Homesostasis- we talk about discipline in day-to-day life. Discipline is necessary for the growth and development of both individuals and institutions. Life itself is a disciplined entity. It's activities are well coordinated and controlled. Obviously, the growth and development of organisms depend on the internal constant conditions (internal discipline) they maitain. Claude Bernard (1857), a French physiologist stated that the maintenance of constant internal environment is the condition for the free life. He distinguished between the continuously changing external environment in which organisms live and the constantly maitained internal environment (tissue fluids) in which the individual cells live. He emphasized the importance of constant internal conditions for the survival of life.For instance mammals and Birds(endotherms) maintain constant body temperature any continuously changing external environment.aquatic organisms maintain constant levels of solute and water concentration in the body in troublesome osmatic environments.Our blood maintains constant levels of various biochemical constituents status glucose,urea,creatine,creatinine etc.More importantly,our cellular metabolic systems work optimally within the narrow limits pH, temperature and other physiological conditions.

CONCEPT OF HOMEOSTASIS

The term homeostasis refers to maintainance of constant internal environment.In 1932,an American physiologist Walter Cannon coined the term homeostasis (homeo=same,stasis=standing)show mechanisms that might in internal steady state in organisms.it helps in maintaining the stability of cellular environment and independence of cells.In this condition the organism as a whole becomes totally independent of it's environment and remains unaffected by the fluctuations in the external conditions.Homeostatic mechanisms are pervasive in nature that includes a variety of processes and mechanisms related to every activity of life ,some of which are listed below

- Maintainance of constant body temperature,
- Maintainance of constant pH by acid base balance of body fluids ,
- Maintainance of water and salt concentration,
- Maintainance of constant blood glucose level,
- Maintainance of constant levels of calcium, phosphate and other minerals,
- Maintainance of constant blood volume, blood pressure,heart rate,
- Maintainance of constant oxygen and carbon dioxide levels.

BASIC MECHANISM OF HOMEOSTASIS

The homeostatic mechanisms are analogous to the control systems found in modern equipment.Like machines,the living systems are open systems.They depend on continuous supply of inputs from the environment.They reach a steady state with their environment by continuously spending energy.The homeostatic control mechanism of living things includes three basic components of a control system;the detectors,regulators(coordinators)and effectors.The detectors include peripheral sense organs, receptors etc., That help in detecting the changes (stimuli) in the environment. The central nervous system(CNS) acts as the regulator or coordinator.it receives inputs from the detectors and gives instructions to the effectors such as muscle or endocrine glands and target organ of the endocrine system.The effectors, inturn show responses by their actions or secretions.(fig 8.1)

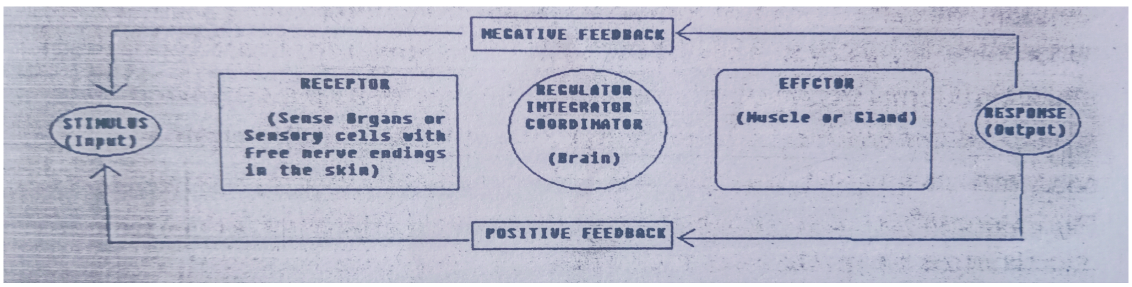


Fig.8.1 Basic components of homeostatic control mechanism.

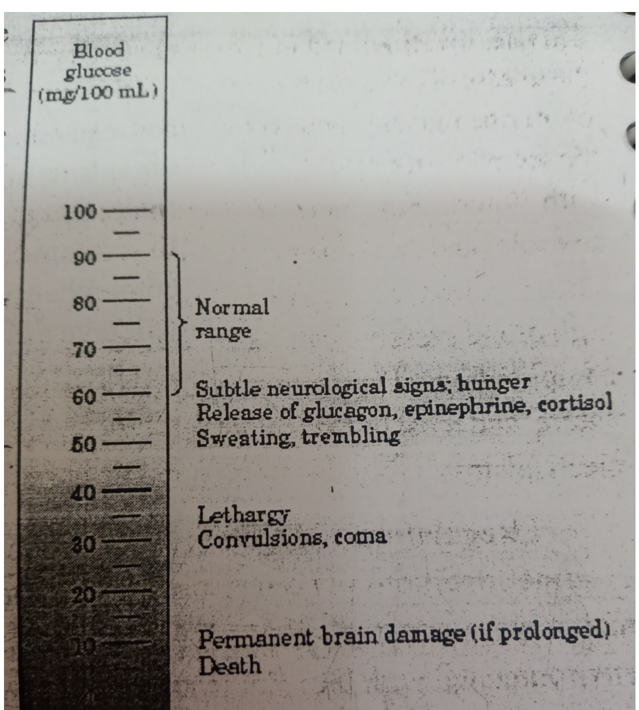
The responses are automatic and involve two feedback loops. In a feedback mechanism, the result or output of a process alters(inhibits or activates) the course of it's events. The feedback may be negative or positive. In the negative feedback loop, stimulus produces an action that ultimately reduces the stimulus.the nature of negative feedback loop becomes clear when we refer to the analogy of thermostat and air conditioner.after the air conditioner has been on for some time the room temperature may fall significantly below the set point of thermostat. When this occurs, the air conditioner will be turned off.The effector (air conditioner) is turned on by high temperature; and ,when activated, it produces a negative change(lowering of the temperature)that ultimately causes the effect to be turned off. In this way, constancy please maintained.For Instance the availability of thyroxine hormone in the blood inhibits further production of thyroxine by thyroid.Positive feedback loop the output or product further activates the stimulus and a box same response again and again. For example the please of oxytocin hormone from the neurohypophysis causes contraction of uterine muscles and labour pains. The latest paints in turn will enhance the secretion of oxytocin.the negative feedback loops are usually associated with illness.for instance high blood pressure can damage arteries and arterioles and the damaged blood vessels are filled with lipid material which narrow down the blood vessels and further increase the blood pressure. Thus, high blood pressure can cause further rise in the blood pressure and lead to complications. Due to this reason the positive feedback loops are rare in nature, and most of the animal activities are controlled by negative feedback mechanisms.

Regulators and conformers:regulating and conforming are two extreme conditions of homeostasis.An animal is said to be a regulator if it maintains a constant physiological state with reference to a particular environmental variable. for instance,freshwater fish is able to maintain stable internal concentration of solute in h blood and interstitial fluid even under conditions of changing external solute concentrations.animal is said to be confirm for a particular environmental variable,if its concentration changes along with the changes in the external environment. For example, some invertebrates (such as spider crab:Libinia) cannot regulate its internal solute concentration but its internal concentration matches with that of external environment.

Homeostasis - Illustrations

Illustrations 1: Hormonal Control of Blood Glucose level

Glucose is the main source of energy for organisms. Glucose is used as a substrate for energy production in cellular respiration. In mammals,some tissues depend almost completely on glucose for their metabolic energy. For the human brain and nervous system,as well as the erythrocytes,tested,renal medulla, and embryonic tissues, glucose from the blood is the sole or major fuel source. The brain alone requires about 120g of glucose each day. Between meals and after vigorous exercise, blood glucose is depleted. Brain cannot work properly under low blood glucose levels. Lack of glucose causes headache, sweating, trembling, fainting and coma. The control of blood glucose level is an important example of homeostatic mechanisms in the body. Under normal conditions,blood maintains about 90 to 100mg of glucose per 100ml. An increase in the glucose level from this set point is called hyperglycemia. It results in diabetes mellitus in which excess sugar is eliminated in urine. Low glucose levels is called hypoglycemia deprive the cells of their energy reserves. Hence,the maintenance of blood glucose level at a set point is essential for normal health.



The homeostasis of blood glucose involves at least six hormones and two negative feedback loops. However,insulin and glucagon play a key role in this process. A rise in glucose level simulates insulin secretion from the beta cells of pancreas. Insulin causes the uptake of glucose by cells in the body (more particularly liver,muscle and adipose cells) and facilitates it's conversion into the storage form of glycogen (glycogen syntesis). As a result the blood glucose levels are brought down to the levels of set-point. Comtrarily,when blood glucose levels falls below the set-point, the alpha cells of pancreas release glucagon which increases blood glucose level by stimulating the breakdown of glycogen from the cells by a process called glycogenolysis. Thus by the complementary action of both insulin and glucagon,the blood glucose level is brought to normal levels. Secretion of both insulin and glucagon are inhibited by their own high levels by negative feedback loops. In addition the glucocorticoids secreted from the adrenal medulla also control blood glucose levels by stimulating gluconeogenesis. Another hormone;thyroxine enhances glucose utilisation in cells by elevating the basal metabolic rate (BMR).

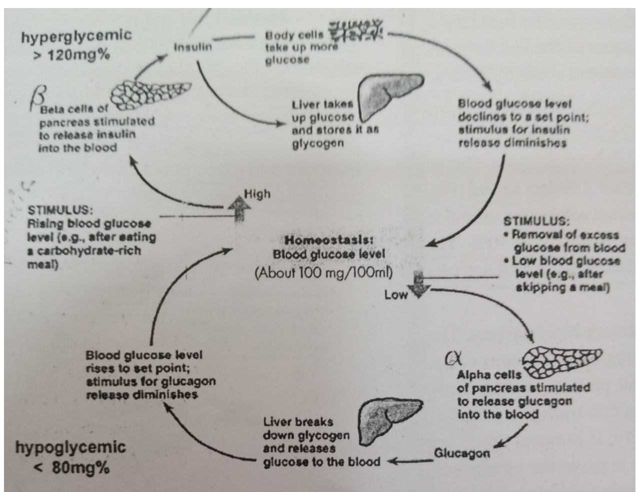


Fig.8.3 Homeostatic control of blood glucose levels in humans

Homeostatic control of blood glucose levels in humans

Water and ionic Regulation by Marine and Freshwater animals:

The physiological systems of cells, tissues, organs and organsystems of all organisms operate in the fluid environment. They work well only in a stable environment in whichthe relative proportion of water and solutes is maintain Ed in the tolerable narrow limits. Aquatic animals aresubjected to life threatening osmotic problems. The fresh water animals live in an environment that threatens to flood and dilute their body fluids by entry of water and loss of salt from body. The Marine and desert animals have dessication problems of water loss and salt gain. Thus the aquatic animals have unique problems related to the maintainance of water and solute concentrations in the body fluids. The animals ability to regulate the chemical composition depends on balancing the up take and loss of water and solutes in the body. This homeostatic mechanism is called osmoregulation. It ensures the control of solutes and water between interstitial fluids and it's surroundings. Homeostatic organs such as kidney, chloride glands, salt glands,and rectalglandsetc.,help in this process.

Osmoregulation in animals:

Marine invertebrates and vertebrates live in a strong salty environment. The sea water is a complex solution of sodium, potassium, calcium, magnesium,chlorides and other ions. It creates osmoregulatory problems that are similar to those of the dehydration problems of the terrestrial environment. Due to the presence of salts, sea water is hyperosmotic to the bodies of marine animals. Conversely, there body fluids are hypoosmatic to the bodies of the sea water and contain higher concentration of water than do the surrounding water. Because of this reason two concentration gradients exist in the marine environment. Firstly the ions tend to diffuse in and secondly, the water tends to move out. Thus. Marine animals are faced with a double problem of water loss and salt gain. The water loss occurs by exosmosis and the salt is gained by diffusion and from the food they eat. In order to survive from this double problem, marine animals developed different adaptive strategies. On the basis of these strategies marine animals are classified into two broad categories; osmoconfer ers and osmoregulatory.

Osmoconfermers maintain a solute concentration similar to that of the sea water. The solute concentration of the body fluids matches(isoosmotic condition) with that of surroundings. In other words, the solute concentration of body fluids confirms to that of sea water. It changes with changes out side and requires a little energy. For instance an invertebrate called Acmaea linatula, which lives in the intertidal zone, maitains isoosmotic salinity range of 1.5to5/. A similar change in humans causes instant death. Similarly sharks and rays(cartilaginous fishes)are osmoconformers. They retain higher concentrations of urea in their body fluids. Unlike many marine bony fishes,they of not experience continuous water loss and at the same time they do not drink sea water. This is because; they maintain a high concentration of urea(derived from the metabolism of proteins and nucleic acids)and trimethylamine oxide(TMAO)in their blood. The TMAO protects proteins from damage by urea. Thus,by storing urea in blood,sharks maintain their body fluids at a hyperosmotic concentration (~1000 osmoles) to that of sea water. Because of this reason shark's meat generate urea(foul) smell,and that is often removed by soaking it in fresh water before cooking. Due to the presence of hyperosmatic blood,water slowly enters the shark's body by osmosis. The small influx of water is disposed of by the kidneys through urine. The kidneys also remove some of the salt from the body and the rest is expelled by rectal glands and some by faeces.

ii. Osmoregulators maintain relatively stable internal solute concentration itrrspective of changes in the salinity of the sea water around them. Many marine arthropods are osmoregulators. One of the best known osmoregulator is the crustacean Artemia salina(fig. 8.4.)that lives in salt ponds. It maintains constant solute concentration when the salinity in its surroundings varies from 1% to 30%. The Gill I this crustacean is the chief osmoregulatory organ that actively transports the excess salt from the body.

Marine vertebrates use similar osmoregulatory mechanisms. The marine bony fishes balance to water loss by drinking large amounts of sea water. At the same time they expel the excess salt present in their body fluids. The gills contain specialized chloride cells that transport chloride ions(Cl^-) out and the sodium ions follow passively. If humans drink sea water, they need huge quantities of fresh water to remove the excess salt from the body. Because of the presence of salt-secreting glands in gills,the fishes have no such problem. Since the salt is completely removed from the sea water, it becomes perfectly suitable for drinking.

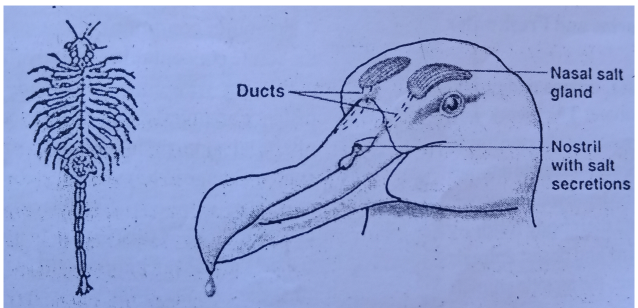
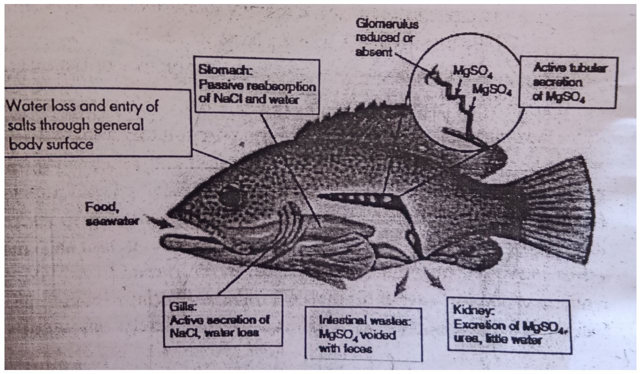


Fig. 8.4. Marine osmoregulators- *Artemia salina* and a marine bird

The other ions are either excreted by the kidneys are sent out through the gut unabsorbed. The kidneys of such fishes are highly specialized (aglomerular kidneys) which dispose of excess calcium,magnesium and sulfate ions through urine. Further, their urine is hypertonic and contains small amounts of water.

Marine birds and reptiles also take sea water through their food. Their kidneys are not efficient salt removers. They actively excrete excess salt through the salt glands located near the eyes,which is drained into the nose through ducts. Marine mammals have efficient kidneys which act as salt-excreting glands. The excess salt is actively transported into the nephric tubules,resulting in the formation of hypertonic urine. However,most of the marine mammals avoid drinking sea water,but take low -solute body fluids of fish they eat.



Osmoregulation in Freshwater animals

The osmoregulatory problems of freshwater animals are opposite to those of marine animals. In fresh water animals the concentration of body fluids is higher than that of water and hence they constantly gain water by osmosis and loose salt by diffusion. If the organism is not able to manage excess water,the cells may swell and rupture. At the same time they have to protect the solute(e.g. Sodium,potassium,magnesium) concentration by spending excess energy for actively transporting back these ions from the water through skin,gills and nephric tubules of kidney. A closer look at the fresh water animals shows different osmoregulatory organs and mechanisms. For instance,in fresh water protozoans like amoeba and paramecium the contractile vacoules remove excess water from the body and thereby prevent cell damage caused by the influx of Freshwater through endosmosis. One of the simplest osmoregulatory systems is the flame cell system or protonephridial system of fresh water flatworms. This system comprises fundamental units called flame cells or proteonephridia that acts as osmoregulatory organs (Flame cells are absent in marine flatworms which live in isoosmotic environment). The flame cells consists of network of tubules distributed throughout the body that send out the excretory materials and water through excretory pores. The excess water present in the intercellular fluids is transported into the flame cells by pinocytosis or cell drinking. The cilia present in the flame bulb of flame cells create water currents that help in passage of water through excretory ducts and its elimination through excretory ducts and pores.

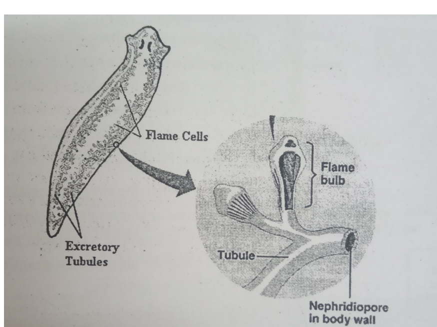


Fig.8.6 Flame cell system in a flatworm (eg. *Planaria*)

Many freshwater fishes maintain water balance by different methods. They eliminate excess water from their body by excreting large amounts of dilute urine. The salt lost by diffusion is replenished by the food and uptake of salt(Na+,Cl-)through the chloride cells present in the gills.

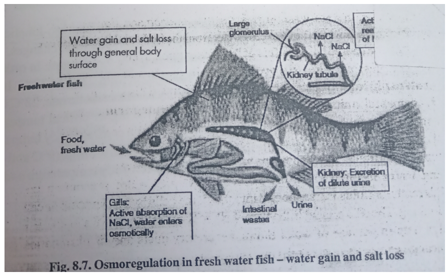


Fig. 8.7. Osmoregulation in fresh water fish – water gain and salt loss

Some euryhaline fishes that migrate between the sea water and freshwater show osmoregulatory mechanisms commonly seen in both marine and freshwater environments. For example, the salmon fish osmoregulates like marine fish in seawater by drinking saltwater and excreting excess salt through gills and urine. When it migrates to rivers,it osmoregulates like a freshwater fish by taking up salt through gills and by producing large quantities of dilute urine. Amphibians have highly developed excretory system. The tadpoles of frogs excrete ammonia like that of fishes. In adult stage they switch over to excrete urea. They drink and excrete huge amounts of water. Like fishes, amphibians tend to loose salt in urine. They also take-up salt from the surroundings by active transport through the skin.

Illustration 3: Temperature Regulation in Man

The term thermoregulation refers to maintenance of constant internal body temperature within a tolerable range. All endotherms (Mammals and Birds)have ability to maintain constant core body temperature irrespective of fluctuations in the levels of external temperature. This ability is crucial for the survival of animals because most biochemical and physiological processes take place optimally at a particular range of temperature inly. The rates of most enzyme-mediated reactions increase two to three fold for every 10degree C temperature till it reaches optimal levels. At high temperature enzymes and proteins begin to denature and they loose their biochemical function. At low temperatures or freezing conditions also enzymes cannot work. Majority of living organisms survive within confined limits of 10-45degree C,a range of temperature commonly called bio-kinetic zone. Thus animal functioning is drastically affected by thermal changes. Hence,animals must maintain comfortable range of temperature in order to survive. Endotherms have a thermoneutal zone from 28-37degree C. In this range,body temperature is maintained by basal metabolic rate. 28degree C is called lower critical temperature and 37degree C is called higher critical temperature. Outside the thrmoneutral zone, maintaining constant body temperature requires the expenditure of energy. Outside extreme limits,(0degree C and 40degree C in this instance),the animal cannot maintain it's body temperature and so dies.

All endotherms, including man are able to balance heat gain and heat loss by generating heat energy internally (fig.8.9). They have internal control mechanism that involves thermoreceptors, effectors and regulator centers of brain. Hypothalamus is the major control centre of thermoregulation. It monitors the changes in body temperature. The changes in the levels of core body temperature activate the core body temperature. The thermoreceptors (1,50,000 cold receptors- 16,000 heat receptors in human) detect changes in temperature and generate and transmit the nerve impulses to the hypothalamus. The sensation of heat or cold is experienced according to the intesitu of the stimulus,duration of stimulus and number of receptors involoved. Similarly, hypothalamus detects the changes in core body temperature with the help of internal thermoreceptors. Hypothalamus contain two distinct regions namely, the heat gain centre and heat loss centre.

The heat gain centre is activated by the increase in temperature. It causes:

Vasodilation and sweating.

Vasodilation: heat exchange between the internal environment and the skin occurs largely through blood flow. For example, when a person's body temperature rises as a result of exercise, blood flow to the skin increase as the blood vessels that brought from the body core to the skin surface becomes quite warm. The heat brought from the body core to the skin by the blood is lost to the environment by radiation, conviction and conduction and helps to bring the body temperature back to normal.

Sweating: when the environmental temperature rises above the upper critical temperature for an endotherm, overheating, becomes a problem. The sweat glands are stimulated to secret. Sweat. Evaporation of sweat from body surface cools an animal as a gram of water a absorbs about 580 calories of heat when it evaporates.

The heat loss centre is activated by cold receptors. It causes;

Vasoconstriction

Heat production through shivering

Increasing the metabolic rate

Vasoconstriction: the blood vessels bringing blood to the skin construct the by decreasing the blood supply to skin and decrease heat loss from the skin by radiation, convection,and conduction. Sweating is also inhibited.

Heat production through shivering: shivering uses the contractile machinery of skeletal muscles to consume ATP. The muscle pull against each other so that little movement other than a tremor results. The energy from the conversion of ATP to ADP in this process is released as heat. Increased muscle tone and increased body movements also contribute to increased heat production in cold environments.

Increasing the metabolic rate: the release of thyroxine and adrenaline cause an increase in metabolic rate which results in heat production.

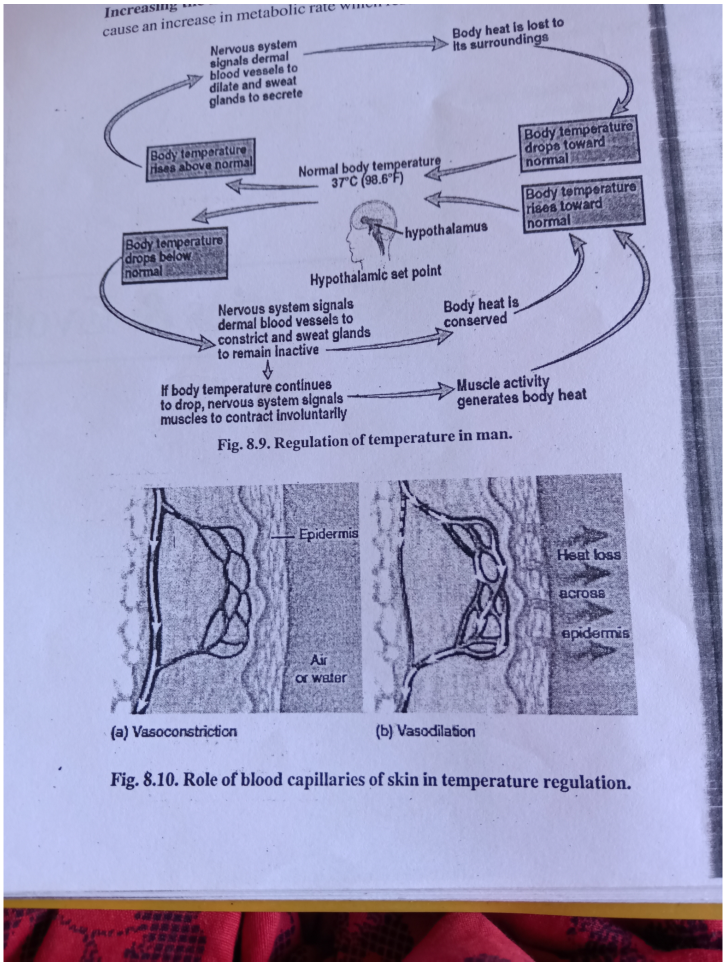


Fig. 8.9. Regulation of temperature in man.

Fig. 8.10. Role of blood capillaries of skin in temperature regulation.