The University of Jordan
Department of Physiology and Biochemistry
Medical and Dental students

Introduction to Homeostasis and Control systems

Follow the links:

https://www.youtube.com/watch?v=LSgEJSlk6W4

https://letstalkscience.ca/educational-resources/backgrounders/introduction-homeostasis-and-regulation

Questions:

Note: Hemostasis → stop bleeding, static
Homeostasis → dynamic process

What we mean by baroreceptors?

Introduction

Homeostasis refers to the inclination [Tendency] to oppose alteration in order to uphold a steady and relatively unchanging internal environment. Typically, homeostasis entails the utilization of negative feedback loops that counterbalance deviations from the desired values, also known as set points. In contrast, positive feedback loops intensify the initial stimuli, thereby steering the system away from its initial state.

[dynamic not static]
[The body's internal enviroment maintained at an almost constant level]

Homeostasis, the tendency to uphold a stable internal environment, encompasses more than just temperature regulation. The body also ensures the steady concentration of various ions, pH levels, and glucose concentration in the blood. Deviations from these values can lead to severe illness.

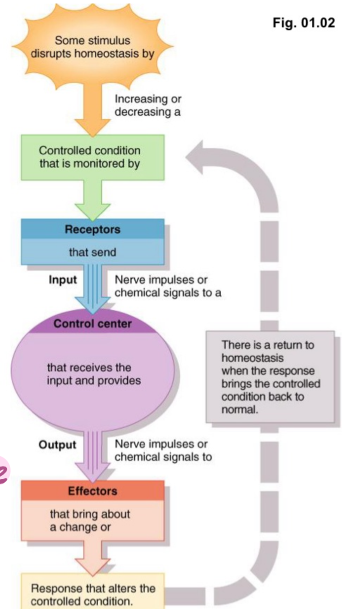
Homeostasis operates at multiple levels, not limited to the entire body's temperature regulation. For instance, the stomach maintains a distinct pH compared to surrounding organs, and individual cells maintain different ion concentrations than the surrounding fluid. Maintaining homeostasis at each level is crucial for the overall functioning of the body.

Maintaining homeostasis: EXAMPLES

Biological systems, such as the human body, are constantly being pushed away from their equilibrium points. When you engage in physical activity, for example, your muscles generate more heat, causing your body temperature to rise. Similarly, consuming a glass of fruit juice leads to an increase in blood glucose levels. The maintenance of homeostasis relies on your body's ability to detect and counteract these changes.

Feed back system

Fig. 01.02



1. Receptors → * monitor changes in a Controlled Condition

* Sends input to control center (the brain)

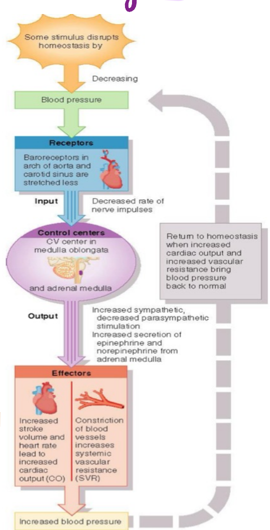
* E.g: Baroreceptor in blood vessels that sense blood pressure

2. Control Center → Brain

* Sets range of values to be maintained

* Evaluate input recieved from receptors and generates output Command

* Brain output Command → done by nervous system and endocrine systems



3. Effectors

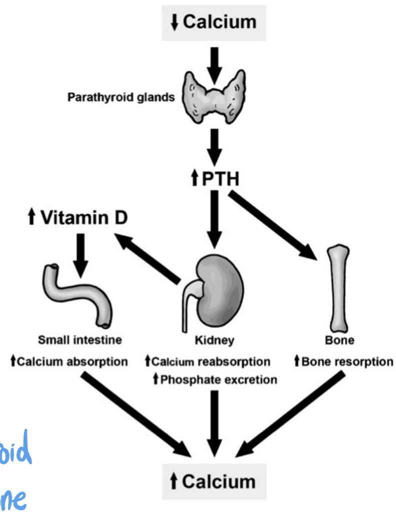
* Recives output from control center

* Produces a response or effect that changes the Controlled conditions

* nearly found in every organ or tissue

e.g: if Baroreceptors sense a decrease in Bp they will send Signals to the Control center (brain), the brain will send Signals to the effector to solve this problem and increase blood pressure back to normal, by increasing Contractility of heart muscle or sending Signals to kidney to increase absorption of water another example →

* when Calcium concentration gets below the normal range, the body will sense that decrease by certain receptors →



* these receptors will send signals to the brain → the brain stimulates the parathyroid gland to release more parathyroid hormone

↳ increases the calcium concentration by;

① increasing bone resorption (breakdown)

② increasing calcuim reaborption by the kidneys

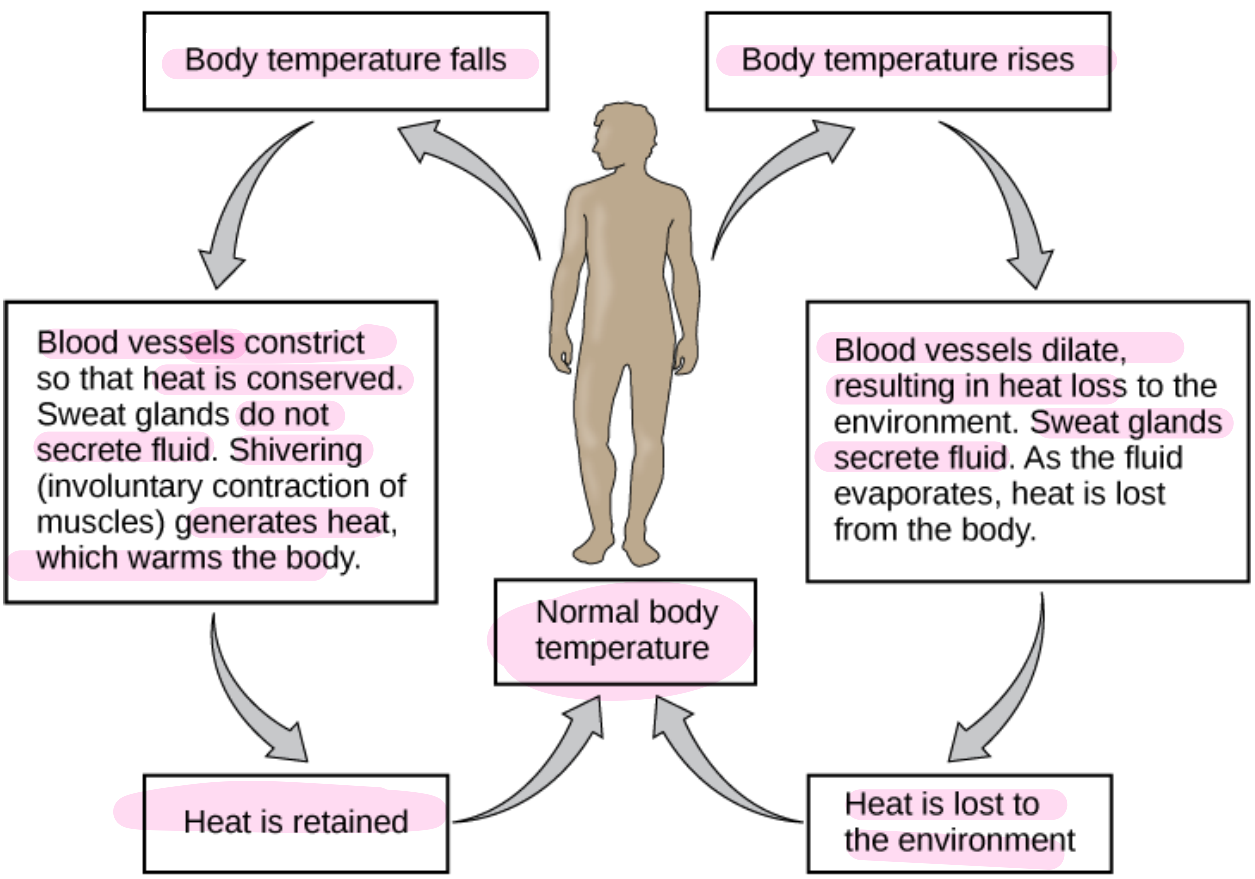
③ Stimulates kidney to transform the inactive form of vitamin D to the active form which will increase absorption of calcium in intestine

The preservation of homeostasis typically involves negative feedback loops, which work to counter the initial stimulus or cue that triggers them. If your body temperature becomes too high, a negative feedback loop will be activated to bring it back towards the desired set point or target value.

So, how does this process work? Initially, sensors, primarily nerve cells located in your skin and brain, detect the elevated temperature and transmit this information to a temperature-regulatory control center in your brain. The control center then processes the data and initiates a response through effectors, such as sweat glands, which work to counteract the stimulus by reducing body temperature.

1. A negative feedback loop consists of four fundamental components: a stimulus, a sensor, a control, and an effector.

2. Negative feedback is responsible for regulating body temperature. The stimulus occurs when the body temperature surpasses 37 degrees Celsius, the sensors are nerve endings located in the skin and brain, the control is the temperature regulatory center in the brain, and the effector refers to the sweat glands distributed throughout the body.



Source: https://storymd.com/asset/VdKXDmuwqK-homeostasis

Certainly, body temperature does not only exceed its target value, but it can also fall below this value. Typically, homeostatic circuits involve at least two negative feedback loops:

One is activated when a parameter, such as body temperature, surpasses the set point and aims to lower it.

One is activated when the parameter falls below the set point and aims to raise it.

To illustrate this concept further, let's examine the opposing feedback loops that govern body temperature control.

Temperature regulation in homeostatic responses

If there is an increase or a decrease in body temperature, sensors in both the periphery and the brain inform the temperature regulation center of your brain, specifically the hypothalamus region, that your temperature has deviated from its set point.

For example, in the event that you have been engaging in rigorous physical activity, your body temperature may exceed its designated level, necessitating the activation of cooling mechanisms. This involves an increase in blood flow to your skin to expedite heat dissipation into the surrounding environment. Additionally, you may experience sweating, as the evaporation of sweat from your skin aids in cooling you down. Furthermore, heavy breathing can contribute to the loss of heat.

When the body temperature becomes excessively high, the blood vessels expand, sweat glands release fluid, and the body dissipates heat. Consequently, as heat is released into the surroundings, the body temperature gradually reverts back to its normal state.

However, in the event that you find yourself in a chilly environment without adequate clothing, the brain's temperature center will activate mechanisms to warm you up. This includes reducing blood flow to the skin, causing shivering to generate additional heat in the muscles. Additionally, you may experience goose bumps, which raise the hair on your body and create a layer of air near the skin, as well as an increase in the release of heat-producing hormones.

Disruptions to feedback disrupt homeostasis.

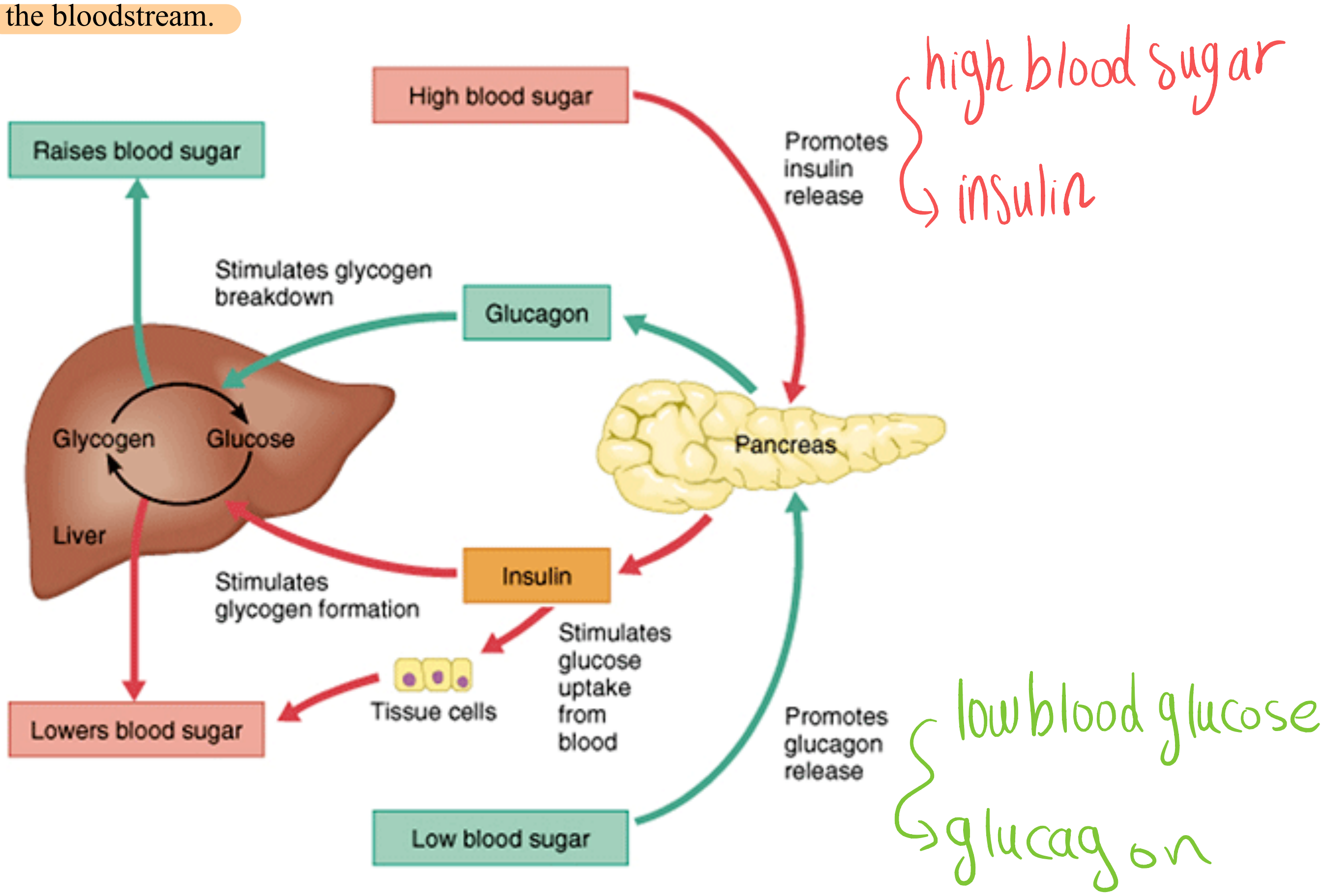
Disruptions to the feedback mechanisms can have a significant impact on homeostasis. Homeostasis relies on negative feedback loops, and any interference with these loops can disrupt the balance. This disruption can lead to various diseases, such as diabetes.

Diabetes is a prime example of a disease that arises from a malfunctioning feedback loop involving insulin. When this feedback loop is broken, the body struggles to regulate high blood sugar levels effectively, making it challenging to bring them down to a healthy level.

To understand how diabetes develops, it's essential to grasp the fundamentals of blood sugar regulation. In a healthy individual, insulin and glucagon, two hormones, work together to control blood sugar levels.

Insulin plays a crucial role in reducing glucose concentration in the blood. After a meal, blood glucose levels increase, prompting the pancreas's β cells to secrete insulin. This hormone acts as a signal, prompting cells throughout the body, including fat and muscle cells, to absorb glucose for energy. Additionally, insulin facilitates the conversion of glucose into glycogen, a storage molecule found in the liver. Both processes help remove sugar from the blood, lowering blood sugar levels, reducing insulin secretion, and restoring overall homeostasis.

When blood glucose concentration exceeds the normal range, insulin is released to stimulate body cells to remove excess glucose from the blood. Conversely, if blood glucose concentration falls below the normal range, glucagon is released to encourage body cells to release glucose into the bloodstream.



Sources: https://www.atrainceu.com/content/4-regulation-blood-glucose

Glucagon functions in the opposite manner, as it elevates the concentration of glucose in the bloodstream. In the absence of food intake for an extended period, the decline in blood glucose levels triggers the release of glucagon from the α cells in the pancreas. Glucagon then acts upon the liver, prompting the breakdown of glycogen into glucose, which is subsequently released into the bloodstream. This process effectively raises blood sugar levels, leading to a reduction in glucagon secretion and the restoration of homeostasis within the system.

Diabetes occurs when the pancreas fails to produce sufficient insulin, or when the body's cells become unresponsive to insulin, or both. Consequently, under these circumstances, the cells in the body do not efficiently absorb glucose, resulting in prolonged high blood sugar levels following a meal. This occurs due to two primary reasons:

1. Insufficient glucose uptake by muscle and fat cells, leading to fatigue and potential wasting of muscle and fat tissues.

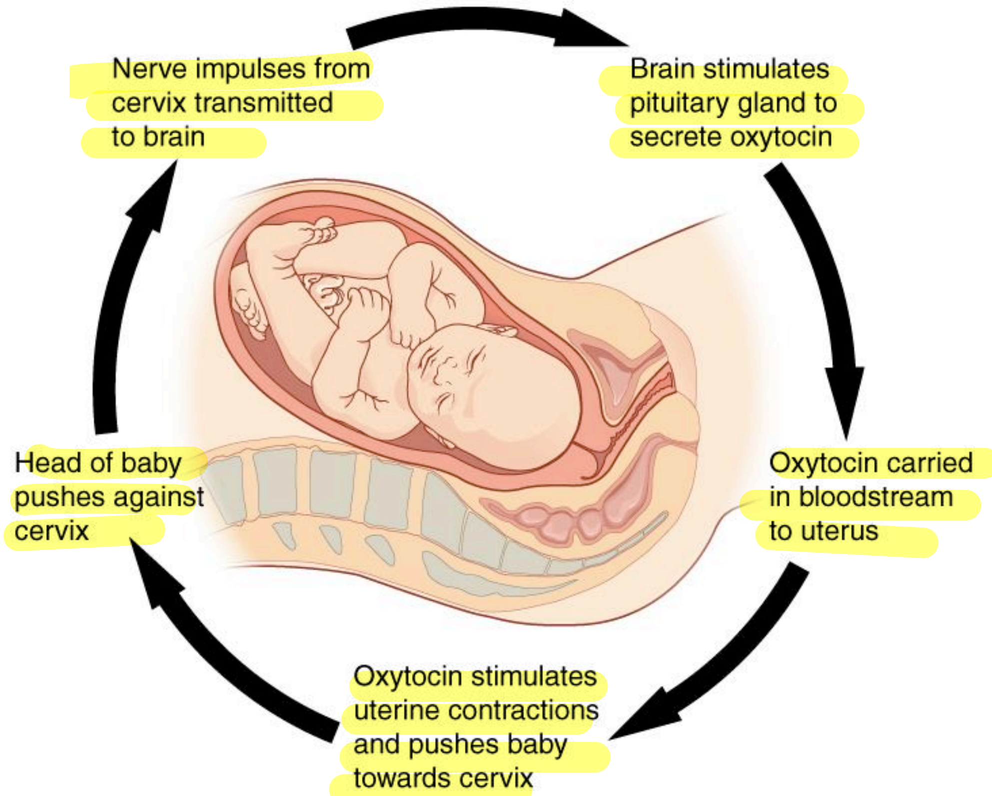
2. Elevated blood sugar levels causing symptoms such as frequent urination, increased thirst, and even dehydration. Over time, this can give rise to more severe complications.

Positive Feedback → usually in emergency situation

Homeostatic circuits typically involve negative feedback loops, which are characterized by their ability to counteract changes and bring a parameter back towards its set point. However, there are some biological systems that utilize positive feedback loops. Unlike negative feedback loops, positive feedback loops amplify the initial signal and are commonly found in processes that require completion rather than maintaining the original status.

One example of a positive feedback loop is observed during childbirth. When the baby's head presses on the cervix, it activates neurons that send a signal to the brain. This signal triggers the release of **oxytocin** from the pituitary gland. Oxytocin **then increases uterine contractions**, leading to more pressure on the cervix. This, in turn, causes the release of even more oxytocin and stronger contractions. The positive feedback loop continues until the baby is born.

It is important to note that normal childbirth is driven by a positive feedback loop, which results in a change in the body's status rather than a return to homeostasis. The feedback loop in this case is drawn clockwise.



Source: OpenStax College, Anatomy & Physiology, CC BY 4.0

1. The transmission of nerve impulses from the cervix to the brain initiates a series of events.

2. Subsequently, the brain triggers the pituitary gland to release oxytocin into the bloodstream.

3. The oxytocin then travels through the bloodstream and reaches the uterus.

4. Once in the uterus, oxytocin stimulates contractions, which in turn push the baby towards the cervix.

5. As the baby's head presses against the cervix, the process continues in a repetitive cycle.

Summary:

Negative feedbacks serve as the body's mechanism to maintain normalcy or stability,

While the positive feedbacks intensify specific effects on the body by ensuring repetition of functions.

additional example :

* when someone is bleeding , the blood Coagulates (يتجلط) [stimulus] , the [response] will be a coagulation to prevent blood loss