Human physiological function and homeostasis

The human organism consists of trillions of cells all working together for the maintenance of the entire organism. While cells may perform very different functions, all the cells are quite similar in their metabolic requirements. Maintaining a constant internal environment with all that the cells need to survive (oxygen, glucose, mineral ions, waste removal, and so forth) is necessary for the well-being of individual cells and the well-being of the entire body. The varied processes by which the body regulates its internal environment are collectively referred to as homeostasis.

What is Homeostasis?

Homeostasis in a general sense refers to stability, balance or equilibrium. It is the body’s attempt to maintain a constant internal environment. Maintaining a stable internal environment requires constant monitoring and adjustments as conditions change. This adjusting of physiological systems within the body is called homeostatic regulation.

Homeostatic regulation involves three parts or mechanisms: 1) the receptor, 2) the control center and 3) the effector.

The receptor receives information that something in the environment is changing. The control center or integration center receives and processes information from the receptor. And lastly, the effector responds to the commands of the control center by either opposing or enhancing the stimulus. This is an ongoing process that continually works to restore and maintain homeostasis. For example, in regulating body temperature there are temperature receptors in the skin, which communicate information to the brain, which is the control center, and the effector is our blood vessels and sweat glands in our skin.

Because the internal and external environments of the body are constantly changing and adjustments must be made continuously to stay at or near the set point, homeostasis can be thought of as a dynamic equilibrium.

Cells depend on the body environment to live and function. Homeostasis keeps the body environment under control and keeps the conditions right for cells to live and function. Without the right body conditions, certain processes (eg osmosis) and proteins (eg enzymes) will not function properly.

All organisms need some control on their internal environmental conditions in order to ensure that they will be able to survive. Since many of the metabolic reactions that occur within an organism depend on the use of enzymes or even the use of other organisms such as prokaryotic bacteria, it is essential that the optimal conditions required for the functioning of that enzyme be provided. Homeostasis therefore, is ‘ the tendency of organisms to regulate and maintain relative internal stability', and involves, among other processes, the maintenance of a constant body temperature, glucose concentration, pH, osmotic pressure, oxygen level, and ion concentrations. The ability to maintain a constant internal environment, with which we are most familiar, is that of a constant body temperature in homeothermic organisms. For example, the average body temperature of a human

The mechanisms that regulate homeostasis operate by feedback mechanisms. Negative and positive feedback mechanisms operate in living things. Negative feedback mechanisms reverse the direction of the change. This maintains the constant, steady state and so represents homeostasis. Positive feedback, on the other hand, acts to change the variable even more in the direction in which it is changing. Thus, positive feedback is not a homeostatic mechanism.

Temperature control is an example of a negative feedback homeostatic mechanism. The region of the brain called the hypothalamus monitors the human body's temperature. Variation from the normal temperature of 98. 6°F (37°C) triggers a response from the hypothalamus. The temperature can be lowered by activation of glands capable of sweating, or raised by signalling muscles to shiver to produce heat.

Homeostatic mechanisms are a fundamental characteristic of living things. Without these mechanisms, facets of a body that need to be kept operating in a steady state, such as temperature, salinity, acidity, hormone levels, concentration of gases such as carbon dioxide, and the concentrations of nutrients, would become so unbalanced as to threaten the life of the organism. In a healthy body, homeostatic mechanisms operate automatically at different levels; molecular, cellular, and at the level of the whole organism.

At the molecular level, the activity controlled by one gene can be under regulatory control by another gene. At the cellular level, a well-studied homeostatic mechanism is contact inhibition, in which cells stop dividing when they begin to crowd in on each other. Cancer, in which a hallmark is the rampant growth and division of cells, is a condition where the homeostatic mechanism of contact inhibition is inoperative or defective.

At the whole organism level, a homeostatic mechanism is a vital part of birth. During labor, the contraction of the uterus causes the release of a hormone called oxytocin from the hypothalamus. The hormone increases contraction frequency, which in turn stimulates the release of more oxytocin. This increasing contraction cycle propels the fetus down the birth canal and into the world. After birth, the oxytocin acts to contract the expanded uterus in order to minimize bleeding, thereby maintaining the mother’s blood volume

The importance of homeostatic mechanisms to the well being of an organism is underscored by the consequences of their failure. For example, at body temperatures of 107°F (42°C), the negative feedback systems cease to function. The high temperature then acts to speed up the body’s chemistry, raising temperature even more. This, in turn, further accelerates body chemistry, causing a further rise in temperature. This cycle of positive feedback is lethal if not halted.

Two hormones are responsible for controlling the concentration of glucose in the blood. These are insulin and glucagon. The diagram illustrates the principle of negative feedback control in action involving blood/sugar levels.

Pancreas Receptors

The receptors of the pancreas are responsible for monitoring glucose levels in the blood, since it is important in every cell for respiration.

Two types of cell release two different hormones from the pancreas, insulin and glucagon. These hormones target the liver, one or the other depending on the glucose concentration

In cases where glucose levels increase, less glucagon and more insulin is released by the pancreas and targets the liver

In cases where glucose levels decrease, less insulin and more glucagon is released by the pancreas and targets the liver

The Liver

The liver acts as a storehouse for glycogen, the storage form of glucose. When either of the above hormones target the liver, the following occurs

Insulin – Insulin is released as a result of an increase in glucose levels, and therefore promotes the conversion of glucose into glycogen, where the excess glucose can be stored for a later date in the liver

Glucagon – Glucagon is released as a result of an decrease in glucose levels, and therefore promotes the conversion of glycogen into glucose, where the lack glucose can be compensated for by the new supply of glucose brought about from glycogen

Diabetes

Diabetes insipidus is a condition where excess urine is excreted caused by the sufferers inability to produce ADH and promote the retention of water.

Diabetes Mellitus is another form of diabetes where the sufferer does not have the ability to produce sufficient insulin, meaning that glucose cannot be converted into glycogen. Anyone who has this condition usually has to take injections of insulin after meals and snacks to maintain their storage of glucose needed in emergencies.

Fight or Flight

In emergencies, adrenaline is released by the body to override the homeostatic control of glucose. This is done to promote the breakdown of glycogen into glucose to be used in the emergency. These emergencies are often known as ‘ fight or flight reactions’.

Adrenaline is secreted by the adrenal glands. The secretion of it leads to increased metabolism, breathing and heart rate. Once the emergency is over, and adrenaline levels drop, the homeostatic controls are once again back in place

Osmoregulation

Osmoregulation is the regulation of water concentrations in the bloodstream, effectively controlling the amount of water available for cells to absorb.

The homeostatic control of water is as follows

A change in water concentration leads to active via negative feedback control

Osmoreceptors that are capable of detecting water concentration are situated on the hypothalamus next to the circulatory system

The hypothalamus sends chemical messages to the pituitary gland next to it.

The pituitary gland secretes anti-diuretic hormone (ADH), which targets the kidney responsible for maintaining water levels.

When the hormone reaches its target tissue, it alters the tubules of the kidney to become more / less permeable to water

If more water is required in the blood stream, high concentrations of ADH make the tubules more permeable.

If less water is required in the blood stream, low concentrations of ADH make the tubules less permeable.

This is illustrated by the flow chart below

Evolutionary Adaptations in Water Regulation

Some of the tutorial pages in the adaptation tutorial investigate some of the evolutionary adaptations that organisms have achieved through natural selection. This looks at

Ways in which both animals and plants can be better adapted to cope with extreme environments (desert or wetlands).

These changes can be behavioural, physical or anatomical, and in some way promote water regulation.

Both plant and animal adaptations are investigated