11.4 Homeostasis

Homeostasis is the relative constancy of the body's internal environment. Because of homeostasis, even though external conditions may change dramatically, internal conditions still stay within a narrow range (Fig. 11.11). For example, regardless of how cold or hot it gets, the temperature of the body stays around 37°C (97° to 99°F). No matter how acidic your meal, the pH of your blood is usually about 7.4, and even if you eat a candy bar, the amount of sugar in your blood is just about 0.1%.

It is important to realize that internal conditions are not absolutely constant; they tend to fluctuate above and below a particular value. Therefore, the internal state of the body is often described as one of dynamic equilibrium. If internal conditions should change to any great degree, illness results. This makes the study of homeostatic mechanisms medically important.

Negative Feedback

A homeostatic mechanism in the body has three components: a sensor, a regulatory center, and an effector (Fig. 11.12*a*). The sensor detects a change in the internal environment; the regulatory center activates the effector; the effector reverses the change and brings conditions back to normal again. Now, the sensor is no longer activated.

Negative feedback is the primary homeostatic mechanism that keeps a variable, such as body temperature, close to a particular value, or set point. A home heating system illustrates how a negative feedback mechanism works (Fig. 11.12*b*). You set the thermostat at, say, 68°F. This is the set point. The thermostat contains a thermometer, a sensor that detects when the room temperature falls below the set point. The thermostat is also the regulatory center; it turns the furnace on. The furnace plays the role of the effector. The heat given off by the furnace raises the temperature of the room to 70°F. Now, the furnace turns off. Notice that a negative feedback mechanism prevents change in the same direction; the room does not get

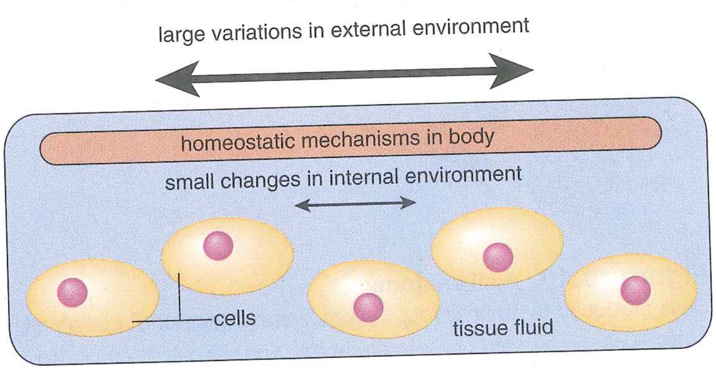


Figure 11.11 Homeostasis.
Because of homeostatic mechanisms, large external changes cause only small internal changes in such parameters as body temperature and pH of the blood.

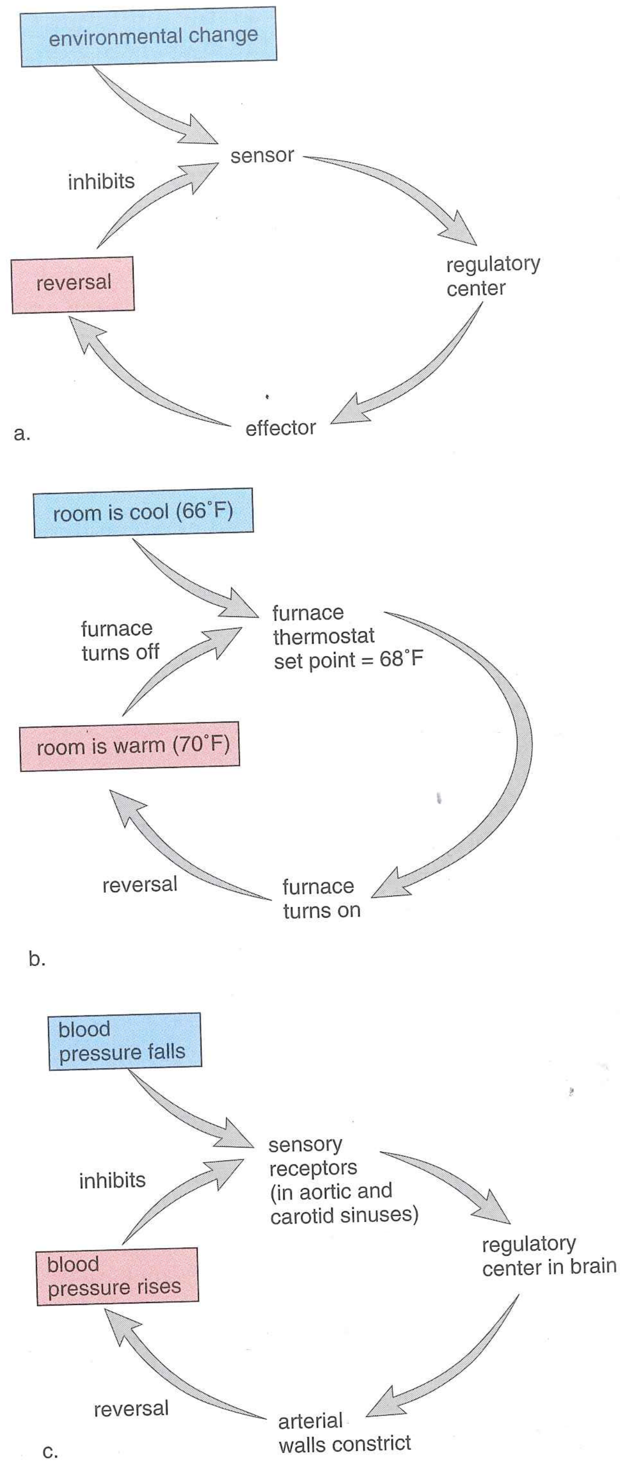


Figure 11.12 Negative feedback.
a. A sensor detects an internal environmental change and signals a regulatory center. The center activates an effector, which reverses this change. **b.** Mechanical example: When the room is cool, a thermostat that senses the room temperature signals the furnace to turn on. Once the room is warm, the furnace turns off. **c.** Biological example: When blood pressure falls, special sensory receptors in blood vessels signal a regulatory center in the brain. The brain signals the arteries to constrict, and blood pressure rises to normal. This response reverses the change.

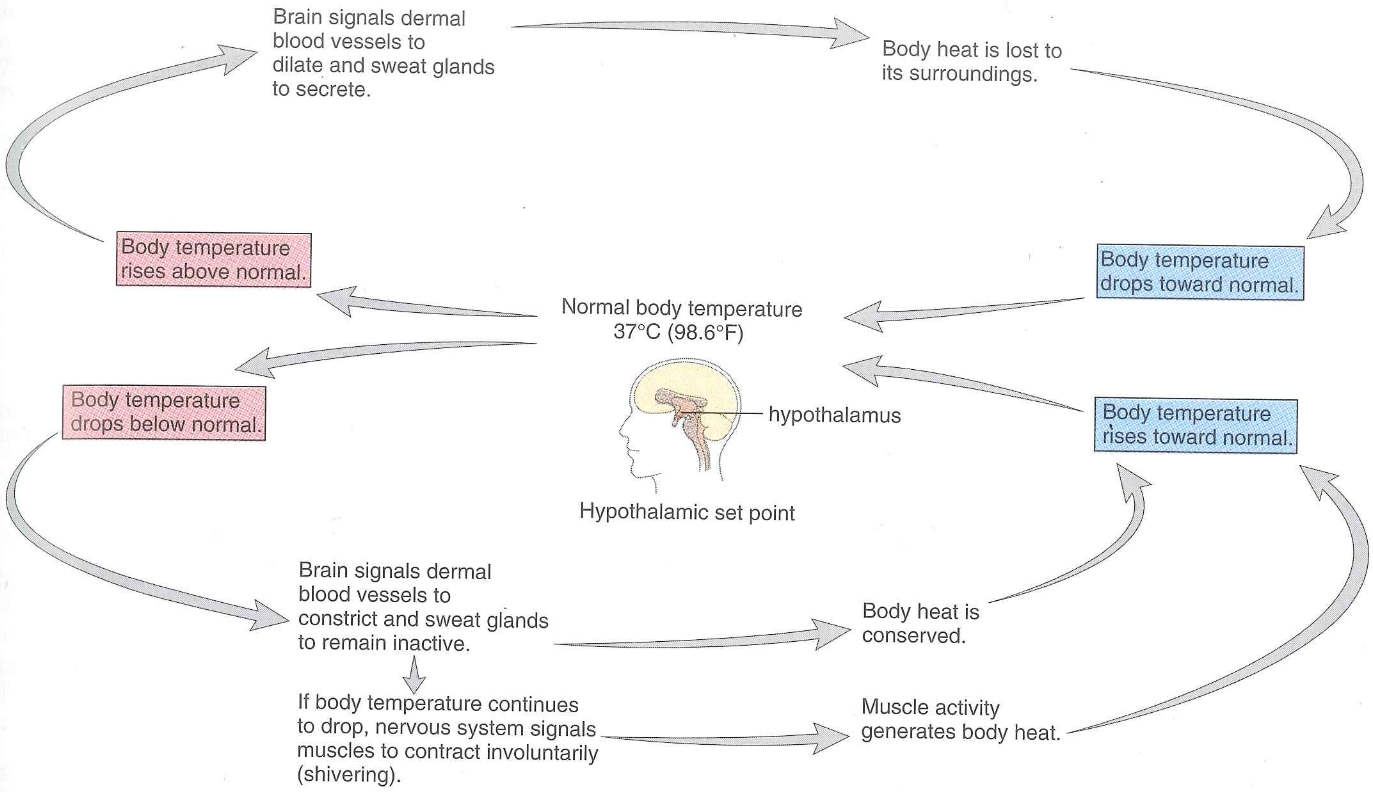
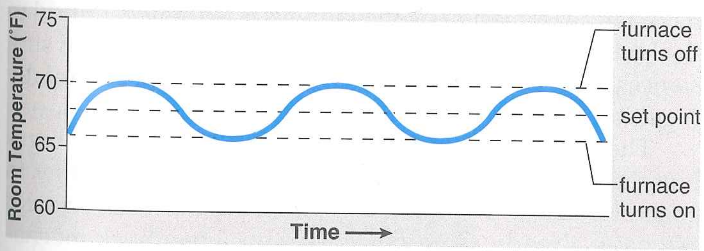


Figure 11.13 Homeostasis and body temperature regulation.
Negative feedback mechanisms control body temperature so that it remains relatively stable at 37°C. These mechanisms return the temperature to normal when it fluctuates above and below this set point.

hotter and hotter because warmth inactivates the system. Also notice that negative feedback mechanisms are activated only by a deviation from the set point, and therefore there is a fluctuation above and below this value.



Negative feedback mechanisms in the body function similarly to this mechanical model (Fig. 11.12*c*). For example, when blood pressure falls, sensory receptors signal a regulatory center in the brain. This center sends out nerve impulses to the arterial walls so that they constrict. Once the blood pressure rises, the system is inactivated.

A negative feedback mechanism maintains stability by its ability to sense a change and bring about an effect that reverses that change.

Regulation of Body Temperature

The thermostat for body temperature is located in a part of the brain called the hypothalamus. When the body temperature falls below normal, the regulatory center directs (via nerve impulses) the blood vessels of the skin to constrict (Fig. 11.13). This conserves heat. If body temperature falls even lower, the regulatory center sends nerve impulses to the skeletal muscles, and shivering occurs. Shivering generates heat, and gradually body temperature rises to 37°C. When the temperature rises to normal, the regulatory center is inactivated.

When the body temperature is higher than normal, the regulatory center directs the blood vessels of the skin to dilate. This allows more blood to flow near the surface of the body, where heat can be lost to the environment. In addition, the nervous system activates the sweat glands, and the evaporation of sweat helps lower body temperature. Gradually, body temperature decreases to 37°C.

The temperature of the human body is maintained at about 37°C due to the activity of a regulatory center in the brain.

Positive Feedback

Positive feedback is a mechanism that brings about an ever greater change in the same direction. When a woman is giving birth, the head of the baby begins to press against the cervix, stimulating sensory receptors there. When nerve impulses reach the brain, the brain causes the pituitary gland to secrete the hormone oxytocin. Oxytocin travels in the blood and causes the uterus to contract. As labor continues, the cervix is ever more stimulated and uterine contractions become ever more strong until birth occurs.

A positive feedback mechanism can be harmful, as when a fever causes metabolic changes that push the fever still higher. Death occurs at a body temperature of 45°C because cellular proteins denature at this temperature and metabolism stops. Still, positive feedback loops like those involved in childbirth, blood clotting, and the stomach's digestion of protein assist the body in completing a process that has a definite cut-off point.

In contrast to negative feedback, positive feedback allows rapid change in one direction and does not achieve relative stability.

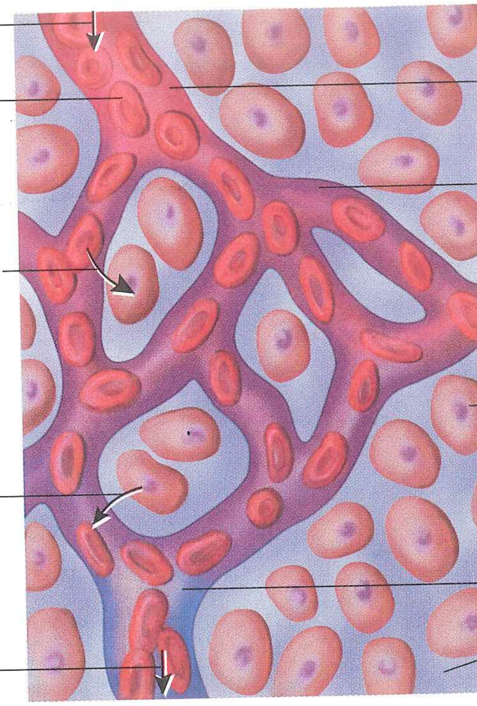


Figure 11.14 Regulation of tissue fluid composition. Cells are surrounded by tissue fluid, which is continually refreshed because oxygen and nutrient molecules constantly exit, and carbon dioxide and waste molecules continually enter the bloodstream.

Homeostasis and Body Systems

The internal environment of the body consists of blood and tissue fluid. Tissue fluid, which bathes all the cells of the body, is refreshed when molecules such as oxygen and nutrients move into tissue fluid from the blood, and when wastes move from tissue fluid into the blood (Fig. 11.14). Tissue fluid remains constant only as long as blood composition remains constant.

All systems of the body contribute toward maintaining homeostasis and therefore a relatively constant internal environment. The cardiovascular system conducts blood to and away from capillaries, where exchange occurs. The heart pumps the blood and thereby keeps it moving toward the capillaries. The formed elements also contribute to homeostasis. Red blood cells transport oxygen and participate in the transport of carbon dioxide. White blood cells fight infection, and platelets participate in the clotting process. The lymphatic system is accessory to the cardiovascular system. Lymphatic capillaries collect excess tissue fluid, and this is returned via lymphatic veins to the cardiovascular veins. Lymph nodes help purify lymph and keep it free of pathogens.

The digestive system takes in and digests food, providing nutrient molecules that enter the blood and replace the nutrients that are constantly being used by the body cells. The respiratory system adds oxygen to and removes carbon dioxide from the blood. The chief regulators of blood composition are the liver and the kidneys. They monitor the chemical composition of plasma and alter it as required. Immediately after glucose enters the blood, it can be removed by the liver for storage as glycogen. Later, the glycogen can be broken down to replace the glucose used by the body cells; in this way, the glucose composition of blood remains constant. The hormone insulin, secreted by the pancreas, regulates glycogen storage. The liver also removes toxic chemicals, such as ingested alcohol and other drugs. The liver makes urea, a nitrogenous end product of protein metabolism. Urea and other metabolic waste molecules are excreted by the kidneys. Urine formation by the kidneys is extremely critical to the body, not only because it rids the body of unwanted substances, but also because it offers an opportunity to carefully regulate blood volume, salt balance, and pH.

The nervous system and the endocrine systems regulate the other systems of the body. They work together to control body systems so that homeostasis is maintained. We have already seen that in negative feedback mechanisms, sensory receptors send nerve impulses to regulatory centers in the brain, which then direct effectors to become active. Effectors can be muscles or glands. Muscles bring about an immediate change. Endocrine glands secrete hormones that bring about a slower, more lasting change that keeps the internal environment relatively stable.

All systems of the body contribute to homeostasis—that is, maintaining the relative constancy of the internal environment, blood, and tissue fluid.