

Introduction to homeostasis

Keeping conditions constant

Conditions in the body are created and maintained so that enzyme-controlled chemical reactions necessary for all life processes can happen. While external conditions may change, the human body must maintain a reasonably constant environment for cells, tissues and organs to continue to function. Homeostasis is the maintenance of a relatively constant internal environment.

Factors that are maintained within the body through exchanges with the external environment include:

- concentration of oxygen and carbon dioxide;
- pH;
- concentration of nutrients, water and salts;
- concentration of waste products;
- temperature;
- volume and pressure.

Every minute

Depending on its activity, every minute the typical human body:

- monitors changes within the body and releases hormones and generates electrical signals (nervous impulses) to maintain a constant internal environment;
- breathes in and out around 12 times and exchanges about 6 dm³ of air between the lungs and the atmosphere;
- uses about 250 cm³ of oxygen and makes about 200 cm³ of carbon dioxide;
- uses about 10 J of energy obtained from food molecules just to maintain life processes – more energy is used by muscles for movement involving the skeleton;
- processes food in the digestive system, absorbing nutrients into the blood for transfer to cells;
- beats the heart about 70 times to pump around 5 dm³ of blood, first to the lungs and then to all the other parts of the body;
- passes more than 1 dm³ of blood through the kidneys, retaining useful materials while getting rid of those that need to be removed in 1 cm³ of urine;
- uses sense organs to detect changes in the external environment and transmits information to the brain as electrical signals (nervous impulses);
- processes information as nervous impulses in the nervous system, sending out control signals to muscles to maintain posture.

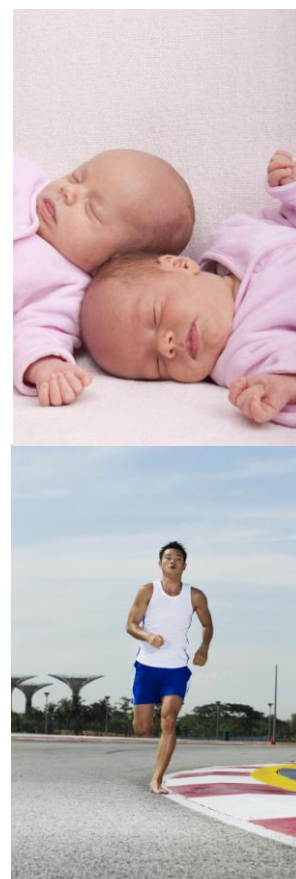


Figure 1 Sleeping, running ... at all times the body is at work.

Negative feedback

A steady state is when variables (factors that can increase or decrease such as temperature) are kept constant by the input of energy.

At steady state a variable has a set point. In the body the actual value is continually changing. Differences that occur from the set point act as signals that set homeostatic mechanisms into action.

In a negative feedback system, an increase or decrease in a variable causes responses which reverse the change. This causes the variable to constantly fluctuate either side of its set point value.

A negative feedback system includes:

- sensors to detect changes in a variable;
- integrators to send instructions to effectors (may involve nervous impulses or hormones);
- effectors which bring about compensatory responses.

For example, a fall in body temperature is detected by nerve cells (sensors). These stimulate the temperature-regulating centre (integrator) in the hypothalamus of the brain which stimulates skeletal muscles (effectors) to contract. This causes shivering which generates heat and raises the temperature.

Responses in negative feedback systems may be coarse or fine-tuned, so some variables may fluctuate a great deal, while others change only slightly.

Feed forward mechanisms anticipate changes in a variable, improving the speed of homeostatic response. For example, presence of food in the intestine stimulates secretion of hormones that promote cellular uptake and storage of the food which is about to be absorbed into the bloodstream.



Figure 2 Shivering helps this boy's body to warm up.

Examples of what can go wrong

The body may fail to make sufficient of a hormone involved in a homeostatic mechanism. For example, blood sugar levels tend to rise after a meal and then to fall lower as glucose is assimilated under the control of insulin. Normally, fluctuations are kept within 70 to 110 mg cm⁻³. In type 1 diabetes cells in the pancreas stop making insulin. Consequently, blood glucose levels rise, causing symptoms such as fatigue, weight loss and frequent urination.

Biochemists and biotechnologists have been able to use genetic engineering to transfer the human insulin gene into bacteria. Type 1 diabetes can be treated with injections of human insulin produced by bacteria in a bioreactor

Ingestion of alkaline drugs can cause an excessive rise in body fluid pH (alkalosis). For example, sodium hydrogencarbonate as baking soda may be used as a self-administered remedy for heartburn. If more is ingested than is necessary to neutralise the stomach acid, excess HCO₃⁻ is absorbed into the blood. This binds with free H⁺ increasing plasma pH.

Finding out

In the gut H⁺ secreted in the stomach is neutralised by HCO₃⁻ secreted by the pancreas.

Commercial alkaline products for treating stomach hyperacidity are designed to prevent a change in acid-base balance and so maintain body fluid pH. They often contain magnesium or aluminium in combination with an alkaline ion such as hydroxide.

- How can this combination lead to an equivalent loss of H⁺ and HCO₃⁻, preventing alkalosis?
- Why should such medicinal drugs not be taken over long periods?