Osmoregulation in Fishes

Osmoregulation is a type of homeostasis which controls both the volume of water and the concentration of electrolytes. It is the active regulation of the osmotic pressure of an organism's body fluids, detected by osmoreceptors. Organisms in aquatic and terrestrial environments must maintain the right concentration of solutes and amount of water in their body fluids. The nature of osmoregulatory problem is quite different in various groups of fishes in different environments. There is always a difference between the salinity of a fish's environment and the inside of its body, whether the fish is fresh water or marine. Regardless of the salinity of their external environment, fish use osmoregulation to fight the process of diffusion and osmosis and maintain the internal balance of salt and water essential to their efficiency and survival. Kidneys do play a role in osmoregulation but overall extra-renal mechanisms are equally more important sites for maintaining osmotic homeostasis. Extra-renal sites include the gill tissue, skin, the alimentary tract, the rectal gland and the urinary bladder.

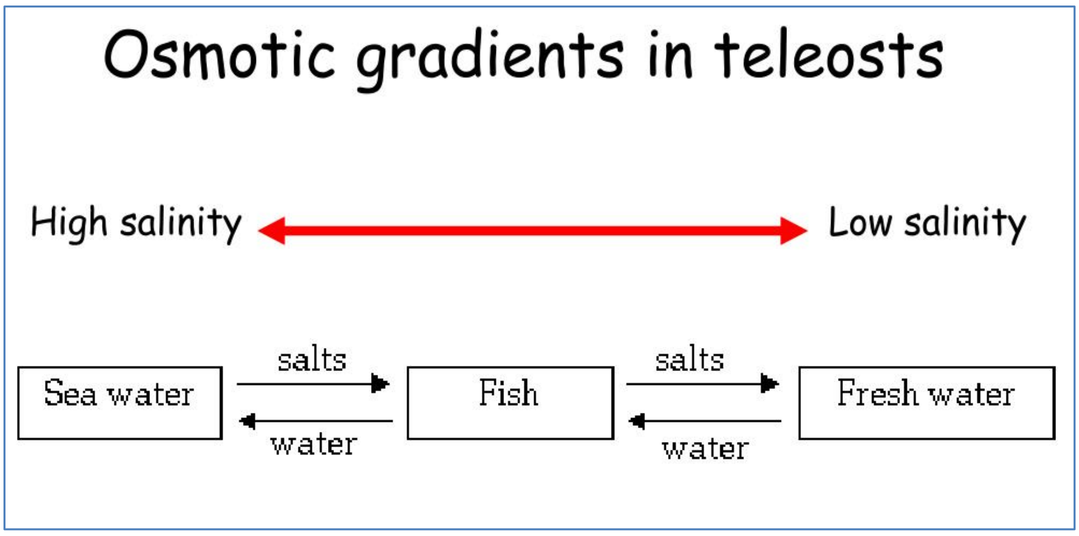
Stenohaline and Euryhaline Fishes:

- ✓ **Stenohaline (steno=narrow, haline=salt):** Most of the species live either in fresh water or marine water and can survive only small changes in salinity. These fishes have a limited salinity tolerance and are called stenohaline.

  e.g., Goldfish

- ✓ **Euryhaline (eury=wide, haline=salt):** Some species can tolerate wide salinity changes and inhabit both fresh water and sea water. They are called euryhaline.

  e.g., Salmon



According to habitat, fishes can be distinguished as (i) Marine, and (ii) Fresh water.

(i) The marine fishes fall into two distinct groups:

a) Those whose osmotic concentration is the same as or slightly above sea water, e.g., hagfish, elasmobranchs, Latimeria etc. This group has no major problem of water balance, because it's inside and outside concentrations are equal, there is no osmotic water flow.

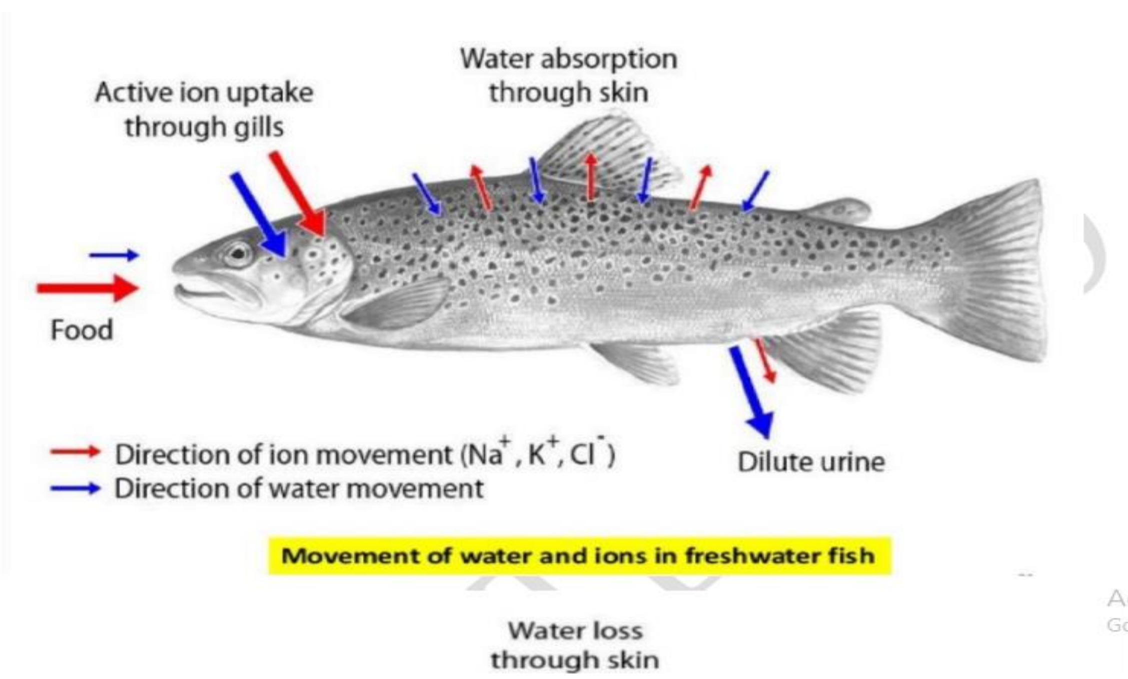
b) Those whose osmotic concentrations are about one third of that of sea water, e.g., lampreys, teleosts, etc. These are hyposmotic animals. They live in constant danger of losing water to the osmotically more concentrated medium.

(ii) The fresh water fishes, on the other hand, have internal concentrations greater than that of their external medium. Thus, they are hyperosmotic to the medium. Therefore, the osmotic problems and the means to solve them differ drastically among fishes of different habitats.

Osmoregulation in Freshwater Fishes

Water Balance:

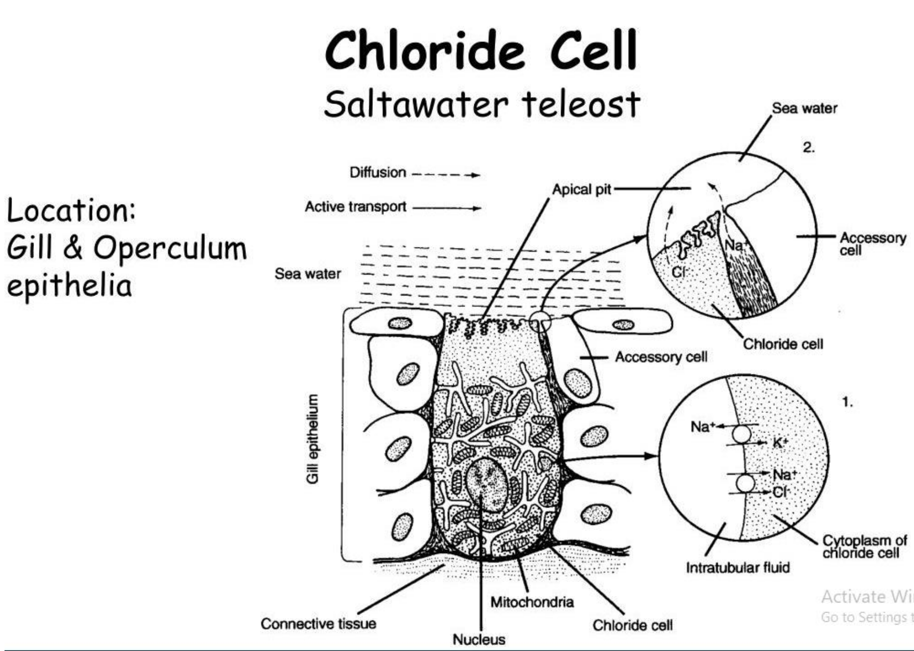
- The osmotic pressure of body fluids depends on mineral and organic compound content. The osmotic pressure of body fluids in fresh water fishes is always higher than that of the surrounding water (hyperosmotic) and the later diffuses into the body through oral membranes, gills and even intestinal surfaces.
- In certain species of fish water may enter through the skin also. To counter the continuous inflow of water through gills, a large amount of hypotonic urine is produced by the freshwater fishes in general.
- The freshwater fishes possess more glomeruli (even more than 10000 in number in the kidney). The kidney is also larger in size and is well vascularized. Water excretion is the main function of the kidneys in these fishes but small quantity of nitrogenous compounds, containing creatine, creatinine, amino acids, ammonia and urea are also present in the urine.
- A freshwater teleost does not drink water as large amount of water enters the body by osmosis and is more than necessary for the fish.



Movement of water and ions in freshwater fish

Salt Balance:

- As the osmotic concentration of the body fluids in freshwater fishes is always higher than the surrounding water, some salts are lost into the water by the process of diffusion which takes place mainly through surface tissues like buccal epithelium, gills and skin. Some salts may be lost in the faeces and urine also.
- The quantity of salts lost per day varies in different species of fishes. In salmon loss of salts may be upto 17% of the body chlorides while in gold fish, *Carassius auratus*, it is only 5%. In the proximal and distal part of the renal tubule active reabsorption takes place and as such the loss of salt is minimum in freshwater fishes.
- Salts are replaced by two ways: firstly through food and secondly by the absorption of salt ions from the surrounding water. Absorption of salt ions from the water takes place mainly through gills and oral membrane. The ions of Sodium (Na+), Calcium (Ca++), Lithium (Li+), Cobalt (Co++), Strontium (Sr++), Bromine (Br-), Chlorine (Cl-), Acid phosphate and Sulphate are absorbed by chloride cells located at the base of the gill lamellae. The entire mechanism of salt balance is under endocrine control.

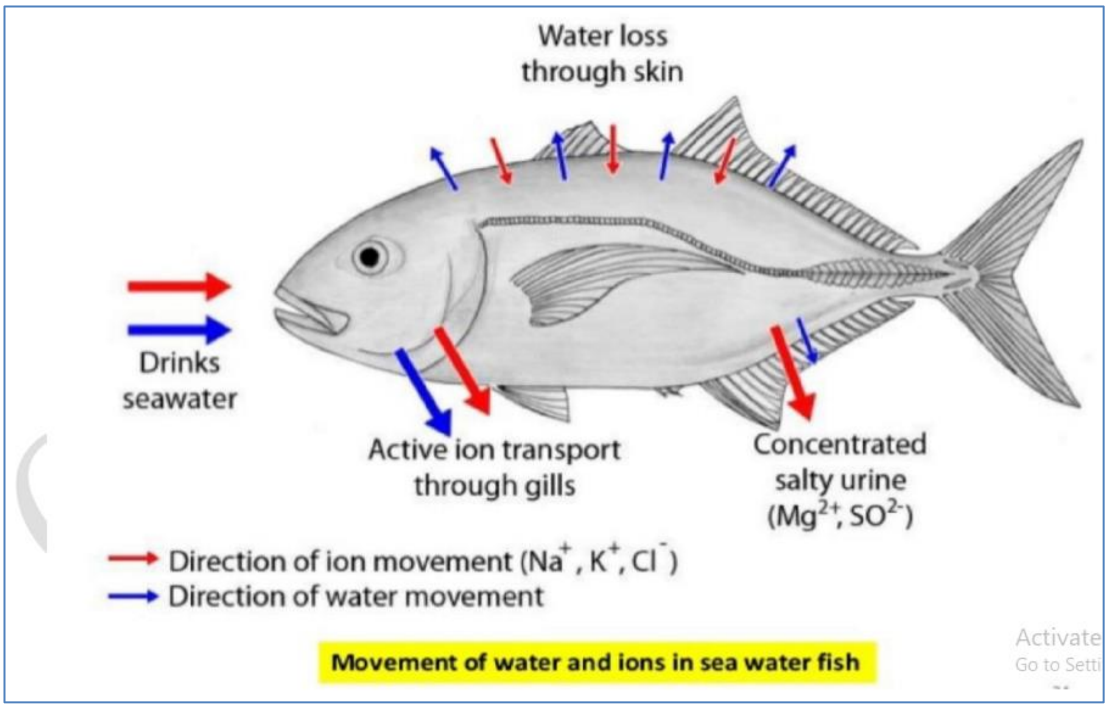


Osmoregulation in Marine Fishes:

- In contrast to freshwater environment marine fishes live in the sea where salt concentration is higher than that of the body fluids of the fish. Naturally, water is lost through the semipermeable membrane by the process of diffusion.
- Fishes have to drink sea water in order to make up the loss and thus salt content of the body increases. Increase of salt in the blood is then eliminated.
- There is marked reduction in the urine output, for conservation of water and the uriniferous tubules are modified for this purpose. In marine teleosts, there is considerable reduction in the size of the kidney tubules. The distal segment of the convoluted tubule is absent in most of the cases. The neck segment also is either absent or constricted in certain species.
- Nitrogenous waste products are excreted mainly through the gills in the form of ammonia. Traces of urea, ammonia and trimethylamine are present in the urine.
- Water is lost through the gills and other tissues because of lower concentration of blood in comparison to the sea water. The marine teleosts, therefore drink water. Water is reabsorbed in the kidney tubules.
- There is physiological control over excess of urine formation and as such large amount of water does not pass out through the glomeruli.
- In many teleosts the glomeruli become degenerate. Even aglomerular kidney may be present in some marine teleosts.
- Salt secreting cells are present in the gills and oral membrane to help the process of excretion because large amount of salt accumulates in the body tissues because the fishes frequently drink sea water to avoid dehydration.
- The Hagfishes are isosmotic to their surroundings, so that there is practically no movement of water across the semipermeable membranes. The Hagfishes

do not drink sea water and their requirement of water for urine formation is met from the blood of host.

- The slime produced from their skin is high in Mg++, Ca++ and K+ content. Their surplus salt is removed through the gills. Monovalent ions reach the blood stream from the intestine and leave through the gills. But, the divalent ions remain in the intestine where they combine with oxides and hydroxides. Thus the insoluble compounds formed in the alkaline medium pass out along with the faces.
- In Elasmobranchs there is no danger of dehydration because they maintain their blood at a higher concentration in comparison to surrounding water. Urine is formed as a result of filtration process in the glomerulus. The urea present in the urine is reabsorbed by special segments of the kidney tubule.
- Moreover, the gills in elasmobranchs are impermeable to urea and as such, the urea is retained in the blood in large quantities. Thus osmotic concentration of the blood is raised and it becomes higher than that of the sea water. The osmotic balance in these fishes is maintained by urea cycle. Salts are excreted in the feces and in the urine. Some salts are reabsorbed in the kidney tubules. Salts are never excreted through gills as there are no special salt excreting cells. They achieve salt balance by secreting a fluid containing higher concentration of sodium and chloride ions from the rectal gland. There is high concentration of urea in the blood of elasmobranchs living in fresh water.



Endocrine Control of Osmoregulation:

The endocrine glands are responsible for water-salt balance including urine flow in fishes. The filtering rate of renal corpuscle is affected by hormones. Diffusion and absorption of the gills have been found to be greatly influenced by hormones. Cortisol is a sea water adapting hormone in fish and prolactin as the fresh water adapting hormone. In salmon, growth hormone acts in cooperation with cortisol to increase sea water tolerance. Cortisol under some conditions may promote ion uptake and interact with prolactin during acclimation to fresh water. In some species thyroid hormone support the action of growth hormone and cortisol in promoting seawater acclimation. In *Anguilla*, adrenaline has been shown to have strong vasodilator effect on the gill vessels. It reduces or completely stops chloride secretion. In salmon, hypothalamus and gonads have been implicated in the process of mineral balance. Thyroid gland and suprarenal bodies secrete adrenocortical hormones which control osmoregulation in fishes.