Temperature of the Body

Normal body Temperatures

Body temperature or ***Core temperature*** is the average temperature of structures present in deeper part of the body; it is always more than oral or rectal temperature. It is about 37.8°C (100°F) and it's usually remains very constant, within ±1°F (±0.6°C), except when a person has a febrile illness. ***The skin temperature***, in contrast to the core temperature, rises and falls with the temperature of the surroundings.

The normal body temperature in human is 37°C (98.6°F) when measured by placing the clinical thermometer in the mouth ***(oral temperature).*** *It varies between 35.8°C and 37.3°C (96.4° and 99.1°F).*

Variations of body temperature

Physiological Variations

1. ***Age:*** In infants, the body temperature varies in accordance to environmental temperature for the first few days after birth. It is because the temperature regulating system does not function properly during infancy. In children the temperature is slightly (0.5°C) more than in adults because of more physical activities. In old age, since the heat production is less, the body temperature decreases slightly.
2. ***Sex:*** In females, the body temperature is less because of low basal metabolic rate as compared to that of males.
3. ***Diurnal variation:*** In early morning, the temperature is 1°C less than normal. In the afternoon, it reaches the maximum (about 1°C more than normal).
4. ***After meals:*** The body temperature rises slightly (0.5°C) after meals.
5. ***Exercise:*** During exercise, the temperature raises due to production of heat in muscles.
6. ***Sleep:*** During sleep, the body temperature decreases by 0.5°C.
7. ***Emotion:*** During emotional conditions, the body temperature increases.
8. ***Menstrual cycle:*** In females, immediately after ovulation, the temperature rises (0.5° to 1°C) sharply. It decreases (0.5°C) during menstrual phase.

Heat Balance

Regulation of body temperature depends upon the balance between heat produced in the body and the heat lost from the body.

Heat gain or heat production in the body

The various mechanisms involved in the production of heat in the body are:

1. ***Metabolic Activities:*** The major portion of heat produced in the body is due to the metabolism of food. Heat production is more during metabolism of fat (about 9 calories/ liter). Then less calories of heat is produced during carbohydrate metabolism (4.7 calories). Protein metabolism produces heat the less of all (4.5 calories).

2. ***Muscular Activity:*** Heat is produced in the muscle both at rest and during activities. During rest, heat is produced by muscle tone. About 80% of heat of activity is produced by the activity of skeletal muscles.

3. ***Role of Hormones:*** Thyroxin (T_4) and adrenaline increase the heat production by accelerating the metabolic activities.

4. ***Radiation of Heat from the Environment:*** Body gains heat by radiation. It occurs when the environmental temperature is higher than the body temperature.

5. ***Shivering:*** Shivering refers to shaking of the body caused by rapid involuntary contraction or twitching of the muscles during exposure to cold.

Heat loss from the body

Maximum heat is lost from the body through skin and small amount of heat is lost through respiratory system, kidney and gastrointestinal tract. When environmental temperature is less than body temperature, heat is lost from the body.

Heat loss occurs by the following methods:

1. ***Conduction:*** Only minute quantities of heat, about 3%, are normally lost from the body by direct conduct from the surface of the body to solid objects, such as a chair or a bed. Loss of heat by conduction to air, however, represents a large proportion of the body's heat loss (about 15%) even under normal conditions.

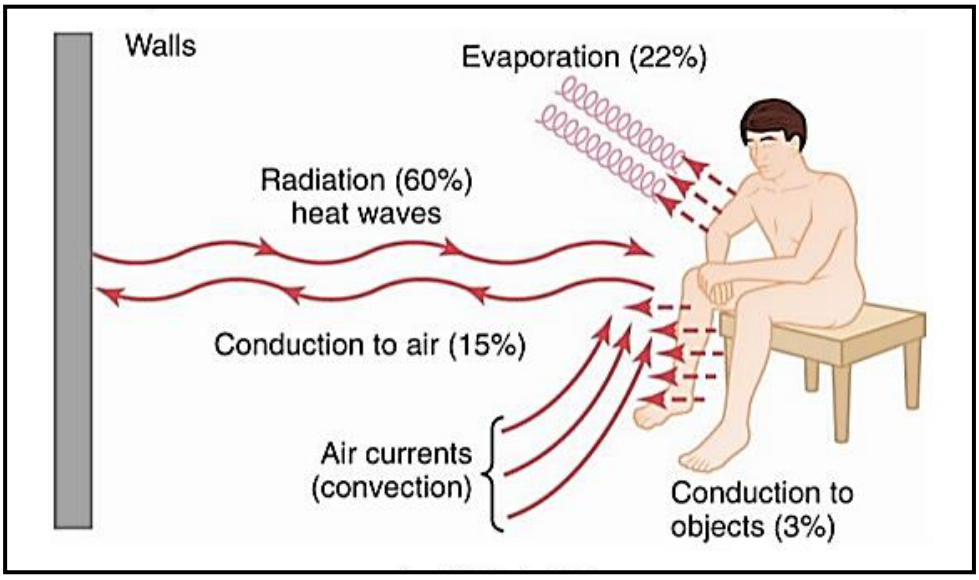
   Once the temperature of the air adjacent to the skin equals the temperature of the skin, no further loss of heat occurs in this way because now an equal amount of heat is conducted from the air to the body.

2. ***Radiation:*** 60% of heat is lost by means of radiation, transfer of heat by infrared ray (electromagnetic ray) radiation from body to other objects through the surrounding air. The human body radiates heat rays in all directions. Heat rays are also being radiated from the walls of rooms and other objects toward the body. If the temperature of the body is greater than the temperature of the surroundings, a greater quantity of heat is radiated from the body than is radiated to the body.

3. ***Convection:*** A small amount of heat convection almost always occurs around the body, about 15% of total heat loss occurs by conduction to the air and then by air convection away from the body. Heat is conducted to the air surrounding the body and then carried away by air currents. The heat from the skin is first conducted to the air and then carried away by the convection air currents.

4. ***Evaporation – Insensible Perspiration:*** Normally, a small quantity of water is continuously evaporated from skin and lungs (22%). So it is called insensible perspiration or insensible water loss. It is about 50 mL/hour. When body temperature increases, more heat is lost by evaporation of more water.

   Insensible evaporation through the skin and lungs cannot be controlled for purposes of temperature regulation because it results from continual diffusion of water molecules through the skin and respiratory surfaces.

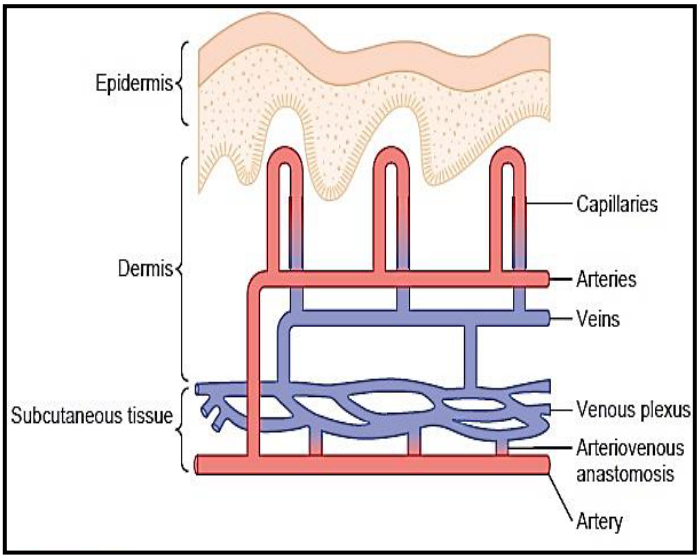


Insulator System of the Body

The skin, the subcutaneous tissues, and especially the fat of the subcutaneous tissues act together as a heat insulator for the body. The fat is important because it conducts heat only one third as readily as other tissues. The insulation beneath the skin is an effective means of maintaining normal internal core temperature, even though it allows the temperature of the skin to approach the temperature of the surroundings.

Blood flow to the skin from the body core provides heat transfer

Blood vessels are distributed profusely beneath the skin. Especially important is a continuous venous plexus that is supplied by inflow of blood from the skin capillaries. In the most exposed areas of the body (the hands, feet, and ears) blood is also supplied to the plexus directly from the small arteries.



The environmental air temperature is affect quantitatively on conductance of heat from the core to the skin surface and then conductance into the air, an approximate eightfold increase in heat conductance between the fully vasoconstricted state and the fully vasodilated state. Therefore, the skin is an effective controlled "***heat radiator***" system, and the flow of blood to the skin is a most effective mechanism for heat transfer from the body core to the skin.

Detection of temperature by receptors in the skin and deep body tissues

Although the signals generated by the temperature receptors of the hypothalamus are extremely powerful in controlling body temperature; receptors in other parts of the body play additional roles in temperature regulation. This is especially true of temperature receptors in the skin and in a few specific deep tissues of the body. The skin has far more cold receptors than warmth receptors in fact, 10 times as many in many parts of the skin. Therefore, peripheral detection of temperature mainly concerns detecting cool and cold instead of warm temperatures. When the skin is chilled over the entire body, immediate reflex effects are invoked and begin to increase the temperature of the body in several ways.

Deep body temperature receptors are found mainly in the spinal cord, in the abdominal viscera, and in or around the great veins in the upper abdomen and thorax. These deep receptors function differently from the skin receptors because they are exposed to the body core temperature rather than the body surface temperature. Yet, like the skin temperature receptors, they detect mainly cold rather than warmth. It is probable that both the skin and the deep body receptors are concerned with preventing hypothermia.

Regulation of body temperature

1- Role of sympathetic nervous system

Heat conduction to the skin is controlled by the sympathetic nervous system.

- Heat conduction to the skin by the blood is controlled by the degree of vasoconstriction of the arterioles and the arteriovenous anastomoses that supply blood to the venous plexus of the skin.
- This vasoconstriction is controlled entirely by the sympathetic nervous system in response to changes in body core temperature and changes in environmental temperature.

2- Role of Hypothalamus in regulation of body temperature

The temperature of the body is regulated almost entirely by ***nervous feedback mechanisms***, and almost ***all these mechanisms operate through temperature regulating centers located in the hypothalamus***. For these feedback mechanisms to operate, there must also be ***temperature detectors*** to determine when the body temperature becomes either too high or too low. The set point under normal physiological conditions is 37°C.

Hypothalamus has two centers which regulate the body temperature:

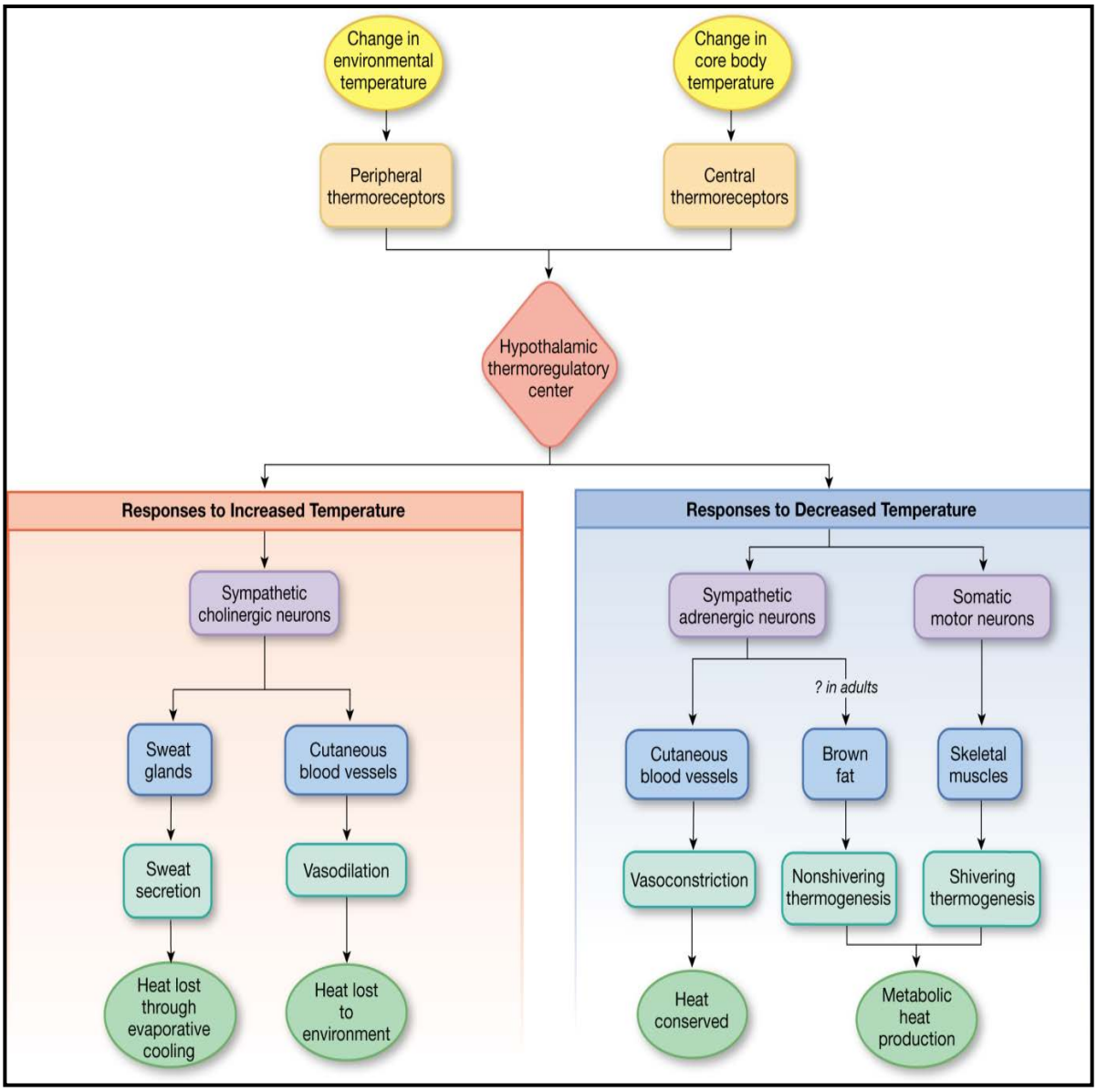
1- Heat loss center- Anterior Hypothalamic- Preoptic Area

2- Heat gain center- Posterior Hypothalamus.

Heat loss center- Anterior Hypothalamic- Preoptic Area

This center is situated in preoptic area of anterior hypothalamus and contains large numbers of ***heat-sensitive neurons***, which are called thermo-receptors, as well as about one third as many ***cold-sensitive neurons***. These neurons are believed to function as temperature sensors for controlling body temperature. Stimulation of preoptic area results in cutaneous vasodilatation and sweating. Therefore, it is clear that the hypothalamic-preoptic area has the capability to serve as a thermostatic body temperature control center.

Figure: Response of hypothalamic thermoregulatory center to temperature change (Sympathetic cholinergic &adrenergic neurons)



2- Heat gain center- Posterior Hypothalamus

It is otherwise known as *heat production center*, it is situated in posterior hypothalamic area. Stimulation of posterior hypothalamus causes shivering. The temperature sensory signals from the anterior hypothalamic preoptic area are also transmitted into this posterior hypothalamic area. Here the signals from the preoptic area and signals from elsewhere in the body is combined and integrated to control heat-producing and heat-conserving reactions of the body.

Mechanisms that decrease or increase body temperature

When the hypothalamic temperature centers detect that the body temperature is either too high or too low, they institute appropriate temperature-decreasing or temperature-increasing procedures:

Temperature-decreasing mechanisms when body temperature increases

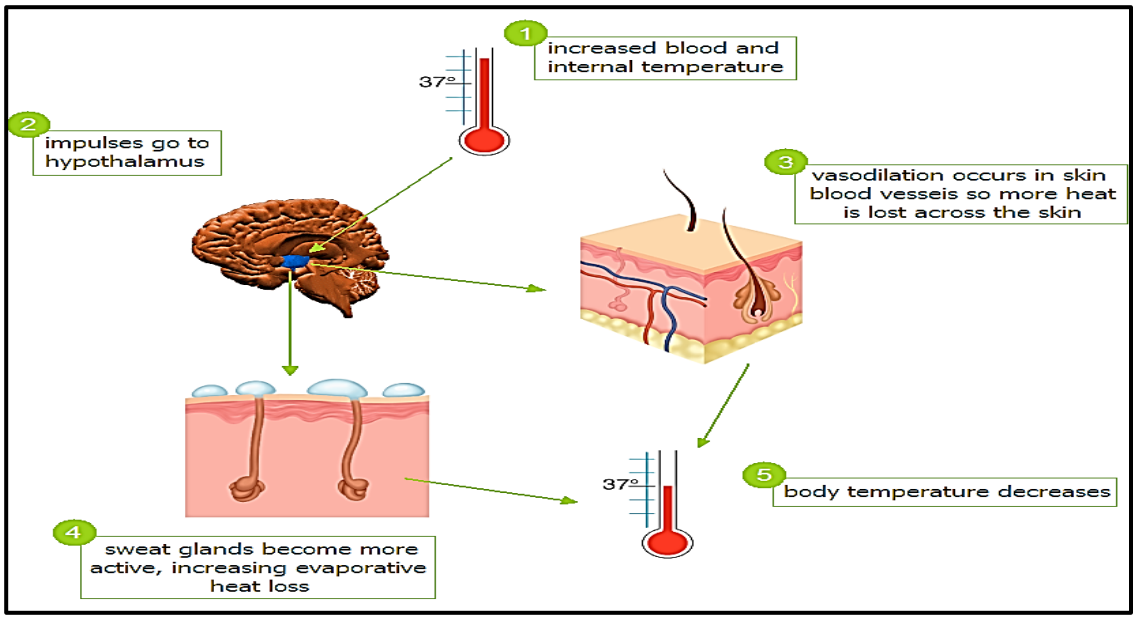
When body temperature increases, blood temperature also increases. When blood with increased temperature passes through hypothalamus, it stimulates the thermoreceptors present in the heat loss center in preoptic area. Now, the heat loss center brings the temperature back to normal ***by promotion of heat loss and prevention of heat production*** through theses mechanisms:

1) Heat loss center promotes heat loss from the body by:

   A- ***Vasodilation of skin blood vessels***- In almost all areas of the body, the skin blood vessels becomes extremely dilated. Full vasodilation can increase the rate of heat transfer to the skin as much as eightfold.

   B- ***Increasing the secretion of sweat***- When sweat secretion increases, more water is lost from skin along with heat.

2) ***Decrease in heat production***- The mechanisms that cause excess heat production, such as shivering and chemical thermogenesis, is strongly inhibited.



Temperature-increasing mechanisms when body temperature decreases

When the body is too cold, the temperature controls system institutes exactly opposite procedures, it is brought back to normal ***by prevention of heat loss and promotion of heat production*** through theses mechanisms:

1. ***Prevention of heat loss by Skin vasoconstriction throughout the body-*** This vasoconstriction is caused by stimulation of the posterior hypothalamic sympathetic centers, (when body temperature decreases, the preoptic thermoreceptors are not activated). The blood flow to skin decreases, and so the heat loss is prevented.

2. ***Increase in thermogenesis (heat production)*** by two ways:

   A- ***Shivering:*** The primary motor center for shivering is situated in posterior hypothalamus. When body temperature is low, this center is activated by heat gain center and, shivering occurs. Enormous heat is produced during shivering due to severe muscular activities.

   B- ***Increased metabolic reactions:*** The sympathetic centers, which are activated by heat gain center, stimulate secretion of adrenaline and noradrenaline. These hormones, particularly adrenaline increase heat production by accelerating cellular metabolic activities. At the same time, hypothalamus secretes thyrotropic releasing hormone (TRH). It causes release of thyroid stimulating hormone (TSH) from pituitary. It in turn increases release of thyroxin (T_4) from thyroid. T_4 accelerates the metabolic activities in the body and increases heat production.

Sympathetic "Chemical" Excitation of heat production

An increase in either sympathetic stimulation or circulating adrenaline and noradrenaline in the blood can rapidly increase the rate of cellular metabolism. This effect is called chemical thermogenesis, or non-shivering thermogenesis.

Chemical thermogenesis: It is the process in which heat is produced in the body by metabolic activities induced by hormones.