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# Gas Exchange

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# Introduction

In aquatic organism the gill is used for external respiration, i.e carrying on gas exchange with the water.

The movement of oxygen from the external media to the cells is by way of diffusion in opposite direction  $\text{CO}_2$  moves the same way.



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# Solubility of gases

Solubility of gases plays important role in physiological process.



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# Effect of pressure and temperature

The amount of gas dissolved in a given volume of water depends on the pressure is doubled, twice as much gas will be dissolved.



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The tension of a gas in solution is defined as the partial pressure of that gas in atmosphere is in equilibrium with the solution.



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# Gas diffusion

In the respiratory organ of animals gas diffuse between the environment and the organism

The rate of diffusion of a gas is inverse by proportional to the square root of its molecular weight.

$$\text{Diffusion rate } \alpha = \frac{1}{\sqrt{\text{Molecular wt of gas}}}$$

$$\text{Diffusion time (t)} = \frac{R^2}{t^2} = \frac{\text{Square root of average diffusion distance}}{\text{average length}}$$



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# Respiration and Gas Exchange

In physiology, **respiration** (often mistaken with breathing) is defined as the transport of oxygen from the outside air to the cells within tissues

**cellular respiration**: the metabolic process by which an organism obtains energy by reacting oxygen with glucose to give water, carbon dioxide and ATP (energy)



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# Classifications of respiration

**Aquatic respiration**

Buccal pumping

**Aquatic respiration** is the process whereby an aquatic animal obtains oxygen from water .

**Buccal pumping** is a method of respiration in which the animal moves the floor of the mouth in a rhythmic manner that is externally apparent.





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# Cartilaginous fish respiration

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.

Water enters through the mouth of the animal, into the pharynx, over the gills and exits through the gill slits.

A smaller opening, the spiracle, lies in front of the first gill slit



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Most sharks rely on ram ventilation, forcing water into the mouth and over the gills by rapidly swimming forward.

**(ram ventilation** The production of respiratory flow in some fish in which the mouth is opened during swimming, such that water flows through the mouth and across the gills.



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In bony fish , the gas exchange organs of fish are called **gills**

The great majority of bony fish species have five pairs of gills.

From each gill arch arise two rows of filaments

The gill arch along with the filaments is called a gill

Each **gill** is composed of many **filaments** that are each covered in many **lamellae**



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The lamellae are very fine structures and contain **blood capillaries** , which have blood flowing in the opposite direction to the water.

This is called “counter current” mechanism and helps in the maximum exchange

The counter current exchange system gives fish 80-90% efficiency in acquiring oxygen



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The gill area of a fish depends on the number and size of the gill filaments and gill lamellae.

The total gill area increases with the increase in body weight during the growth of the fish.

The teleostean gill is capable of diffusing 60-80% of oxygen from water to blood at the gills.



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By inhalation and exhalation of water in the buccal cavity causes purification of blood.



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# Double pump system

In majority of teleosts, 2 respiratory pumps, buccal and opercular function in co-ordination with each other, to propel water through the gills. These 2 pumps are operated by a set of muscles resulting in contraction or expansion of the buccal and opercular cavities.

The process can be described as below

The mouth is opened and the buccal cavity is enlarged by lateral expansion of its walls.



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Mouth is closed and volume of opercular cavity is increased. But the opercular opening remains closed

When the operculum is closed, the gills must extract as much oxygen as possible.





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# Fish blood as a gas carrier

• **Haemoglobin** ( also spelled **haemoglobin** and abbreviated **Hb** or **Hgb**) has the iron -containing oxygen -transport and Hg is the metalloprotein in the red blood cells of all vertebrates (except the fish family Channichthyidae) and the tissues of some invertebrates

- Haemoglobin is a large protein with four polypeptide chains and four haemo groups.
- Each haeme group is enfolded in one of 2 or 4 chains of amino acid units that collectively constitute the protein part of the molecule called globin.



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As much as oxygen is taken up, transported and released by the RBC, we may speak of the processes of “loading” and “unloading” of oxygen and of the respective tensions at which these processes occur

The oxygen dissociation curve describes the equilibrium of oxygen with hb.



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# Ventilation of gills

In tuna like fast moving fishes has immobile gill cover and obtain the require high water flow over the gill by taking water into the mantle cavity, and by ejecting the water by jet propulsion



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# Counter Flow Mechanism

The stream of water flowing over the gill and the stream of blood running within the gill flow in opposite direction to each other and this will help for effective removal of oxygen and this called counter current flow



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# Ram Ventilation

The fishes like tunas swim with its mouth parts open in a high speed. There are no visible breathing movements and water flows continuously over the gills; this is called ram ventilation



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# Oxygen dissociation curve

At high oxygen concentration the hemoglobin (Hb) combines with oxygen to form oxyhemoglobin ( $\text{HbO}_2$ )

The hemoglobin is saturated according to the given  $\text{O}_2$  concentration

Thus by plotting the oxyhemoglobin for a given oxygen concentration, a curve oxygen hemoglobin dissociation curve is obtained. This curve will be normally in sigmoid shape.



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In some animals the blood has high affinity to oxygen (it gives up oxygen less readily), and the dissociation curve is located further to the left. The blood of others gives up oxygen more readily (the affinity and oxygen is lower), and the dissociation curve is located further to the right



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# Carbon dioxide transported in the blood

There are three main ways in which  $\text{CO}_2$  is transported in the blood

A small percentage of the  $\text{CO}_2$  that is in the blood is dissolved molecular  $\text{CO}_2$ .

A larger amount of  $\text{CO}_2$  reacts with  $-\text{NH}_2$  groups of hemoglobin and other proteins to form carbamino compounds

However, most of the  $\text{CO}_2$  that is transported in the blood is in the form of bicarbonate ( $\text{HCO}_3^-$ )





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The change of bicarbonates into carbon dioxide and water is catalyzed by the enzyme carbonic anhydrase

Mackerel is a fish of high seas that never encounters low levels of oxygen and lives under uniform but low carbon dioxide tensions

Factors that influence oxygen consumption include activity, age, reproductive state, nutrition, disease and intrinsic regulatory mechanisms (nervous and hormonal control)



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# **Accessory respiratory organs in fishes**

**Buccopharyngeal epithelium**

**Skin**

**External gills**

**Labyrinthiform organs**

**Opercular lungs**

**Air bladder/ swim bladder**

**A special part of alimentary canal**