# Effects of low temperatures on the body

**Homoeothermic animals** try to maintain a constant body temperature, because of the functionality of enzymes at this temperature. The human body is an open thermodynamic system, i.e. a system that exchanges energy with its environment. There are a number of mechanisms that maintain a **constant body temperature** in response to changes in **environmental temperature**:

1. **Shivering thermogenesis**
2. **Non-shock thermogenesis**

There is a **constant heat exchange** between the environment and the organism of different temperature; these processes tend towards a state of **thermal equilibrium**. Heat exchange occurs by conduction, radiation and convection. The ideal temperature of the human body is **36.6 °C**.

Homoeothermic animals produce heat and maintain a **constant core** (internal organ) temperature that is almost independent of the environment. By **thermal equilibrium** of the body we mean a state in which heat production corresponds to heat expenditure. Animals maintain thermal equilibrium mainly by **regulating the rate of heat removal**, and there is little regulation of heat production. Heat is dissipated through the skin and lungs; inside the body, heat dissipation is mainly through blood exchange, and thus the **thermal conductivity** of internal tissues is not normally of much importance for heat distribution.

## Heat loss

Heat loss from the body occurs by mechanisms that are divided into direct and indirect:

##### Direct heat loss:

- Radiation.
- conduction (conduction)
- convection (flow)

##### Indirect heat loss:

- evaporation (sweating)

1. noticeable
2. imperceptible

- evaporation from the lungs

### Radiation

Every body radiates heat in the form of **electromagnetic radiation**. The wavelengths of this radiation vary depending on the ambient temperature, i.e. at high temperatures they correspond to ultraviolet radiation, at low temperatures to visible light, and under normal conditions to infrared radiation.

According to the Stefan-Boltzmann law, the amount of energy radiated is proportional to the fourth power of the absolute temperature of the body. Since the environment acts on the body in the same way, the total energy radiated is then **proportional to the difference of the fourth power of the surface temperature** of the body and the temperature of the objects in its surroundings.

For the **radiation intensity** (derived for the ideal case of radiation from an absolutely black body):

$$E = \sigma T^4$$

σ - Stefan-Boltzmann constant = $5{,}670400.10^{-8}\ Wm^{-2}K^{-4}$

Radiative heat loss accounts for about 40-60% of the total heat loss, the exact magnitude of which also depends on the ambient temperature and humidity. The amount of radiated heat is controlled by the degree of blood flow, changes in skin temperature and surface size. The amount of heat loss can be reduced by the use of appropriate clothing (or coat colour in animals). The wavelength of skin radiation is 5-20 micrometers.

### Conduction

Conduction is the **transfer of heat** from a warmer place to a colder place, with the molecules of the warmer place transferring their kinetic energy to neighbouring molecules in the colder region. In conduction, no mass is transferred but only thermal energy.

The amount of energy Q transferred in time r [s] between two conduction sites depends on the difference in the distance of the sites d [m], the difference in their temperatures Δt [K], the area S [m2] over which the transfer takes place, and the coefficient of thermal conductivity λ [J/m.s.K], which indicates the ability of a given substance to **conduct heat**, according to the following relation:

$Q = \lambda S \Delta t \tau / d$

Liquids are good conductors, so the conduction of heat in the body is provided by the blood. The function of thermal insulator in the human body is mainly occupied by **adipose tissue**. Conduction losses amount to 15-30% of the total losses and are influenced by **ambient conditions**.

### Convection

Very closely related to heat conduction. Heat must first be transferred by conduction to a substance, whose flow is then dissipated to the surroundings. In flow, in addition to the transfer of energy, there is also a transfer of substance. The amount of heat that is transferred in time t (s) by flow from the surface of a body of area S (m2) to the surroundings at a temperature lower than Δt (K) can be expressed by the equation:

$Q = \alpha S \Delta t \tau$, where (W/K.m2) is the interface heat transfer coefficient.

The coefficient α is not a material constant because its value depends on many factors that are not easily measurable. It is determined experimentally by means of so-called alphameters. It is known, for example, that an organism can tolerate frost better at low relative humidity than temperatures above freezing point at intense flow and high humidity.

### Evaporation of water

Water evaporation occurs during **breathing** and **sweating**. These losses account for up to 25% of the body's heat loss. During respiration, the exhaled air is almost saturated with water vapour. At low temperatures, sweating does not occur.

## Shivering thermogenesis

It's a primal reaction to cold. At first, it merely increases **muscle tone'**, this state gradually changes to spontaneous shivering at a frequency of 10-20 contractions per second, during which the muscles do no work but only generate heat. Its triggering and regulation is controlled in the anterior hypothalamus, it is an uncontrolled process.

## Non-shock thermogenesis

Two basic reactions are described here:

1. Increase in metabolism
2. Blocking oxidative phosphorylation in brown fat

### Increase in metabolism

A process controlled by the humoral washout of adrenalineu and noradrenalineu into the bloodstream. This results in physiological reactions such as an increase in heat rate, fat and glycogenu breakdown, an increase in the concentration of glucose in the blood, and an increase in the diameter of the bronchi in the lung. With prolonged exposure to cold, adrenalineu and noradrenalineu hormone take over the function thyroxine, which accelerates the breakdown of fats and increases the activity of mitochondria.

### Blocking oxidative phosphorylation in brown fat

'**Brown fat** is a special tissue that is found in greater abundance in juvenile hairless mammals and hibernacula. In children, the largest deposits of brown fat are in the neck, around the scapulae and around the renal gland. The brown colouration is due to the huge amount of mitochondria in this tissue. The Heat is generated in mitochondria, which have blocked ATP synthesis. To give a simple idea, this process can be described as spinning the ATP mill idle. Some studies show that hardy people can delay the start of the thermogenesis burst, the explanation could be just the use of brown fat.

## Temperature control in the thermoregulatory centers of the hypothalamus

Control of body temperature is via **thermoreceptors**, which are located in the skin, the viscera (these are not involved in conscious temperature perception) and the CNS (hypothalamus). '**Hypothalamus'** has the function of '**thermoregulatory centre of the organism***, being superior to other thermoreceptors. It receives information from thermoreceptors (located in the skin) for cold and heat. From the hypothalamus, stimuli are then sent to change* ***muscle tone****. The hypothalamus can also further send stimuli going to the pituitary, which, by controlling the activity of the thyroid and thus the hormone thyroxine, helps in long-term adaptation to cold.* The mechanisms that help to raise or lower the body's temperature (vasoconstriction, vasodilation, thermogenesis, cold shivering, etc.) always try to align the body's temperature with that of the **thermoregulatory centre**. Processes that maintain the body's normal temperature then occur.

## Pathological effects of cold

Prolonged exposure to cold and general exhaustion of the body results in hypothermia, a condition where the body core temperature drops below 35 °C. First, the peripheral parts of the body and the superficial layers are cooled, then the cold spreads into the core of the body to the deep organs. The factors that distinguish the effects of low temperatures on the body are the *amount of air exhaled* (causing significant heat loss), the length of time the body is exposed to the cold (the process of cooling from the periphery to the core is gradual), and the surface area of exposed body parts (the greater the temperature difference between exposed and exposed body parts, the greater the contribution to heat loss in this way).

In **hypothermia**, there is initially **tachycardia** (increasing body temperature) and '**altered circulation'**. In this state, the blood circulation struggles to maintain the temperature necessary for the performance of basic life functions, resulting in significant differences in blood temperature between the core and periphery. Care must be taken when treating an individual affected by prolonged exposure to cold, and thus, for example, the administration of alcohol to a hypothermic individual is highly counterproductive as it will dilute the blood from the core and periphery, which can have fatal consequences as the blood in the core will rapidly cool.

After *tachycardia, there is **bradycardia**, which is part of a gradual **dampening of the organism** that can lead to sleep (a consequence of general depression).*

When the core temperature drops to 34 °C, consciousness disturbances begin, and at 32 °C, unconsciousness occurs. If the core temperature falls below 24 °C, it is lethal state and heart failure occurs.

Prolonged exposure of the extremities to low temperatures can lead to **frostbite**. This process occurs at an ambient temperature of 15 °C or less. The body tries to cope with this condition by reducing blood flow to the periphery, **to keep the core of the body intact**. We divide frostbite into 4 groups according to severity (up to necrosis of the affected body part may occur).

However, the effect of low temperatures on the body also has positive benefits. In addition to **cryotherapy**, it is mainly used for '**hypothermia during surgery**. For example, during heart surgery, when the blood circulation is knocked out, which would normally lead to damage to the CNS, the oxygen consumption of the brain is reduced due to hypothermia (at 30  °C to half, and at 20 °C even to only a tenth), leading to a prolonged time when the patient can tolerate even a prolonged interruption of blood circulation without consequences.

## Zdroje


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