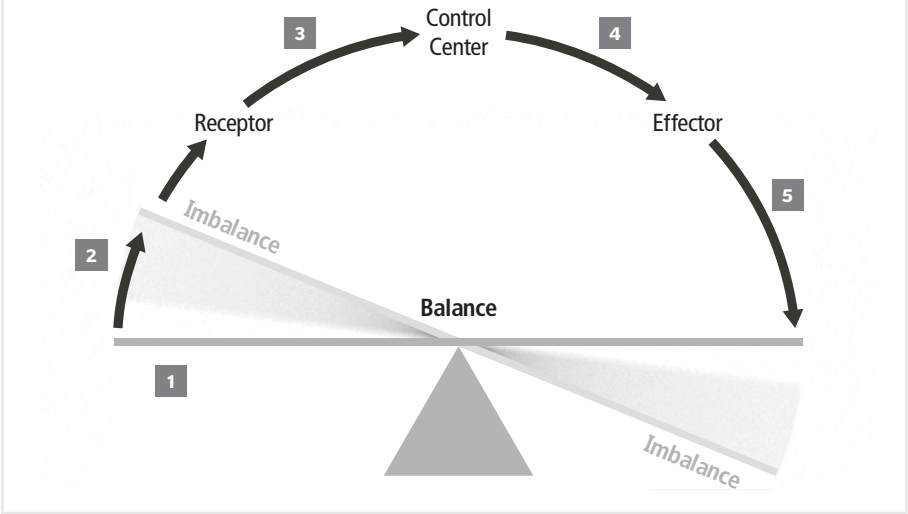
Control Systems in Organisms

External and internal factors such as temperature changes, infection, stress, and pollution challenge the stability of an organism. In the same way that a cell must maintain stable conditions, an organism must maintain stability despite changes in its internal state or within the environment in which it lives.

Control Systems

Fortunately, the body has many control systems that keep its internal environment stable. Together, these control systems are responsible for maintaining homeostasis. Homeostasis is the regulation and maintenance of the internal environment within the narrow ranges that are necessary to support life at the cellular level.

FIGURE 2: Control systems maintain homeostasis.



As shown in Figure 2, homeostasis is maintained through the following steps:

1. A stimulus is anything from the internal or external environment that causes an imbalance in the internal conditions of a cell, organ, organ system, or organism.
2. Stimuli are detected by receptors. There are thousands of internal receptors, as well as specialized receptors that detect information about changes in the organism's external environment.
3. The receptor sends information to a control center, often in the central nervous system. The control center compares the information to set points. Set points are ideal values for the conditions at which the body functions best.
4. If the control center detects movement away from the set point, it responds by sending messages through one of the organism's communication systems. Messages sent by the control center are carried to effectors that carry out the response.
5. The response restores balance by returning internal conditions to their set points.

Gather Evidence
Identify a change in your environment that might affect homeostasis. Explain using the terms *stimulus, control center, set point, receptors, effectors,* and *imbalance* in your answer.

Homeostasis depends on communication between the receptors, the control center, and the effectors. In the human body, communication is the joint responsibility of the nervous system and the endocrine system.

Model Use the homeostatic control systems diagram in Figure 2 to explain how shivering can help body temperature return to normal.

The nervous system sends messages along a direct route between the receptor and the control center, or between the control center and the effector. The control center in the human body is the central nervous system, which consists of the brain and the spinal cord. Some responses, such as shivering, are generated by the spinal cord and are called reflex responses. Information that requires more interpretation, such as visual and auditory input, is routed through the brain.

Unlike the nervous system, the endocrine system uses a more indirect—but still rapid—method of communication. Hormones are chemicals secreted into the bloodstream by ductless endocrine glands. The hormones then travel throughout the body, acting only on cells that have receptors for those particular hormones.

In order to maintain homeostasis, receptors throughout the organism must constantly compare current conditions to the appropriate set points. Set points are actually narrow ranges of acceptable conditions in a cell or organism. If receptors detect a change in an internal condition causing it to stray outside the set point, the control center communicates instructions to the effector. The effector acts to restore the internal environment to its set point. This interaction between the receptor, the control center, and the effector is known as a feedback loop.

Hands-On Activity

Modeling Feedback

Have you ever lost and recovered your balance? If so, you've experienced a feedback loop between your center of balance and your skeletal muscles. In this activity, you will balance a book on your head while walking.

Predict How would you need to adjust your balance to keep a book balanced on your head?

FIGURE 3: Feedback will help you balance a book on your head.

MATERIALS

- Hardcover book, at least 6" × 8"

PROCEDURE

1. Balance the hardcover book on your head.
2. Walk 3 meters forward and backward—once with your eyes open, then with your eyes closed.
3. Always walk with a partner when your eyes are closed and clear any objects from your path.

ANALYZE

1. What type of receptors provided information about the position of the book while you walked?
2. How did you respond whenever the book changed position? Did you find it more or less difficult to maintain balance with your eyes closed? Explain your answer.

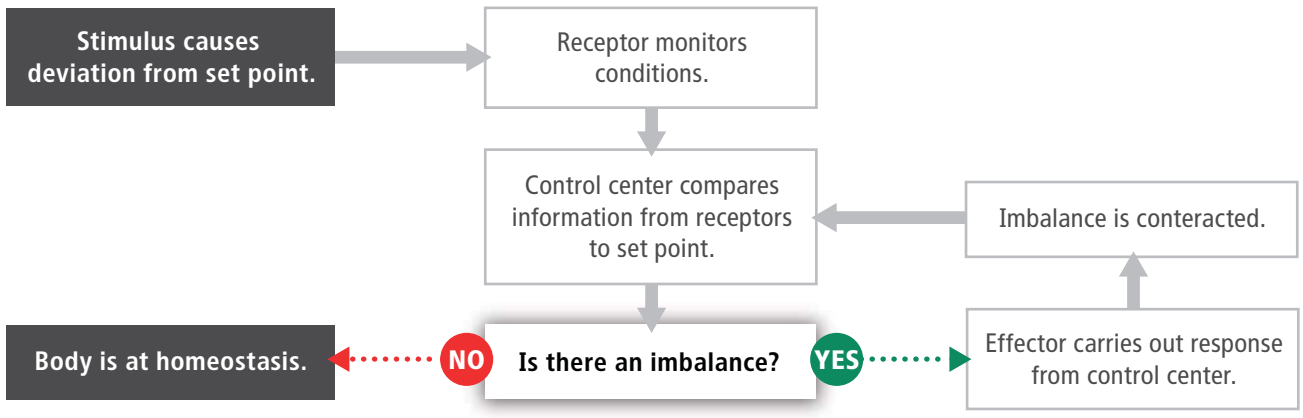
Negative Feedback Loops

Consider what happened in the book-balancing activity. You responded to a change in the book's position by changing your speed or moving your body in the opposite direction until the book returned to balance. You continued to make adjustments to maintain that balance until you removed the book from your head.

What you experienced was the result of a negative feedback loop. In a negative feedback loop, a stimulus causes an imbalance in one direction. This imbalance is detected by receptors that send information to the control center. The control center evaluates the information and sends a signal to the effectors to make an adjustment that is in the opposite direction from the stimulus, returning the system to balance.

Why is this process called a loop? The receptors also check the new conditions that result from the actions of the effector and then update the control center. The control center then signals any additional actions that the effector needs to take. These small changes cause conditions to hover around the set point and maintain homeostasis.

FIGURE 4: Negative Feedback Loop Flow Chart



The thermostat of a furnace is a nonliving example of a negative feedback loop. The thermostat contains a receptor (thermometer), a control center (microprocessor), and an effector (switch). The set point is the programmed temperature. When the thermometer detects that the air temperature is lower than the set point, it signals the thermostat's microprocessor, which responds by turning on the switch of the furnace.

While the heating system is running, the thermometer continues to measure air temperature and send updates to the microprocessor, which compares it to the desired temperature. Once the air temperature reaches the set point or just slightly above it, the control center turns off the furnace until the room temperature once again drops below the set point. As a result, the room temperature remains within a couple of degrees of the set point.

Your body has its own internal thermostat. Humans need to maintain a body temperature between 36.7 °C and 37.1 °C (98.2 °F and 98.8 °F). This narrow range is maintained by several mechanisms. Two of these mechanisms are sweating to cool down when the temperature exceeds 37.1 °C and shivering to warm up when it drops below 36.7 °C.

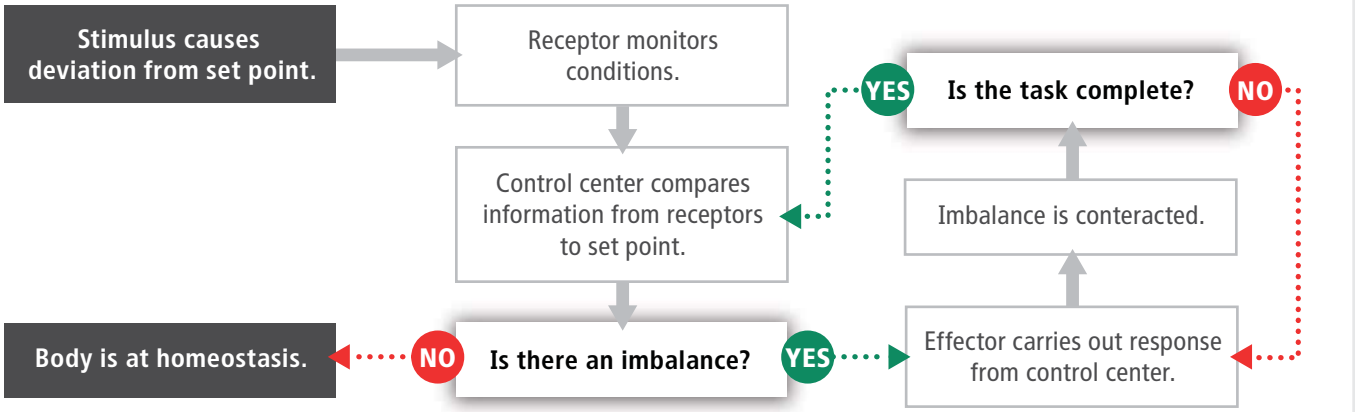
Analyze Based on Figure 4, explain how the body uses a negative feedback loop to regulate body temperature. Use the terms *control center, stimulus, set point, receptors, effectors,* and *imbalance* in your answer.

Positive Feedback Loops

Just as there are negative feedback loops in living systems, there are also positive feedback loops. A negative feedback loop makes adjustments in the opposite direction of a stimulus, but a positive feedback loop makes adjustments in the same direction as the stimulus. Scientists sometimes refer to positive feedback loops as reinforcing loops, because they amplify the stimulus instead of counteracting it.

Have you ever experienced a loud screech coming from a loudspeaker in an auditorium or at a show? This is an example of a positive feedback loop. The sound from the microphone is amplified and sent through the loudspeaker. Sometimes, the microphone will pick up that sound again, it is amplified, and sent through the speaker again. This loop continues again and again. Eventually, you hear the high-pitched screech from the loudspeaker.

FIGURE 5: Positive Feedback Loop Flow Chart



Collaborate Oxytocin is a pituitary hormone that stimulates the muscles in the uterus to contract during birth. It also stimulates the release of prostaglandins from the placenta, causing more uterine contractions. With a partner, explain how this process is a positive feedback loop.

Positive feedback is important when rapid change is needed, such as when you cut your finger. Your body depends on maintaining blood volume and blood pressure. A cut results in blood loss, so the body depends on a positive feedback loop to quickly generate a clot to stop the bleeding. This occurs as platelets and clotting factors stimulate the activation of more platelets and clotting factors at the wound. Once the cut has healed, a clot is no longer needed (and could be dangerous if it gets into the bloodstream). The body then uses another positive feedback loop to dissolve the clot.

Positive feedback loops are not as common in the body as negative feedback loops, but they are important for maintaining homeostasis. For example, some hormones are regulated by positive feedback loops. The release of one hormone may stimulate the release or production of other hormones or substances, which stimulate further release of the initial hormone.

Explain The body relies on positive and negative feedback loops to maintain homeostasis. One such feedback loop is used to maintain water balance in the body. What type of feedback loop returns the body to homeostasis when it becomes dehydrated? Use evidence from this lesson to support your answer.