2/The Body Temperature

The animal kingdom can be broadly classified into two groups, depending upon their body temperature. Those who can maintain their body temperature relatively constant in the face of wide variations of environmental temperature are known as *warm-blooded* animals or *homoiotherms*, whereas those whose temperature fluctuates with fluctuations of the environmental temperature are termed *cold-blooded* animals or *poikilotherms*. In the course of evolution, from poikilotherms to homoiotherms, there exist another group who are known as *hibernants*, going into hibernation in winter, otherwise behaving like the warm-blooded animals in the remaining period. Hibernating mammals do not require an external source of heat to raise their body temperature to normal and can rouse themselves probably by activating their large stores of brown fat.

Even in homoiotherms, who are capable of maintaining constant body temperature, it has been found that different parts of the body, even different organs, have different temperatures, and this is a normal phenomenon. However, the average temperature as measured, has been found to lie within a constant range, hence justifying the statement of having a constant body temperature.

Normal temperature. Oral 97°F.—99°F. or 36·11 C.–37·22°C. (average 98·4°F. or 36·89°C.). **Axillary** (or groin) temperature is 1°F. or 0·55°C. less, while **rectal** and **oesophageal** temperatures are 1°F. or 0·55°C. more.

The body is hypothetically divided into **core** and **shell** (Fig. 2.1). The core temperature, i.e., temperature of intra-abdominal, intrathoracic and intracranial contents is maintained at a constant temperature. Rectal and oesophageal temperatures represent *core temperature.* Oesophageal temperature taken at heart level is a good index of rapid changes of cardiac and aortic blood temperatures (as during induction of hypothermia, re-warming from hypothermia), whereas rectal temperature gives a poor reflection of rapid change of blood temperature and may be misleading. *Shell temperature,* i.e. temperature of the limbs and the surface layer of the trunk exhibits wide variation of the temperature. Although rectal and oesophageal temperatures are most reliable, yet, for practical advantage, oral temperature is taken for routine clinical purposes. In some special circumstances axillary temperature may have to be taken. *Clinical thermometer* is the commonest instrument used. It should be kept under the tongue for 2 to 5 minutes for precise measurement. [*Thermocouple* is a more sensitive instrument and is routinely used during and after heart surgery, neurosurgery and in

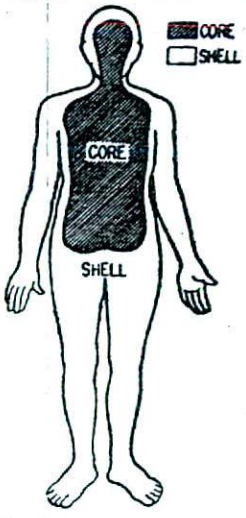


Fig. 2.1. Division of the body into hypothetical areas of 'core' and 'shell'.

intensive care units in clinical practice. Besides these, the instrument is also used for experimental purposes. The temperature recorded by a thermocouple on the tympanic membrane has been found to reflect accurately changes in arterial temperature.]

FACTORS AFFECTING BODY TEMPERATURE

1. **Diurnal variation.** It is highest in the evening (after the day's labour—between 5 and 7 p.m.) and lowest in the early hours of the morning (after the night's rest). In the night-workers, the rhythm is reversed. The average range of variation is 1°F. (0·55°C.) to 1·5°F. (0·83°C.).

This diurnal variation is related to exercise and specific dynamic action (SDA) of food. Fasting and absolute bed rest abolishes this variation.

2. **Age.** In infants regulation is imperfect. Hence, range of variation is wider. A fit of crying may raise and a cold bath may lower the body temperature. In old age, the body temperature may be subnormal due to low BMR.

3. **Size.** Heat production and heat loss depend upon the **ratio of mass to body surface area.** In a mouse, heat production is 452 large calories per kilogram body weight per 24 hours. Whereas in a horse it is only 14·5 large calories.

4. **Sex.** In females the body temperature may be a little lower. This is due to relatively low BMR and thick layer of subcutaneous fat (non-conductor). During menstruation, temperature slightly falls (0·3°F. or 0·17°C.). Then it gradually rises and becomes maximum 24 to 48 hours **after the ovulation.** This rise is due to progesterone level of blood which is secreted by the corpus luteum. Regular record of oral temperature in the early morning is sometimes used to detect the exact date of ovulation in a woman, in clinical practice.

5. **Food.** Protein food, due to high SDA may raise body temperature. The act of ingestion of food may also raise body temperature.

6. **Exercise.** Increases temperature (only 25% of muscular energy is converted into mechanical work, the rest comes out as heat.

7. **Atmospheric conditions.** Temperature, humidity and movement of air are directly concerned with the amount of heat loss from the surface and thus affect body temperature.

8. **Cold and warm baths.** These have a far greater influence than air at the same temperature, but since the duration of exposure to these baths are short, they have little effect on the normal body temperature. However, body temperature may remain elevated for a considerable time after a prolonged hot water bath.

9. **Sleep.** Because of muscular inactivity, sleep results in a slight fall of body temperature.

10. **Emotion.** Body temperature may rise due to emotional disturbances. The rise of temperature may be as high as 2°C.

11. *General anaesthetics* or *chlorpromazine* reduce the body temperature by depressing the activity of the ascending reticular system. *Tubocurarine* paralyses the skeletal muscle, and reduces heat production and results in fall of temperature. *Antipyretic drugs,* e.g., sodium salicylate and acetylsali-

cylic acid (aspirin) antagonise the action of pyrogen on the hypothalamus, induce cutaneous vasodilatation and sweating and thereby help in reduction of temperature in febrile states.

12. Posture, piloerection and clothing are also important factors which affect the body temperature. All animals and even man may conserve heat or may prevent heat loss by curling them up during exposure to cold.

REGULATION OF BODY TEMPERATURE

Although a large amount of heat is produced and lost from the body constantly, yet the body temperature remains fixed within a limited range. This shows that there is a strong machinery which keeps an exact balance between gain and loss of heat and thereby maintains a constant body temperature. The physiologic process of heat production in the body is known as **thermogenesis.** Dissipation of bodily heat by means of radiation, evaporation, etc., is called **thermolysis.** The mechanism by which

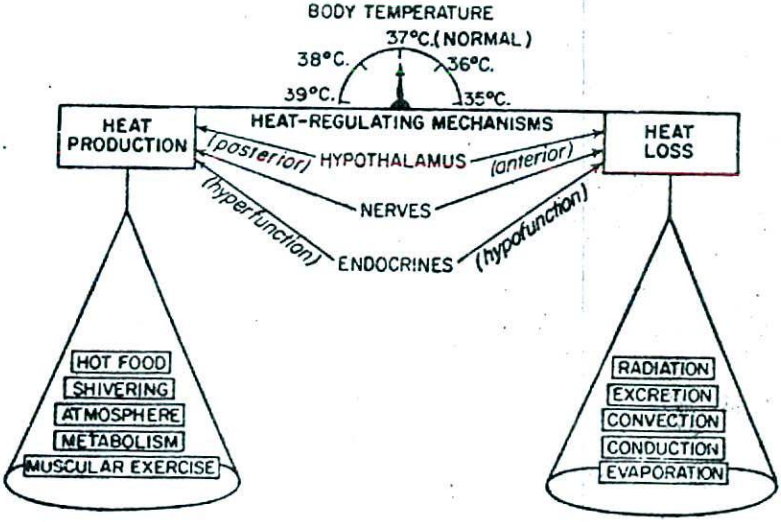


Fig. 2.2. Diagrammatic representation of the mechanism of heat production and heat loss in the body.

body temperature is normally adjusted is known as the **thermotaxis** (Fig. 2.2). The controlling mechanism consists of the following:

I. Mechanisms of heat production (Thermogenesis). (1) Heat production takes place through physiological **oxidation of food materials** in the body—by combustion of carbohydrates, proteins and fats. Cold climate stimulates appetite. Subjects take more food and proportionately higher amounts of fat. Higher fat intake increases heat production. (2) Although heat produced by **skeletal muscles** is variable and depends upon physical activity, yet the heat produced by skeletal muscles is by far the more important. As these constitute about one-half of the active structures of the body, they furnish the largest amount of heat produced among the body tissues. Increasing the activity of the muscles

whether voluntarily or involuntarily thus automatically increases the heat production. Shivering increases heat production although not as high as voluntary muscular exercise. (3) Ingestion of **hot foods** or drinks contributes to heat production in negligible amounts. (4) Of the organs, the **liver** contributes the highest amount. Heat produced by liver and heart is relatively constant. (5) The action of some **internal secretion** and enzymes, e.g., thyroxine and epinephrine (possibly) also helps to heat production. (6) During digestion the **peristaltic action** of intestines and the activity of various digestive glands produces heat.

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.**

II. Mechanisms of heat loss (Thermolysis). Heat is lost from the body by three channels, the (1) **skin,** (2) **lungs** and (3) **excretion,** mainly through the processes of radiation, conduction, convection and evaporation. The bodily changes that regulate the exchange of heat between the body and the environment are referred to as **physical heat regulation.**

(1) **From the skin** (Proportional to the total surface area)—(*a*) *Radiation*—Due to the difference of temperature existing between the body and the cooler environment heat is lost from the body by radiation (loss by electromagnetic waves). The body however does not radiate to the surrounding air, but through the air to the solid objects in the vicinity. When a number of people present in a room, they radiate towards one another as well as to the surrounding objects. Amount of heat lost by this process is about 55% of total heat lost. The amount of radiation from an object is determined by several factors. It is proportional to the surface area of the body, to its emissive power, and to the difference in temperature between the radiating body and the surrounding objects (actually to the difference between the *fourth power of the absolute temperatures* of each respectively). The colour of clothings may play a part, white and pastel shades being suitable for tropical climate. However, the colour of human skin has no effect upon the degree of radiation, both white and black skin is a 97% perfect black body. [A body absorbing 100% of the radiant energy falling on its surface is a perfect black body.]

(*b*) *Conduction and Convection*—About 20% of heat is lost from the body through conduction and convection. The heat loss through these processes depends upon the temperature of the surrounding atmosphere. When the temperature of the surrounding atmosphere is low, heat is lost from the skin to the surrounding air. The molecules of the air gradually get warmedand move away from the skin. Another layer of cooler air takes its place. Heat loss through convection depends upon the relative density and temperature of air and wind velocity but not on relative humidity of the air. Besides these factors adjustment of the blood vascular system plays an important role. Not only variation of blood flow and calibre of the cutaneous blood vessels alter the skin temperature, but arteriovenous anastomoses and alignment of veins and arteries—**venae comites** also help to regulate temperature. Vasoconstriction of the cutaneous vessels reduces

blood flow and thereby less heat is lost from the body, whereas vasodilatation produces opposite effect. Wearing woollen clothes, which are bad conductors of heat, also decrease the heat loss through conduction. Heat loss is prevented due to the entrapment of air between cloths and body surface. 1-4 units of **CLO** can keep a man comfortable at 12°C. [One **CLO** is defined as the amount of clothing necessary to keep a standard man comfortable in low temperatures.]

(*c*) *Evaporation*—About 25% of heat is lost by evaporation from the body including lungs. From skin: (*i*) **Insensible perspiration** occurs due to continuous diffusion of fluid from the capillaries of the deeper layer of skin to the dry surface of skin. (*ii*) The **sweat** is vaporised from the surface of the skin, which decreases its temperature, because it is found that 1 g of water vaporised from the surface produces the loss of about 580 kcal. Evaporation decreases to a great extent if the humidity of the atmosphere is high. For this reason a person can better tolerate high but dry atmospheric temperature than high humid one.

(2) **From lungs**—(*a*) Evaporation of water in expired air is the main pathway through which heat is lost in dogs and sheep. (*b*) Heat lost for warming the inspired air is about 2% in man.

(3) **Excreta**—urine, faeces, etc., about 2%. Protrusion of the tongue facilitates heat loss through salivation in dogs.

The simultaneous influences of convection, evaporation and radiation in relation to metabolism and heat change can be determined by the technique of **partitional calorimetry.**

When equilibrium exists, i.e., when heat production is balanced by heat loss, the exchange of heat between body and environment can be expressed by the equation

$$M \pm C \pm R - E = \pm S$$

where M (*metabolic heat production*) is always *positive,* E (*heat lost by evaporation*) always *negative,* while C (*heat lost/gained by convection and conduction*) and R (*heat lost/gained by radiation*) may be either positive or negative. In some conditions, equilibrium is not maintained and heat may be either stored or lost, which is denoted by S. Thus, in vigorous exercise, heat produced is not lost as rapidly and thus body gains heat. On the other hand, on exposure to cold, heat loss is great, and the body temporarily is in negative heat balance.

III. Nervous system and **thermotaxis.** Nervous system controls both heat production and heat loss in the following ways:

(*a*) **Role of cerebrum.** *Removal of cerebrum* makes very little change. The regulating capacity only becomes slightly restricted. The animal responds normally to external heat or cold but the body temperature falls if kept in the cold room for a long time.

(*b*) **Role of hypothalamus.** *The heat-regulating centre lies in the* **hypothalamus.** Section below the hypothalamus (midbrain preparation) destroys the mechanism and makes the animal cold-blooded. These findings show that the hypothalamus is the main centre (Fig. 2.3). Stimulation of the cephalic or anterior part of the hypothalamus causes vasodilatation, swating, etc., and helps in heat loss. Lesion (disease) of the anterior part of the hypothalamus abolishes these reactions and leads to a loss of power to withstand high temperature. The respnose

to reduced temperature is controlled by the posterior part of the hypothalamus. Lesion of the posterior part of the hypothalamus leads to subnormal body temperature. Thus, it may be concluded that the anterior part contains the **antirise centre** which controls the rate of heat loss and thereby prevents overheating and the posterior part (**antidrop centre**) governs heat production and thereby prevents chilling of the body. **Shivering centre** is also situated in the posterior part of the hypothalamus. Hypothalamus exerts its effects by *controlling autonomic nervous system* and *by controlling the ductless glands.*

(*c*) **Role of autonomic nervous system.** Only a few thermal responses are mediated by the parasympathetic division, e.g. salivary secretion, secretion of glands of the pharynx and respiratory tract, and local vasodilatation followed by activity. Greater part of the generalised thermal responses in visceral effectors is due to sympathetic control, e.g. constriction of peripheral vessels, erection of hair and feathers, liberation of epinephrine and norepinephrine, sweating and cutaneous vasodilatation. It has been definitely established that adrenal medulla is an integral part of the sympathetic system.

(*d*) **Role of spinal cord in heat regulation.** Spinal cord is the connecting path between the heat-regulating centres in the hypothalamus, peripheral thermoreceptors and effector organs (muscles). The cervical segments of the spinal cord transmits greater part of the sympathetic outflow, which regulates peripheral circulation and hence heat regulation. Spinothalamic tracts of the spinal cord carries the efferent impulse for shivering from higher centres. Effect of section through spinal cord on thermoregulation depends upon the level. When the section of the cord is made above or

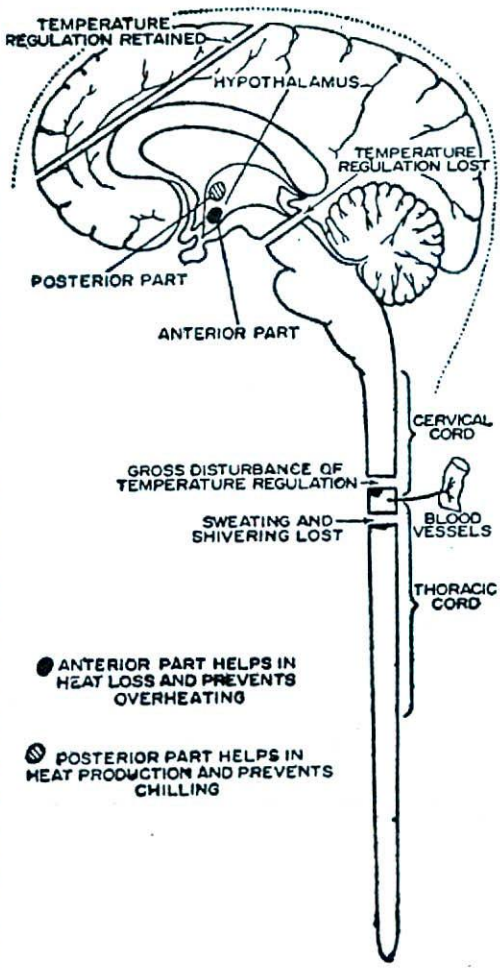


Fig. 2.3. Diagrammatic representation of the role of different parts of central nervous system in thermotaxis.

through the level of sympathetic outflow (cervical segments), gross disturbance of temperature regulation occurs. Transection of the spinal cord from the level of upper thoracic segments downwards abolishes sweating and shivering below the level of transection, i.e. in the paralysed parts (Fig. 2.3).

(*e*) **Role of motor fibres of the cerebrospinal system in heat regulation. Muscle tone** alone (even without locomotion and exercise) is a continuous source of heat production. Central nervous system maintains the muscle tone (thermal muscle tone) by continuous discharge of impulses to the muscles *via* the motor fibres. Exaggerated 'thermal muscle tone' to the extent of tremor is described as shivering. Shivering impulses from the shivering centre are not transmitted *via* the sympathetic system but *via* the motor fibres of cerebrospinal system.

Interaction of central and peripheral factors. Central and reflex control—The *normal stimulus* which mobilises nervous influence arises in two ways: (1) Variations of external temperature affect the skin thermal receptors and reflexly regulate the heat-regulating centres of the hypothalamus. Recent evidences indicate that there are temperature sensitive cells in the hypothalamus **(thermodetectors)** that respond to high temperature. (2) Temperature of blood, directly bathing the heat-regulating centres, adjusts its activities. For instance, warming the blood in the carotid artery causes those changes which increase heat loss, viz., sweating, cutaneous vasodilatation, increased respiration, etc. Cooling the carotid blood causes opposite changes. The relative roles played by peripheral and central thermoreceptors in the regulation of body temperature are not easily determined. There are species differences as well as differences among individuals of the same species as to the mode of interaction. The skin thermal receptors are responsible for bringing about early thermoregulatory changes in response to environmental temperature changes. Hypothalamic thermodetector cells are more important in that, final thermoregulatory adjustments are brought about by them.

IV. **Role of endocrines.** Certain endocrine glands also take part in heat production and heat loss. For instance: (*a*) **Thyroid**—Thyroxine stimulates BMR. Cold stimulates and heat reduces thyroid secretion. In cold, excess thyroid-stimulating hormone (TSH) is liberated from the anterior pituitary and thereby excess thyroid hormones are secreted from the thyroid gland in controlling low body temperature. In cretinism and myxoedema body temperature is subnormal. Thyroidectomised animals cannot maintain the normal body temperature. (*b*) **Anterior pituitary**—Thyrotrophic hormone stimulates secretion of thyroxine and helps in the maintenance of body temperature. Adrenocorticotrophic hormone (ACTH) is secreted under increased or decreased body temperature (cold stress or heat stress respectively). (*c*) **Adrenal medulla**—It helps in both ways. Cold reflexly stimulates adrenaline secretion, which increases heat production by stimulating metabolism. There is increased tissue oxidation and also accelerated conversion of liver glycogen to bloos glucose. The former is of special importance in temperature regulation. It also reduces heat loss by peripheral vasoconstriction. (*d*) **Adrenal cortex**—Adrenal corticoid secretion is stimulated by the increase or decrease of environmental temperature. Usually a low body temperature has been noted in Addison's disease (hypofunction of adrenal cortex).

The hypothalamus contains high concentration of **5-hydroxytryptamine (serotonin)** and **noradrenaline (norepinephrine).** The effect of these two amines, so far the temperature regulation is concerned, varies in different animals. It is presumed that these hypothalamic amines play some part in the regulation of body temperature in normal and in pathological states.

Temperature regulation in the new-born infant

Body temperature of neonates is generally unstable. They cannot control heat loss by controlling of sweat glands and cutaneous circulation. Infants rarely shiver but can raise metabolic rate by 2-3 times. This occurs principally in two ways: (*a*) by utilising brown fat and (*b*) by increasing O_2 consumption. 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 intacellular fat droplets.

EFFECTS OF EXPOSURE TO HIGH AND LOW ATMOSPHERIC TEMPERATURE

I. Physiological alterations of body mechanisms on exposure to hot atmosphere

1. Excessive sweating: When the atmospheric temperature is higher than that of body temperature, heat loss occurs mainly from *evaporation of sweat.* If the humidity is high, it will prevent rapid evaporation of sweat and reduce heat loss.

2. Rise of pulse rate, increase of cardiac output initially, followed by fall of cardiac output; fall of diastolic blood pressure due to diminished peripheral resistance resulting from vasodilatation.

3. Normal postural adjustment of vascular tone does not occur. Prolonged erect posture may result in fainting attack.

4. Hyperpnoea and respiratory alkalosis develops.

5. Urine volume diminishes, reaction of urine becomes alkaline, NH_3 formation by the kidney decreases.

In **heat exhaustion** syndrome besides hyperpyrexia, sweating is profuse, there is profound loss of Na^+, Cl^- and water. Due to *anhydraemia* and *salt loss* there are changes in the muscular activity, e.g. fatigue and heat cramp. There is tachycardia and fall of blood pressure.

There is another syndrome known as **heat stroke.** This also occurs after exposure to excessive heat. There is also *hyperpyrexia.* The rectal temperature is high. The skin remains dry. The patient may suddenly become unconscious. The heat-regulating mechanisms completely fail. If severe, the nervous system may be permanently damaged.

Life in deserts. Despite excessive temperature, many animals adapt desert life. Mechanism of survivals depends largely on the size of the animal. Small animals like kangaroo rats burrow hole and hide themselves under the ground in the daytime. A camel sits down early in the morning in a cool patch of sand and tucks its legs underneath exposing as little as possible of its surface to the sun in the daytime.

Sweating is minimal in or absent in desert animals. Thereby they conserve water. They pass dry faeces. Their urine is highly concentrated. Salt content of the urine of kangaroo rats and camel is higher than sea-water. This is probably due to their relatively long renal tubules particularly the loops of Henle. Their long and tortuous upper respiratory tract helps in minimising loss of water.

They can withstand a greater amount of water loss (up to 30% of body wt.). Drinking capacity of a camel in one sitting is more than 150 litres. Camel's body temperature remains steady if it has plentiful of water. However a camel can tolerate a 10°C. swing of body temperature. a camel has a body coat of several cm thick, which gives it a good protection against heat gain by radiation.

Man has no special adaptations for desert life. Provided there is liberal supply of water and salt he can keep his body temperature within normal range. An explosive heat rise takes place before 15% of the original body water has been lost. In deserts long loose all-enveloping clothes are preferable to shorts.

II. Physiological alterations of body mechanisms on exposure to cold atmosphere

When the atmospheric temperature is lower, the body temperature is maintained in two ways: (1) by increasing heat production and (2) by reducing heat loss. **Heat production** is increased by (*a*) stimulating thyroxine and adrenaline secretion (reflexly) which increase the metabolic activities. (*b*) Increased intake of food (proteins, due to high SDA, are of additional value). (*c*) Causing reflex shivering, if the cold is too severe. **Heat loss** is reduced by (*a*) reflex vasoconstriction of the skin (less blood to the surface, hence less heat loss), (*b*) depression of sweating (less heat loss due to less evaporation), (*c*) thick layer of subcutaneous fat, (*d*) clothing.

Extreme or protracted exposure of the limbs to cold may cause vascular changes of the limb, which depend upon the duration of exposure, wetness and chilling. After prolonged exposure, on re-warming the limb shows colour changes of varying degrees, pain and swelling. In its extreme form, the limb may show complete or patchy gangrene (death of tissues). The condition has been designated by various names according to the cause, e.g. frost bite, 'Immersion foot', 'Trench foot', etc. Causes of this cold injury are many of which the most important ones are: (*a*) formation of ice crystals within the tissues, (*b*) alteration of local blood supply, (*c*) alteration of local electrolyte concentration, and (*d*) alteration of tissue pH.

III. Effect of sudden change of atmospheric temperature

When a person enters into a warm room after having been out in the cold or from an air-conditioned room, he may feel much colder or even may start shivering. Sudden vasodilatation produced by the warmth leads to sudden drop in blood temperature due to initial return of cold blood from the skin.

PYREXIA (FEVER)

Body temperature, between 99°F. (37·22°C.) and 105°F. (40·57°C.) and onwards, is called **pyrexia,** while rise of body temperature above 107°F (41·66°C) is called **hyperpyrexia.**

Body temperature rises due to derangement of the heat-regulating mechanism. Toxins (pyrogens) act on WBC and produce endogenous pyrogen. This acts directly on the anterior hypothalamus and the body temperature is elevated. Fever occurs due to any of the causes such as infections (e.g. pneumonia, typhoid fever, etc.), injury to nervous centres, dehydration, tissue destruction, administration of some drugs, etc. In some fever, e.g. malaria, shivering or rigor occurs.

Physiological responses due to pyrexia (fever)

1. Metabolism increases.
2. Blood pressure, pulse rate and cardiac output increase.
3. Rate of respiration increases.
4. There occurs negative nitrogen balance.
5. There occurs dehydration and fall of plasma chloride level.

HYPOTHERMIA

Deliberate reduction of body temperature in order to facilitate some surgical operations, e.g. operation on the heart and great blood vessels, and on brain, have been practised with great success. This deliberate lowering of body temperature is known as hypothermia. There are three grades of hypothermia according to the temperature:

1. Mild hypothermia .. .. .. 35°C.-31°C.
2. Moderate hypothermia .. .. 30°C.-25°C.
3. Deep hypothermia .. .. .. below 25°C.

The **cooling** may be achieved by various means, e.g.

1. **Surface cooling,** i.e. by exposing the body surface to icepacks, or cold water.

2. **Blood stream cooling,** i.e. blood is collected from major veins (superior vena cava and inferior vena cava or the femoral vein), passed through a system outside the body (heat exchanger) and again returned to an artery with the help of a pump (Fig. 2.4).

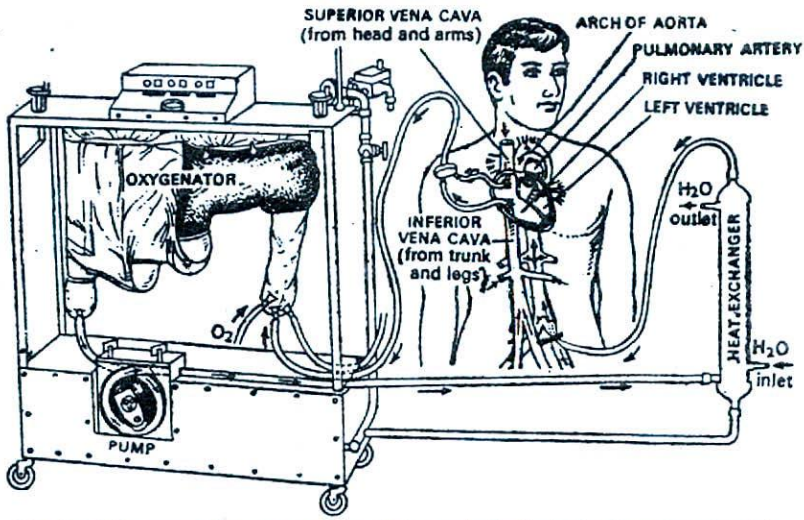


Fig. 2.4. Diagrammatic representation of the method of inducing hypothermia with the help of a heat exchanger incorporated in an extracorporeal circuit (heart-lung mechine) consisting of a pump (= heart) and a bubble oxygenator (= lung).

3. **Cavity cooling.**

Physiological responses to (deliberate) hypothermia

When hypothermia is induced deliberately as an adjunct to surgery, some of the normal physiological responses to cold exposure, e.g. shivering, vasoconstriction, etc., are also stopped by giving muscle relaxants (Curari) and vasodilators (Largactil). By preventing shivering and vasoconstriction, the cooling is accelerated and deleterious effects of unintentional hypothermia or accidental hypothermia as happens in ship-wrecked mariners may be averted. The physiological responses to

hypothermia when shivering is stopped are different from unintentional hypothermia with shivering and are of great practical value.

1. **Metabolism.** In absence of shivering, the oxygen consumption falls as the body temperature is reduced. The whole body oxygen consumption may be reduced to half when the mean body temperature is lowered by 10°C.

The glucose metabolism is impaired when the body temperature is lowered to 30°C. due to inhibition of hexokinase activity. Glucose given intravenously is redistributed into extracellular fluid and injection of insulin do not help in the utilisation of sugar.

2. **Heart.** With the reduction of temperature heart rate is also reduced being halved at 25°C. due to the effect of cooling on the pacemaker. In absence of shivering, cardiac output falls with diminishing temperature. Though oxygen uptake by the heart diminishes under hypothermia, yet it remains relatively higher, as compaired to most other tissues. When the temperature is lowered below 25°C., ventricular fibrillation starts.

3. **Respiratory system.** There is an increase in the anatomical and physiological dead spaces under hypothermia, probably due to bronchodilatation. A combined respiratory and metabolic acidosis develops.

4. **Circulatory changes.** With the reduction of body temperature, blood flow through brain, coronary arteries, kidneys and splanchnic areas is reduced.

5. **Brain.** At normothermia, brain cannot withstand oxygen lack for more than 3 minutes. But when the body temperature is lowered to 25°C., brain circulation can be kept arrested for more than 10 minutes. This advantage of hypothermia is taken in undertaking brain and cardiac operations by stopping circulation through the heart. In absence of shivering cerebrospinal fluid pressure falls under hypothermia.

6. **Kidney.** At 25°C. body temperature there is 30 per cent. reduction in the glomerular filtration rate and blood flow through the kidney.

7. **Endocrine function.** Deliberate hypothermia under anaesthesia and in absence of shivering, causes of all ductless glands to remain markedly depressed. But if shivering is there, most of the endocrine glands show marked activity.