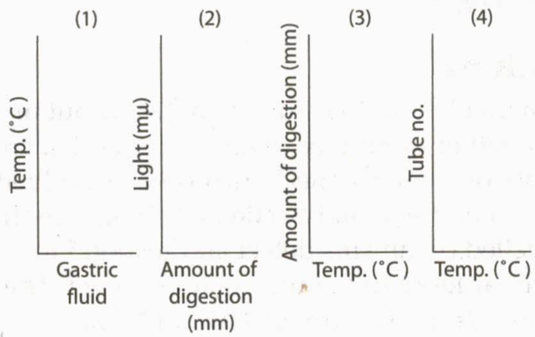
38. State the amount of digestion (in mm) that might be expected after 48 hours in a test tube that is identical to the other 5 test tubes, but at a temperature of 15°C.

(1) less than 2.5 mm
(2) between 2.5 and 4 mm
(3) between 4.0 and 7.5 mm
(4) more than 7.5 mm

39. The best graph of the results of this investigation would be made by plotting the data on which set of axes?



40. The student repeated this same experiment using a glass tube containing potato instead of egg white. After 48 hours, he found no evidence of any digestion.

Explain why no digestion occurred. [1]

41. During the winter, many fish eat very little. Some students thought this might be because less oxygen is dissolved in the cold winter water than in the same water during the warm summer months. The students tested the water and found that cold water holds more dissolved oxygen than warm water. They also discovered that the fish have nearly as much food available during the winter as in the summer.

Explain why the fish eat very little during the winter. [1]

Feedback and Homeostasis

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. Stability (homeostasis) results when the organism detects deviations (changes) in the environment and responds with an appropriate corrective action that returns the organism's systems to normal. If an organism's monitoring systems or control mechanisms fail, disease or even death can result.

As you go about your daily tasks, your body temperature readjusts, your heart and breathing rates alter slightly, and your blood flow increases or decreases. If your monitoring were to fail, these small adjustments would not be made. Soon, your body's homeostasis would begin to deteriorate. Under extreme conditions, you could become quite ill or even die. However, simple corrective actions usually take care of problems with your homeostasis and life goes on. Some examples of responses organisms have to changes they encounter are shown in Table 2-4.

Table 2-4. Responses to Environmental Change

Organism	Change (stimulus)	Response
Species of bacterium	Temperature falls below a certain point.	Bacterium produces a chemical that acts as an antifreeze.
Many plants	Air is hot and dry.	Leaf pores close to conserve water.
Monarch butterflies	Seasons change.	Butterflies migrate.
Human	Person hears a loud noise.	The person becomes alert; heart rate increases for "fight or flight."

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. The stability that results from these responses is called homeostasis or a "steady state." To many biologists, the phrase *steady state* suggests an

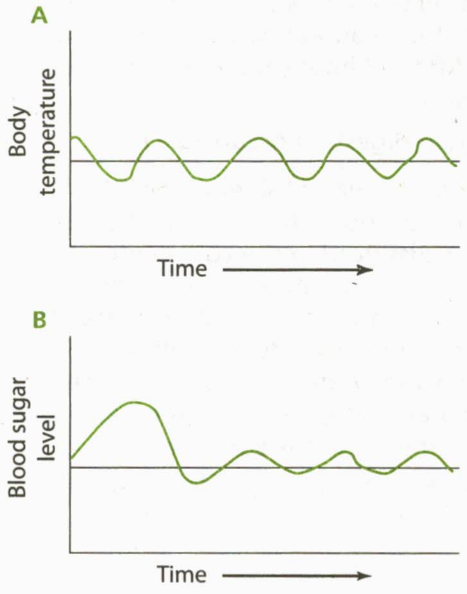


Figure 2-9. Dynamic equilibrium: (A) Temperature: Our body temperature shows a regular pattern of slight changes around a "normal" temperature of about 98.6°F (37°C). The graph represents the slight differences in temperature that are part of a daily cycle. Mechanisms such as shivering and sweating help 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.

unchanging condition. They prefer to use the term **dynamic equilibrium** to describe the constant small corrections that normally keep the internal environment within the limits needed for survival.

In Figure 2-9, notice that these small corrections include a normal range of variations. Certain microorganisms or diseases can interfere with dynamic equilibrium, and therefore with homeostasis. Organisms, including humans, 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.

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** (changes in the environment). Multi-celled organisms detect and respond to change both at the cellular level and at the organism level. Their systems detect deviations from the normal state and take corrective actions 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 behavior, such as bird migration.

Positive Feedback Feedback mechanisms can be either positive or negative. In positive feedback systems, a change prompts a response, which leads to a greater change and a greater response. Childbirth is an example of 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. This 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.

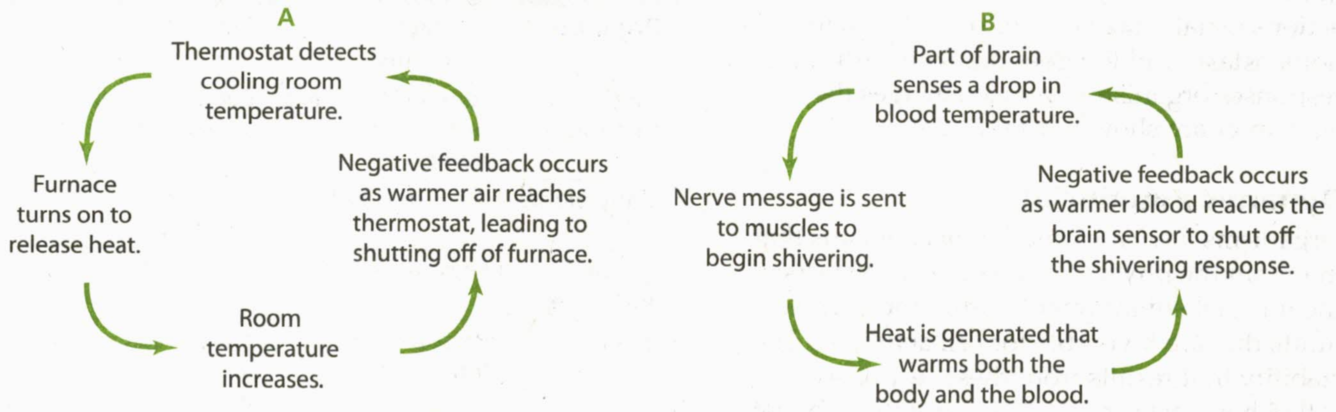


Figure 2-10. Negative feedback systems: (A) The furnace and thermostat in most houses are part of a negative feedback system. (B) Like the household heating system, the regulation of body temperature is a negative feedback system.

Negative Feedback Negative feedback systems are the most common. 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 2-10.)

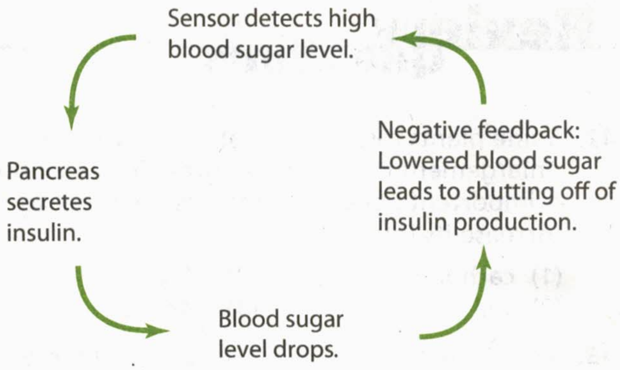


Figure 2-11. Negative feedback involving blood sugar level

Regulating human body temperature uses a similar system. A structure in the brain detects that the temperature of the blood 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.

Negative Feedback and Cell/Organ System Interaction

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, an endocrine organ called the **pancreas** 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 hormone prompts the release of glucose stored in the liver. The negative feedback process involving insulin is shown in Figure 2-11.

Other examples of cell/organ feedback interactions include:

- Increased muscle activity is often accompanied by an increase in heart rate and breathing rate. If this did not occur, the muscles would not receive the increase in blood flow and oxygen they need to continue working.
- When plant leaves detect a shortage of water, **guard cells**—specialized cells that surround pores on the surface of the leaf—change shape to close the pores and reduce evaporation. The process is shown in Figure 2-12.

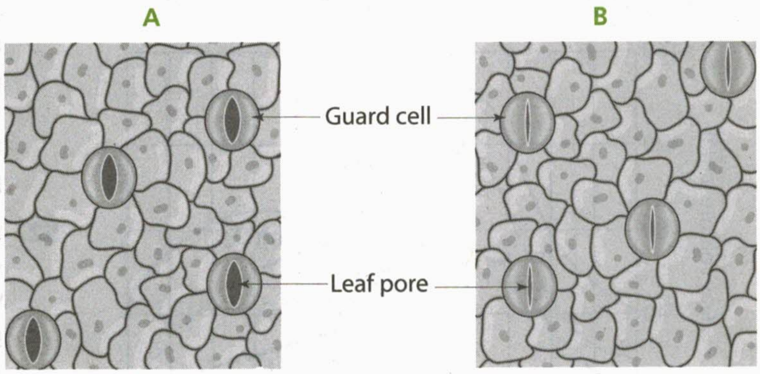


Figure 2-12. Guard cell activity on the surface of a leaf: (A) The guard cells have opened the pores in the leaf, allowing gas exchange between the leaf and the environment. Water can exit from the leaf, and CO_2 can enter. This situation commonly exists when the sun is shining, the air is warm, and water is available from the soil. (B) The guard cells have nearly closed the pores in the leaf, thus protecting the leaf from drying out. Under these conditions, gas exchange is limited. Photosynthesis slows down because little CO_2 is available. This situation commonly exists when the sun is shining, the air is hot and dry, and little water is available from the soil.