UNIT 5 OSMOTIC AND IONIC REGULATION

Structure

5.1 INTRODUCTION

In the previous unit you have learnt that ammonotelism, ureotelism and uricotelism are the adaptations of the animals for the removal of toxic nitrogenous wastes and thereby maintain homeostasis. Animals regulate the concentration of water and salts in their body fluids in accordance with their external environment. The process of maintenance of osmotic concentration of the body fluids is called **osmoregulation**. Osmoregulation and excretion are intimately related as the ultimate aim of these processes is to maintain homeostasis. These processes are performed by the same set of organs. Kidney is the major organ of osmoregulation in vertebrates. Gills, integument, salt glands and rectal glands assist kidneys in this endeavour. The osmoregulatory organs of invertebrates are nephridia, antennal glands and malpighian tubules. The cuticle of insects also performs an excellent osmoregulatory function in both aquatic and terrestrial insects. In this unit you shall study about the osmotic environments, osmotic exchanges between animal and the environment, the mechanisms used by various animals to cope up with environmental osmotic extremes and also about role of hormones in osmotic and ionic regulation.

Objectives

After reading this unit you shall be able to :

- explain the meaning of osmoregulation
- discuss how aquatic animals cope up with the osmotic problems
- explain how migratory fishes maintain constant osmotic pressure of their body fluids
- discuss the mechanisms the terrestrial animals have evolved to face the extremes of desert conditions
- explain the secret of the survival of kangroo rat in the arid desert,
- discuss role of hormones in regulating water and electrolyte balance in the body fluids.

5.2 PROBLEMS OF OSMOREGULATION

You have learnt in the course LSE-01 : Cell Biology that, water, some inorganic salts, nutrient molecules are some of the important components of the body fluids. It is essential for the animals to maintain appropriate concentration of these components for the survival.

It is agreed that life originated in the sea, and during the course of evolution animals spread from oceans into the estuaries, rivers and onto the land. These new environments are osmotically different from that of the sea. Since life originated in the sea, body fluids of the animals are more or less similar to that of seawater in its general composition. Therefore, animals inhabiting marine environment do not have the problem of osmoregulation, because their body fluids are isotonic to their external environment, the sea. But animals spread over to brackish, freshwater, and terrestrial environments have the problem of osmoregulation because their body fluids are hypertonic to their external environment. Therefore, these animals evolved various physiological and behavioural adaptations to cope up with the rigors of the osmotic environments. The osmoregulatory organs of these animals play a vital role in this effort.

An osmoregulatory animal is generally in an osmotic steady state eventhough there may be hourly and daily variations in osmotic balance. The concentration of internal salts and water is maintained relatively constant. The intake and outflow of water and salts are equal. Such osmotic homeostasis is maintained at the cost of metabolic energy, obtained from ATP (Fig. 5.1).

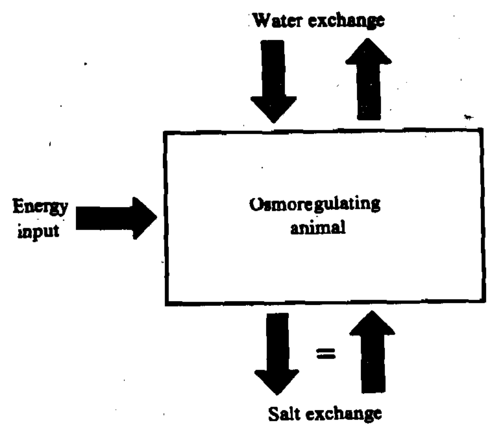


Fig. 5.1 : Osmotic homeostasis in osmoregulatory animal

The need for the evolution of efficient osmoregulatory mechanism gave chance for animal speciation and diversification. The resourcefulness of evolutionary adaptations can be realised if we consider the adaptations of arthropods and vertebrates. If they had not evolved suitable osmoregulatory mechanism how they have been so successful in both terrestrial and aquatic environments — the environments that are osmotically hostile and difficult. You will learn about such adaptions in the following sections of the unit.

The osmotic exchanges that take place between an animal and its environment are of two different types :

1) obligatory exchanges and
2) regulated exchanges.

In **obligatory exchange** osmotic exchanges occur mainly in response to physical factors over which the animal has little or no physiological control. Whereas in **regulated exchanges**, the osmotic exchanges are physiologically controlled and it serves to aid in maintaining internal homeostasis. Regulated exchanges generally serve to compensate for the obligatory exchanges.

Animals that maintain osmolarity of their body fluids constant irrespective of the medium in which they live are termed **osmoregulators.** Animals that do not actively control the osmotic condition of their body fluids and instead conform to the osmolarity of the medium in which they live are termed **osmoconformers**. Most vertebrates, except elasmobranchs and hagfishes are strict osmoregulators, maintaining the composition of body fluids within small osmotic range. Marine invertebrates are in osmotic balance with seawater. The concentration of Na^+ K^+, Ca^{2+}, Mg^{2+} and Cl^- in their body fluids is close to the concentration of these ions in the seawater, in which they live. This is clearly illustrated in Fig. 5.2. In the following section we shall learn about life in different osmotic habitats.

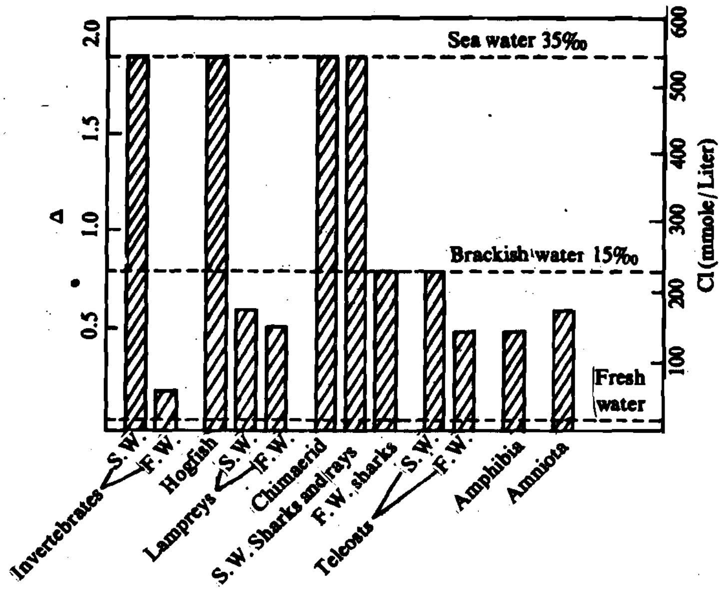


Fig. 5.2 : Osmolarity of body fluids in different groups of animals in relation to the tonocity of their environments

SAQ 1

Match the terms given in column I with their definitions given in column II and compare your answers to those given in section 5.8

Column I			Column II
a) Obligatory exchange	[ ]	i)	Animals that maintain an internal osmolarity different from the medium in which they live
b) Regulated exchanges	[ ]	ii)	Physiologically controlled osmotic exchanges to maintain internal homoeostasis
c) Osmoregulators	[ ]	iii)	Animals that do not actively control the osmotic condition of their body fluids, and instead conform to the osmolarity of the medium in which they live.
d) Osmoconformers	[ ]	iv)	Osmotic exchanges that occur mainly in response to the physical factors over which the animals have no physiological control.

5.3 OSMOREGULATION IN AQUEOUS ENVIRONMENTS

You are aware that the aqueous environments are of two types: i) Freshwater and ii) Seawater. The osmotic concentration of these environments ranges from several milliosmoles per litre in freshwater lakes to about 1000 milliosmoles per litre in ordinary seawater. It is even more in landlocked saltseas. The whole body and the respiratory surface of the aquatic animals is immersed in these osmotically extreme environments.

The animals which can tolerate a wide range of salinities are called **euryhaline** and those which tolerate only a narrow osmotic range are termed **stenohaline**. In the following sub-section we shall learn about osmotic regulation in freshwater and seawater animals.

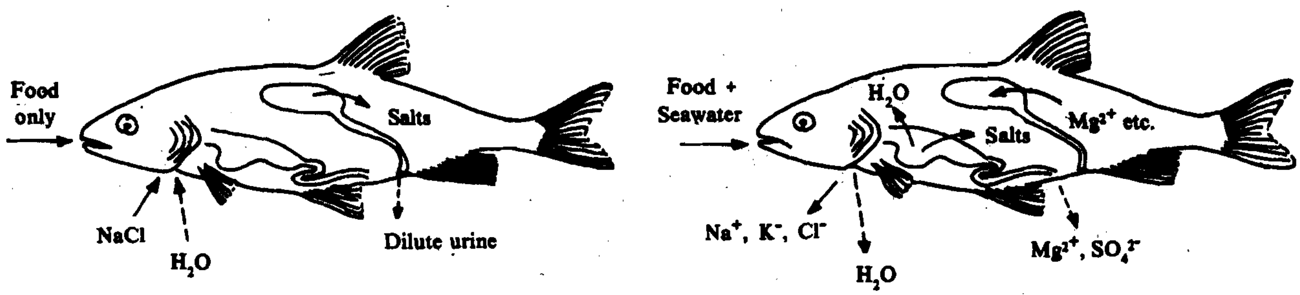
5.3.1 Freshwater Animals

In Fig. 5.2 you have seen that the body fluids of freshwater animals are hyperosmotic to their aqueous surroundings. This results in two kinds of osmotic problems;

i) due to osmotic gradient water moves into their bodies resulting in swelling of their body.

ii) since the surrounding environment is low in salt content, there is continuous loss of body salts.

Therefore, freshwater animals must prevent net gain of water and net loss of salts. Net gain of water is prevented by producing dilute urine. Freshwater fishes produce copious urine than the marine fishes. The useful salts are largely retained by reabsorption in the kidney tubules. The salts which are passed out in urine are replaced partly from the ingested food. Salts are also extracted from the hypoosmotic surroundings by active transport across the **transporting epithelia**. The transporting epithelia for example are found in the gills of fish and in the skin of amphibians. The active transport of NaCl in gills takes place against a concentration gradient in excess of 100 folds (Fig. 5.3a).



(a) Freshwater teleost (b) Marine teleost

Fig. 5.3 : Salt and water exchange in (a) freshwater and (b) marine teleosts. Solid arrows indicate active transport, broken arrows indicate passive transport processes.

In some freshwater animals including fishes, reptiles, birds and mammals water uptake and salt loss are minimised due to the presence of the integument, which is less-permeable to water and salts. Fresh water animals other than reptiles, birds and mammals who have relatively impermeable integument do not drink excess of freshwater, reducing the need to expell excess water as done by their cohabitants having integument permeable to water and salts.

5.3.2 Marine Animals

You have learnt through Fig. 5.2 that the composition of body fluids of marine invertebrates, including the ascidians are similar to seawater. Such animals need not expend much energy in regulating the osmolarity of their body fluids. In a few vertebrates too plasma is found isosmotic to their environment. In hagfish (*Myxine*), for example, the concentrations of Ca^{2+}, Mg^{2+} and SO_4^{2-} are maintained significantly lower than they are in the seawater, whereas Na^+ and Cl^- are maintained higher in the body fluids than the seawater. Like the hagfish, the cartiligenous fishes such as sharks, rays and skates have plasma that is isosmotic to the seawater. However, in these fishes the concentration of inorganic electrolyte is maintained far lower than the seawater. The excess inorganic electrolytes such as NaCl are excreted via the kidneys and also by means of a special excretory organ, the **rectal gland**, located at the end of the alimentary canal.

The body fluids of marine teleosts are hypotonic to seawater, so these fishes lose water to the environment specially across the gill epithelium. To replace the lost volume of water they drink seawater (Fig. 5.3 b). The ingested seawater along with NaCl and KCl is absorbed across the intestinal epithelium. 70 to 80% of it enters the bloodstream. Most of the divalent ions such as Ca^{2+}, Mg^{2+} and SO_4^{2-} are expelled through the anus. The excess salt absorbed along with the water is subsequently eliminated from the blood by active transport of Na^+ and Cl^- and perhaps K^+ across the gill epithelium into the seawater. Divalent salts are also secreted by the kidneys. Gills have special type of secretory epithelium known as **chloride cells.** These cells actively secrete chloride and probably sodium also into the seawater (Fig. 5.4).

The urine of marine teleosts is isotonic to the blood, but rich in those salts (Mg^{2+}, Ca^{2+} and SO_4^{2-}) that are not secreted by the gills. The net result of the combined

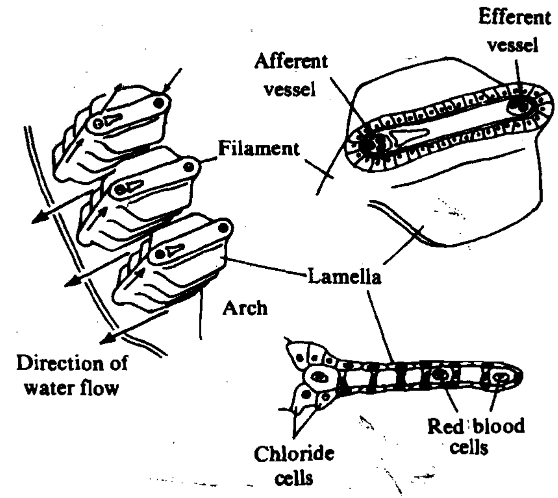


Fig. 5.4 : Chloride cells in the gills

osmotic work of gills and kidneys in the marine teleosts is a net retention of water that is hypotonic to both the ingested seawater and to the urine. Migratory fishes for example, the salmon of North-west pacific make use of this facility to maintain a more-or-less constant plasma osmolarity even though they migrate between marine and freshwater environments.

Marine reptiles for example, iguanas, estuarine sea turtles, crocodiles, sea snakes and marine birds like the marine teleosts do not produce urine which is hyperosmotic to their body fluids. Instead they have specialised organs for the secretion of salts known as **salt glands**, located in the cranium of the animals. In birds these are generally present on the bill below the eyes and in lizards they are near the nose or eyes. In the brackishwater crocodiles salt glands are found in the tongue. Although neither reptilian nor avian kidneys are capable of producing a very hypertonic urine, the salt glands of marine reptiles and birds secrete enough salt to enable them to drink salt water even though their kidneys are unable to produce urine more concentrated than seawater (Fig. 5.5).

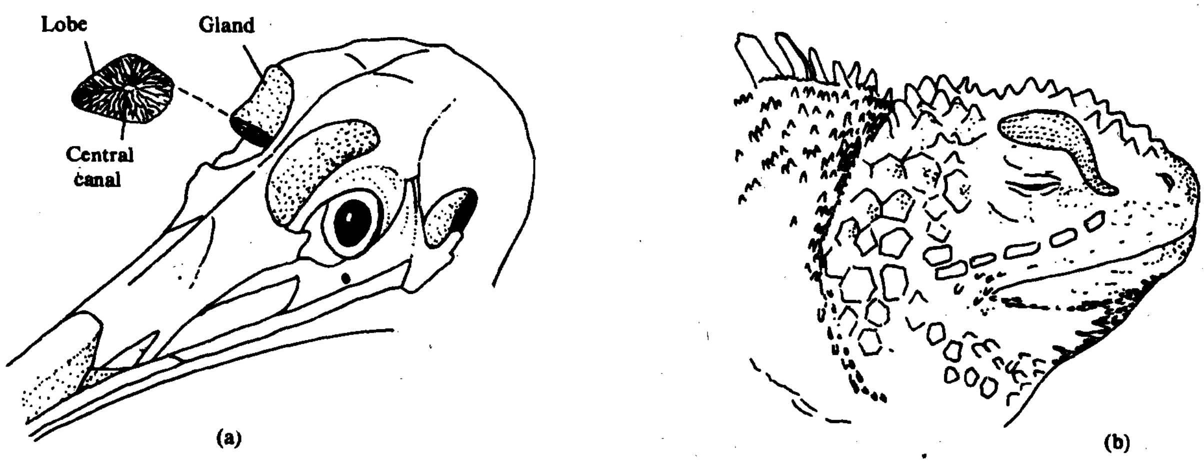


Fig. 5.5 : Salt glands in birds and reptiles

Salt glands, along with the gills of marine teleosts, compensate in these groups for the inability of the sub-mammalian kidney to produce a urine that is strongly hypertonic to their body fluids.

Marine mammals such as sea lions, whales, seals have no external salt-secreting organs. But the kidneys of these animals are capable of producing a very hypertonic urine. Marine mammals do not imbibe sea water. They only ingest the seawater that is present in their food. Another source of water for marine mammals is the metabolic water. You have learnt in Units 11 and 12 of Cell Biology (LSE-01) that metabolic water is obtained from the metabolism of food molecules, during which hydrogen atoms combine with oxygen to produce water.

Human beings, like other mammals cannot drink seawater because their kidneys can remove only up to 6 g of Na^+ from the bloodstream per litre of the urine produced. Seawater contains 12 g of Na^+ per litre. This causes accumulation of salt in the body and they cannot drink equivalent amount of water for its removal, and would lead to rapid dehydration.

SAQ 2

State whether the statements given below are true or false.

i) The animals which can tolerate a wide range of salinities are called euryhaline and those which tolerate only a narrow osmotic range are termed stenohaline.

ii) Osmotic concentration of seawater is about 1000 million osmoles per litre.

iii) Freshwater fishes produce copious urine than the marine fishes.

iv) In freshwater fishes salt is extracted from the hypoosmotic surroundings by active transport in the gills across its transporting epithelia.

v) The body fluids of marine invertebrates are hypotonic to the seawater.

vi) The chloride cells, located in the gills of marine teleost expel the excess salt by active transport.

vii) In marine mammals the excess salt is secreted by the salt glands.

5.4 OSMOREGULATION IN TERRESTRIAL ENVIRONMENT

In the earlier section of this unit you have learnt about osmoregulation in aquatic environment. In this section, we shall study how the terrestrial animals cope up with the problems of osmoregulation.

Just like the aquatic animals which are submerged in an aqueous medium, animals in a terrestrial environment can be thought of as submerged in an ocean of air. Unless the humidity of the air is high, animals having a water permeable epithelium will be subjected to dehydration very much as if they were submerged in a hypertonic medium such as seawater. In order to avoid dehydration, the epithelium should be totally impermeable to water. The evolutionary process was not found this to be a feasible solution to the problem of desiccation, since an epithelium that is impermeable to water will be dry and such a type of epithelium will have limited permeability to respiratory gases. This mechanism will not fulfil the respiratory needs of a terrestrial animal. Due to the presence of permeable respiratory epithelia, air-breathing animals lose water across it, which would result in dehydration. Various means have been evolved to minimise the water loss into the air through the respiratory epithelium and also other parts of the body. We shall now learn about them.

i) Water movement through the integument

The integument of most terrestrial animals is relatively impermeable to water and very little water is lost through the skin (Table 5.1).

Table 5.1 : Evaporative Water Loss of Animals under Desert Conditions

Species	Water loss ($mg/cm^2/h$)	Remarks
Arthropods		
Eleodes armata (beetle)	0.20	30°C; 0% r.h.
Hadrurus arizonensis (scorpion)	0.02	30°C; 0% r.h.
Locusta migratoria (locust)	0.70	30°C; 0% r.h.
Amphibian		
Cyclorana alboguttatus (frog)	4.90	25°C; 100% r.h.
Reptiles		
Gehydra varegata (gecko)	0.22	30°C; dry air
Ulta stansburiana (lizard)	0.10	30°C

Birds		
Amphispiza belli (sparrow)	1.48	30°C
Phalaenptilus nuttallii (poorwill)	0.86	35°C
Mammals		
Peromyscus eremicus (cactus mouse)	0.66	30°C
Oryx beisa (African oryx)	3.24	22°C
Homo sapiens	22.32	70 kg; nude, sitting in sun; 35°C

(r.h. stands for relative humidity)

You have seen in the above table that insects lose very little moisture through the integument. It is due to the presence of waxy cuticle which is highly impermeable to water. The wax is deposited on the surface of the exoskeleton through fine canals that penetrate the cuticle (Fig. 5.6).

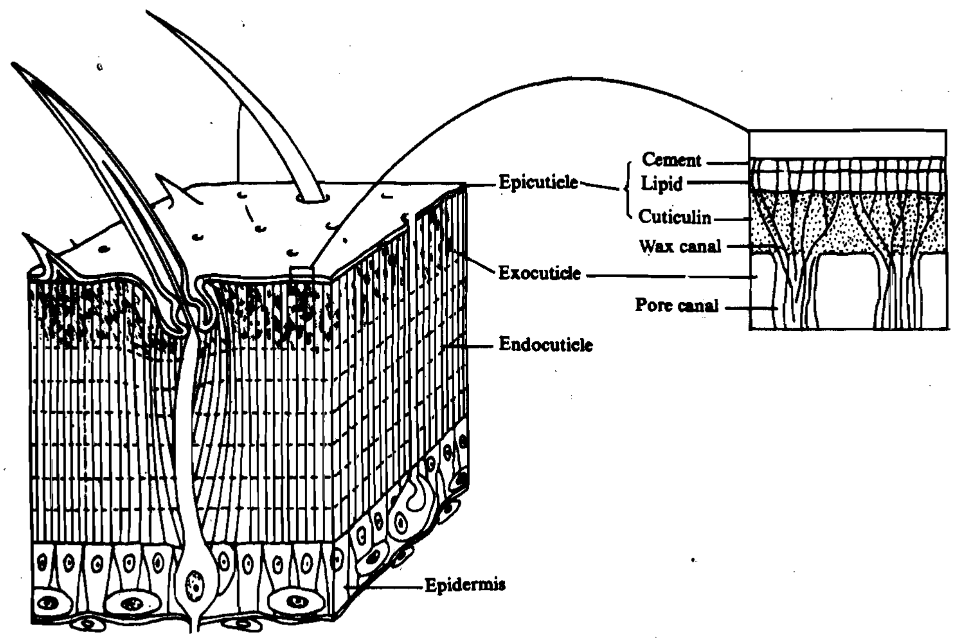


Fig. 5.6 : General features of insect integument

You must have noted in Table 5.1 that water permeability property of vertebrate integument varies widely. Reptiles, some desert amphibians, birds and many mammals have relatively impermeable skins. However, amphibians, as well as mammals that perspire, can become dehydrated at low humidity due to water loss through the integument. Animals with highly permeable skin are simply not able to tolerate very hot, dry environments. Most amphibians stay close to water and replenish their supply of water. These animals avoid desiccation by staying in cool, damp microenvironments during hot, dry times of the day. Toads which may temporarily wander away from a body of water or may have to wait for rains have oversized urinary bladders in which they store water. When necessity arises water will move osmotically from the lumen of the bladder into the interstitial fluid and the blood. The epithelium of the bladder like the amphibian skin is capable of actively transporting Na^+ and Cl^- from the bladder lumen into the body to compensate the salts lost during times of excessive hydration. Many anurans have specialised regions of the skin on the abdomen and thighs called **seat patches.** These regions when immersed can take up water at a rate of three times the body weight per day.

ii) Water loss during air breathing

You have learnt that water is lost through the respiratory surface. In the terrestrial vertebrates the evaporative loss is reduced, because the respiratory surface in them (the lungs) is internal to the body cavity. Even within the lungs ventilation of the respiratory epithelium by unsaturated air will cause evaporation of the moisture wetting the epithelial surface. In birds and mammals such evaporative loss is enhanced because of the difference between the body temperature and ambient temperature. Warmer air can hold more moisture when saturated than cool air. Since the expired air is more warmer than the inspired air, water is lost during expiration.

In a number of vertebrates the respiratory loss of water is minimised through a mechanism known as **temporal countercurrent system**. During inspiration cool air entering the lungs via nasal passage gets warmed by the heat of the nasal passage and absorbs moisture from the respiratory epithelium of the lungs. During expiration, the same air loses most of the heat it gained earlier as it warms the cool nasal passage on its way out. As the expired air gives up some of its heat to the tissue of the nasal passage, most of the moisture acquired from the respiratory epithelium condenses on the cool nasal epithelium. With the next inhalation, this condensed moisture again contributes to the humidification of the inspired air, and the cycle is repeated (Fig. 5.7).

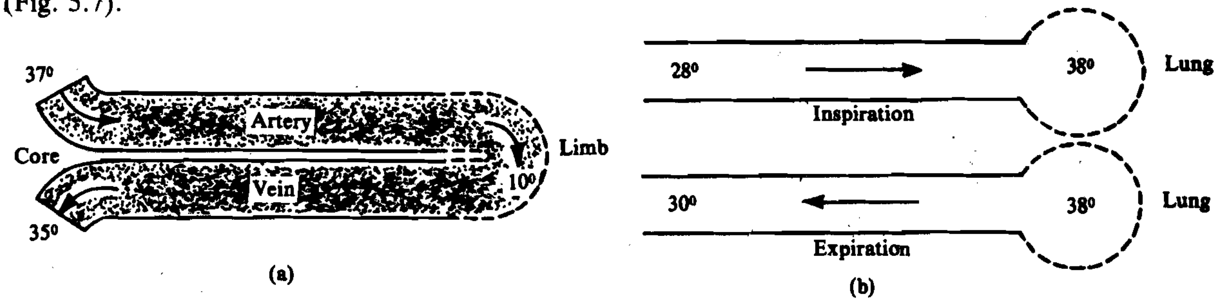


Fig. 5.7 : Temporal countercurrent system

You have learnt that cuticle is highly impermeable and thus in insects there is no water loss through this route. The major route of water loss in terrestrial insects is via the **tracheal system**. You have learnt in Unit 2 that tracheal system consists of air-filled **tracheoles** that supply oxygen to the tissue. The entrance of the tracheoles are known as **spiracles**. The spiracles have muscles and function like valves of the tracheoles. The spiracles remain closed to prevent the water loss. They open periodically for a very short while for leting in oxygen for respiration and close. The leting out of carbon dioxide does not follow the leting in of oxygen. Carbon dioxide is accumulated and expelled out at one burst. Water may be lost only at this moment. The periodic opening and closing of the spiracles is done by the **spiracular muscles.** Certain terrestrial arthropods have the ability to extract water vapour directly from air.

iii) **Water loss during excretion**

In terrestrial animals body water is also lost during excretion of nitrogenous wastes. A number of physiological adaptations have taken place to minimise the loss of water associated with this phenomena. You have learnt in the previous Unit that among terrestrial invertebrates, insects are highly effective in conserving water. In terrestrial vertebrates, kidney is the chief organ of osmoregulation and excretion. The loop of Henle is the specialised part of the nephron which produces hyperosmotic urine. Amphibians and reptiles which are unable to produce a hyperosmotic urine, as an adaptive consequence, cease urine production entirely during the period of osmotic stress.

Kangroo Rat : A Classical Example of Adaptations for Desert Life

Kangroo rat *Dipodomys merriami*, a native of South-West America is a classical example of how small mammals survive in desert. It exhibits all the osmoregulatory adaptations for desert life. It survives in arid conditions without ingesting any free water by the following adaptations:

i) It avoids much of the daytime heat through nocturnal life-style, keeping cool during daylight hours by remaining in a burrow. This conserves water loss through evaporative cooling.

ii) It conserves respiratory moisture by an efficient nasal countercurrent mechanism.

iii) It secretes highly concentrated urine.

iv) The rectum absorbs water from the faeces resulting in dry faecal pellets.

Kangroo rat is not known to drink water. It gets only a trace of free water from the dry seeds it eats. Primarily it depends upon the metabolic water for its survival.

	Blood concentration relative to environment	Urine concentration relative to blood
Marine elasmobranch	Isotonic	Isotonic
Marine teleost	Hypotonic	Isotonic
Freshwater teleost	Hypertonic	Strongly hypotonic
Amphibian	Hypertonic	Strongly hypotonic
Marine reptile	Hypotonic	Isotonic
Desert mammal	–	Strongly hypertonic
Marine mammal	Hypotonic	Strongly hypertonic
Marine bird	–	Weakly hypertonic
Terrestrial bird	–	Weakly hypertonic

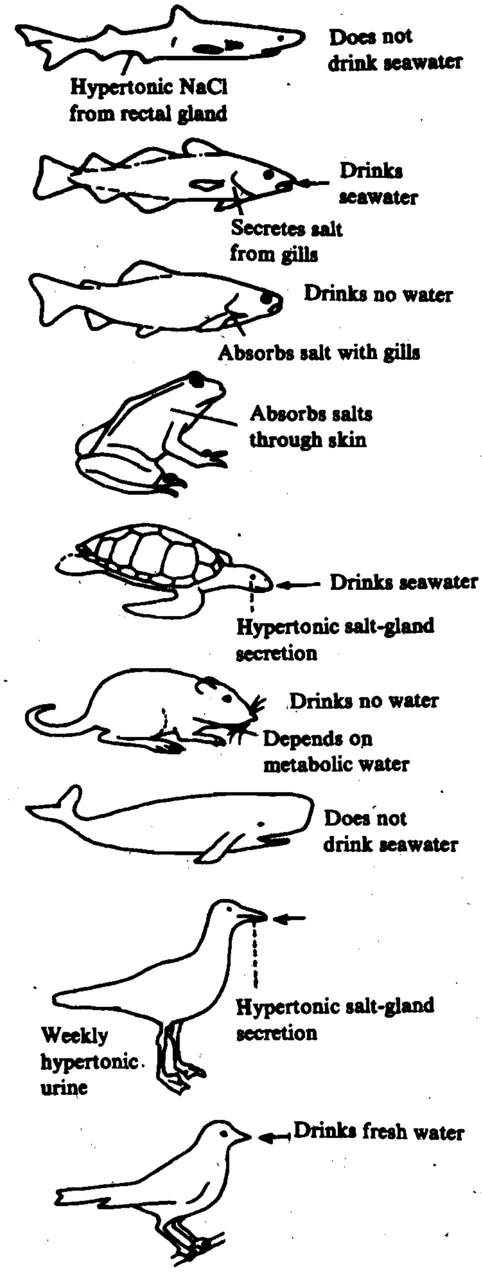


Fig. 5.8 : Osmoregulatory mechanisms in various groups of animals

SAQ 3

What is the role of the following in osmoregulation. Explain in just two or three lines.

i) The cuticle of insect: ....

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ii) Temporal countercurrent system: ....

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iii) Spiracular muscles: ....

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5.5 HORMONES IN WATER AND ELECTROLYTE REGULATION

In the earlier sections of this unit you have learnt how animals regulate the salt and water content of their body. Hormones play a significant role in osmotic and ionic regulation. In this section we shall learn about the mechanism of hormonal control of osmoregulation in both invertebrates and vertebrates.

5.5.1 Invertebrates

Regulation of water and ions in invertebrates is done by neuroendocrine mechanism. It operates at the level of Malpighian tubules and the rectum in insects. A neurosecretory substance termed, **diuretic hormone** inhibits water resorption from the rectum and also stimulates water uptake by the Malpighian tubules. In some insects an **antidiuretic hormone** lowers the rate of water output by the tubules and increases water absorption by the rectum. Another neurosecretory hormone termed **Chloride transport stimulating hormone** is known to regulate electrolyte balance in insects. It causes a two-to-three fold increase in cyclic AMP levels in the rectal tissues, which in turn activates the chloride pump of the rectal cells, actively transporting chloride ions into the haemocoel.

5.5.2 Vertebrates

In terrestrial vertebrates hormones such as prolactin, antidiuretic hormone and adrenocortical steroids are known to control water and salt balance. Hormones of urohypophysis and corpuscles of Stannius are also involved in some of the aquatic forms. Parathyroid glands and ultimobranchial bodies maintain the levels of calcium and phosphorus. Catacholamines and angiotensin also participate in this regulatory system. The hormones operate jointly or individually on all the target organs concerned with water/ion balance. Let us now learn about them separately.

i) **Prolactin**

Prolactin is secreted by the pituitary gland. In fishes, some amphibians, birds and mammals it acts on the organs concerned with water and electrolyte balance. In migratory fishes prolactin secretion promotes the physiological changes. It inhibits loss of salts and stimulates production of copius urine low in ionic content.

ii) **Antidiuretic Hormone (ADH)**

It is also called vasopressin. ADH aids in retention of water. It is synthesised in the neurosecretory cells of the hypothalamus and stored in the neurohypophysis. ADH increases the permeability of the collecting ducts, possibly by the enlargement of cell pores. This results in the movement of water out of the tubules and increase in the concentration of salts in the surrounding fluids and blood capillaries. The effect of ADH on the urine passing out of the kidney is to make it more hypertonic. The urine enters the collecting duct as hypertonic to blood and leaves it as hypotonic. The role of ADH in the retention of water is supported by adrenocortical hormones. Recently it has been discovered that another set of hormones called **prostaglandins**, produced in the kidney function antagonistic to ADH.

iii) **Adrenocortical Steroids**

The adrenal cortex secretes two types of steroid hormones: i) **glucocorticoids**, concerned with regulation of glucose and ii) **Mineralocorticoids**, concerned with salt regulation. This distinction between glucocorticoids and mineralocorticoids is found in mammals where as nonmammalian vertebrates do not maintain such distinction. In general the action of corticosteroids is adaptive. Salt output or retention is altered in accordance with environmental demands.

In mammals **aldosterone**, a mineralocorticoid is concerned with electrolyte balance. It is produced in response to **adrenocorticotropic hormone** (ACTH) secreted by the pituittary. ACTH itself is released in response to a **corticotropin releasing factor** (CRF) from the hypothalamus. **Glomerulotrophic hormone** from the pineal gland is also known to stimulate aldosterone secretion. In nonmammalian vertebrates apart from aldosterone, another mineralocorticoid, **cortisol** is known to promote NaCl absorption. The mineralocorticoids increase the tubular absorption of sodium and promote the renal excretion of potassium.

iv) **Angiotensin**

Besides the stimulation of the adrenal cortex by ACTH and glomerulotrophic hormone to release aldosterone, kidneys themselves monitor the levels of sodium by **renin-angiotensin** system. When the sodium level falls, juxtaglomerular cells of the glomerulus release an enzyme renin into the blood. Renin acts on a precursor plasma protein angiotensin, hydrolysing it to the active hormone angiotensin. Angiotensin acts on the adrenal cortex and promotes aldosterone secretion. Aldosterone in turn promotes uptake of sodium by the renal tubules. Aldosterone also acts on the kidney arterioles ensuring a regular blood flow in the organ. In Fig. 5.9 you can see the complex interactions of all the hormones in the maintenance of water and salt balance.

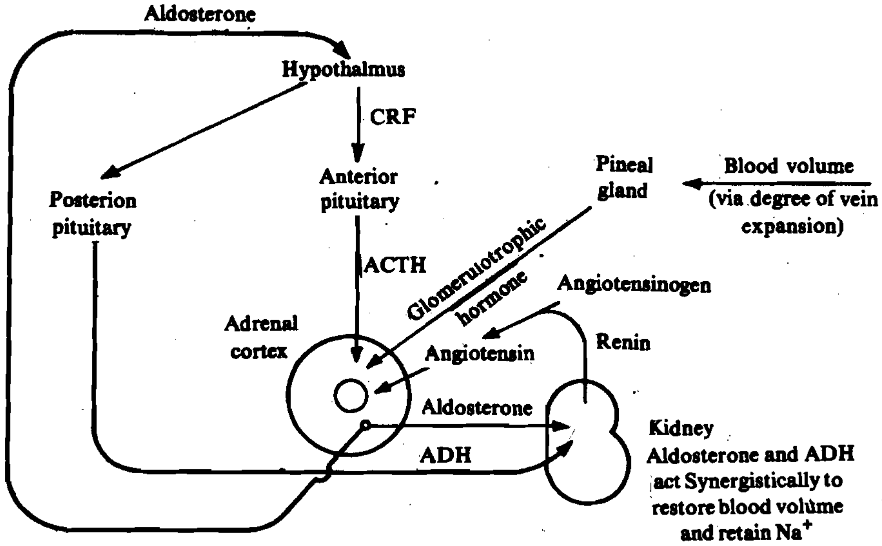

Fig. 5.9 : The hormonal mechanism involved in osmoregulation

SAQ 4

Explain briefly role of the following hormones in osmoionic regulation.

i) Antidiuretic hormone : ....

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ii) Prolactin : ....

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iii) Aldosterone : ....

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5.6 SUMMARY

You have learnt in this unit that:

- Osmoregulation is a process for the maintenance of osmotic concentration of the body fluids. Animals have adapted various physiological and behavioural mechanisms to cope up with the rigors of the osmotic environments.
- Since the body fluids of freshwater animals are hyperosmotic to their aqueous surroundings water moves into their body due to osmotic gradient and body salts leak out of their body. They prevent net gain of water by producing copius urine. The lost salts are replaced partly from the food they eat and much is extracted from the hypoosmotic surrounding by active transport.
- The body fluids of some marine animals are isosmotic to the seawater. Therefore, they need not expend much energy for regulating the osmolarity of the body fluids. Marine animals specially the teleosts, whose body fluids are hypoosmotic to the seawater, tend to lose water from their body. Therefore, they drink seawater to replace the lost water. The excess salts that enter the body along with the seawater is expelled through the anus, kidneys and also across the gills by active transport. Marine reptiles and birds have salt glands for the secretion of salts that entered the body through the seawater they drink.
- In the terrestrial environment animals face the problem of loss of body water due to the arid condition. Salts are also lost along with the water. Animals inhabiting arid environment avoid loss of water by adopting noctural habits and by staying in cool, damp microenvironments during the hot, dry times of the day. Physiologically they evolved mechanisms such as temporal countercurrent system and production of highly concentrated urine to avoid water loss during respiration and excretion respectively.
- Hormones such as diuretic hormone, antidiuretic hormone, chloride transport stimulating hormone play a vital role in the regulation of water and electrolyte balance in invertebrates. Prolactin, antidiuretic hormone, mineralocorticoids, angiotensin, prostaglandins are the hormones involved in the osmoionic regulation in vertebrates.

5.7 TERMINAL QUESTIONS

1) Explain briefly how do migratory fishes cope up with the problem of osmoregulation.

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2) Explain briefly the adaptations found in kangroo rats for the arid conditions.

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5.8 ANSWERS

Self-assessment Questions

1) a) iv, b) ii, c) i, d) iii

2) i) True
   ii) True
   iii) True
   iv) True
   v) False
   vi) True
   vii) False

3) i) The cuticle of insects is highly impermeable to water. It avoids loss of moisture from the haemolymph and prevents dehydration in the insects.

   ii) It is a mechanism by which animals and birds of arid desert regions minimise the respiratory loss of water. The cool air that enters the nasal passage gets heated by the heat of the nasal passage and absorbs water from the respiratory epithelium. During expiration, the same air warms the cool nasal passage and the water content in it gets condensed at the nasal passage thereby preventing the loss of water.

   iii) In terrestrial insects spiracular muscles help in reducing loss of water from body fluids. The major route of water loss in terrestrial insects is through tracheal system. Therefore, the spiracles are closed to check the loss of water. They are open periodically for a very short time for the intake of oxygen. The carbon dioxide is accumulated and expelled out in one burst. The periodic opening and closing of spiracles is done by the spiracular muscles.

4) i) Refer to section 5.5
   ii) Refer to section 5.5
   iii) Refer to section 5.5

Terminal Questions

1) Refer to sub-section 5.3.2
2) Refer to section 5.4

GLOSSARY

Aestivation : 'summer sleep'. During dry and hot seasons, animals remain in cool and shady place in a resting state to avoid increase in body temperature.

Aorta : largest of the arteries arising from heart.

Atherosclerosis : a common type of thickening and hardening of medium and large arteries, in which raised areas or plaques within the tunica intina are formed from smooth muscle cells, cholesterol and other lipids. These plaques block arteries.

Atrium : (L. atriun : enterance hall) either of the two chambers of heart that receive venous blood.

Bile : alkaline fluid produced by the liver and stored in the gall bladder, that contains bile salts, bile pigments, cholesterol and other molecules. The bile is secreted into the small intestine and is essential for digestion of fat.

Bile salt : bile acid such as cholic acid, confugated with glycine or taurine promoting emulsification and solubilisation of fats in intestine.

Choanocytes : flagellated cells that line the body canal in sponges. Their beating causes water to currents throughout the body of the sponge. This brings food and oxygen to the cells and takes away carbon dioxide and other wastes.

Cretinism : a condition caused by insufficient thyroid secretion before birth or early childhood. Leads to stunted growth and inadequate mental development.

Chyme : the thick semisolid substance that results from actions of stomach on food.

Deamination : removal of NH_2 group from a compound.

Endocytosis : the cellular uptake of particles that are too large to cross cellular membranes. This occurs by invagination of cell membrane until a membrane enclosed vesicle is pinched off within the cells.

Megaloblastic anaemia : anaemia characterised by formation of large immature red blood cells that are deficient carriers of oxygen. Caused by deficiency of folic acid and hence faulty synthesis of haem.

Menke's syndrome : rare genetically determined copper absorption defect. Characterised by sparse brittle hair arterial and cerebral degeneration. Formerly children did not survive for more than 3 years. Now there is hope with copper supplements.

Miscelles : particles formed by an aggregate of molecules.

Myxedema : a type of oedema associated with hypothyroidism; it is characterised by accumulation of mucoproteins in tissue fluid.

Parenteral nutrition : nutrition given by injection through subcutaneous, intramuscular intravenous or any other route except through alimentary canal.

Pellegra : niacin deficiency disease characterised by skin lesions that are aggravated by exposure to sunlight and by gastrointestinal, mucosal, neurological and mental symptoms. The four Ds associated with the disease are dermatitis, diarrohea, dementia and death.

Pernicious anaemia : chronic anaemia in which red blood cells are larger and paler than normal. Caused by absence of intrensic factor present in gastric juice required for absorption of B_{12}.

FURTHER READING

General and Comparative Physiology. William S. Hoar (Third Edition) 1991. Prentice Hall of India Private Ltd., New Delhi.

Textbook of Biochemistry. K. Ranganathan Rao (Third Edition) 1991. Prentice Hall of India Private Ltd., New Delhi.

Dear Student,

While studying these units you may have found certain portions of the text difficult to comprehend. We wish to know your difficulties and suggestions in order to improve the course. Therefore, we request you to fill and send us the following questionnaire which pertains to this block.

QUESTIONNAIRE

LSE-05
Block-1

Enrolment No. | | | | | | | | | | |

1) How many hours did you need for studying the units?

Unit Number					
No. of hours					

2) How many hours (approximately) did you take to do the assignments pertaining to this block?

Assignment Number		
No. of hours		

3) In the following table we have listed 4 kinds of difficulties that we thought you might have come across. Kindly tick (√) the type of difficulty and give the relevant page number in the appropriate columns.

Page Number	Types of difficulties			
	Presentation is not clear	Language is difficult	Diagram is not clear	Terms are not explained

4) It is possible that you could not attempt some SAQs and TQs.
In the following table are listed the possible difficulties. Kindly tick (√) the type of difficulty and the relevant unit and question numbers in the appropriate columns.

Unit No.	SAQ No.	TQ No.	Type of difficulty			
			Not clearly posed	Cannot answer on basis of information given	Answer given (at the end of Unit) not clear	Answer given is not sufficient

5) Were all the difficult terms included in the glossary. If not, please list in the space given below.

6) Any Other Suggestion(s)

To,

The Course Coordinator (LSE-05; Physiology; Blocks 1 & 2)
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