Body temperature regulation

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A healthy body functions best at an internal temperature of about 37°C (98.6°F). But everyone has their own individual "normal" body temperature, which may be slightly higher or lower. Our bodies also constantly adapt their temperature to environmental conditions. It goes up when we exercise, for instance. And it is lower at night and higher in the afternoon than in the morning.

Our internal body temperature is regulated by a part of our brain called the hypothalamus. The hypothalamus checks our current temperature and compares it with the normal temperature of about 37°C. If our temperature is too low, the hypothalamus makes sure that the body generates and maintains heat. If, on the other hand, our current body temperature is too high, heat is given off or sweat is produced to cool the skin.

Strictly speaking, body temperature refers to the temperature in the hypothalamus and in the vital internal organs. Because we cannot measure the temperature inside these organs, temperature is taken on parts of the body that are more accessible. But these measurements are always slightly inaccurate.

Thermoregulation, by definition, is a mechanism by which mammals maintain body temperature by tightly controlled self-regulation, no matter the temperature of their surroundings. Temperature regulation is a type of homeostasis, which is a process that biological systems use to preserve a stable internal state to survive. **Ectotherms**, are the animals that depend on their external environment for their body heat, and **endotherms** are animals that use thermoregulation to maintain a somewhat consistent internal body temperature to survive, even when their external environment changes. Humans and other mammals and birds are endotherms. Human beings have a normal core, or internal, temperature of around 37 degrees Celsius, which is equivalent to around 98.6 degrees Fahrenheit. Core temperature is most accurately measured via rectal probe thermometer. This is the temperature at which the human body’s systems work together at their optimum, which is the reason the body, has such tightly regulated mechanisms. Thermoregulation is crucial to human life. Without thermoregulation, the human body would not be able to adequately function and, inevitably, will expire.

When the body is too hot, it decreases heat production and increases heat loss. One way of increasing heat loss is through peripheral **vasodilation**, the dilation of blood vessels in the skin. When these vessels dilate, large quantities of warmed blood from the core of the body are carried to the skin, where heat loss may occur via radiation, convection, and conduction. Evaporation of fluids from the body also causes heat loss. Humans constantly lose fluids from the skin and in exhaled air. The unconscious loss of fluid is **called insensible perspiration.**

Cellular regulation

Viral illness or another infectious disease can cause a person to develop a fever, and the body no longer has that same core temperature of 37 degrees Celsius. This is because when the body experiences an infection from invading pathogens, it tries to fight back by releasing pyrogens such as cytokines, prostaglandins, and thromboxane—all of which increase the body’s temperature. By releasing these pyrogens, the foreign pathogens are not able to breed. This allows for antibodies to develop and enzymes to be activated to fight the infection further.

Central regulation:

The brain, or more specifically the hypothalamus, controls thermoregulation. If the hypothalamus senses external temperatures growing too hot or too cold, it will automatically send signals to the skin, glands, muscles, and organs. For example, when the body is in a very hot external environment, or simply undergoing high activity levels such as exercise, it’s temperature will rise, causing the hypothalamus to send signals to the cells of the skin that produce sweat. Sweating is the body's approach to cooling itself down. As the body’s temperature rises, sweat is expelled, the muscles relax, and body hair lies flat against the skin. These are all ways to release heat and therefore lower the temperature of the body.

In contrast, when the body experiences a cold environment, the skeletal muscles tense up leading to the shivering reflex, and the arrector pili muscles, a type of smooth muscle, raise the bodily hair follicles where they are attached. These processes, in turn, create warmth and trap heat, respectively.

Role of hormones in body temperature regulation:

Hormones such as epinephrine, norepinephrine, and thyroid hormone increase the metabolic rate by stimulating the breakdown of fat. Humans also change posture, activity, clothing, or shelter to adjust for fluctuations in temperature. The goose bumps that arise on the skin in the cold are another sign the body is trying to prevent heat loss. They are due to piloerection, the erection of the hair follicles on the skin. This is a vestige of the time when humans were covered in hair: piloerection would trap air and retain heat.

Body temperature is regulated by a system of sensors and controllers across the body. The brain receives signals regarding body temperature from the nerves in the skin and the blood. These signals go to the hypothalamus, which coordinates thermoregulation in the body. Signals from the hypothalamus control the sympathetic nervous system, which affects vasoconstriction, **metabolism**, shivering, sweating, and hormonal controls over temperature. In general, the posterior hypothalamus controls responses to cold, and the **anterior** hypothalamus controls responses to heat.

Overall mechanism of thermoregulation:

Thermoregulation has three mechanisms: afferent sensing, central control, and efferent responses. There are receptors for both heat and cold throughout the human body. Afferent sensing works through these receptors to determine if the body is experiencing either too hot or too cold of a stimulus. Next, the hypothalamus is the central controller of thermoregulation. Lastly, efferent responses are carried out primarily by the body’s behavioural reactions to fluctuations in body temperature. For example, if a person is feeling too warm, the normal response is to remove an outer article of clothing. If a person is feeling too cold, they choose to wear more layers of clothing. Efferent responses also consist of automatic responses by the body to protect itself from extreme changes in temperature, such as sweating, vasodilation, vasoconstriction, and shivering.

As in other mammals, **thermoregulation in humans** is an important aspect of homeostasis. In thermoregulation, body heat is generated mostly in the deep organs, especially the liver, brain, and heart, and in contraction of skeletal muscles. Humans have been able to adapt to a great diversity of climates, including hot humid and hot arid. High temperatures pose serious stress for the human body, placing it in great danger of injury or even death. For humans, adaptation to varying climatic conditions includes both physiological mechanisms resulting from evolution and behavioural mechanisms resulting from conscious cultural adaptations.

There are four avenues of heat loss: convection, conduction, radiation, and evaporation. If skin temperature is greater than that of the surroundings, the body can lose heat by radiation and conduction. But, if the temperature of the surroundings is greater than that of the skin, the body actually gains heat by radiation and conduction. In such conditions, the only means by which the body can rid itself of heat is by evaporation. So, when the surrounding temperature is higher than the skin temperature, anything that prevents adequate evaporation will cause the internal body temperature to rise. During sports activities, evaporation becomes the main avenue of heat loss. Humidity affects thermoregulation by limiting sweat evaporation and thus heat loss.

In hot conditions:

- Eccrine sweat glands under the skin secrete sweat (a fluid containing mostly water with some dissolved ions), which travels up the sweat duct, through the sweat pore and onto the surface of the skin. This causes heat loss via evaporative cooling; however, a lot of essential water is lost.
- The hair on the skin lie flat, preventing heat from being trapped by the layer of still air between the hair. This is caused by tiny muscles under the surface of the skin called arrector pili muscles relaxing so that their attached hair follicles are not erect. These flat hairs increase the flow of air next to the skin increasing heat loss by convection. When environmental temperature is above core body temperature, sweating is the only physiological way for humans to lose heat.
- Arteriolar vasodilation occurs. The smooth muscle walls of the arterioles relax allowing increased blood flow through the artery. This redirects blood into the superficial capillaries in the skin increasing heat loss by convection and conduction.

In hot and humid conditions:

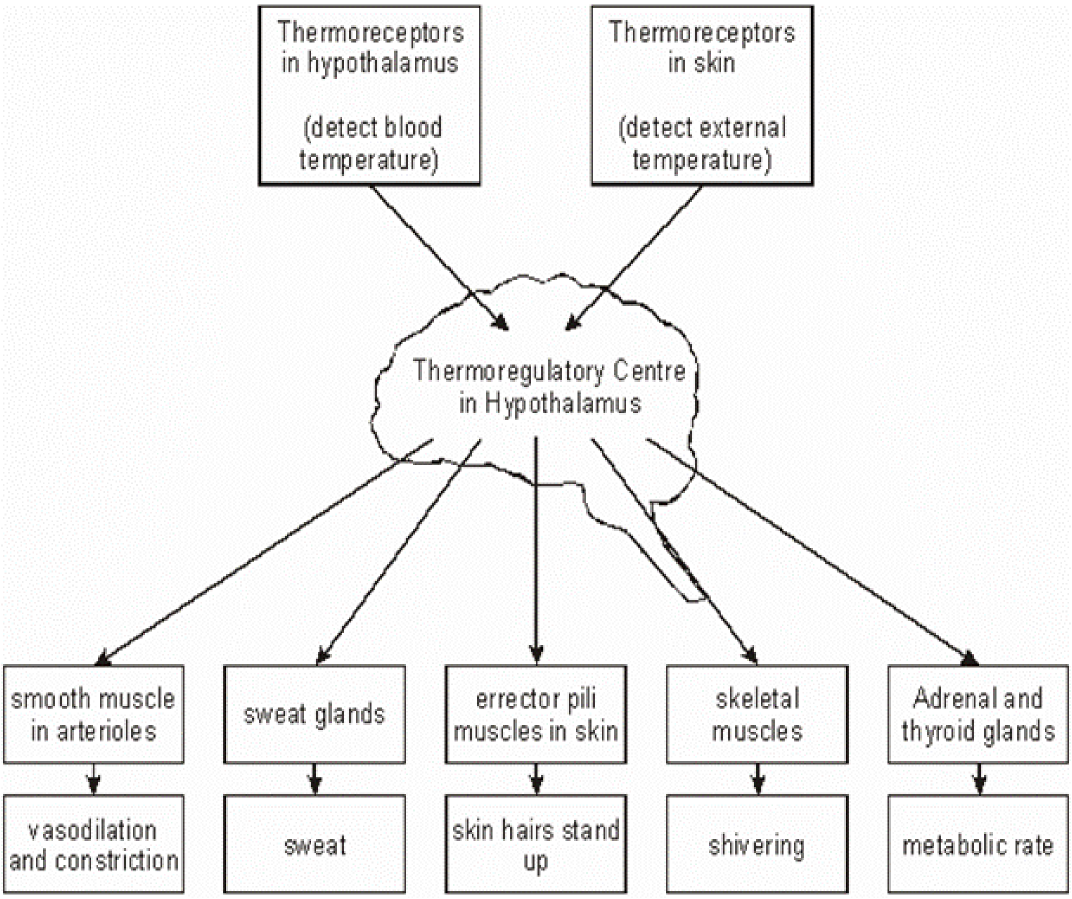
In general, humans appear physiologically well adapted to hot dry conditions. However, effective thermoregulation is reduced in hot, humid environments such as the Red Sea and Persian Gulf (where moderately hot summer temperatures are accompanied by unusually high vapor pressures), tropical environments, and deep mines where the atmosphere can be water-saturated. In hot-humid conditions, clothing can impede efficient evaporation. In such environments, it helps to wear light clothing such as cotton, that is pervious to sweat but impervious to radiant heat from the sun. This minimizes the gaining of radiant heat, while allowing as much evaporation to occur as the environment will allow. Clothing such as plastic fabrics that are impermeable to sweat and thus do not facilitate heat loss through evaporation can actually contribute to heat stress.

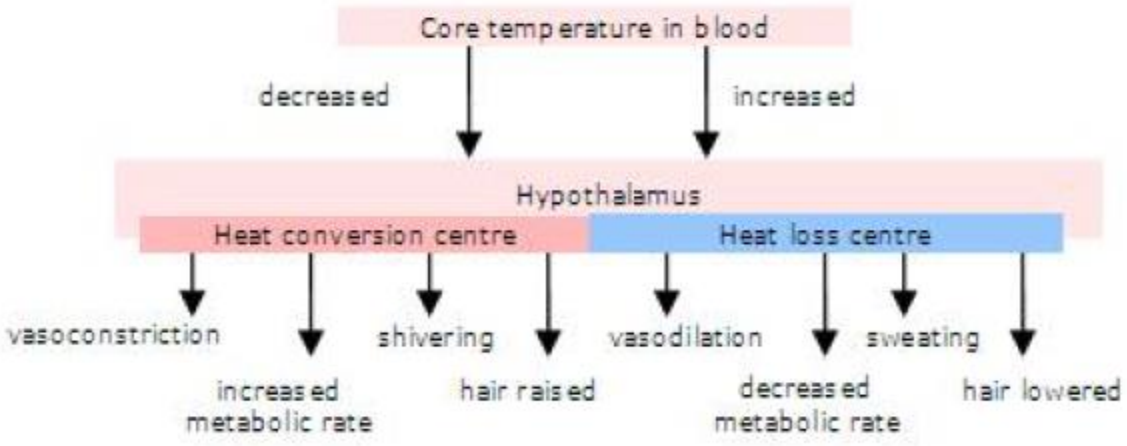
In cold conditions:

- Heat is lost mainly through the hands and feet.
- Sweat production is decreased.
- The minute muscles under the surface of the skin called arrector pili muscles (attached to an individual hair follicle) contract (piloerection), lifting the hair follicle upright. This makes the hairs stand on end, which acts as an insulating layer, trapping heat. This is

what also causes goose bumps since humans do not have very much hair and the contracted muscles can easily be seen.

- Arterioles carrying blood to superficial capillaries under the surface of the skin can shrink (constrict), thereby rerouting blood away from the skin and towards the warmer core of the body. This prevents blood from losing heat to the surroundings and also prevents the core temperature dropping further. This process is called vasoconstriction. It is impossible to prevent all heat loss from the blood, only to reduce it. In extremely cold conditions, excessive vasoconstriction leads to numbness and pale skin. Frostbite occurs only when water within the cells begins to freeze. This destroys the cell causing damage.
- Muscles can also receive messages from the thermoregulatory center of the brain (the hypothalamus) to cause shivering. This increases heat production as respiration is an exothermic reaction in muscle cells. Shivering is more effective than exercise at producing heat because the animal (includes humans) remains still. This means that less heat is lost to the environment through convection. There are two types of shivering: low-intensity and high-intensity. During low-intensity shivering, animals shiver constantly at a low level for months during cold conditions. During high-intensity shivering, animals shiver violently for a relatively short time. Both processes consume energy, however high-intensity shivering uses glucose as a fuel source and low-intensity tends to use fats. This is a primary reason why animals store up food in the winter.Brown adipocytes are also capable of producing heat via a process called **non-shivering thermogenesis**. In this process, triglycerides are burned into heat, thereby increasing body temperature.





Overall mechanism of thermoregulation

Effects on different organs in body temperature regulation:

Multiple organs and body systems are affected when thermoregulation is not working correctly. During heat illness as a result of improper thermoregulation, the following organs and systems are impaired. Notice that many of these issues cause or are influenced by the other issues.

- The heart experiences an increased burden due to elevations in heart rate and increased cardiac output.
- The circulatory system sustains intravascular dehydration.
- The brain suffers from cerebral ischemia and/or cerebral edema.
- The gastrointestinal tract is vulnerable to hemorrhage and also sepsis because the mucosa of the intestines increases its permeability.
- The lungs suffer when ARDS (Acute respiratory distress syndrome) results from the increase of hyperventilation, hyperpnoea, and pulmonary vasodilation.
- Acute renal failure can commence because of the dehydration and impairment in circulation.
- Liver cells suffer because of the fever, ischemia, and cytokines increase in the intestinal tract.
- Various organs can result in DIC (Disseminated intravascular coagulation) and microthrombi.
- Electrolyte abnormalities are likely as well as hypoglycemia, metabolic acidosis, and respiratory alkalosis.

When body temperatures severely decrease in hypothermia, the body’s systems are negatively affected. The cardiovascular system experiences dysrhythmias such as the Osborn, or J, wave on EKG/ECG. The central nervous system's (CNS) electrical activity is noticeably diminished, noncardiogenic pulmonary edema will occur, as well as cold diuresis, and decreases in glomerular filtration rate (GFR) and renal blood flow (RBF). Basically, hypothermia causes pre-glomerular vasoconstriction, which leads to decreased GFR and RBF.

Short notes on Hypothermia and Hyperthermia

Hypothermia, or low body temperature, is a result of prolonged exposure to cold. With a decrease in body temperature, all metabolic processes begin to slow. Hypothermia can be life-threatening.

Hyperthermia describes a body temperature that is higher than normal. One example of hyperthermia is fever. A fever is generally considered to be a body temperature over 38 degrees Celsius (100.4 degrees Fahrenheit). A fever is the body's natural defence to an infection by a bacterium or virus. Fevers are one of the body's mechanisms for eliminating an invading organism. Fevers may even make the immune system work more effectively. Heat exhaustion and heatstroke are other examples of hyperthermia. These occur when heat production exceeds the evaporative capabilities of the environment. Heatstroke may be fatal if untreated.