9.2 Homeostasis and Feedback Mechanisms

The detection-correction or feedback systems that the body uses to maintain homeostasis are constantly detecting internal and external conditions. These homeostatic mechanisms then evaluate the conditions to determine whether or not they represent any deviations from the norm. If conditions are outside of the optimal functioning range, the mechanisms take corrective action to bring the body back into balance. In this section, you will explore feedback mechanisms that regulate the internal environment.

Negative Feedback Mechanisms

negative feedback the response of a system that acts to maintain equilibrium by compensating for any changes made to the system

sensor the element of a feedback system that detects changes in the environment

Feedback is important for any system whose behaviour is a reaction to its environment. The primary mechanism of homeostasis is **negative feedback**, in which a stimulus resulting from a change in the external or internal environment triggers a response that compensates for the change. Homeostatic mechanisms include three elements: a sensor, an integrator, and an effector (**Figure 1**). The **sensor** consists of tissues or organs that detect any change—or stimulus—in external or internal factors, such as the pH, temperature, or concentration of molecules (for example, hormone or glucose molecules).

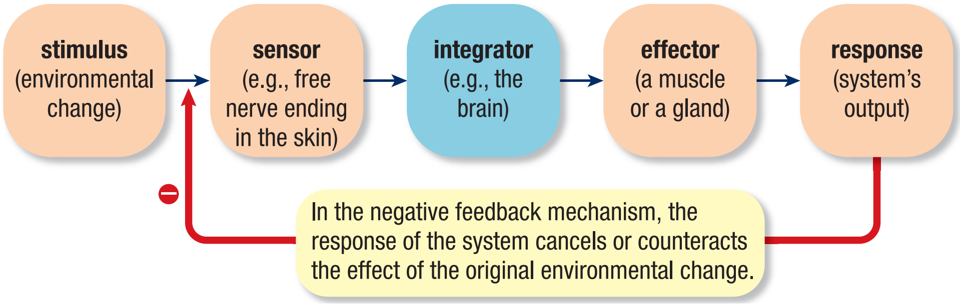

Figure 1 The components and process of a negative feedback loop that maintains homeostasis

integrator the element of a feedback system that compares existing conditions with ideal conditions

set point the optimal value for a given variable of a system

effector the element (or elements) of a feedback system that acts to return the system to its optimal state

Once the sensor gathers the information, it is transmitted to the **integrator**, which acts as a processing or control centre. The integrator compares the environmental conditions with the optimal functioning conditions, called **set points**. The set point represents a range of values within which a condition controlled by the mechanism is to be maintained. If the environmental condition is outside the set point, the integrator activates the **effector**, which is the system that returns the measured condition to the desired set point. This action is called the response. The sensor and integrator are usually part of the nervous or endocrine system, whereas the effector may include parts of any tissues and organs. To bring internal conditions back into balance, negative feedback mechanisms use antagonistic effectors. The "antagonistic" in their name means that they act to produce the opposite effect of the change recorded by the sensor.

The Thermostat as a Negative Feedback Mechanism

You are probably familiar with the thermostat that maintains a constant temperature in a modern home. Most systems engineered by humans use antagonistic effectors. Heating and cooling systems are good examples. A sensor inside the thermostat measures the temperature (**Figure 2**). A circuit (integrator) in the thermostat compares the measured temperature to the set point programmed by the user. If the temperature increases or decreases by any amount, the integrator circuit activates an electrical effector (either a furnace or an air conditioner), which returns the temperature to the set point. When the temperature falls, the furnace is activated and warmer air is added to the home until the temperature rises to the set point. When the temperature rises, the air conditioner is activated and colder air is added to the room until the temperature falls to the set point. You may find it helpful to keep this example in mind when considering how organ systems act as effectors to maintain homeostasis in the body.

Figure 2 The sensor that measures the temperature in a digital thermostat is a thermistor. A thermistor is a resistor in which electrical resistance varies with changes in temperature.

Negative Feedback Mechanisms in Animals

Mammals and birds also have a homeostatic mechanism that maintains body temperature within a relatively narrow range around a set point. The integrator in this mechanism is located in a brain centre called the hypothalamus. Portions of the hypothalamus act like a thermostat for the body. In the human body, groups of neurons in the preoptic region of the anterior hypothalamus receive information from thermoreceptors in various locations, including the skin, the spinal cord, and the hypothalamus itself. This information is then compared to the set point. For humans, the set point for body temperature has a small range, 35 to 37.8 °C, which is centred on 37 °C. If the temperature deviates from the set point, the hypothalamus activates a set of physiological and behavioural responses to re-establish the normal body temperature.

The particular set of effectors that is activated depends on whether our body temperature is above or below the set point (**Figure 3**). If the temperature drops below the set point, the hypothalamus activates effectors that induce vasoconstriction in the skin. As blood flow through the skin is reduced, less thermal energy is lost to the environment, which causes our body temperature to increase. Additional effectors may induce homeostatic behaviour, such as shivering, which generates body heat. Signals from the hypothalamus make us aware of our lowered body temperature, which may cause us to put on warmer clothes or move to a warmer place.

Investigation 9.2.1

Investigating Homeostatic Feedback Mechanisms (p. 455)

In this investigation, you will explore how homeostasis is maintained by negative feedback mechanisms.

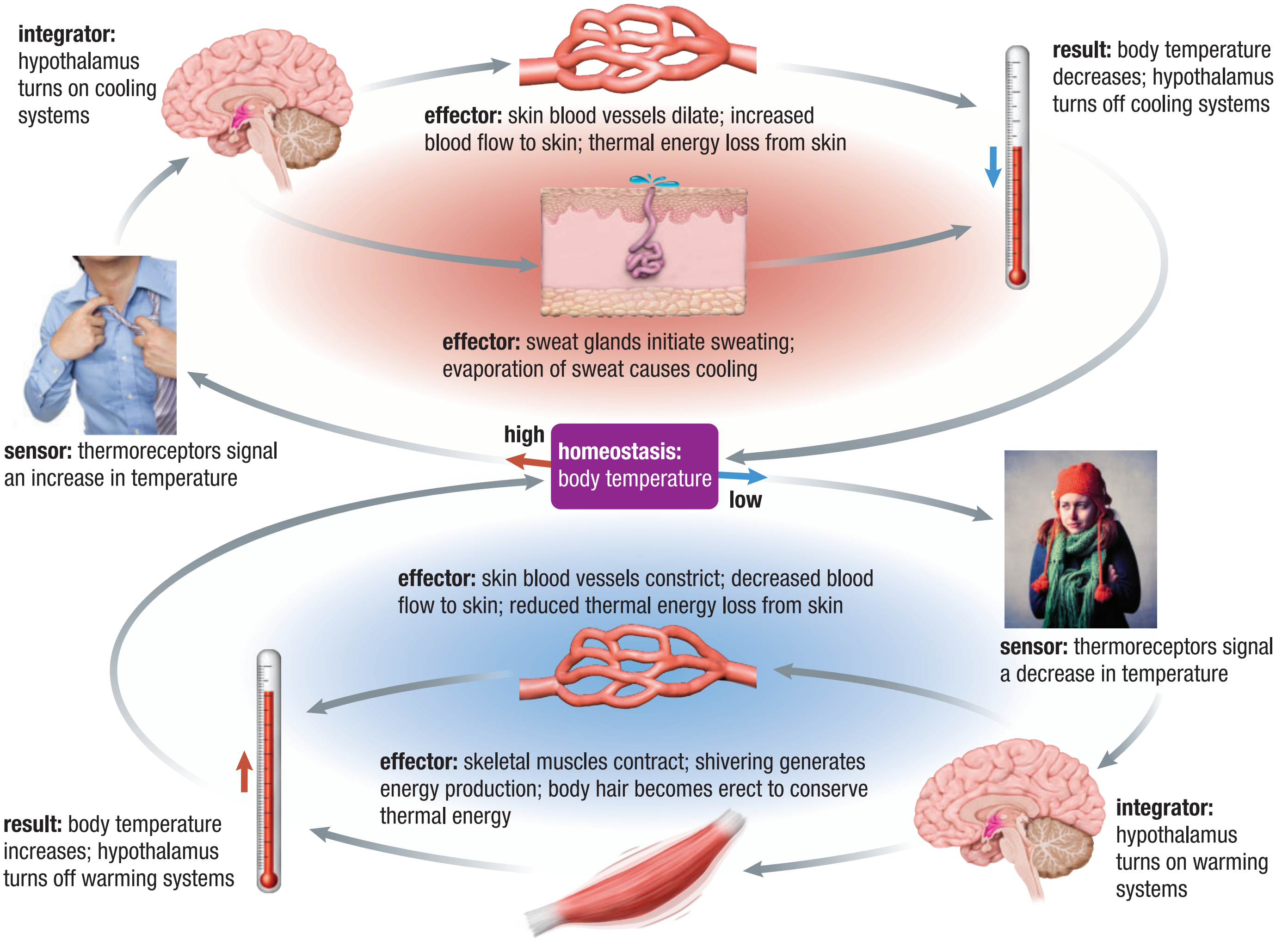

Figure 3 The evaporation of sweat and dilation of blood vessels provide a negative feedback response by cooling the body. The constriction of blood vessels, shivering, and the erection of body hairs provide a negative feedback response that helps conserve thermal energy.

Figure 4 Homeostatic mechanisms maintain the body temperature of a dog when the environmental temperature is high.

Figure 5 A painted lady butterfly is basking in the sunlight before it takes off.

Another mechanism is activated if our body temperature rises above the set point. The hypothalamus triggers effectors that induce vasodilation in the skin, which increases blood flow and loss of thermal energy to the environment. Signals from the hypothalamus make us aware of overheating, and we may take off warm clothing or move to a cooler area. Other effectors cause the body to sweat, which causes loss of thermal energy when the sweat evaporates.

There are times when the ideal temperature set point changes and the feedback mechanisms work to readjust body temperature to the new set point. For example, if you have an infection caused by a virus or bacteria, the homeostatic effectors increase your temperature, causing a fever. This increase helps the body fight off the infection. Once the infection is cleared, the set point is readjusted to its normal level.

All mammals use similar homeostatic mechanisms to maintain their body temperature set point. Birds and dogs pant to release thermal energy from their body (**Figure 4**). Many terrestrial vertebrates use water to cool off. Mammals and birds are able to regulate their internal temperature within a narrow range, but other vertebrates can thrive within a much broader range. For example, reptiles alter their behaviour in response to changes in body temperature. They absorb thermal energy by basking on sunny rocks during cooler parts of the day, and then move to cooler areas when the temperature becomes warmer. Some large fish, such as tuna and hunting sharks, are able to generate enough thermal energy by contraction of the swimming muscles to maintain a body temperature many degrees above the surrounding water. Even insects use feedback mechanisms to maintain their body temperature. Flight muscles operate best at higher temperatures, so some insects bask in the sunlight to warm their muscles before taking off (**Figure 5**). Other insects, such as dragonflies, bees, and moths, contract their flight muscles in a process similar to shivering in mammals. During the cold winter months, hives of honeybees form large masses to maintain body temperature, and contract their flight muscles to generate thermal energy. Even plants have thermal energy control mechanisms, often to aid in their development and to attract pollinators. For example, the lotus plant minimizes transpiration to stay cool and breaks down carbohydrates to increase thermal energy.

Positive Feedback Systems

positive feedback the response of a system that acts to increase the effect of any changes made to the system

Another type of feedback mechanism is **positive feedback**, which actually increases the change in the environmental condition. Positive feedback mechanisms usually (with some exceptions) do not result in homeostasis, since they cause the system to become unstable. They almost always operate when a continuous increase in some internal variable is required. For example, when an animal is attacked, the body releases adrenaline and hormones into the blood to prime the muscles and organ systems for the "fight or flight" reactions. The release of these chemicals stimulates *further* release, in a positive feedback cycle, making the animal even more fit to survive the attack.

More examples of positive feedback occur during reproduction and child care. The initial uterine contractions during childbirth stimulate the release of the hormone oxytocin from the pituitary gland. Oxytocin increases and intensifies the contractions, which results in the release of more oxytocin and stronger contractions. In this positive feedback cycle, continued contractions, and thus increased pressure, eventually lead to the delivery of the baby as quickly as possible (thus minimizing the risk of harm to both the baby and the mother). Once the baby is delivered, the contractions stop, which, in turn, stops the release of oxytocin. During child rearing, mammalian young suckle milk from the mother. The sensation of suckling stimulates glands in the mother to produce milk. Of course, this milk production leads to more suckling from the young, again causing further milk production in a positive feedback cycle. When the baby is satiated, and ceases to suckle, the milk production is triggered to stop.

Positive feedback mechanisms often operate within a larger negative feedback mechanism, which ultimately works over the long term to bring the body back into balance. Since this chapter deals with maintaining a homeostatic balance, you will be focusing on negative feedback mechanisms.

UNIT TASK **BOOKMARK**

As you work on your Unit Task (page 566), you may want to consider what role positive and/or negative feedback mechanisms play in how your selected factor influences homeostasis.

9.2 Review

Summary

- Negative feedback occurs when a system responds to change by attempting to compensate for this change.
- Homeostasis is accomplished by negative feedback mechanisms. A negative feedback mechanism includes three components: a sensor, which detects changes in the body's conditions; an integrator, which compares the sensory information to the desired set point; and an effector, which acts to re-establish homeostasis.
- All animals use many negative feedback mechanisms to maintain homeostasis, and responses can be physiological or behavioural.
- Positive feedback mechanisms enhance the effect of a change in the internal or external environment, but usually do not result in homeostasis.

Questions

1. Put the following terms in the correct order as they apply to a negative feedback mechanism: effector, stimulus, sensor, response, integrator. Give an example of each. K/U
2. Identify and explain, in simple terms, a negative feedback system found in everyday life. K/U C A
3. For each of the items below, indicate whether you think the statement describes a homeostatic response. Explain your thinking. K/U
   (a) Marathon runners are sweating profusely at 12 km.
   (b) Children enjoy pop, so they drink more.
   (c) The pupils constrict when a light is pointed into the eyes.
   (d) A child spins around and feels dizzy afterwards.
   (e) A patient is infected with a virus and begins to sweat and feel hot.
4. Homeostasis in animals is usually maintained through negative feedback systems rather than positive feedback systems. Why do you think this is so? T/I
5. Explain, in simple terms, how your body uses positive feedback when it reacts to being frightened. K/U C
6. Create a flow chart, similar to Figure 1 (p. 432), to describe the body's reaction to a bacterial infection. K/U C
7. Compare and contrast negative feedback and positive feedback. Give an example of each. K/U
8. Apply what you learned from the thermostat analogy to the way that dragonflies and other flying insects prepare to take off. Be sure to identify the sensor, the integrator, the effector, and the responses. A
9. Plants often require an abundant amount of light to survive. Describe a mechanism that plants use to meet their need for sunlight. K/U
10. When people and other animals become scared or intimidated, their hair often stands on end. Explain why this may happen and how it relates to positive feedback. C A
11. Draw and label a diagram of the negative feedback system for a household thermostat and furnace. Include the following in your diagram: thermostat, furnace, temperature set point, increase and/or decrease arrows. K/U C
12. In addition to negative and positive feedback systems, the body also uses a feed-forward system of control. In a feed-forward system, a mechanism in a system monitors performance inputs rather than outputs, and reacts to maintain a specified state. Using the Internet or other resources, research an example of a feed-forward system that our bodies use for homeostasis. Describe the system in your own words. T/I C A
13. Do you think the clotting of blood after an injury is a positive or a negative feedback response? Explain your reasoning. K/U T/I
14. How might positive feedback control be harmful to the body's systems? Give an example to support your answer. K/U T/I
15. Create a word web or other type of graphic organizer to illustrate possible relationships between the following terms: homeostasis, internal environment, homeostatic mechanism, sensor, integrator, set point, effector, negative feedback. Cluster groups of related terms and connect them, explaining their relationship to one another. Share your graphic organizer with a classmate. K/U T/I C A

WEB LINK