Temperature regulation or Thermoregulation

Thermoregulation:- The way in which the organisms maintain their body temperature with in a certain limited range is termed as thermoregulation.

Thermogenesis:- The physiologic process of heat production in the body is known as thermogenesis.

Thermiolysis:- Dissipation of bodily heat by means of radiation, evaporation etc is called thermolysis.

Thermotaxis:- The mechanism by which body temperature is normally adjusted is known as the thermotaxis.

Body temperature:- The temperature of the body core or internal part is usually referred to as body temperature. For this purpose the temperature of skin, shell or superficial tissues is not considered, because it varies considerably with changing temperature of the surroundings. It is the core temperature which is kept fairly constant in an individual. For the purposes of expressing the total amount of heat stored in the body the average or mean temperature is determined.

This can be calculated by the equation :-

Mean or average body temperature = 0.33 × skin temperature + 0.67 × rectal temperature.

Considering various aspects of temperature regulation animals are classified :-

① **Poikilotherms or ectotherms:-** The body temperature fluctuates with changes in the external environment. These animals are called poikilotherms or ectotherms.

E.g. → Fishes, frog and reptiles.

② **Homeotherm or endotherm:-** Animals maintain relatively constant body temperature which does not depend on environmental temperature. They are called homeotherms or endotherms meaning that they can produce and regulate their own body heat.

E.g. → Birds and mammals.

③ There are some mammals which do not regulate body temperature under unfavourable environmental conditions and become dormant. They let their body temperature fall in this condition to a critical temperature of about 15° to 20°C. Any further drop awakens them from dormancy and then they again maintain their usual body temperature.

* Heterotherm / Haliotherm :⇒

Range of body temperature:- The day and night temperature of body may vary considerably in different species. In hippopotamus it varies from 39°c to 34°c, in camel 39°c to 36°c and in bear 38·7°c to 36·7°c.
In man it ranges between 36·10° to 37·25°c (97°-99°F). The average normal temperature is generally taken to be 98·4°F or 37°c.

Heat balance in the body:-
Heat balance of the body depends upon the interplay of factors increasing heat production and decreasing or increasing heat loss.

(a) Factors increasing heat production
1. Increase of metabolic rate.
2. Exercise or shivering
3. Increase in muscle tension.
4. Increased production of thermogenic hormones and increase in sympathetic activity.
5. Specific dynamic action.
6. Pyrogenic substances as in fever.

(b) Factors decreasing heat loss:-
1. Shifts in blood distribution.
2. Decrease in tissue conductance (Vasoconstriction)
3. Counter current heat exchange.
4. Arterio venous shunt opening.
5. Increase in clothing or fur insulation
6. Increase in moisture in the air in hot environment.
7. Pilo erection.

(c) Factors increasing heat loss:-
1. Sweating.
2. Panting.
3. Cooler environment.
4. Increased skin circulation (Vasodilatation)
5. Decreased clothing or shorter fur insulation.
6. Increased insensible perspiration
7. Increased radiating surface
8. Increased air movement (convection)
9. Drinking or eating cold food materials.
10. Increase in moisture in cold environment.

* Thermoneutral range:- The lower critical air temperature for a naked man in summer is 25°-27°c. Similarly the upper critical temperature has been noted out to be 27°-29°c. The range between upper and lower values of critical temperature is termed zone of thermal neutrality or thermoneutral range. In the zone of thermal neutrality, warming and cooling of the body can

occur quite easily because physiological mechanisms of muscular, cardiovascular and metabolic changes are not activated. ③

Temperature regulating mechanism!- N.V.I

Mechanism activated by cold!-

① Increase heat production!-

② Increase of metabolic rate!-

Body gain heat by its metabolic activity, from objects hotter than itself in the surrounding medium and from hot foods. Basal metabolic rate in a young adult male normally produces about 40 cal/hr./sq metre body surface.

③ Shivering!- If heat produced by the resting metabolic rate is not enough to maintain the body temperature, increase in metabolism occures by the involuntary contraction of skeletal muscles. These contractions may consist of micro-vibrations and shivering at rates of of 7 to 13/second. Shivering centre is also situated in the posterior part of the hypothalamus. Shivering which increases heat production to about four times of normal results from activation of posterior hypothalamus or from cooling of spinal canal by the cold.

④ Exercise!- On exercise the metabolic activity of individual muscles can increase to about 60 times, producing a proportionate rise in body temperature. Contraction of the total musculature of body at the maximum rate may increase the metabolic rate even from 1.5 to 2000% above the resting level. So the voluntary muscular activity is one of the most effective procedures for increasing metabolic rate and heat production.

⑤ Sympathetic nervous system and heat production!-

Maximum increase in sympathetic activity can increase the metabolic rate by 20 to 30% in man and even upto 100% in some animals). Norepinephrine and epinephrine are responsible for thermogenesis even without effecting muscle activity (as a result of increased metabolic activity of all the cells of the body). ~~This occur even after the use of muscle relaxants like curare~~.

(e) Specific dynamic action (SDA):- Consumption of food produces an increase in the basal metabolic rate which is called specific dynamic action (SDA) of food. Fat has a ~~slight~~ relatively slight effect on this, while proteins produces greater SDA than carbohydrates. This value is different than the Caloric value of the substances. The heat value of proteins and carbohydrate is 18% and 7% of their caloric value values respectively. On addition the protein effect lasts much longer.

(f) Hormones and heat production:-

Cooling the anterior hypothalamic pre optic area of the hypothalamus also increases the production of the neurosecretory hormone thyrotropin releasing hormone by the hypothalamus. This hormone is carried by way of the hypothalamic portal veins to the anterior pituitary gland where it stimulates the secretion of thyroid stimulating hormone. Thyroid-stimulating hormone in turn stimulates increased out put of thyroxine by the thyroid gland. The increased thyroxine increases the rate of cellular metabolism through out the body, which is another mechanism of chemical thermogenesis. ~~However, this increase in metabolism doesn't occur immediately but requires several~~

Adrenal corticoids also influence heat production to some extent.

(g) Brown fat:- All new born mammals possess 'brown fat' which has rich blood and sympathetic adrenergic nerve supply. When the infants are exposed to cold, the blood supply to the fat increases and there occurs depletion of intracellular fat droplets. Brown fat located between and around the scapula. Brown ~~adipose~~ adipose tissue (BAT), sometimes called brown fat, which has only been identified in the placental mammals. BAT produces considerable amounts of heat, because there lipids are respired (*)

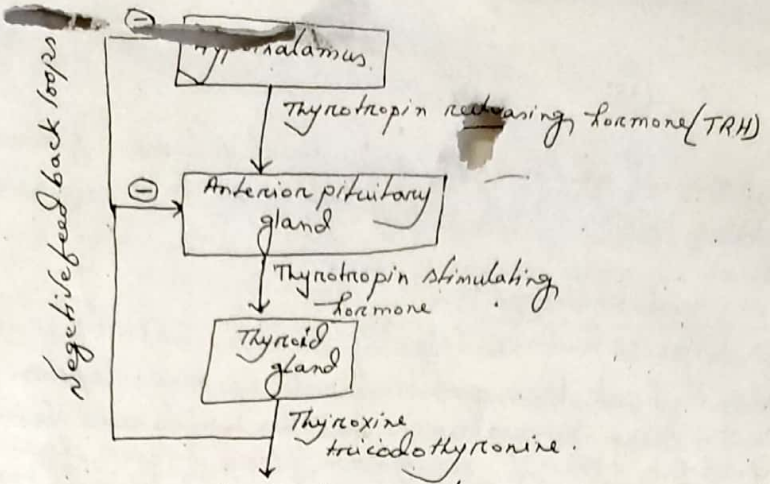
(h) ~~Decrease heat loss~~:- ~~decrease heat loss~~:-

(a) Curling up:- Curling up ~~decreases the body surface exposed to the environment thereby the heat loss is decrease.~~

(b) ~~Vasoconstriction~~:-

There is also of number of others, more biochemical means by which heat production may be increased in endotherms. These mechanisms are collectively termed nonshivering thermogenesis. One mechanism involves brown adipose tissue (BAT), some times called brown fat which has only been identified in the placental mammals. When BAT is stimulated, the fat is metabolized with in the mitochondria of the fat cells and heat is produced.

(*) With little or no ATP formation, most energy is released as heat.



The control of the secretions of the thyroid glands.

(2) Decrease heat loss:-

(a) Curling up:- Curling up decreases the body surface exposed to the environment.

(b) Vasoconstriction:- Vasoconstriction of cutaneous vessels reduces blood flow and here by less heat is lost from the body. It reducing blood flow to peripheral organs.

(c) Pilo erection:- Most mammals have a significant layer of hair or fur. The hair is raised and brought upinto a more or less vertical position by contraction of the erector pilimuscles. The advantage of this is that air gets trapped in the spaces between the hairs. This air is warmed by the body and being a poor conductor of heat it serves as an insulatory layer around the animal. In humans the body hair is much reduced, its place being taken by cloths. In birds the same function is performed by the feathers. In humans, contraction of the erector-pili muscles results in 'goose flesh'.

(d) Heat insulation of the body:-

The insulation characteristics of the cutaneous region greatly vary in different individuals. The subcutaneous fat beneath the dermis of the skin serves as an insulator and reduces heat loss from the body. It is interesting that animals living in very cold habitats, the polar bear and seal for example, have a particularly thick layer of subcutaneous fat.

Apart from the natural characteristics of the skin to regulate heat outflow, its insulation can be improved artificially by clothing. The clothes entrap air which is prevented from moving away.

(e) Anterio-Venous shunt opening:- In exposed structure such as the ears there are special shunt vessels interconnecting the arterioles and venules that take blood to and from the superficial capillaries of the skin. In cold conditions these shunt vessels dilate so that blood by passes the surface of the skin.

This is aided by a general reduction in the total volume of circulating blood, achieved by some of the blood being taken up into reservoirs such as the spleen.

(f) Counter-current heat exchange:-

The flippers of dolphins and the legs of ducks, both of which are highly susceptible to heat loss particularly if they happen to be in cold water. In these structures the arteries and veins are very close to each other, as warm blood flows down the arteries heat passes from them into the cooled blood that is returning in the veins. This achieves two things, firstly it means that the arterial blood has already been cooled by the time it reaches the end of the limb, so that relatively little heat is ~~almost~~ lost to the surroundings and secondly it has the effect of warming the venous blood before it gets back to the main part of the body.

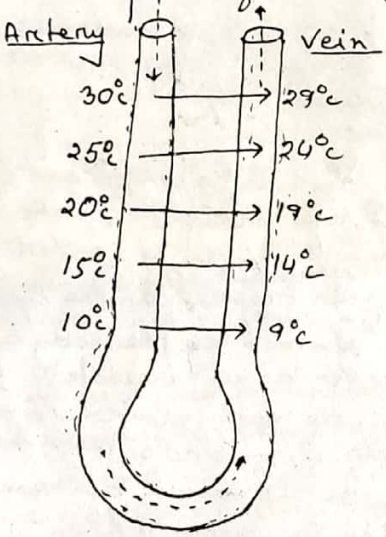


Diagram showing the counter current heat exchange system in a limb.

Mechanism activated by heat:-

(1) Increase heat loss:-

(a) Radiation:- It is the diffusion of heat from a warm body to relatively colder objects via the air, can be a major source of heat loss. A man sitting in a room whose temperature is 21°c can lose as much as 60% of his heat this way.

(b) conduction:- It is the transfer of heat from the hotter to the cooler of two objects in contact with each other. A dog lying on a floor whose temperature is lower than that of the body, will lose heat to the floor by conduction.

(c) convection:- convection, the movement of the molecules of a gas or a liquid at one temperature to another location that is at a different temperature, aids, conduction.

(d) Evaporation:- It is the change of a liquid to a vapour, is always accompanied by cooling. Evaporation of water from the surface of the body depends on various factors such as temperature, humidity and air currents, but it can account for a substancial loss of heat. A man at 21°c can lose 25% of his heat by evaporation.

In conditions when the temperature of surroundings is higher than the body, instead of losing it starts gaining heat. Under these conditions heat can be lost only by evaporation.

(e) Vasodilation:- The superficial blood vessels are dilated so that blood is brought up near the surface from which it can lose heat to the surrounding atmosphere. The shunt vessels are constricted and the total blood volume is raised, thereby further increasing the flow of blood to the surface.

(f) Sweating:- Sweating involves the secretion of a watery fluid from sweat glands in the skin. Evaporation of the sweat from the surface of the body cools the skin and the blood flowing through it. As a means of dissipating heat, sweating is extremely important. Indeed when the environmental temperature exceeds the body temperature there is no other way of getting rid of heat. The cooling effect of sweating depends not only on the temperature of the surrounding air but also in its relative humidity, i.e. the degree to which the atmosphere is saturated with moisture. When the relative humidity is low, evaporation and hence cooling are rapid. When the humidity is high, evaporation and cooling are slow.

In normal ~~condition~~ circumstances the evaporating power of the atmosphere is greatly enhanced by air movements.

(g) Panting:- In the dog and cat families there are no sweat glands and heat is lost by panting. The rapid, shallow breathing greatly increases the amount of water vaporized in the mouth and ~~respiration~~ respiratory passages and therefore the amount of heat lost.

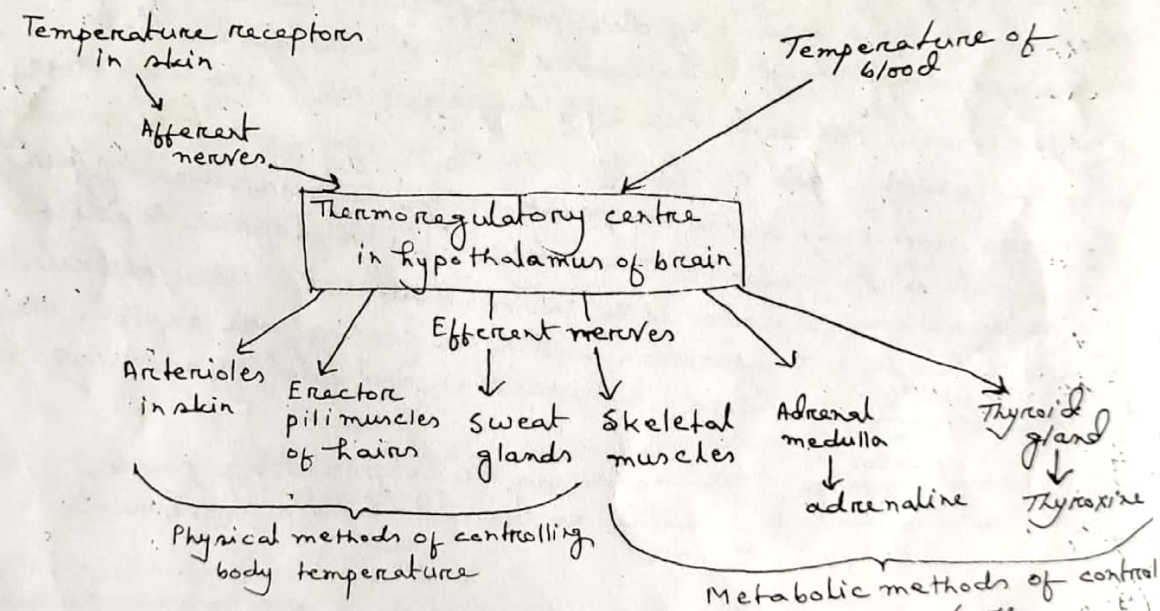
Temperature regulatory mechanisms:-

(1) Hormonal control:- Adrenal medulla secretes epinephrine into the blood. The secretion is carried to all parts of the body and enhances many metabolic processes to generate more heat. It acts on the muscles that control vasoconstriction and pilo erection. This hormone initiates the burning of brown fat which is automatic furnaces of the body. The functioning of adrenal medulla is under nervous control.

(2) Nervous control:- The acute temperature changes are mediated through nervous system. The Thermal receptors scattered in the skin or in the mucous membrane are stimulated by the change in temperature and the impulses are carried to the brain.

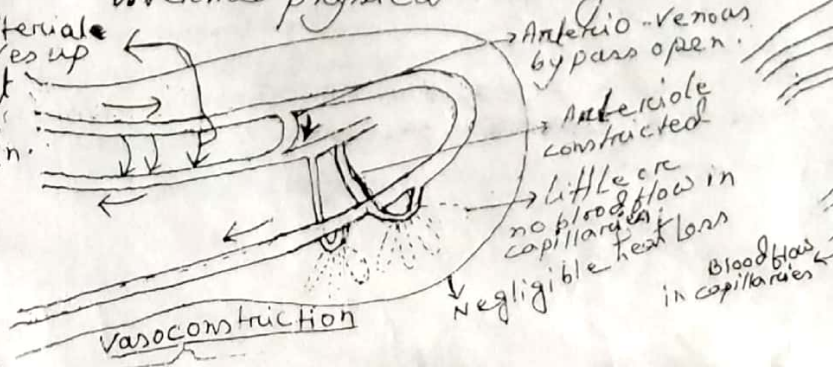
It contains thermoreceptors for measuring temperature of blood passing through it. In addition, the hypothalamus part of brain is the physiological thermostat. The anterior part of hypothalamus of mammals is responsible for protection against heat and the posterior part of hypothalamus confers resistance to cold. These control and co-ordinate various homeostatic activities occurring in the animal, such as muscular activity for heat production, to raise the body temperature, to increase O_2 consumption etc. Hypothalamus induces vasoconstriction or vasodilation.

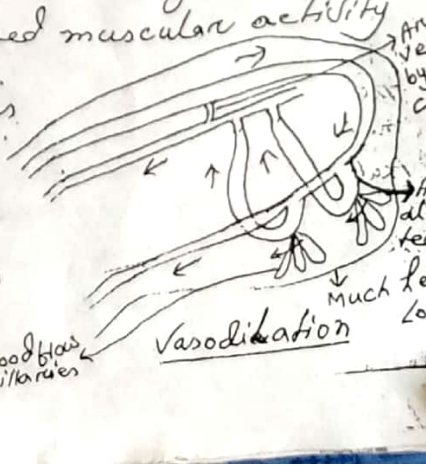
Most thermoreceptors are unmyelinated nerve ending, a few are encapsulated. Receptors for warmth are situated more superficially in the skin.



Summary of the structures involved in the reflex control of body temperature in a mammal.

- The reflex responses activated by cold are controlled from the posterior hypothalamus.
- Increased heat production which occurs by increasing the BMR and metabolic activity is termed chemical thermogenesis.
- While the heat production by increased muscular activity is termed physical thermogenesis.





Temperature regulation of Camel

The camel uses a combination of several approaches that help reduce the heat gain from the environment and thus the use of water.

① Storage of heat is reflected in an increase in body temperature. In a normal camel that is watered every day and is fully hydrated, the temperature varies by about 2°C, between about 36 and 38°C. When the camel is deprived of drinking water, however, the ~~did~~ daily temperature fluctuations become much greater.

The morning temperature may be as low as 34°C and the highest temperature in the late afternoon may be nearly 41°C. This large increase in body temperature during the day constitutes a storage of heat.

On the cool night, the stored heat can be unloaded by conduction and radiation without use of water.

② The high body temperature during the day has a further advantage, beyond that of storing heat. When the body temperature is increased, the temperature gradient from the hot environment to the body is reduced. This reduction in environmental heat gain is at least as important as heat storage with regard to water savings.

③ The camel has thick fur with a high insulation value. This imposes a heavy insulating layer between the body and the source of the heat and thus reduces the heat gain from the environment.