Temperature of the Body

Normal body Temperatures

Body core temperature and skin temperature

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 when compared to that of males.
3. ***Diurnal variation:*** In early morning, the temperature is 1°C less. 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 foodstuffs. Heat production is more during metabolism of fat. When 1 liter of oxygen is utilized, about 9 calories of heat is produced during metabolism of fats; and 4.7 calories of heat produces during carbohydrate metabolism. Protein metabolism produces 4.5 calories/liter.

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

***Most of the heat produced in the body is generated in the deep organs, especially the liver, then brain and heart, also in the skeletal muscles during exercise**. **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**.*

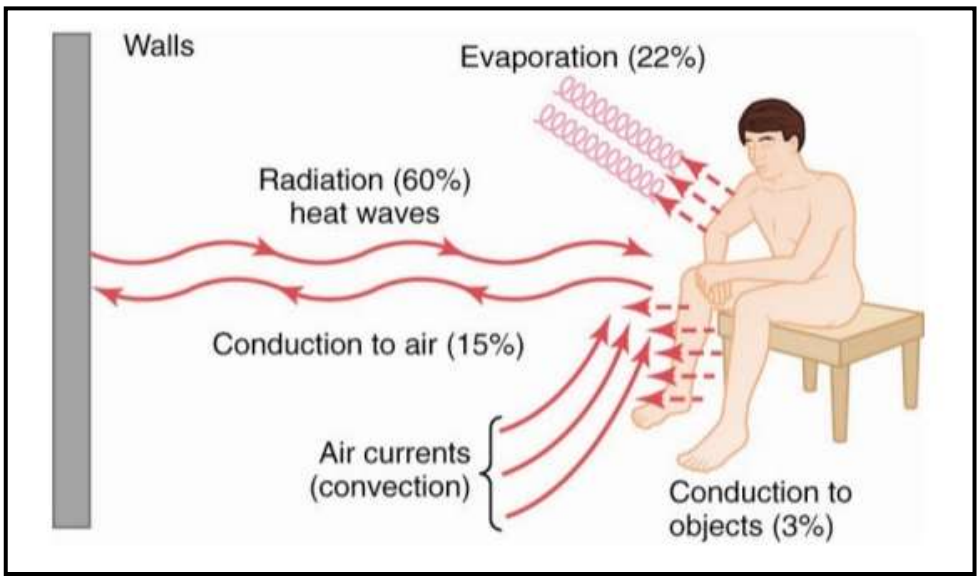
Heat loss occurs by the following methods:

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 sizable 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.

Sweating and its regulation by the autonomic nervous system

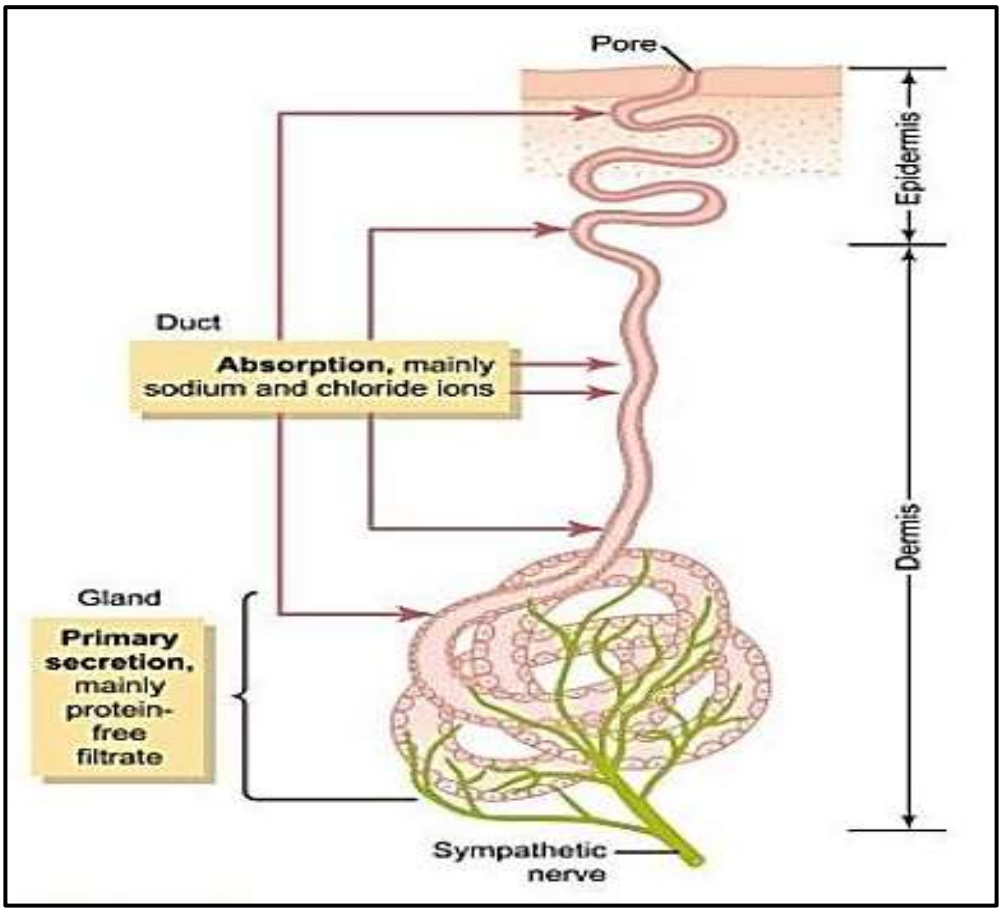
Stimulation of the anterior hypothalamus-preoptic area in the brain either electrically or by excess heat causes sweating. The nerve impulses from this area that cause sweating are transmitted in the autonomic pathways to the spinal cord and then through sympathetic outflow to the skin everywhere in the body. These glands can also be ***stimulated to some extent by epinephrine or norepinephrine*** circulating in the blood, even though the glands themselves do not have adrenergic innervation.

This mechanism is important during exercise, when these hormones are secreted and the body needs to lose excessive amounts of heat produced by the active muscles.

Mechanism of Sweat Secretion

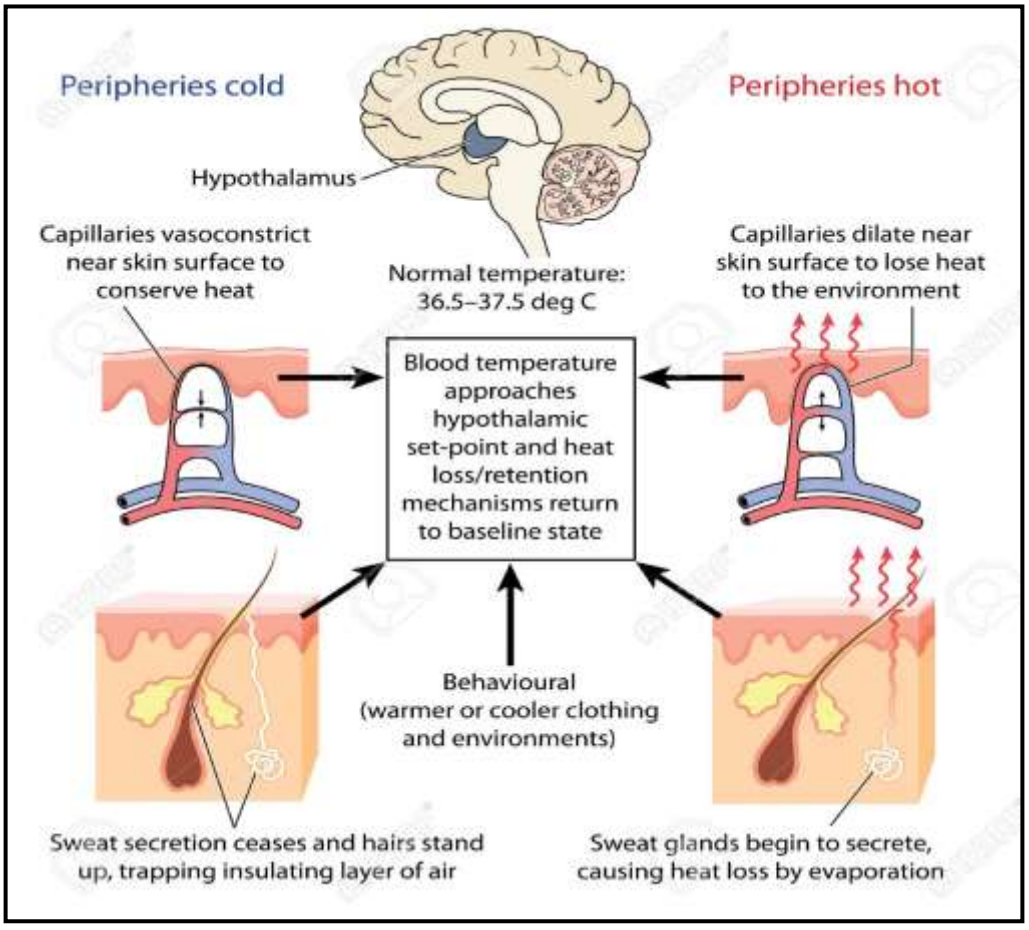
As is true of so many other glands, the secretory portion of the sweat gland secretes a fluid called the primary secretion or precursor secretion; the concentrations of constituents in the fluid are then modified as the fluid flows through the duct. ***The precursor secretion*** is an active secretory product of the epithelial cells lining the coiled portion of the sweat gland. Cholinergic sympathetic nerve fibers ending on or near the glandular cells elicit the secretion.

The composition of the precursor secretion is similar to that of plasma, except that it does not contain plasma proteins. As this precursor solution flows through the duct portion of the gland, it is modified by reabsorption of most of the sodium and chloride ions. The degree of this reabsorption depends on the rate of sweating.



When the sweat glands are stimulated only slightly, the precursor fluid passes through the duct slowly. In this instance, essentially all the sodium and chloride ions are reabsorbed, and the concentration of each falls to very small concentrations.

Conversely, when the sweat glands are strongly stimulated by the sympathetic nervous system, large amounts of precursor secretion are formed, and the duct may reabsorb only slightly more than half the sodium chloride; the concentrations of sodium and chloride ions are then slightly less than half the concentrations in plasma. Furthermore, the sweat flows through the glandular tubules so rapidly that little of the water is reabsorbed. Therefore, the other dissolved constituents of sweat are only moderately increased in concentration.

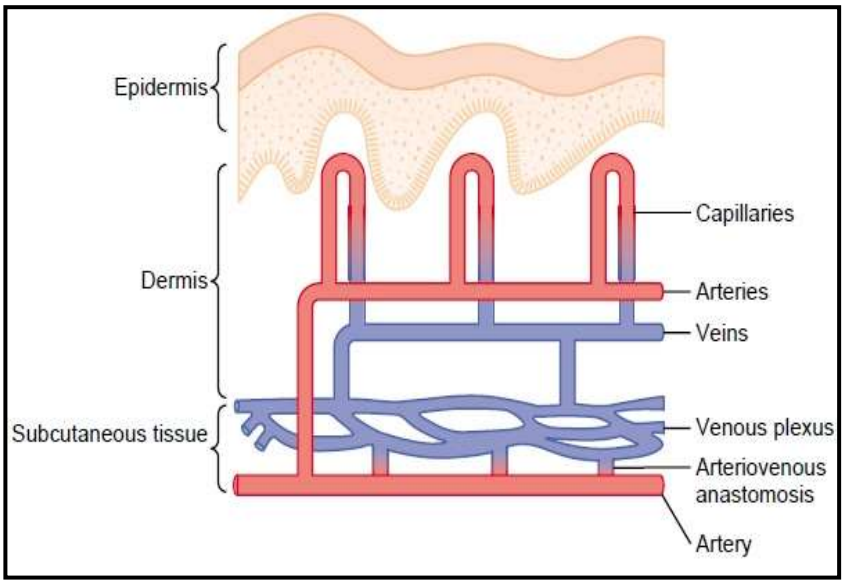


Insulator System of the Body

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 rate of blood flow into the skin venous plexus can vary extremely; a high rate of skin flow causes heat to be conducted from the body core to the skin with great efficiency, whereas reduction in the rate of skin flow can decrease the heat conduction from the core.

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.

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