Osmoregulation in Fish

Fish live their lives completely surrounded by water on all sides. It surrounds them externally in their habitat and also comprises much of their body mass. Fish must therefore strike some sort of balance between these two separate, and very different, water environments which determine so much about their health. This balance is met through the processes of osmosis and osmoregulation. To explain osmosis, we'll first discuss the concepts of diffusion and equilibrium. Diffusion is simply the tendency of molecules to passively move from an area where they are more highly concentrated to an area where they are at a lower concentration - as a result of random movement..

Osmosis is a concept similar to diffusion which involves the passive movement of water through a membrane which is permeable to the water, but not to the solutes dissolved in the water. With osmosis, the water moves from an area of lower solute concentration to an area of higher solute concentration. While this may initially seem to be the opposite of diffusion, one must consider that the water is still moving from where the water is most abundant to where it is least abundant.

The biological importance of hypertonic, hypotonic, and isotonic solutions and their effects on living organisms can be observed by subjecting a single cell to each of them, when the cell has no means of adapting to each new environment. A cell placed into a hypotonic solution will have water rush inside of it (where solutes are more concentrated) and cause the cell to burst. A cell placed into a hypertonic solution will experience dehydration as water leaves the cell for the surrounding environment. A cell placed into an isotonic solution will experience water entering the cell at the same rate at which it leaves, and so will be at equilibrium and appear normal.

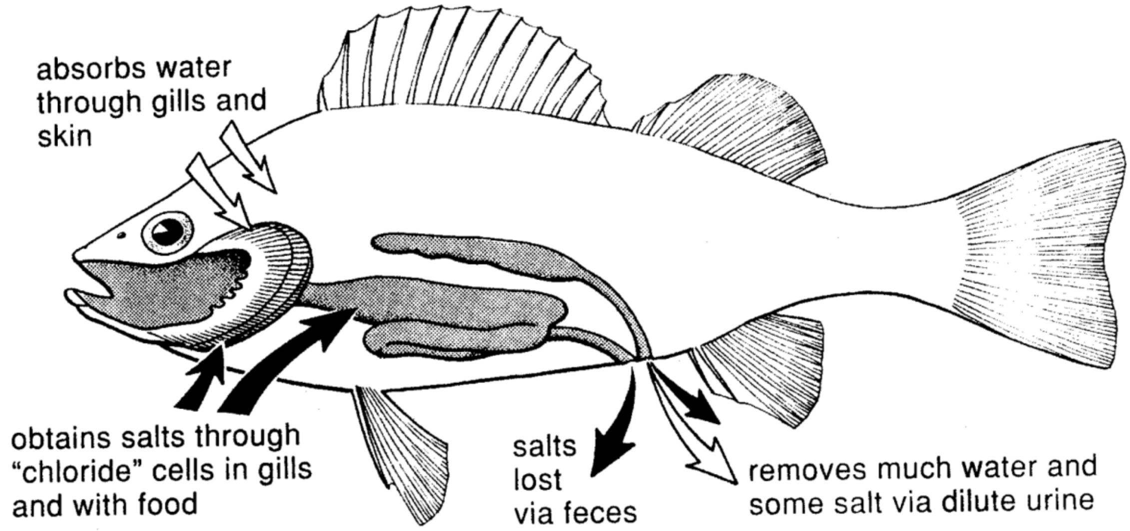
Fish do not always find themselves in isotonic environments. Thus, their body cells must have a means by which to adapt to changing salt concentrations in their bodies and environments. Osmoregulation controls this balance of water/salt concentrations..

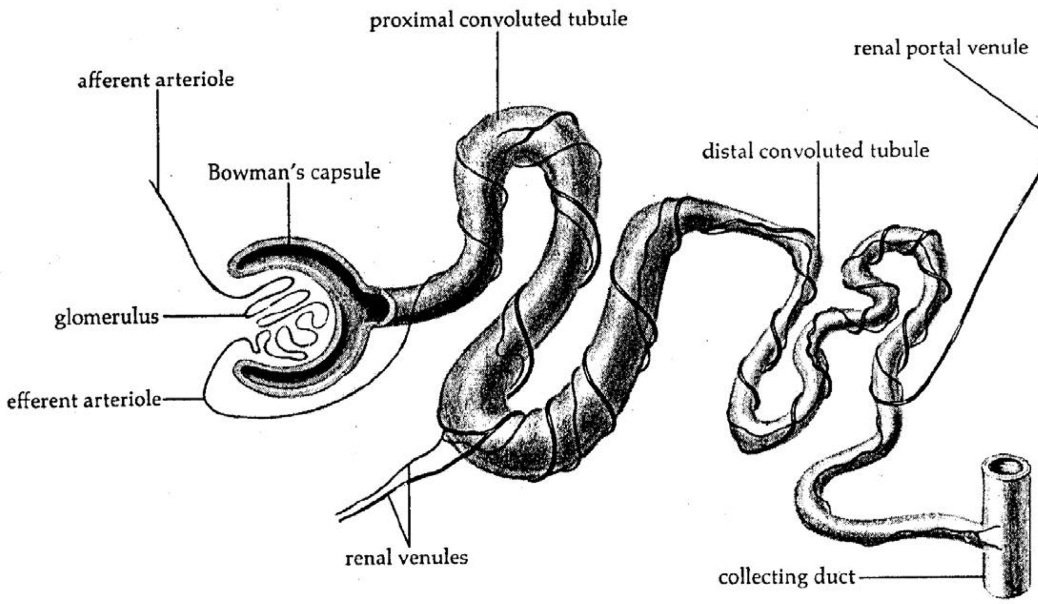
Hagfish

The hagfish are all strictly marine and are stenohaline (able to tolerate only a narrow range of salinities). Thus the hagfishes have a total salt concentration in their body fluids which is very similar to that of sea water, the only vertebrate with this characteristic. They can be described as osmoconformers rather than osmoregulators.

Fresh water teleost

As their internal environment is more concentrated than their environment (hyperosmotic to the surrounding medium) , they are continually gaining water by diffusion through oral membrane and gills. The excess water is continually excreted by well-developed kidney as a large volume of dilute urine. The control of diuretic (urine producing) processes is influenced by blood pressure changes induced by pituitary hormones (e.g. arginine vasotocin). The kidneys of freshwater teleosts are very large in relation to their body size and contain a large number of glomeruli. The glomeruli are also large in size to permit formation of large amount of glomerular ultrafilterate and later to the formation of a copious amount of urine. Due to copious secretion of urine, many freshwater teleosts have developed an urinary bladder for storage.

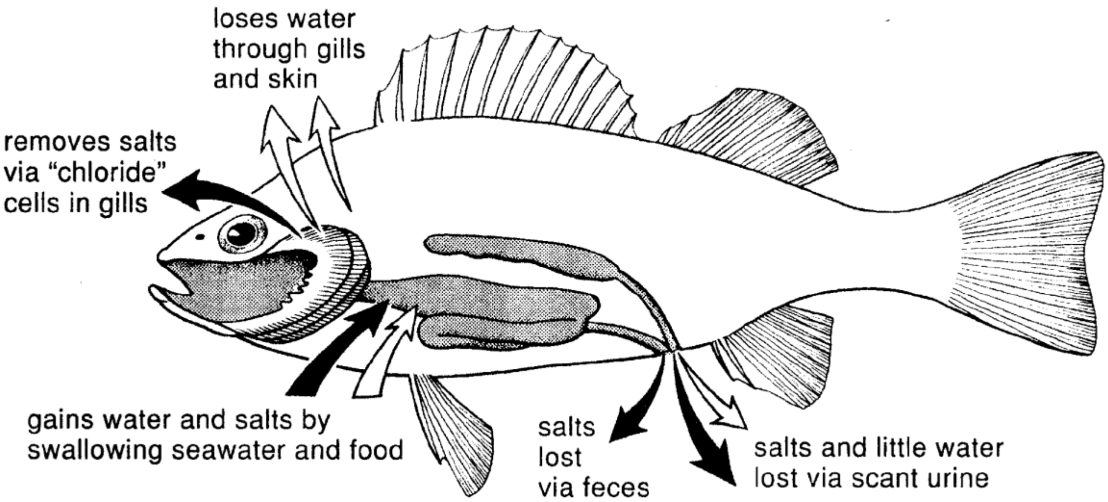




Although the urine contains little salts, the copious flow causes a significant amount of salts to be lost. Salts are also lost by diffusion from the gill tissues. These losses are balanced by salt intake in food and by active absorption through the gills. Special cells in gill lamellae contain sodium and chloride pumps. These pumps are special enzymes that use energy to move the ions up their concentration gradient to maintain their higher concentration in the body.

As the fluid passes down the kidney tubule, substances are reabsorbed at specific locations. Glucose is reabsorbed in the proximal tubule, and salts are reabsorbed in the distal tubule, the walls of which are impermeable to water in many fishes. The urinary bladder appears to function in osmoregulation in teleosts. Its walls are impermeable to water and it is the site of ion reabsorption. Damage to the kidneys through bacterial infection or other means is often deadly as these organs extract the large amounts of water which continually diffuse into the fish's body. Fish with ascites or bloat are often suffering from kidney damage.

Marine teleosts



The salt concentrations of the internal environment of these fishes is approximately 1/3 that of their environment (they are hyposmotic to surrounding water), and so they are in danger of losing water from their body. Some species have been shown to lose from 30 to 60% of their water intake by osmosis. To reduce the loss of water, the skin of marine teleosts is impermeable to water, as well as to the salts. The number and size of glomeruli in marine teleosts is either much reduced or completely lost. Also a water impermeable distal convoluted tubule is lacking, in order to conserve the water. Further, the glomerular filtration rate is much reduced, and the volume of urine formed is less to check the loss of water. Consequently the urine of marine teleosts become much concentrated than that of the freshwater teleosts.

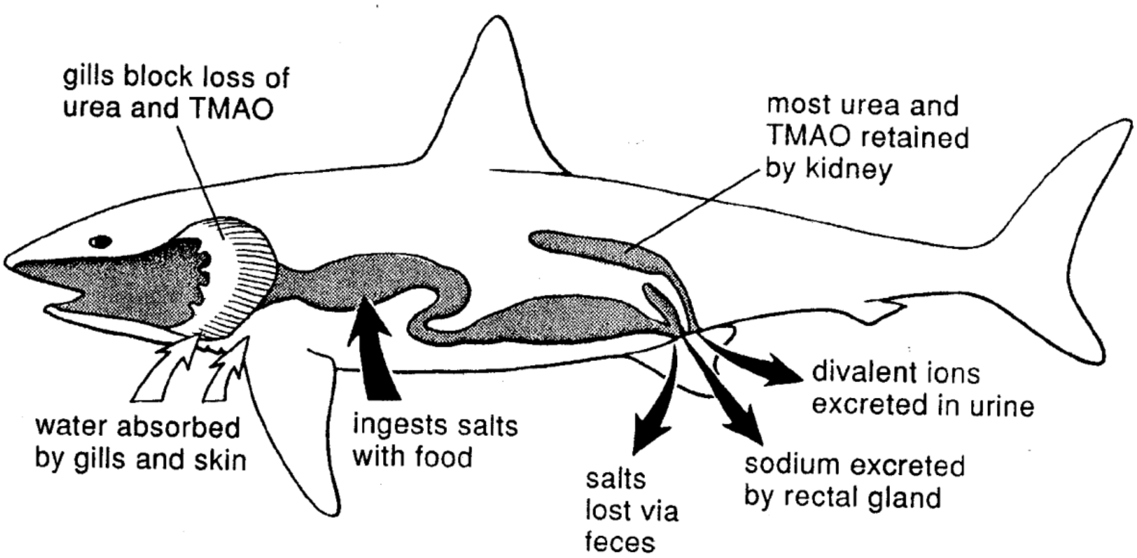
Marine teleosts use to drink large amounts of sea water to prevent dehydration. Rate of drinking varies with species, and within species it varies with salinities. The higher the salinity, the greater the rate of drinking. Marine species commonly swallow sea water amounting to from 7 to over 35% of their body weight per day. This results in a large intake of salts leading to increase the salt quantity of the body.

* Monovalent ions like Na, K and Cl are excreted mainly through gills via cells called chloride cells that resemble the salt-secreting cells of other animals. These cells are extremely rich in mitochondria.

* Divalent ions like Ca, Mg and So_4 remain mostly in the gut and excreted with feces, but small part of these salts are absorbed, enter blood stream and excreted by kidney via tubular secretion. The role of kidney in marine teleosts as a water pump is diminished because of the extrarenal losses of water. Consequently, the glomeruli are generally smaller and fewer than freshwater fishes. Several species of marine teleosts have lost the glomeruli and have minimized renal loss of water. Among these fishes, seahorses, scorpion fish, angler fish and puffers. In addition to this, marine fishes lack the distal segment of the kidney tubule.

Marine elasmobranches

Marine elasmobranches have solved the problem of osmoregulation in an entirely different way. They have evolved a specialized segment of the nephron that reabsorbs (70-90%) urea and return it to the blood. Trimetyl amine oxide (TMAO) another nitrogenous wastes product is reabsorbed in the kidney tubule and concentrated in the blood. The influx of urea, a toxic nitrogenous waste product for most vertebrate, and TMAO raise the osmotic pressure of the



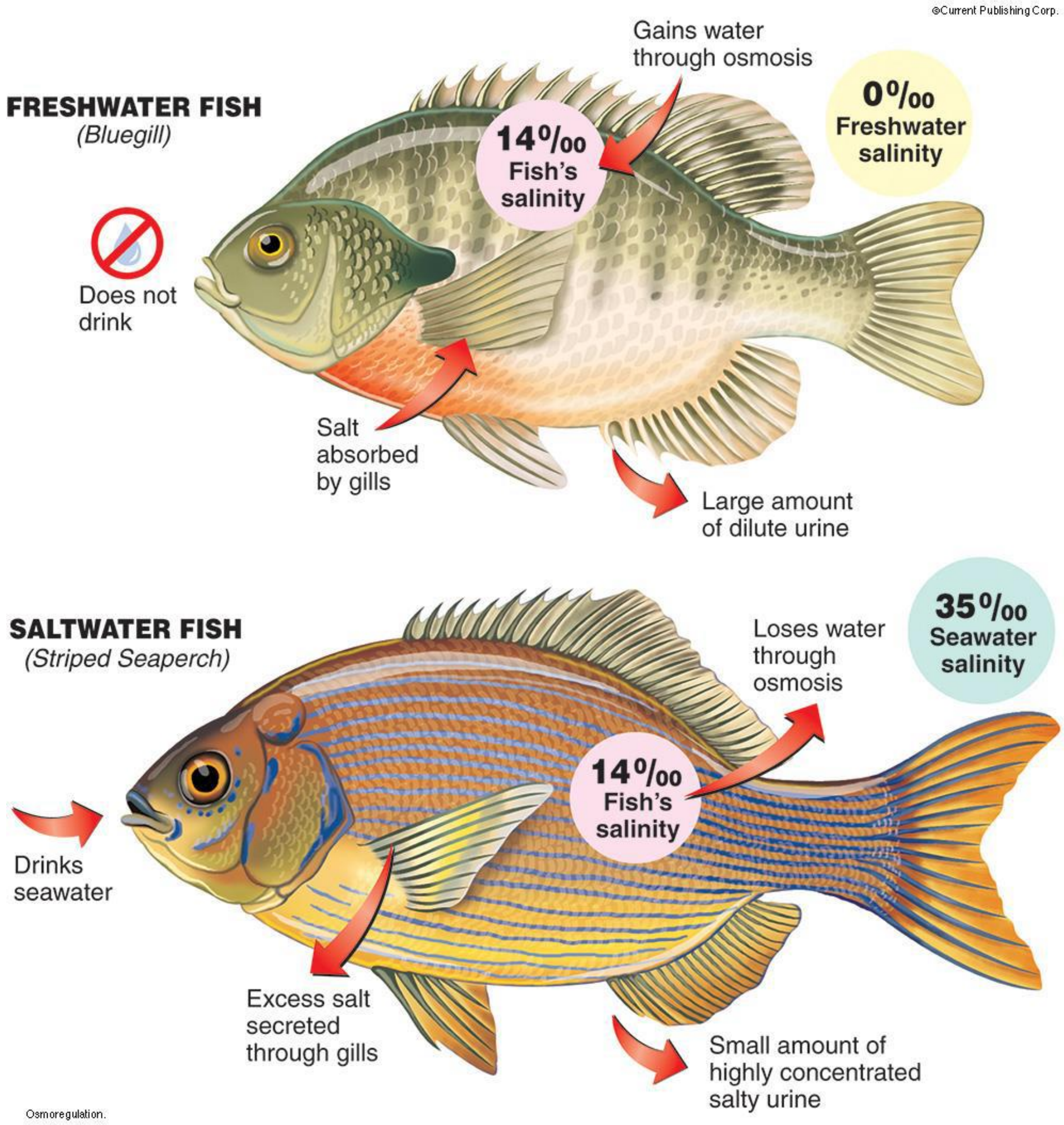
blood to a level just above that of sea water. The gills of elasmobranches are relatively impermeable to urea and TMAO.

Being hyperosmotic to sea water, elasmobranches tend to gain water by osmosis. Influx is mainly through the gills, as the skin is nearly impervious. This excess water is excreted as urine. Salts enter the marine elasmobranches by diffusion, as well as via ingested food because their body fluids have a more dilute concentration of salts than the medium. These are excreted via two main pathways:

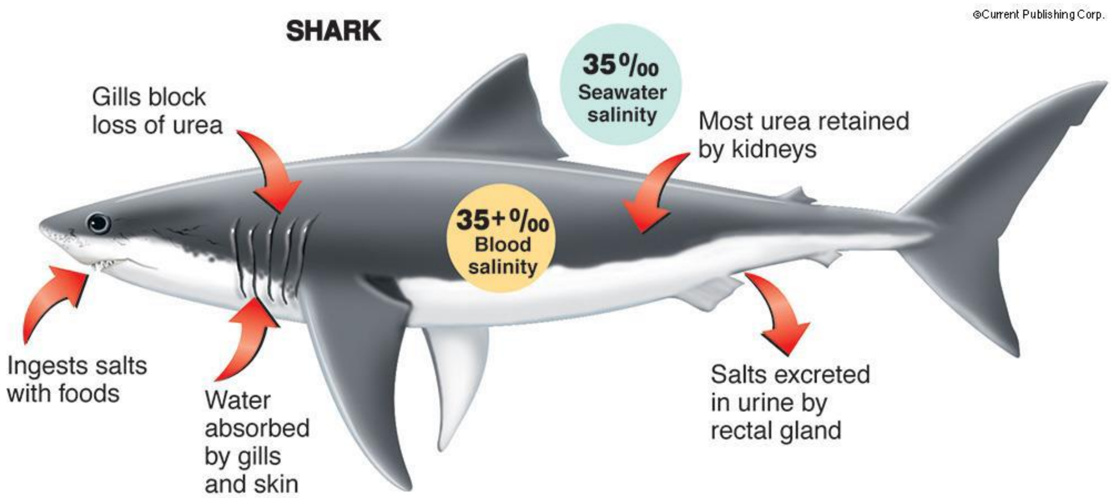
* The urine is the most important medium for excretion of divalent ions (Ca, Mg and So4). Their concentrations in urine were found more than 30 times the concentration in plasma.

* Sodium is excreted by rectal gland.

* Appreciable amounts of sodium are excreted from the gills of elasmobranches, but this elimination is small compared to the amounts released by the kidneys and rectal gland.



Osmoregulation.



Osmoregulation.

Diadromous and other euryhaline fishes

Many species are capable of living in both fresh and salt water. Anadromous fish are hatched in fresh water; subsequently move to the sea to feed and grow, and then return to fresh water to spawn. Catadromous species reverse the two media. Many other species have a wide tolerance for salinity and can move freely between fresh and salt water. All of these must be able to adjust osmoregulatory mechanisms more or less rapidly depending upon the speed with which they change habitat. Adaptation of euryhaline fishes to salt water generally requires drinking of the medium. Fishes such as eels that swallow little or no water while in fresh water may drink about 4 to 15% of

their body weight per day in salt water. *Tilapia mossambica* may swallow nearly 30% of body weight per day. Many species respond to the saline medium by changes in kidney function. The glomerular filtration rate may diminish dramatically, and the tubular reabsorption of water usually increases. Urine flow decreases to 10% or less of the flow in fresh water. Chloride secretory cells in the gills become active.