Gills As Respiratory Organs In Vertebrates

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Most fish exchange gases using gills on either side of the pharynx, forming the Splanchnocranium; the Splanchnocranium being the portion of the skeleton where the cartilage of the cranium converges into the cartilage of the pharynx and its associated parts. Gills are tissues which consist of threadlike structures called filaments. These filaments have many functions and are involved in ion and water transfer as well as oxygen, carbon dioxide, acid and ammonia exchange. Each filament contains a capillary network that provides a large surface area for the exchange of gases and ions. Fish exchange gases by pulling oxygen-rich water through their mouths and pumping it over their gills. In species like the Spiny dogfish and other sharks and rays, a spiracle exists near the top of the head that pumps water into the gills when the animal is not in motion. In some fish, capillary blood flows in the opposite direction to the water, causing countercurrent exchange. The muscles on the sides of the pharynx push the oxygen-depleted water out the gill openings. In bony fish, the pumping of oxygen-poor water is aided by a bone that surrounds the gills called the Operculum (fish).

Many aquatic animals have developed gills for respiration which are specifically adapted to their function. In fish, for example, they have:

1. A large surface area to allow as much oxygen to enter the gills as possible because more of the gas comes into contact with the membrane
2. Good blood supply to maintain the concentration gradient needed
3. Thin membrane to allow for a short diffusion pathway
4. Each gill arch has two rows (hemibranchs) of gill filaments
5. Each gill filament has many lamellae.

In osteichthyes, the gills contain 4 gill arches on each side of the head, two on each side for chondrichthyes or 7 gill baskets on each side of the fish's head in Lampreys. In fish, the long bony cover for the gill (the operculum) can be used for pushing water. Some fish pump water using the operculum. Without an operculum, other methods, such as ram ventilation, are required. Some species of sharks use this system. When they swim, water flows into the mouth and across the gills. Because these sharks rely on this technique, they must keep swimming in order to respire.

Bony fish use countercurrent flow to maximize the intake of oxygen that can diffuse through the gill. Countercurrent flow occurs when deoxygenated blood moves through the gill in one direction while oxygenated water moves through the gill in the opposite direction. This mechanism maintains the concentration gradient thus increasing the efficiency of the respiration process as well and prevents the oxygen levels from reaching equilibrium. Cartilaginous fish do not have a countercurrent flow system as they lack bones which are needed to have the opened out gill that bony fish have.

Fish gills are organs that allow fish to breathe underwater. Most fish exchange gases like oxygen and carbon dioxide using gills that are protected under gill covers on both sides of the pharynx. Gills are tissues that are like short threads, protein structures called filaments. These filaments have many functions including the transfer of ions and water, as well as the exchange of oxygen, carbon dioxide, acids and ammonia. Each filament contains a capillary network that provides a large surface area for exchanging oxygen and carbon dioxide.

Fish exchange gases by pulling oxygen-rich water through their mouths and pumping it over their gills. In some fish, capillary blood flows in the opposite direction to the water, causing counter-current exchange. The gills push the oxygen-poor water out through openings in the sides of the pharynx. Some fish, like sharks and lampreys, possess multiple gill openings. However, bony fish have a single gill opening on each side. This opening is hidden beneath a protective bony cover called the operculum.

Juvenile bichirs have external gills, a very primitive feature that they share with larval amphibians.

Previously, the evolution of gills was thought to have occurred through two diverging lines: gills formed from the endoderm, as seen in jawless fish species, or those form by the ectoderm, as seen in jawed fish. However, recent studies on gill formation of the little skate (*Leucoraja erinacea*) has shown potential evidence supporting the claim that gills from all current fish species have in fact evolved from a common ancestor.

Sharks and rays typically have five pairs of gill slits that open directly to the outside of the body, though some more primitive sharks have six or seven pairs. Adjacent slits are separated by a cartilaginous gill arch from which projects a long sheet-like septum, partly supported by a further piece of cartilage called the gill ray. The individual lamellae of the gills lie on either side of the septum. The base of the arch may also support gill rakers, small projecting elements that help to filter food from the water.

A smaller opening, the spiracle, lies in the back of the first gill slit. This bears a small pseudobranch that resembles a gill in structure, but only receives blood already oxygenated by the true gills. The spiracle is thought to be homologous to the ear opening in higher vertebrates.

Most sharks rely on ram ventilation, forcing water into the mouth and over the gills by rapidly swimming forward. In slow-moving or bottom dwelling species, especially among skates and rays, the spiracle may be enlarged, and the fish breathes by sucking water through this opening, instead of through the mouth.

Chimaeras differ from other cartilaginous fish, having lost both the spiracle and the fifth gill slit. The remaining slits are covered by an operculum, developed from the septum of the gill arch in front of the first gill.

The shared trait of breathing via gills in bony fish and cartilaginous fish is a famous example of symplesiomorphy. Bony fish are more closely related to terrestrial vertebrates, which evolved out of a clad of bony fishes that breathe through their skin or lungs, than they are to the sharks, rays, and the other cartilaginous fish. Their kind of gill respiration is shared by the "fishes" because it was present in their common ancestor and lost in the other living vertebrates. But based on this shared trait, we cannot infer that bony fish are more closely related to sharks and rays than they are to terrestrial vertebrates.

In bony fish, the gills lie in a branchial chamber covered by a bony operculum. The great majority of bony fish species have five pairs of gills, although a few have lost some over the course of evolution. The operculum can be important in adjusting the pressure of water inside of the pharynx to allow proper ventilation of the gills, so that bony fish do not have to rely on ram ventilation (and hence near constant motion) to breathe. Valves inside the mouth keep the water from escaping.

The gill arches of bony fish typically have no septum, so that the gills alone project from the arch, supported by individual gill rays. Some species retain gill rakers. Though, all but the most primitive bony fish lack a spiracle, the pseudobranch associated with it often remains, being located at the base of the operculum. This is, however, often greatly reduced, consisting of a small mass of cells without any remaining gill-like structure.

Fish transfer oxygen from the sea water to their blood using a highly efficient mechanism called countercurrent exchange. Countercurrent exchange means the flow of water over the gills is in the opposite direction to the flow of blood through the capillaries in the lamellae. The effect of this is that the blood flowing in the capillaries always encounters water with a higher oxygen concentration, allowing diffusion to occur all the way along the lamellae. As a result the gills can extract over 80% of the oxygen available in the water.

Marine teleosts also use their gills to excrete osmolytes (eg. Na^+, Cl^-). The gill surface area tends to create a problem for fish that seek to regulate the osmolarity of their internal fluids. Seawater contains more osmolytes than the fish's internal fluids, so marine fishes naturally lose water through their gills via osmosis. To regain the water, marine fishes drink large amounts of sea water while simultaneously expend energy to excrete salt through the Na^+/K^+-ATPase ionocytes. Conversely, fresh water less osmolytes than the fish's internal fluids. Therefore, freshwater fishes must utilize their gill ionocytes to attain ions from their environment to maintain optimal blood osmolarity.

In some primitive bony fishes and amphibians, the larvae bear external gills, branching off from the gill arches. These are reduced in adulthood, their function taken over by the gills proper in fishes and by lungs in most amphibians. Some amphibians retain the external larval gills in adulthood, the complex internal gill system as seen in fish apparently being irrevocably lost very early in the evolution of tetrapods.