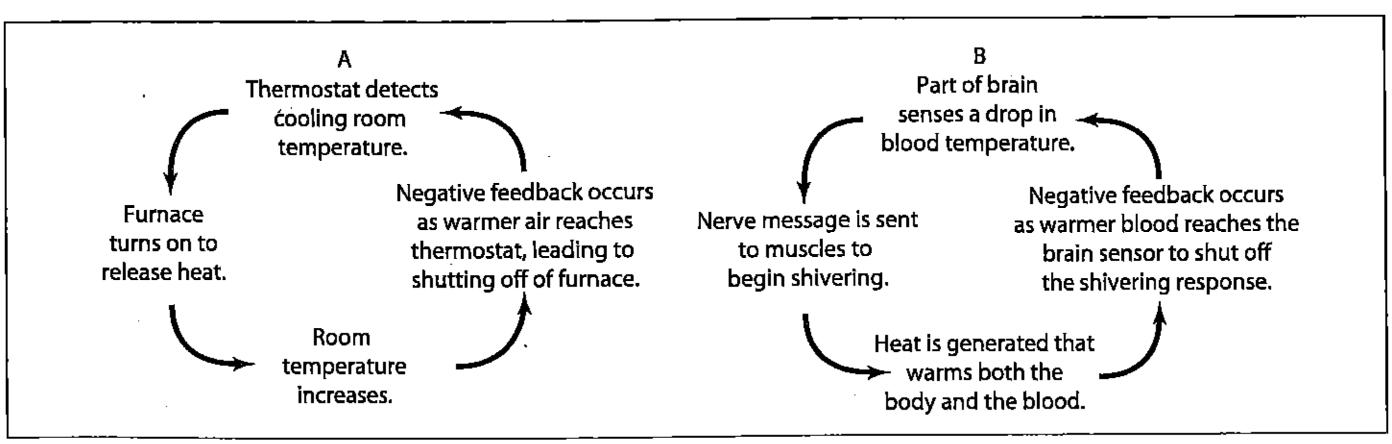

Figure 4-12. Negative feedback systems: (A) The furnace and thermostat in most houses are part of a negative feedback system. **(B)** Like the household heating system, the regulation of body temperature is a negative feedback system.

Regulating human body temperature uses a similar system. A structure in the brain detects a blood temperature that is too low. This brain structure then sends a signal to muscles, causing them to contract and relax in rapid cycles. The result is shivering, which generates body heat. When shivering has sufficiently warmed the body and blood, sensors in the brain detect the change, and the signal to shiver stops.

Cell/Organ Feedback Interactions

Maintaining dynamic equilibrium often involves interactions between cells and body organs or systems. For example, certain cells in the body monitor the level of glucose in the blood. When the glucose level is above normal limits, the pancreas, an organ of the endocrine system, secretes insulin. Insulin is a hormone that prompts glucose to move from the blood into body cells, resulting in a lower glucose level in the blood.

Another hormone secreted by the pancreas works in the opposite way. When the glucose level in the blood is too low, this second hormone prompts the release of glucose stored in the liver. The negative feedback process is shown in Figure 4-13.

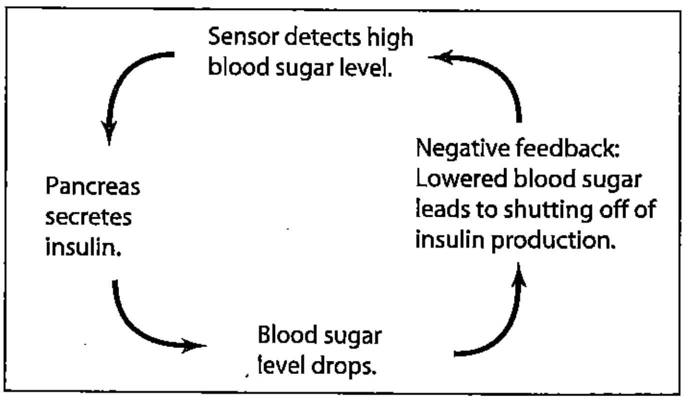

Figure 4-13. Negative feedback involving blood sugar level

Other examples of cell/organ feedback interactions include the following:

- Increased muscle activity often stimulates an increase in heart rate and breathing rate. If this did not occur, the muscles would not receive the increase in blood flow to provide the nutrients and oxygen they need to continue working.

- When leaves detect a water shortage (either due to a drought or just a very hot, dry day), **guard cells**—specialized cells that surround stomate pores on the surface of the leaf—change shape to close the stomates and reduce evaporation. When the stomates are open, water can exit from the leaf, and CO_2 can enter. This situation commonly exists when the sun is shining, the air is warm, and water is available in the soil. With the stomate pores closed, gas exchange is limited and photosynthesis slows down because little CO_2 is available. The process is shown in Figure 4-14.

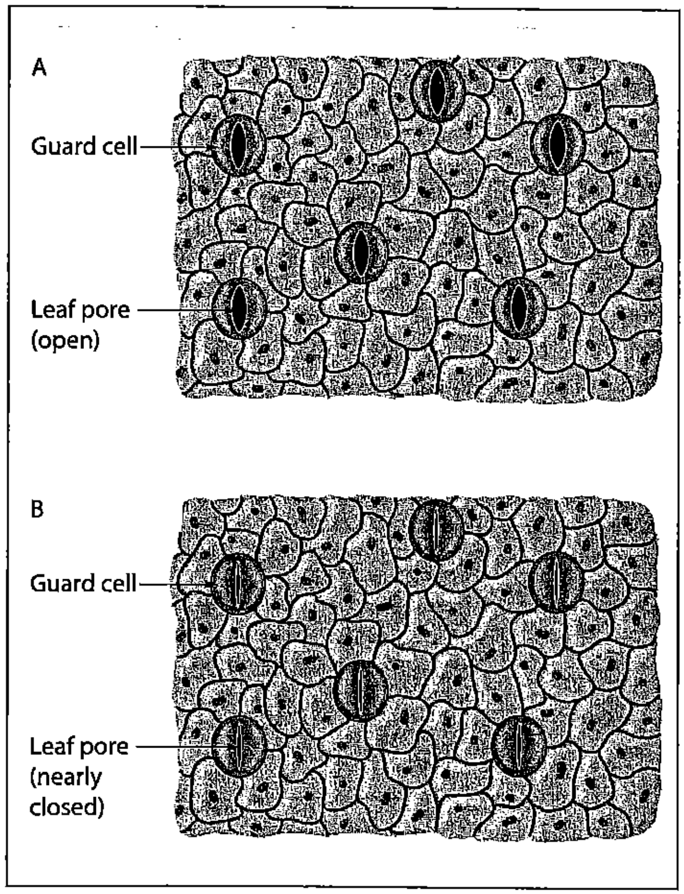

Figure 4-14. Guard cell activity on the surface of a leaf: **(A)** The guard cells have opened the pores (stomates) in the leaf, allowing gas exchange between the leaf and the environment. **(B)** The guard cells have nearly closed the pores in the leaf, thus protecting the leaf from drying out.

Disease and Homeostasis

Disease is any condition that prevents the body from working as it should. As a result, the body may fail to maintain homeostasis. Diseases in humans may be caused by infectious organisms, called pathogens, or result from abnormal cells in the body that lead to cancer. **Contagious diseases** are diseases caused by pathogens that can be passed from one person to another by direct or indirect contact. One example is the flu. The flu can spread from one person to another when the infected individual coughs or sneezes, or through physical contact. Disease may also result from toxic substances, poor nutrition, organ malfunction, an inherited disorder, or risky personal behavior. All can lead to a disruption of the body's ability to function normally—that is, to maintain homeostasis. Some examples of these kinds of diseases are noted in Table 4-3.

Table 4-3. Causes of Disease

Cause of Disease	Examples
Inherited disorders	Down syndrome, cystic fibrosis, sickle cell disease
Exposure to toxins	Lead poisoning, radiation poisoning
Poor nutrition	Scurvy (vitamin C deficiency), goiter (iodine deficiency)
Organ malfunction	Heart attack, diabetes
High-risk behaviors	Lung cancer, drug addiction, skin cancer, AIDS

PATHOGENS There are many potentially dangerous disease-causing organisms in the air, water, and food we take in every day. A variety of **pathogens**—viruses, bacteria, fungi, and other parasites—can interfere with normal functioning and cause serious illness. Plants and other animals can also be infected by these kinds of organisms. Some examples of pathogens and diseases they can cause are shown in Table 2-4.

CANCER Certain genetic mutations in a cell can result in uncontrolled cell division called **cancer**. Exposing cells to certain chemicals and radiation increases mutations and thus increases the chance of cancer. In this disease, genes that control and coordinate a cell's normal cycle of growth and division are altered by mutation. As a result, the cell begins to divide abnormally and uncontrollably. The result is a mass of abnormal cells called a **tumor**.

PROTECTION AGAINST DISEASE Plants, animals, and other living organisms are vulnerable to disease. Humans and other complex animals have the advantage of possessing a well-developed immune system. Plants and many simple animals also have a variety of adaptations that help protect them from pathogens.

Pathogens, foreign substances, and cancer cells have molecules on their outer surfaces that usually identify them to the immune system.

Table 4-4. Pathogens and Disease

Type of Pathogen	Description of Pathogen	Examples of Disease Caused by Pathogen
Viruses	Viruses are particles composed of nucleic acid and protein. They reproduce when they invade living cells.	Examples include the common cold, influenza, and AIDS.
Bacteria	Bacteria are one-celled organisms.	Bacterial illnesses include poisoning (from the toxins given off by some bacteria), strep throat, and food poisoning.
Fungi	Fungi include yeasts and molds. They eat by absorbing organic substances.	Examples include athlete's foot and ringworm.
Parasites	Some animals and one-celled organisms are parasites that survive by living and feeding on other organisms.	Parasites include leeches and tapeworms. Malaria and heartworm (a parasitic worm that lives in dogs and cats) are caused by parasites.

These molecules, called **antigens**, trigger a response from the immune system. Toxins, the poisonous wastes of certain pathogens, also can act as antigens.

All cells have potential antigens on their surfaces, but the immune system can usually tell the difference between the molecules of "self" cells, which belong to the body, and "non-self" (foreign) cells, which come from outside the body. When cells of our immune system recognize foreign antigens, specialized white blood cells and antibodies attack the cells bearing those antigens.

WHITE BLOOD CELLS AND ANTIBODIES Some white blood cells are specialized to surround and engulf invading pathogens that are recognized as a threat. Others produce **antibodies**—proteins that either attack the pathogens or mark them for killing. The marked pathogens may then be killed by other white blood cells. In Figure 4-15, notice the Y-shaped antibodies that match the shape of antigens.

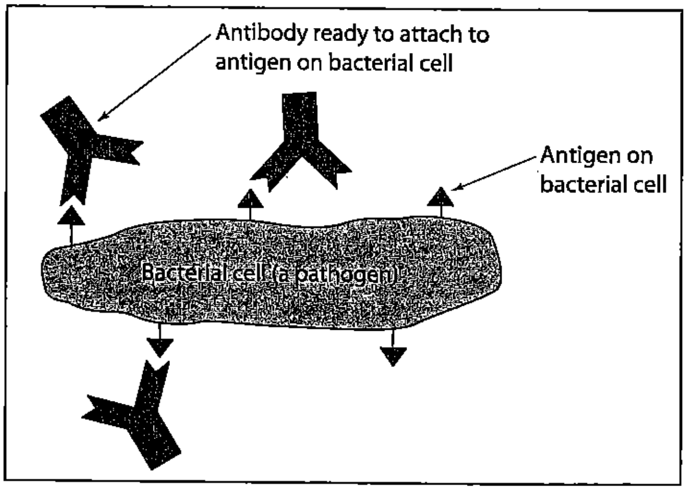

Figure 4-15. Certain white blood cells produce Y-shaped antibodies: The antibodies match the shape of certain antigens on pathogens or abnormal proteins on cancer cells. Note that the antibodies and antigens are not drawn to scale. They would be *much* smaller than the pathogen.

Most of the antibodies and white blood cells that attack an invader break down soon after they have defended the body. However, some specialized white blood cells remain. These cells are capable of quickly dividing and producing more antibodies of the same kind to fight off later invasions by the same invader.

DID YOU KNOW?

Remember germs? At one time, *germ* was the word of choice for people who were talking about the tiny living things that cause disease. Scientists now usually use the term *pathogen*. One reason is that the meaning of pathogen also includes viruses, those tiny "almost organisms" that don't quite fit the description of a living thing.

DAMAGE TO THE IMMUNE SYSTEM The immune system may weaken because of age or other factors. Stress and fatigue, for example, can lower our resistance and make us more vulnerable to disease. Some viral diseases, such as **AIDS**, result from an attack on the immune system. Damage from the disease may leave the person with AIDS unable to deal with infections and cancerous cells. A weakened immune system is one reason that people with AIDS often die of infections that a healthy immune system would easily destroy.