Neurophysiology

Body temperature regulation

Lecture 8

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The body temperature of humans remains relatively constant despite changes in the environmental temperature. This ***homeothermy*** *applies only to the* ***core temperature (≈37 °C)*** *of the body*

*The extremities and skin ("shell") exhibit **poikilothermy, i.e., their temperature** varies to some extent with environmental temperature. In order to maintain a constant core temperature, the body must balance the amount of heat it produces and absorbs with the amount it loses; this is **thermoregulation***

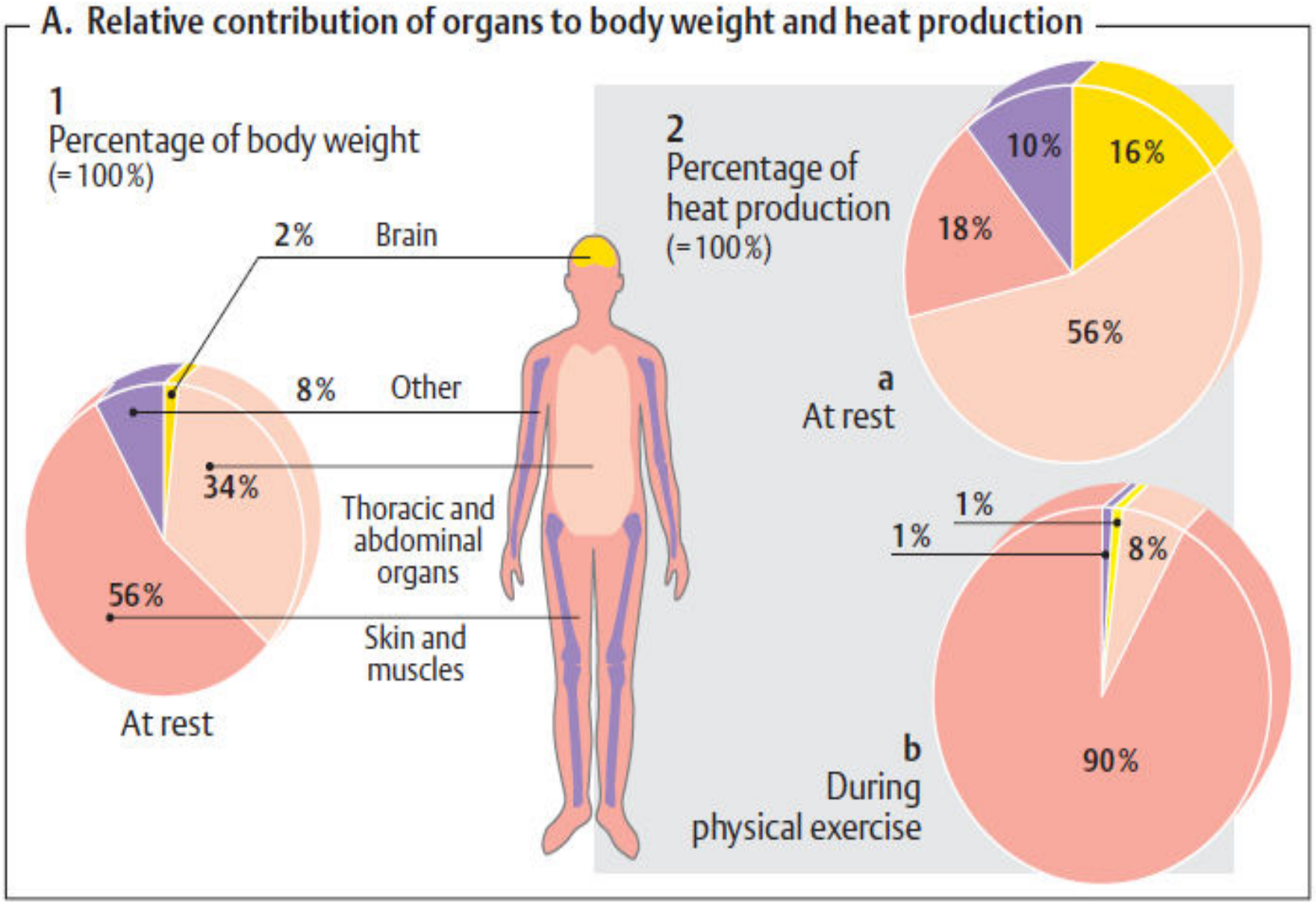
Heat production

The amount of heat produced is determined by energy metabolism. At rest, approximately 56% of total heat production occurs in the internal organs and about 18% in the muscles and skin. During physical exercise, heat production increases several-fold and the percentage of heat produced by muscular work can rise to as much as 90% .

To keep warm, the body may have to generate additional voluntary (limb movement) and involuntary (shivering) muscle contractions.

Cold stimulates a reflex pathway resulting in norepinephrine release in fatty tissues, which in turn stimulates (1) lipolysis and (2) the expression of *lipoprotein lipase (LPL**) and** thermogenin. LPL increases the supply of free* fatty acids. Thermogenin localized in the inner mitochondrial membrane is an uncoupling protein that functions as an H+ uniporter.

Heat produced in the body is absorbed by the bloodstream and conveyed to the body surface. In order for this internal flow of heat to occur, the temperature of the body surface must be lower than that of the body interior. The blood supply to the skin is the chief determinant of heat transport to the skin.


A. Relative contribution of organs to body weight and heat production
1
Percentage of body weight
(= 100%)
2%
Brain
8%
Other
34%
Thoracic and abdominal organs
56%
Skin and muscles
At rest
2
Percentage of heat production
(= 100%)
10%
16%
18%
56%
a
At rest
1%
1%
8%
90%
b
During physical exercise

Heat loss

Heat loss occurs by the physical processes of radiation, conduction, convection, and evaporation

1. Radiation: *Loss of heat by radiation means loss in the form of infrared heat rays the amount of heat lost by radiation from the skin is chiefly determined by the temperature of the radiator . Heat net– radiates from the body surface to objects or individuals when they are cooler than the skin, and net–radiates to the body from objects (sun) that are warmer than the skin.*

2. Conduction : *These processes involve the transfer of heat from the skin to a cooler object (e.g. Sitting on rock) in contact with the body (conduction).*

3.Convection: *Conduction of heat from the body to the air is self-limited unless the heated air moves away from the skin, so that new, unheated air is continually brought in contact with the skin, a phenomenon called air convection*

4-Evaporation:

The above mechanisms alone are unable to maintain adequate temperature homeostasis at high environmental temperatures or during strenuous physical activity. Evaporation is the means by which the body copes with the additional heat. The water lost by evaporation reaches theskin surface by diffusion (*insensible perspiration)* and by neuron-activated sweat glands.

The surrounding air must be relatively dry in order for heat loss by evaporation to occur. Humid air retards evaporation.

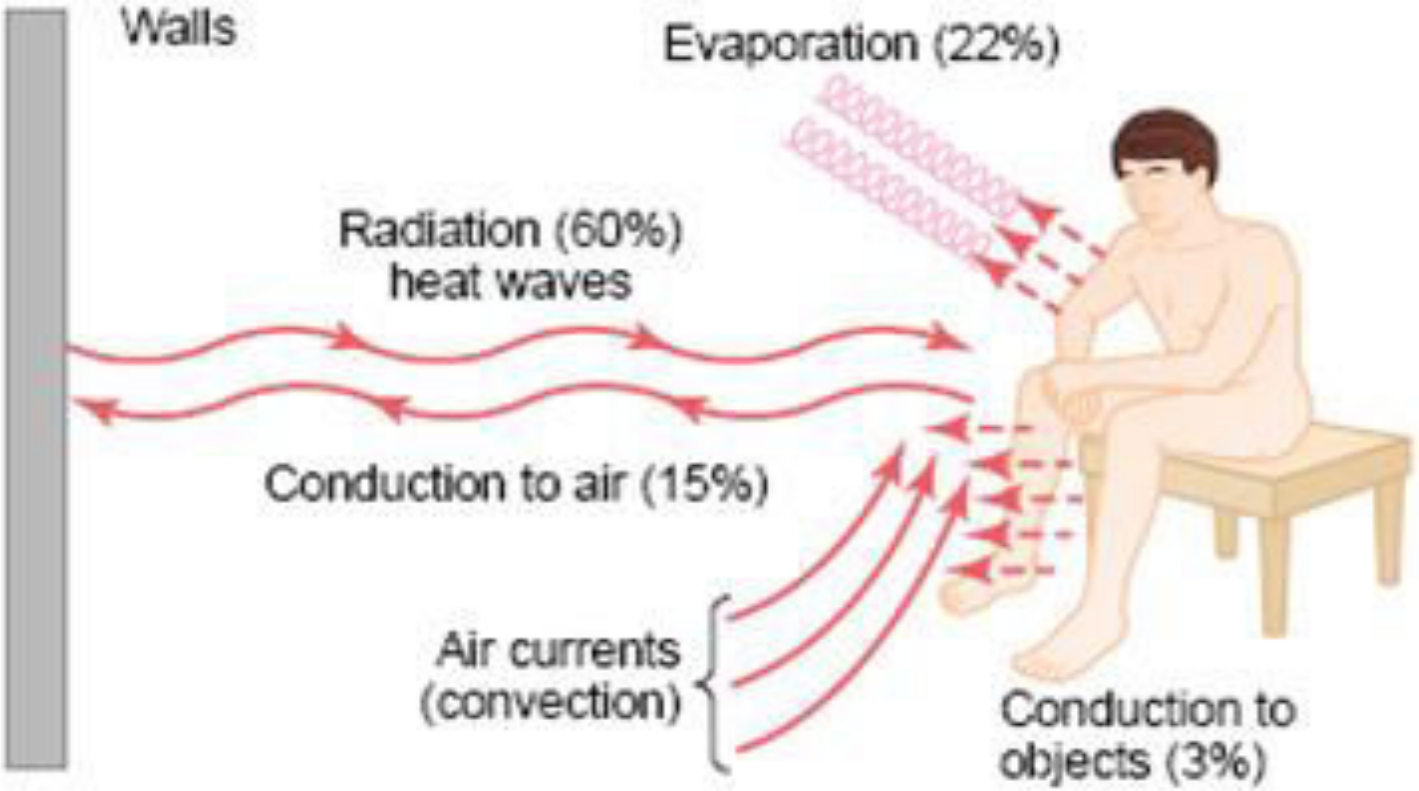


Figure 73–4

Mechanisms of heat loss from the body.

Thermoregulation

Thermoregulation maintains the ***core temperature*** *at a constant set point (37°C) despite fluctuations in heat absorption, production, and loss. The core temperature exhibits circadian variation.*

It fluctuates by about 0.6 °C and is lowest around 3 a.m., and highest around 6 p.m. The set point changes are controlled by an intrinsic biological clock . Extended set-point fluctuations happen during the menstrual cycle and fever.

Temperature detection mechanisms

1-Anterior Hypothalamic-Preoptic Area

The principal areas in the brain where heat or cold from a thermode affects body temperature control are the preoptic and anterior hypothalamic nuclei of the hypothalamus.

The anterior hypothalamicpreoptic area has been found to contain large numbers of heat-sensitive neurons as well as about one third as many cold-sensitive neurons. These neurons are believed to function as temperature sensors for controlling body temperature.

2-Detection of Temperature by Receptors in the Skin and Deep Body Tissues:

Sensory receptors in the skin is endowed with both cold and warmth receptors.

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.

Posterior Hypothalamus Integration of temperature sensory signals

The temperature sensory signals from the anterior hypothalamic-preoptic area are transmitted into this posterior hypothalamic area.

Here the signals from the preoptic area and the signals from elsewhere in the body(heat and cold receptors in the skin and deep tissues) are combined and integrated to control the heat-producing and heat-conserving reactions of the body.

Neuronal Effector 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

The temperature control system uses three important mechanisms to reduce body heat when the body temperature becomes too great:

1. *Vasodilation of skin blood vessels. This is caused by inhibition of the sympathetic centers in the posterior hypothalamus that cause vasoconstriction.*
2. *Sweating. Stimulation of the anterior hypothalamus-preoptic area in the brain either electrically or by excess heat causes sweating.*
3. *Decrease in heat production.*

Temperature-Increasing Mechanisms

When the body is too cold, the temperature control system institutes exactly opposite procedures. They are:

1. Skin vasoconstriction throughout the body.This is caused by stimulation of the posterior hypothalamic sympathetic centers.

2. Piloerection. Piloerection means hairs "standing on end". This is not important in human beings, but in lower animals, upright projection of the hairs allows them to entrap a thick layer of "insulator air" next to the skin, so that transfer of heat to the surroundings is greatly depressed.

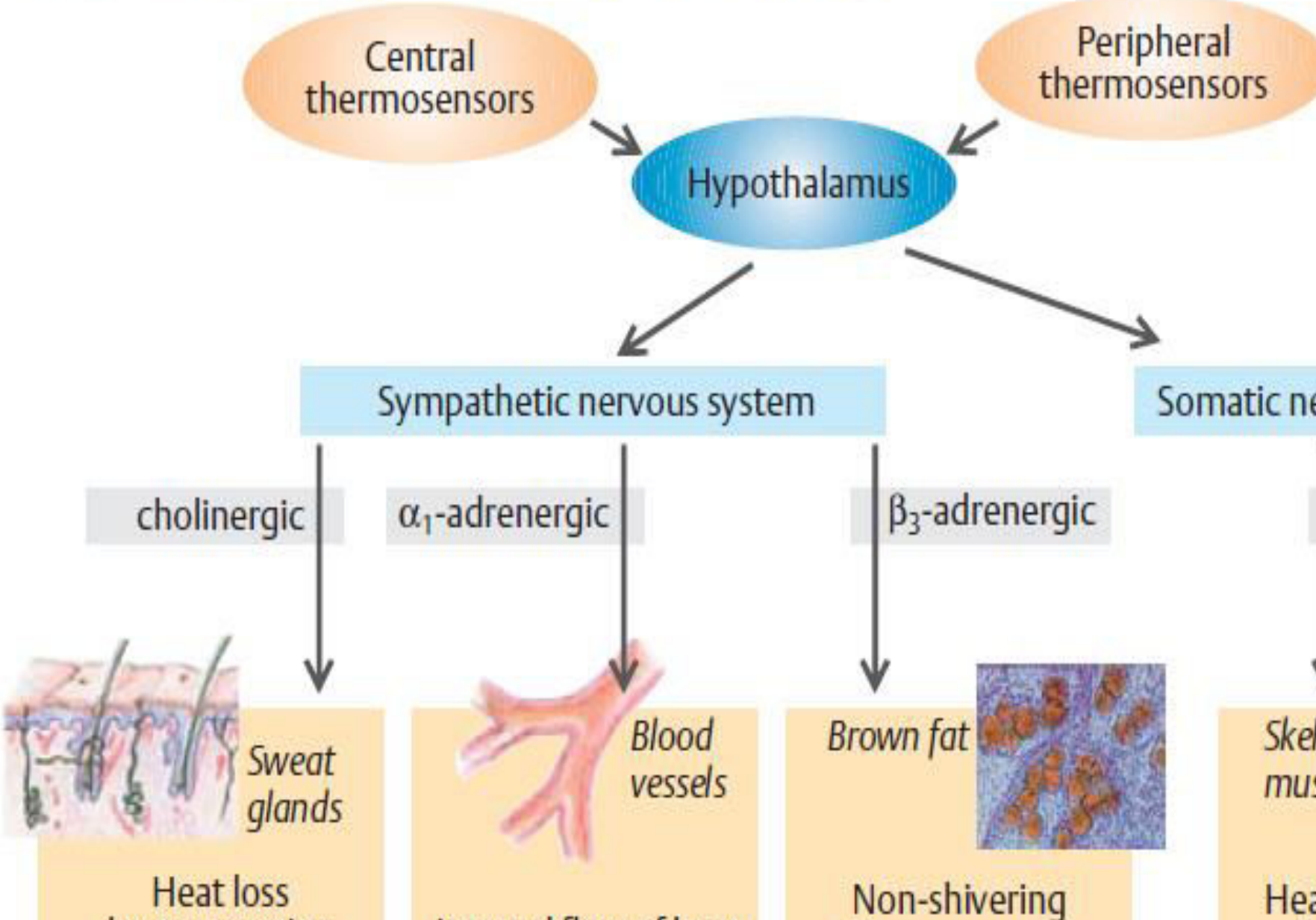
3. Increase in thermogenesis (heat production). Heat production by the metabolic systems is increased by promoting shivering, sympathetic excitation of heat production, and thyroxine secretion.

Fever

Exogenous (e.g., bacteria) and endogenous pyrogens (various interleukins and other cytokines from macrophages) can cause the set-point temperature to rise above normal. This is triggered by prostaglandin PGE2 in the hypothalamus.

In the initial phase of fever, the core temperature (although at its normal level) is too low compared to the elevated set-point. This results in shivering to raise the core temperature. As the fever decreases, i.e. the set-point returns toward the normal temperature, the core temperature is now too warm compared to the normalized set-point, resulting in vasodilatation and sweating to lower the core temperature again.

D. Neural factors affecting thermoregulation



Hypothermia

Means reduction of the core body temperature below 35 C .It is caused either accidentally upon exposure to cold environment or secondary to lesion in the hypothalamus .

Thanks