

Regulation of body temperature

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 almost entirely by the sympathetic nervous system in response to changes in body core temperature and changes in environmental temperature.

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

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. The heat-sensitive neurons increase their firing rate 2- to 10-fold in response to a 10°C increase in body temperature. The cold-sensitive neurons, by contrast, increase their firing rate when the body temperature falls. Stimulation of preoptic area results in cutaneous vasodilatation and sweating. When the preoptic area is heated:

- 1- The skin all over the body immediately breaks out in a profuse sweat.
- 2- The skin blood vessels over the entire body become greatly dilated. This response is an immediate reaction to cause the body to lose heat, thereby helping to return the body temperature toward the normal level.
- 3- In addition, any excess body heat production is inhibited. Therefore, it is clear that the hypothalamic-preoptic area has the capability to serve as a thermostatic body temperature control center.

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:

- 1) By providing a strong stimulus to cause shivering, with a resultant increase in the rate of body heat production.
- 2) By inhibiting sweating, if this is already occurring.
- 3) By promoting skin vasoconstriction to diminish loss of body heat from the skin.

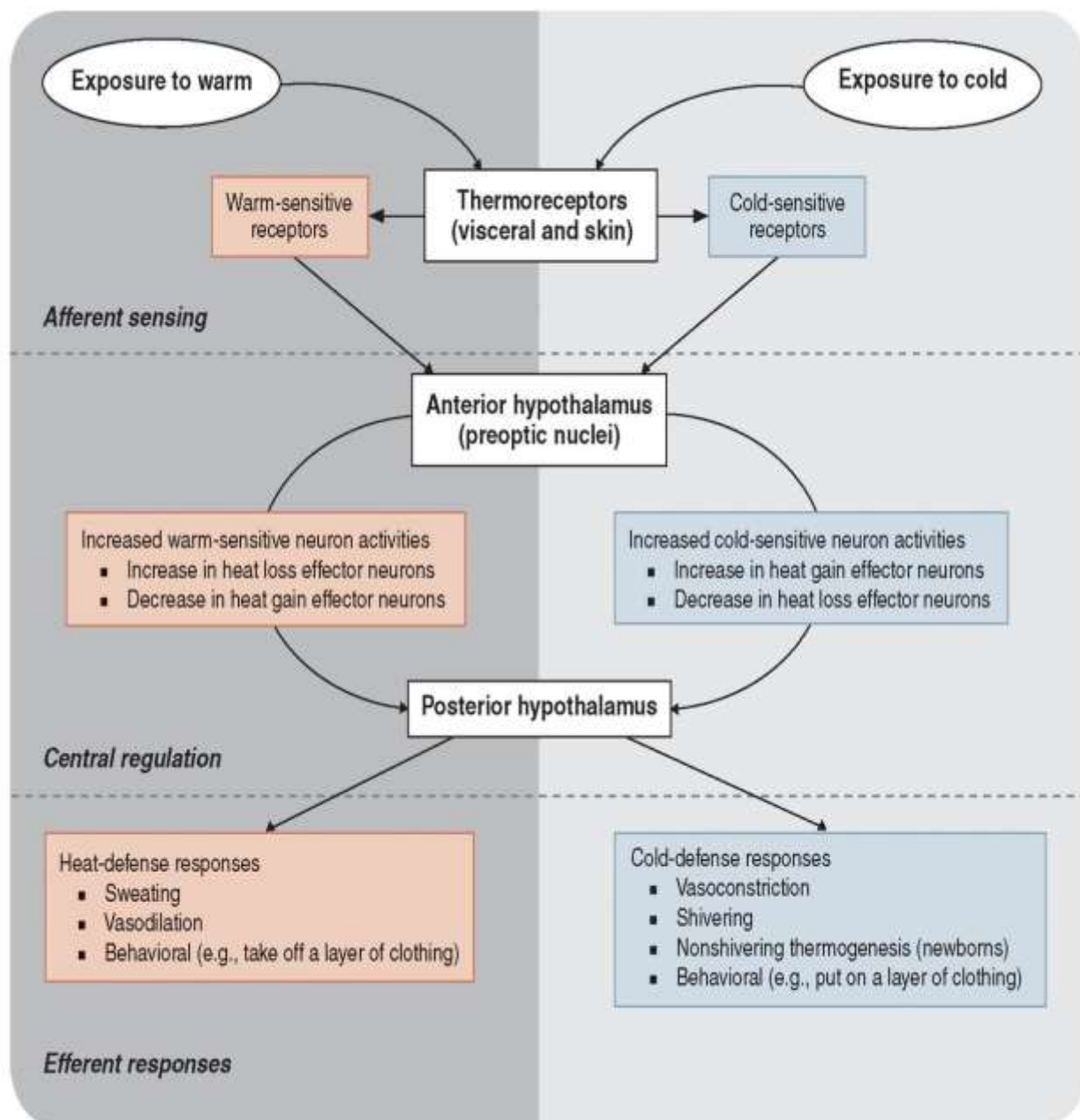
Deep body temperature receptors are found mainly in the spinal cord, in the abdominal viscera, and in or around the great veins in the upper abdomen and thorax. These deep receptors function differently from the skin receptors because they are exposed to the body core temperature rather than the body 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.

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.

Figure: Response of thermoreceptors to cold and warm



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 two mechanisms:

1. Promotion of heat loss
2. Prevention of heat production

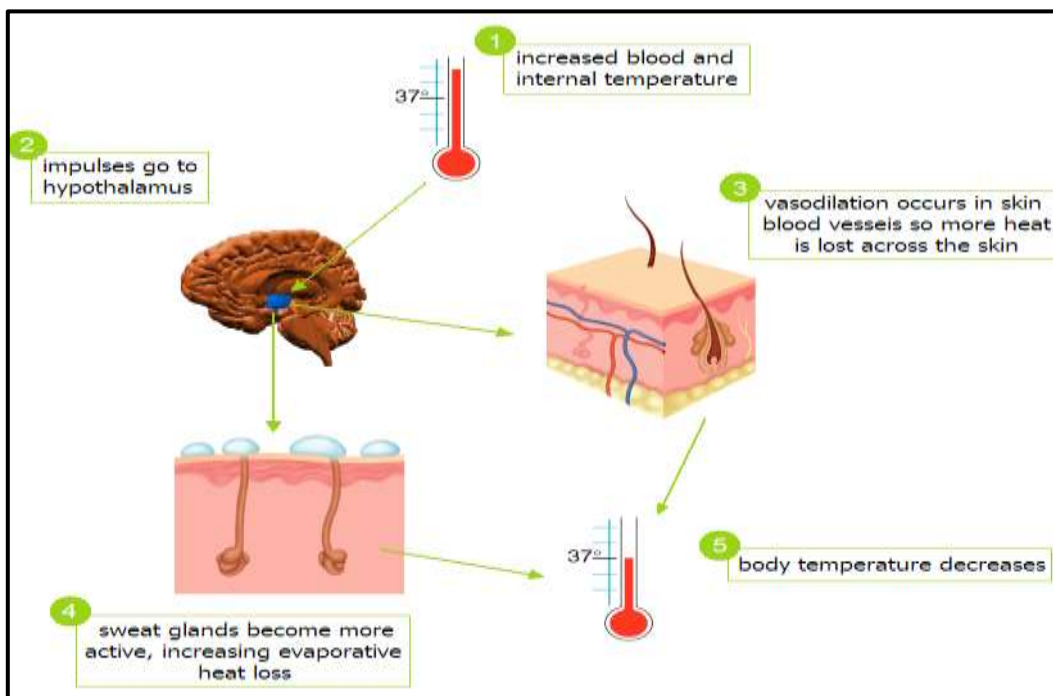
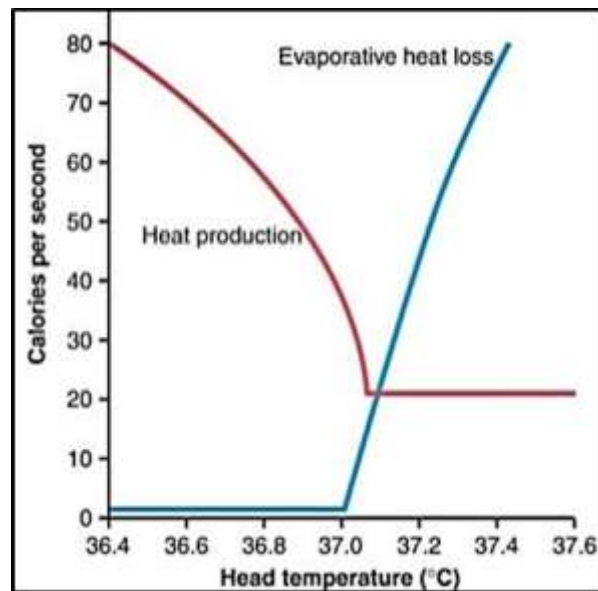
1) Heat loss center promotes heat loss from the body by:

A- ***Vasodilation of skin blood vessels***- In almost all areas of the body, the skin blood vessels becomes intensely 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.

The effect of increased body temperature to cause sweating is demonstrated by the blue curve in the figure, which shows a sharp increase in the rate of evaporative heat loss resulting from sweating when the body core temperature rises above the critical level of 37°C.

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 two mechanisms:

1. Prevention of heat loss
2. Promotion of heat production.

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.

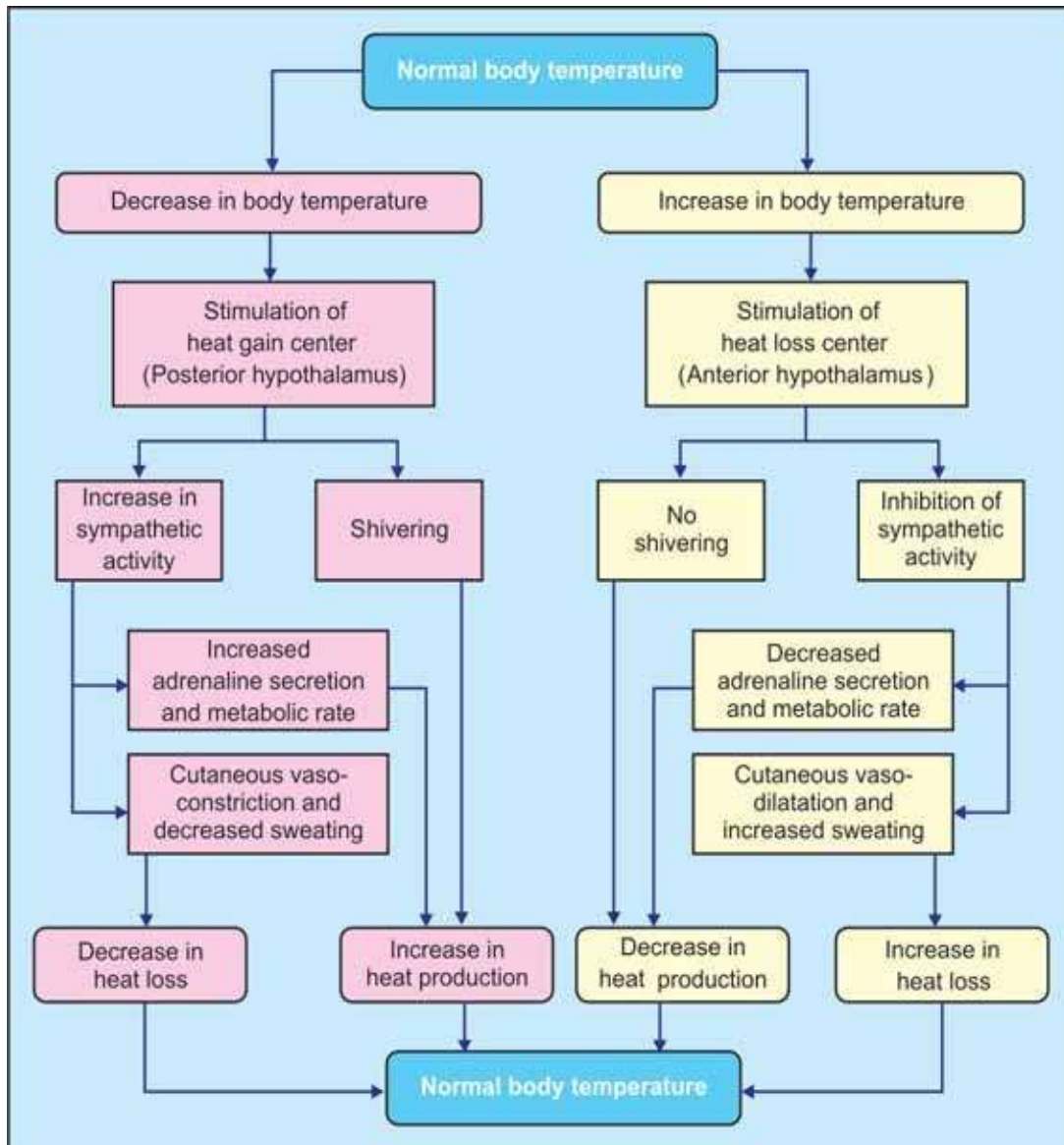
At the same time, hypothalamus secretes thyrotropic releasing hormone (TRH). It causes release of thyroid stimulating hormone (TSH) from pituitary. It in turn increases release of thyroxin (T_4) from thyroid. T_4 accelerates the metabolic activities in the body and increases heat production.

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

Sympathetic “Chemical” Excitation of heat production

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

Figure: Stimulation of heat gain center to decrease body temperature and heat loss center to increase body temperature

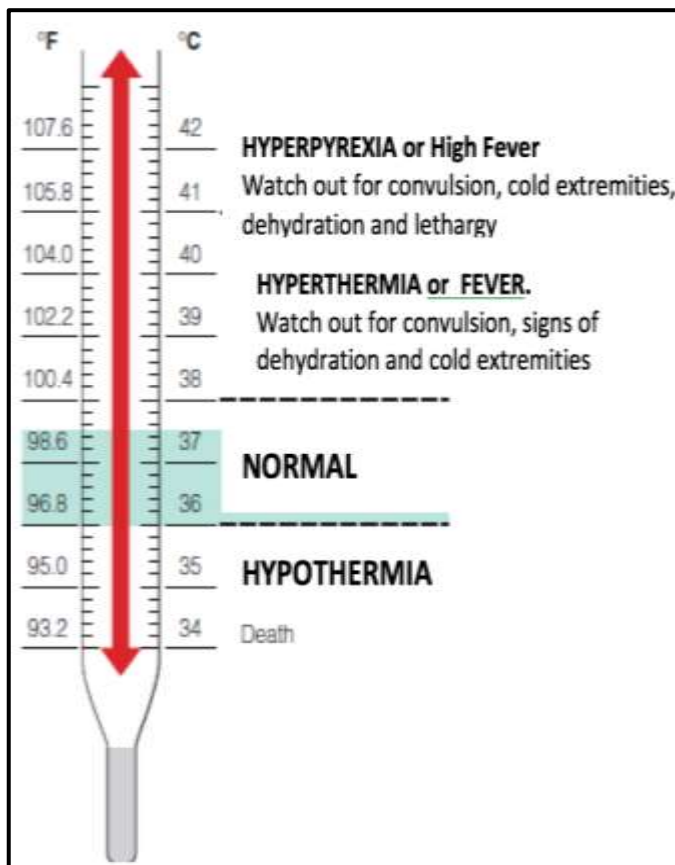


Pathological Variations

Abnormal increase in body temperature is called hyperthermia or fever and decreased body temperature is called hypothermia.

Fever

Fever, which means a body temperature above the usual range of normal, can be caused by abnormalities in the brain or by toxic substances that affect the temperature regulating centers. Some causes of fever are including bacterial or viral infections, brain tumors, and environmental conditions that may terminate in heatstroke.



	Measurement site		
	Mouth / armpit	Ear / forehead	Rectum
Low temperature	< 35.8	< 35.7	< 36.2
Normal temperature	35.9 - 37.0	35.8 - 36.9	36.3 - 37.5
Increased temperature	37.1 - 37.5	37.0 - 37.5	37.6 - 38.0
Light fever	37.6 - 38.0	37.6 - 38.0	38.1 - 38.5
Moderate fever	38.1 - 38.5	38.1 - 38.5	38.6 - 39.0
High fever	38.6 - 39.5	38.6 - 39.4	39.1 - 39.9
Very high fever	39.6 - 42.0	39.5 - 42.0	40.0 - 42.5