Class Copy

Human Physiology/Homeostasis

Human Physiology — Cell physiology →

Homeostasis — Cells — Integumentary — Nervous — Senses — Muscular — Blood — Cardiovascular — Immune — Urinary — Respiratory — Gastrointestinal — Nutrition — Endocrine — Reproduction (male) — Reproduction (female) — Pregnancy — Genetics — Development — Answers

* Respond to questions on a separate sheet of paper!

Overview

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 brain.

Because the internal and external environment 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 *synthetic equilibrium.*

Positive and Negative Feedback (know the difference between these two!)

When a change of variable occurs, there are two main types of feedback to which the system reacts:

→ ***Negative feedback***: a reaction in which the system responds in such a way as to reverse the direction of change. Since this tends to keep things constant, it allows the maintenance of homeostasis. For instance, when the concentration of carbon dioxide in the human body increases, the lungs are signaled to increase their activity and expel more carbon dioxide. Thermoregulation is another example of negative feedback. When body temperature rises (or falls), receptors in the skin and the hypothalamus sense a change, triggering a command from the brain. This command, in turn, effects the correct response, in this case a decrease in body temperature.

- **Home Heating System Vs. Negative Feedback'**

Great Example

When you are at home, you set your thermostat to a desired temperature. Let's say today you set it at 70 degrees. The thermometer in the thermostat waits to sense a temperature change either too high above or too far below the 70 degree set point. When this change happens the thermometer will send a message to the "Control Center", or thermostat, Which in turn will then send a message to the furnace to either shut off if the temperature is too high or kick back on if the temperature is too low. In the home-heating example the air temperature is the "NEGATIVE

FEEDBACK." When the Control Center receives negative feedback it triggers a chain reaction in order to maintain room temperature.

- ***Positive feedback***: a response is to amplify the change in the variable. This has a destabilizing effect, so does not result in homeostasis. Positive feedback is less common in naturally occurring systems than negative feedback, but it has its applications. For example, in nerves, a threshold electric potential triggers the generation of a much larger action potential. Blood clotting and events in childbirth are other types of positive feedback.
- *'Harmful Positive Feedback'*

→ not always!

Although Positive Feedback is needed within Homeostasis it also can be harmful at times. When you have a high fever it causes a metabolic change that can push the fever higher and higher. In rare occurrences the body temperature reaches 113 degrees and the cellular proteins stop working and the metabolism stops, resulting in death.

Summary: Sustainable systems require combinations of both kinds of feedback. Generally with the recognition of divergence from the homeostatic condition, positive feedbacks are called into play, whereas once the homeostatic condition is approached, negative feedback is used for "fine tuning" responses. This creates a situation of "metastability," in which homeostatic conditions are maintained within fixed limits, but once these limits are exceeded, the system can shift wildly to a wholly new (and possibly less desirable) situation of homeostasis.

Homeostatic systems have several properties

- They are ultra-stable, meaning the system is capable of testing which way its variables should be adjusted.
- Their whole organization (internal, structural, and functional) contributes to the maintenance of balance.
- Physiology is largely a study of processes related to homeostasis. Some of the functions you will learn about in this ~~book~~ course are not specifically about homeostasis (e.g. how muscles contract), but in order for all bodily processes to function there must be a suitable internal environment. Homeostasis is, therefore, a fitting framework for the introductory study of physiology.

Where did the term "Homeostasis" come from?

The concept of homeostasis was first articulated by the French scientist Claude Bernard (1813-1878) in his studies of the maintenance of stability in the "milieu interior." He said, "All the vital mechanisms, varied as they are, have only one object, that of preserving constant the conditions of life in the internal environment" (from *Leçons sur les Phénonèmes de la Vie Commune aux Animaux et aux Végétaux*, 1879). The term itself was coined by American physiologist Walter Cannon, author of *The Wisdom of the Body* (1932). The word comes from the Greek *homoios* (same, like, resembling) and *stasis* (to stand, posture).

Cruise Control on a car as a simple metaphor for homeostasis

When a car is put on cruise control it has a set speed limit that it will travel. At times this speed may vary by a few miles per hour but in general the system will maintain the set speed. If the car starts to go up a hill, the systems will automatically increase the amount of fuel given to maintain the set speed. If the car starts to come down a hill, the car will automatically decrease the amount of fuel given in order to maintain the set speed. It is the same with homeostasis- the body has a set limit on each environment. If one of these limits increases or decreases, the body will sense and automatically try to fix the problem in order to maintain the pre-set limits. This is a simple metaphor of how the body operates—constant monitoring of levels, and automatic small adjustments when those levels fall below (or rise above) a set point.

1. What is homeostasis?
2. Explain the difference between positive & negative feedback. Provide an example of each!

Pathways That Alter Homeostasis

A variety of homeostatic mechanisms maintain the internal environment within tolerable limits. Either homeostasis is maintained through a series of control mechanisms, or the body suffers various illnesses or disease. When the cells in the body begin to malfunction, the homeostatic balance becomes disrupted. Eventually this leads to disease or cell malfunction. Disease and cellular malfunction can be caused in two basic ways: either, *deficiency* (cells not getting all they need) or *toxicity* (cells being poisoned by things they do not need). When homeostasis is interrupted in your cells, there are *pathways* to correct or worsen the problem. In addition to the internal control mechanisms, there are external influences based primarily on lifestyle choices and environmental exposures that influence our body's ability to maintain cellular health.

Things to think about!

- **Nutrition:** If your diet is lacking in a specific vitamin or mineral your cells will function poorly, possibly resulting in a disease condition. For example, a menstruating woman with inadequate dietary intake of iron will become anemic. Lack of hemoglobin, a molecule that requires iron, will result in reduced oxygen-carrying capacity. In mild cases symptoms may be vague (e.g. fatigue), but if the anemia is severe the body will try to compensate by increasing cardiac output, leading to palpitations and sweatiness, and possibly to heart failure.
- **Toxins:** Any substance that interferes with cellular function, causing cellular malfunction. This is done through a variety of ways; chemical, plant, insecticides, and/or bites. A commonly seen example of this is drug overdoses. When a person takes too much of a drug their vital signs begin to waver; either increasing or decreasing, these vital signs can cause problems including coma, brain damage and even death.
- **Psychological:** Your physical health and mental health are inseparable. Our thoughts and emotions cause chemical changes to take place either for better as with meditation, or worse as with stress.
- **Physical:** Physical maintenance is essential for our cells and bodies. Adequate rest, sunlight, and exercise are examples of physical mechanisms for influencing homeostasis. Lack of sleep is related to a number of ailments such as irregular cardiac rhythms, fatigue, anxiety and headaches.
- **Genetic/Reproductive:** Inheriting strengths and weaknesses can be part of our genetic makeup. Genes are sometimes turned off or on due to external factors which we can have some control over, but at other times little can be done to correct or improve genetic diseases. Beginning at the cellular level a variety of diseases come from mutated genes. For example, cancer can be genetically inherited or can be caused due to a mutation from an external source such as radiation or genes altered in a fetus when the mother uses drugs.
- **Medical:** Because of genetic differences some bodies need help in gaining or maintaining homeostasis. Through modern medicine our bodies can be given different aids, from anti-bodies to help fight infections, or chemotherapy to kill harmful cancer cells. Traditional and alternative medical practices have many benefits, but like any medical practice the potential for harmful effects is present. Whether by nosocomial infections, or wrong dosage of medication, homeostasis can be altered by that which is trying to fix it. Trial and error with medications can cause potential harmful reactions and possibly death if not caught soon enough.

The factors listed above all have their effects at the cellular level, whether harmful or beneficial. Inadequate beneficial pathways (deficiency) will almost always result in a harmful waiver in homeostasis. Too much toxicity also causes homeostatic imbalance, resulting in cellular malfunction. By removing negative health influences, and providing adequate positive health influences, your body is better able to self-regulate and self-repair, thus maintaining homeostasis.

3. Choose one of the examples above and explain how it alters homeostasis in the human body (use your own words please!)

Case Study

Example

Heat stroke and Heat exhaustion

If you have ever performed heavy manual labor or competed in an athletic event on a sweltering hot day, chances are you may have experienced symptoms of heat exhaustion. Typically these include an elevated core body temperature (above 104F or 40C), profuse sweating, pale color, muscle cramps, dizzines, and in some extreme circumstances, fainting or loss of consciousness.

Heat exhaustion occurs as a consequence of disruption of the body's own system of thermoregulation, the means by which it adjusts temperature. Sweating is the principal means through which the body cools itself down, but diverting blood from other regions toward the skin also serves this purpose. Although sweat allows excess heat to dissipate as the moisture reaches the skin surface, it can also have dangerous implications for blood pressure and volume. As sweating increases, blood volume can drop precipitously, meaning that the brain and other body systems are at risk for insufficient oxygen and nutrient supplies. Furthermore, diverting blood away from other systems and towards the skin compounds the changes in blood volume and blood pressure induced through sweating.

Heat stroke is a far more serious condition. This happens when the body's temperature rises out of control due to the failure of the thermoregulating system. If the body is unable to reduce its temperature due to outside or physical influences, the brain will start to malfunction. Delirium and loss of consciousness set in. The center of the brain controlling the sweat glands will stop functioning, halting the production of sweat. This causes the body's temperature to rise even faster. Furthermore, with the increase of the body's temperature, the metabolic process will speed up causing even more heat in the body. If left untreated this will result in death. One of the easiest ways to spot heat stroke is the skin. If it is flushed due to the increase of blood flow but dry because the sweat glands have stopped secreting, the individual will need prompt medical attention.

Other Examples

- Thermoregulation
  - The skeletal muscles can shiver to produce heat if the body temperature is too low.
  - Non-shivering thermogenesis involves the decomposition of fat to produce heat.
  - Sweating cools the body with the use of evaporation.
- Chemical regulation
  - The pancreas produces insulin and glucagon to control blood-sugar concentration.
  - The lungs take in oxygen and give off carbon dioxide, which regulates pH in the blood.
  - The kidneys remove urea, and adjust the concentrations of water and a wide variety of ions.

Main examples of homeostasis in mammals are as follows:

- The regulation of the amounts of water and minerals in the body. This is known as osmoregulation. This happens primarily in the kidneys.
- The removal of metabolic waste. This is known as excretion. This is done by the excretory organs such as the kidneys and lungs.
- The regulation of body temperature. This is mainly done by the skin.
- The regulation of blood glucose level. This is mainly done by the liver and the insulin and glucagon secreted by the pancreas in the body.

Most of these organs are controlled by hormones secreted from the pituitary gland, which in turn is directed by the hypothalamus.

4. What is the difference between heat exhaustion and heat stroke at the physiological level?

5. How are both of these conditions related to the concepts of homeostasis, positive and/or negative feedback?

What is homeostasis?

Jan 3, 2000

Emeritus Professor Kelvin Rodolfo of the University of Illinois at Chicago's Department of Earth and Environmental Sciences provides this answer:

Homeostasis, from the Greek words for "same" and "steady," refers to any process that living things use to actively maintain fairly stable conditions necessary for survival. The term was coined in 1930 by the physician Walter Cannon. His book, *The Wisdom of the Body*, describes how the human body maintains steady levels of temperature and other vital conditions such as the water, salt, sugar, protein, fat, calcium and oxygen contents of the blood. Similar processes dynamically maintain steady-state conditions in the Earth's environment.

Image: *AMERICAN PSYSIOLOGICAL SOCIETY* **WALTER CANNON** devised the term homeostasis in 1930 while referring to how the body maintains its temperature, among other key variables.

Homeostasis has found useful applications in the social sciences. It refers to how a person under conflicting stresses and motivations can maintain a stable psychological condition. A society homeostatically maintains its stability despite competing political, economic and cultural factors. A good example is the law of supply and demand, whereby the interaction of supply and demand keeps market prices reasonably stable.

Homeostatic ideas are shared by the science of cybernetics (from the Greek for "steersman"), defined in 1948 by the mathematician Norbert Wiener as "the entire field of control and communication theory, whether in the machine or in the animal." Cybernetic systems can "remember" disturbances and thus are used in computer science to store and transmit information. Negative feedback is a central homeostatic and cybernetic concept, referring to how an organism or system automatically opposes any change imposed upon it.

For example, the human body uses a number of processes to control its temperature, keeping it close to an average value or norm of 98.6 degrees Fahrenheit. One of the most obvious physical responses to overheating is sweating, which cools the body by making more moisture on the skin available for evaporation. On the other hand, the body reduces heat-loss in cold surroundings by sweating less and reducing blood circulation to the skin. Thus, any change that either raises or lowers the normal

temperature automatically triggers a counteracting, opposite or negative feedback . Here, negative merely means opposite, not bad; in fact, it operates for our well being in this example. Positive feedback is a response to change from the normal condition that increases the departure even more.

For example, if a person's temperature is raised to about 107 degrees Fahrenheit, the negative feedback systems stop operating. A person with a high fever has hot, dry skin if they do sweat to help cool it. Not only have the negative feedback systems shut down in such a case; the increased temperature speeds up the body chemistry, which causes the temperature to rise even more, which in turn speeds up the body chemistry even more, and so forth. This vicious cycle of positive feedback, a "runaway" process, can only end in death if not stopped.

It is important to emphasize that homeostatic reactions are inevitable and automatic if the system is functioning properly, and that a steady state or homeostasis may be maintained by many systems operating together. For example, flushing is another of the body's automatic responses to heating: the skin reddens because its small blood vessels automatically expand to bring more heated blood close to the surface where it can cool. Shivering is another response to chilling: the involuntary movements burn body tissue to produce more body heat.

Negative feedback arises out of balances between forces and factors that mutually influence each other. To illustrate several of its important characteristics, we can regard a car and its driver as a unified, complex, homeostatic or "goal-seeking"

ving keeps turning the wheel slightly to the left and right, seeking the wheel positions that will bring the naturally meandering car back on track. Disturbance, or departure from equilibrium, is every bit as important as negative feedback: Systems cannot correct themselves if they do not stray.

Oscillation is a common and necessary behavior of many systems. If the car skids, the driver automatically responds by quickly steering in the opposite direction. Such abrupt negative feedback, however, usually over-corrects, causing the car to move toward the other side of the road. A negative feedback, if it is as large as the disturbance that triggered it, may become an impressed change in the direction opposite to that of the original disturbance. The car and driver recovers from the skid by weaving from side to side, swerving a little less each time. In other words, each feedback is less than the last departure from the goal, so the oscillations "damp out." Negative feedback takes time and such a time lag is an essential feature of many natural systems. This may set the system to oscillating above and below the equilibrium level.

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6. Explain the phrase: "negative merely means opposite, not bad."