

Q

A

## Does the anatomy of freshwater and saltwater fish differ?

*Eli, a high school student  
from Australia*

There are almost 28,000 species of fish in the world, more than the number of amphibian, reptile, bird, and mammal species combined. Slightly more than half of these fish, including swordfish, tuna, and angelfish live only in salt water. Another 40 percent, such as goldfish, guppies, and channel catfish, reside only in fresh water. The remaining few percent, like salmon, eel, and striped bass, can switch between fresh water and salt water at various stages in their life cycles.

While fish have many adaptations to their environments—such as body shape, size, and color—there are no general anatomical differences that distinguish freshwater fish from marine fish. The differences instead relate to how they regulate water and salts in their cells.

Ocean water has a salinity of roughly 35 parts per thousand (ppt), or 35 grams of dissolved salts per liter of water. Fresh water varies but is usually less than 0.5 ppt. However, all fish, no matter where they live, have virtually identical salt concentrations in their blood—around 10 ppt. Since this blood concentration falls between the salinity of salt water and fresh water, saltwater and freshwater fish are constantly facing opposite osmotic pressures: In fresh water, the natural tendency is for water to seep into the fish, and salt out. In salt water, though, environmental salt tends to diffuse into the fish and the water in the internal fluid of the fish tends to be pushed out. To adapt to these diverging physiological demands, freshwater and saltwater fish differ in the function of their osmoregulation machinery—the organs that help

balance ions and water between the environment and the fish's blood.

Two major osmoregulatory organs in fish are the gill and the kidney. Let's focus on the gill. Both freshwater and saltwater fish have specialized chloride cells in their gills. These large round cells are rich in mitochondria, to produce energy, and in ion transporters, which use that energy to pump salts across the membrane. In marine fish, the chloride cells pump salts out of the gills into the surrounding environment. In freshwater fish that are constantly trying to stay saltier than the surrounding water, however, the chloride cells pump sodium, calcium, and chloride into the fish.

Which, where, and how many ion transporters and channels are present in these chloride cells is under complex regulation by various genes. Expression of these genes may stay constant throughout a fish's life or may change in response to environmental shifts in salinity. Chloride cells in fish migrating between fresh and salt water, for example, express different pumps in the different environments. Studying what genetic makeup allows for adaptation to different salinity environments will help us understand how freshwater and saltwater fish evolved as well as what mechanisms nature has selected for ion and water regulation, which goes beyond fish and relates to human disease and health.

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#### FURTHER READING

"Why Can Some Fish Live in Freshwater, Some in Saltwater, and Some in Both?" W. A. Wurts  
World Aquaculture 1998 29(1): 65

"Molecular Biology of Major Components of Chloride Cells" S. Hirose *et al.* Comparative Biochemistry and Physiology Part B (2003) 136:593–620

"Evolution of Blood Pressure Regulation in Humans" J. H. Young  
Current Hypertension Reports (2007) 9(1):13–18

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