Homeostasis in the Human Body

Homeostasis regulates many different things in organisms, such as temperature, water balance, salt levels, pH, nutrients, and gases. Because all of these things have set points, the body requires feedback loops for each one in order to maintain homeostasis. Remember that at its most basic level, the body is composed of many groups of specialized cells. These cells are further organized into organs, which in turn are organized into systems. Whatever affects one organ system affects the body as a whole. This means that whenever an imbalance occurs in one organ system, the imbalance affects the entire organism.

Explore Online

Hands-On Lab

Negative and Positive Feedback
Analyze data and generate graphs to determine whether a process is an example of a negative or positive feedback loop.

Interacting Organ Systems

All of your body systems interact to maintain homeostasis, much like a group of dancers interact to perform a highly choreographed ballet. If one dancer misses a cue, it throws the rest of the dancers out of step and time. Consider the importance of a healthy blood pressure to the body. Blood pressure is the force with which blood pushes against the walls of blood vessels. Receptors in the blood vessels and heart detect changes in blood pressure, then signal the brain. The brain stimulates the heart to beat faster or slower to help restore the blood pressure to its correct level.

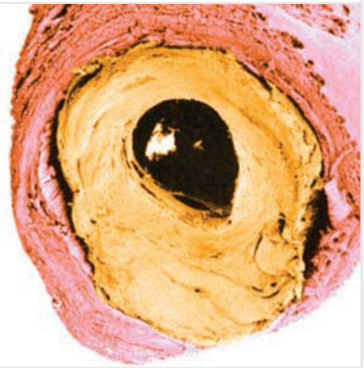
Arteries are a type of blood vessel in the circulatory system that carry oxygen-rich blood throughout the body. If blood pressure is too low, the brain tells the heart to beat faster to increase the amount of blood in the arteries, which increases the pressure exerted by the blood on the walls of the arteries. If the pressure is too high, the heart beats slower, reducing the amount of blood in the arteries and so lowering the blood pressure. In this case, the systems working together to maintain blood pressure homeostasis are the nervous system and the circulatory system.

Cause and Effect

Blood pressure depends on how elastic and unblocked the arteries are and on the strength of the heart contraction. The less elastic the arteries and the more blockages that reduce blood flow, the harder the heart must pump. As a result, blood pressure rises. Blood pressure also rises naturally with activity, stress, and strong emotions, but it should drop again with rest. If the pressure remains high, there could be a problem in the circulatory system.

Predict If a person's blood pressure is too high or too low, how might the other organ systems in their body be affected?

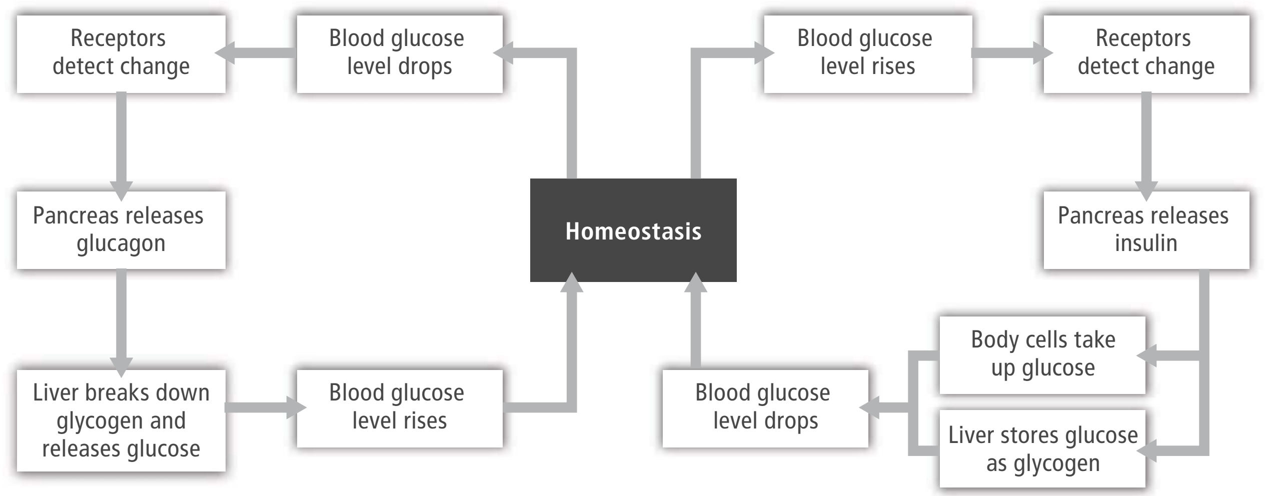
FIGURE 6: Blocked Artery



Maintaining Glucose Concentrations

The cells in the human body rely heavily on glucose to supply the energy needed to survive and grow. However, glucose concentrations in the blood must be maintained within a very narrow range for good health. Glucose needs can vary widely depending on what activities the body is performing. A person's activity levels are always changing, so the body must work constantly to maintain homeostasis.

FIGURE 7: Glucose levels are regulated by a negative feedback loop.



Blood glucose levels are controlled by two feedback loops, shown in Figure 7. Each loop relies on the endocrine system to respond to changing levels. When blood glucose levels rise, such as when you eat a meal, the increase is detected by beta cells in the pancreas. The beta cells respond by releasing insulin, which stimulates cells to absorb glucose from the blood stream. It also causes the liver to store excess glucose in the form of glycogen. Once levels return to the set point, insulin secretion subsides. This feedback keeps blood glucose levels from exceeding the maximum set point.

Analyze Why are the insulin and glucagon feedback loops examples of negative feedback loops?

The body has a second feedback loop that maintains a minimum blood glucose level. Blood glucose levels can drop after a long time passes without eating or during prolonged exercise. When the brain detects levels below the minimum set point, it signals pancreatic alpha cells to produce glucagon. Glucagon stimulates the liver to convert glycogen to glucose and release it into the blood stream. If the liver is unable to release glucose rapidly enough, the brain signals a feeling of hunger in order to obtain additional glucose.

Explore Online

Hands-On Lab

Investigating Homeostasis and Exercise Investigate how the circulatory system, respiratory system, and perspiration levels are affected by exercise.

Maintaining Carbon Dioxide Concentrations

Every time you exercise, lie down to rest, or simply stand up, your needs for oxygen and nutrients change. Your heart speeds up or slows down and you breathe faster or slower, depending on your level of activity. The respiratory system interacts with the nervous system to maintain homeostasis. Control centers in the brain monitor dissolved gases in the blood, particularly carbon dioxide (CO_2) and oxygen (O_2) concentrations.

As you become more active, CO_2 levels increase and the blood becomes more acidic. Sensors signal this change to the brain. The brain sends messages through the nervous and endocrine systems that stimulate the diaphragm and rib cage muscles to work more rapidly. This allows you to take in more O_2 and release CO_2, returning levels in your body to homeostasis.

In humans, gas exchange is a cooperative effort of the circulatory and respiratory systems. The circulatory system distributes blood and other materials throughout the body, supplying cells with nutrients and oxygen, and carrying away wastes. Blood vessels are organized so that oxygen-poor blood and oxygen-rich blood do not mix.

The circulatory system has three types of blood vessels: arteries, veins, and capillaries. Arteries carry oxygen-rich, or oxygenated, blood away from the heart. Veins are blood vessels that carry oxygen-poor, or deoxygenated, blood back to the heart. Capillaries are responsible for delivering O_2 directly to cells and removing CO_2 and waste. With a wall only one cell thick, it is easy for materials to diffuse easily into and out of capillaries. The capillary system serves as a connection between arteries and veins, ensuring a continuous path for blood flow throughout the body.

Once the veins deliver deoxygenated blood to the heart, it is immediately transported to the lungs, where gases can be exchanged with the air. As shown in Figure 8, when you inhale, the air flows from your nose or mouth through the trachea to the bronchi (*sing.* bronchus). The air continues into smaller branches called bronchioles and finally into small, thin-walled air sacs called alveoli. A network of capillaries surrounds each alveolus, taking in O_2 and releasing CO_2. When you exhale, the CO_2 exits through your nose or mouth.

FIGURE 8: Circulatory System

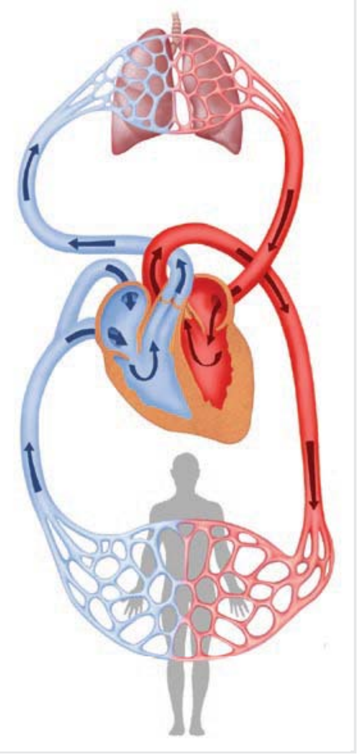
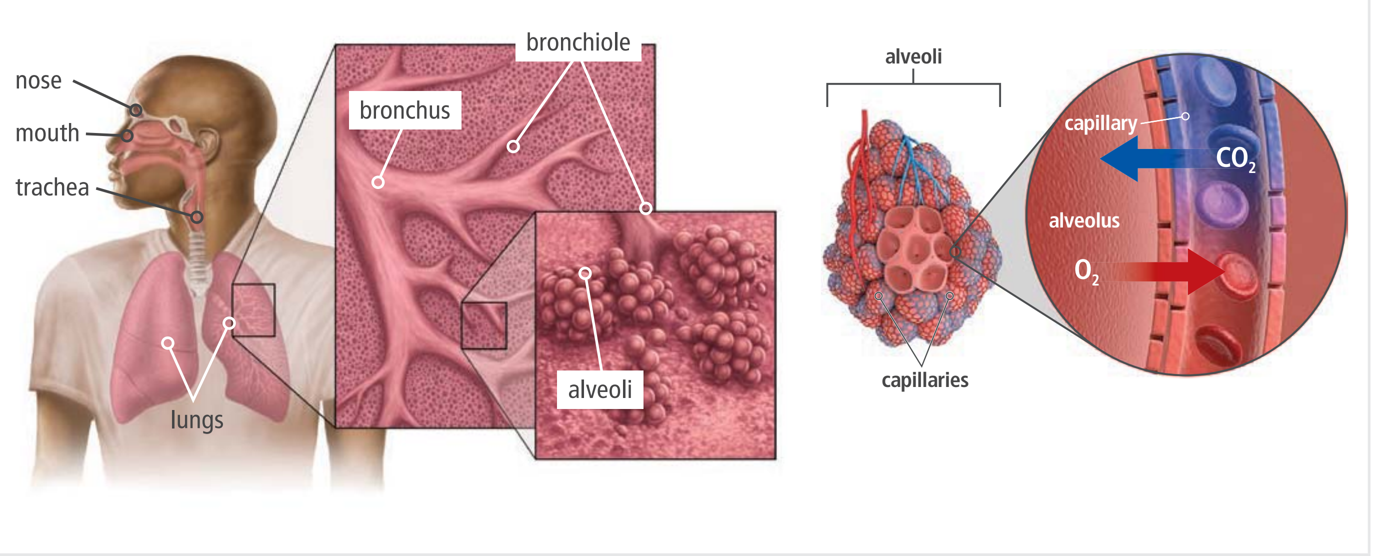


FIGURE 9: Diffusion of gases into and out of the alveoli maintains oxygen and carbon dioxide homeostasis.



Gas homeostasis in the blood is maintained through diffusion. When you inhale, the air has a higher concentration of O_2 than the blood in the capillaries surrounding the alveoli. This allows O_2 to diffuse down a concentration gradient into the blood. From there, the blood is taken to the heart and pumped through the body. The concentration of O_2 in the blood is higher than in the cells, so it diffuses out of the blood. Carbon dioxide diffuses in the opposite direction—from the cells into the blood. The concentration of CO_2 is higher in the cells than in the blood because cells produce CO_2 as a waste product. Once in the blood, it travels back to the heart and then into the lungs, where it diffuses into the alveoli and is exhaled out of the lungs.

Model Create a flow

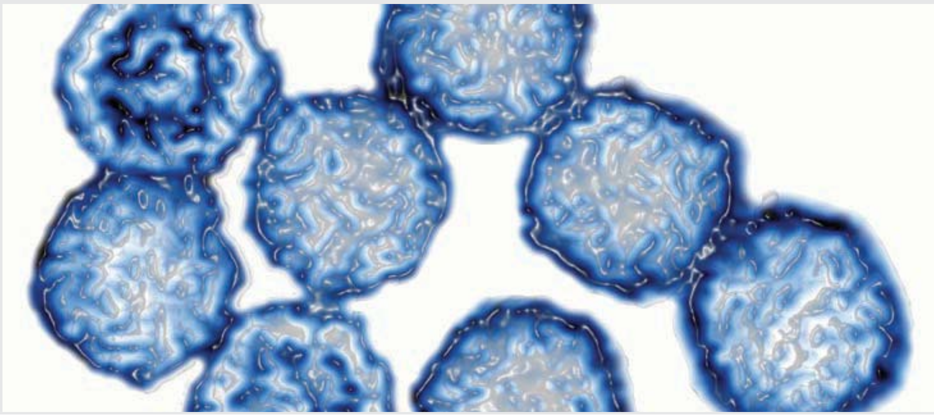
Make a flow chart explaining how homeostasis is maintained when you become more active. How do the respiratory and nervous systems interact to maintain appropriate CO_2 and O_2 levels and prevent the blood from becoming too acidic?

Disrupting Homeostasis

Homeostatic mechanisms usually work quickly, but sometimes a change in the environment can occur too rapidly or be of too great a magnitude to be controlled through feedback mechanisms. When this happens, homeostasis is disrupted. Disruptions can happen for several reasons including the failure of sensors to detect a change in the internal or external environment, sending or receiving the wrong message, serious injury, or disease-causing agents, such as bacteria or viruses.

A rhinovirus, shown in Figure 10, can change the body's internal chemistry to cause the common cold. This results in disruption of one or more homeostatic mechanisms. One commonly disrupted mechanism is body temperature, resulting in fever. A fever occurs when the hypothalamus raises the set point for internal temperature. This makes you feel cold, because your internal temperature is below the set point. Your body may shiver to raise your internal temperature closer to the new set point.

FIGURE 10: The common cold is caused by a rhinovirus.



Short-Term Effects

Collaborate With a partner, discuss whether your body's response to the common cold is an example of negative or positive feedback. Use evidence to support your claim.

Many disruptions in homeostasis are temporary. A cold is an excellent example of a short-term disruption in homeostasis. When the virus first enters your body, it may multiply too rapidly for your immune system to destroy it. When that happens, you may experience cold symptoms, such as a sore throat or runny nose. In only a few days, however, your immune system develops antibodies that can mark the virus for destruction, restoring homeostasis. Lasting damage from the common cold is very rare.

Recall that shivering is the body's response to decreased body temperature. Shivering occurs when you are sick not because you are experiencing cold environmental temperatures, but because your body is trying to adjust to a new—higher—set point for body temperature. In other words, your body is shivering to produce a fever.

Long-Term Effects

Long-term disruptions of homeostasis can cause more damage than short-term disruptions. One form of long-term disruption is Cushing's syndrome. This disorder is caused by a long-term elevation of the hormone cortisol. Cushing's can result from tumors of the adrenal or pituitary gland, or from long-term cortisone treatment. Cortisol is one of the body's stress hormones. When it remains elevated for long periods of time, it disrupts glucose and fat metabolism, immune response, and sleep, and causes blood pressure to increase. Each of these disruptions can lead to other disorders, such as hypertension, diabetes, strokes, and heart attacks.

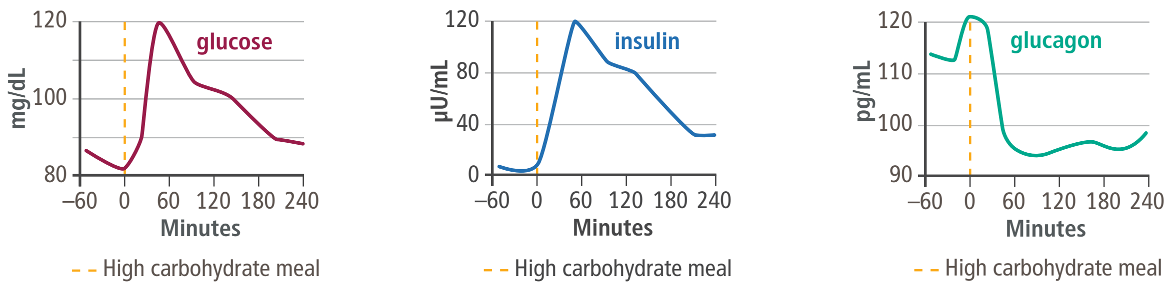
Data Analysis

Understanding Diabetes

Recall that the regulation of blood glucose levels occurs through negative feedback loops. The insulin loop is stimulated by elevated blood glucose levels, and the glucagon loop is stimulated by lowered blood glucose levels.

Diabetes mellitus is a long-term disruption of the insulin feedback loop. Type 1 occurs when the body's immune system destroys the ability of beta cells in the pancreas to produce insulin. Type 2 is caused when pancreatic insulin production decreases or when insulin cannot move glucose from the blood into cells.

FIGURE 11: Blood glucose, insulin, and glucagon responses to a high-carbohydrate meal.



Two variables are inversely related if an increase in the value of one variable is associated with a decrease in the value of the other variable. For example, the levels of insulin and glucose increase and glucagon decreases when a person eats. Therefore, insulin and glucose levels have an inverse relationship to glucagon. This relationship can be seen in Figure 11.

Analyze Answer the following questions in your Evidence Notebook:

1. What is the relationship between blood glucose levels, insulin levels, and glucagon levels in the blood stream?
2. Type 1 Diabetes occurs when the body's immune system destroys the ability of the pancreas to produce insulin. How would these graphs look different in a person with Type 1 diabetes?

Homeostasis is critical for the health of any organism and requires various systems to interact. To maintain some homeostasis some organisms may use methods similar to those in humans, and others may require different methods specific to their environment.

Explain Choose an example of a homeostatic variable from this lesson. Explain the feedback loop responsible for maintaining homeostasis for this variable. Then describe how homeostasis for this variable can be disrupted.