

GAS EXCHANGE AND RESPIRATION IN FISHES

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Gas Exchange

- The transfer of oxygen (O_2), carbon-di-oxide (CO_2) and to a lesser extend, ammonia (NH_3) between the environment and the cell/tissue site of use or production

Respiration

- Physiology- It is defined as the transport of oxygen from the outside air to the cells within tissues, and the transport of carbon dioxide in the opposite direction



- ❖ The **biochemical definition** of respiration, which refers to **cellular respiration**:
- ❖ Cellular respiration is the metabolic process by which an organism obtains energy by reacting oxygen with glucose to give water, carbon dioxide and ATP (energy).
- ❖ Although physiologic respiration is necessary to sustain cellular respiration and thus life in animals
- ❖ The processes are distinct: cellular respiration takes place in individual cells of the animal, while physiologic respiration concerns the bulk flow and transport of metabolites between the organism and the external environment.



Aerobic Respiration	Anaerobic Respiration
Oxygen is present when this form of respiration takes place.	Oxygen is absent when this form of respiration takes place.
Gases are exchanged in this form of respiration.	Gases are not exchanged in this form of respiration.
It can be found in the cytoplasm and the mitochondria.	It can be found only in the cytoplasm.
Glucose breaks down into carbon dioxide and water.	Glucose breaks down into ethyl alcohol, carbon dioxide and energy.
All higher organisms such as mammals have this type of respiration.	Lower organisms such as bacteria and yeast use this type. In other organisms, it occurs during heavy activities.



RESPIRATORY ORGANS IN FISHES

- ❖ Respiration in fish takes place with the help of gills.
- ❖ Most fish possess **gills** on either side of their head. Gills are tissues made up of feathery structures called **gill filaments** providing a large surface area for exchange of gases.
- ❖ A large surface area is crucial for gas exchange in aquatic organisms as water contains very little amount of dissolved oxygen.
- ❖ The filaments in fish gills are organized in rows in the **gill arch**.
- ❖ Each filament comprises **lamellae**, which are discs supplied with **capillaries**.
- ❖ Blood moves in and out of the gills through these small blood vessels.
- ❖ Though gills in fish occupy only a small section of their body, the extensive respiratory surface produced by the filaments renders the whole organism with efficient gas exchange.

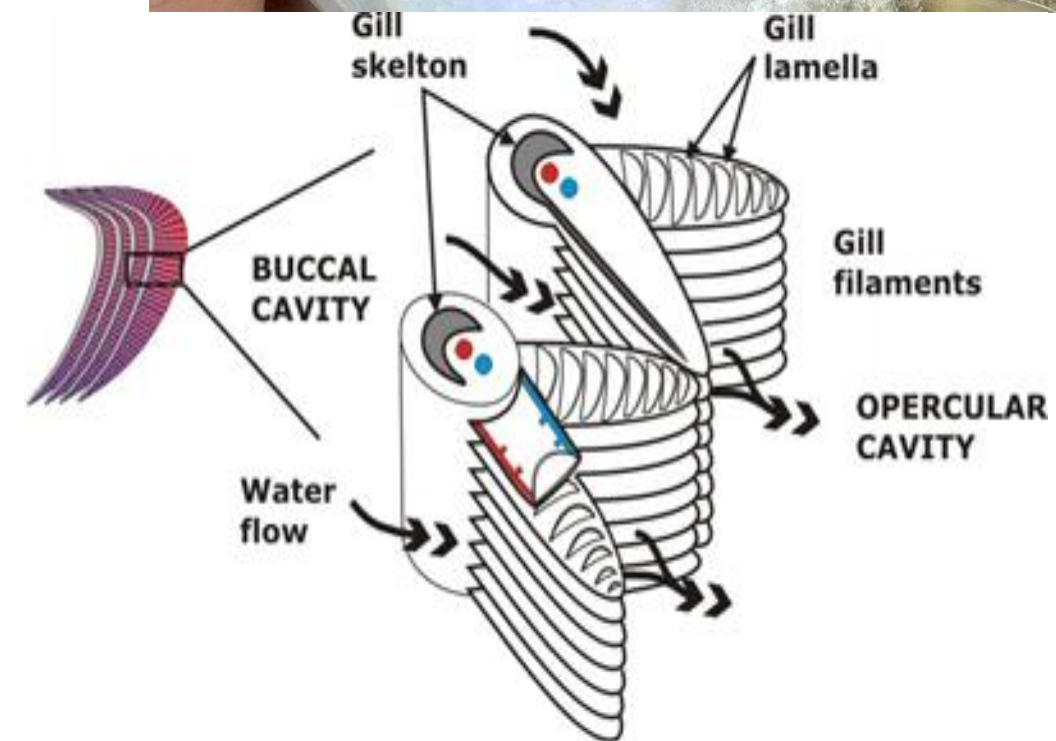


STRUCTURE OF GILL IN BONY FISH

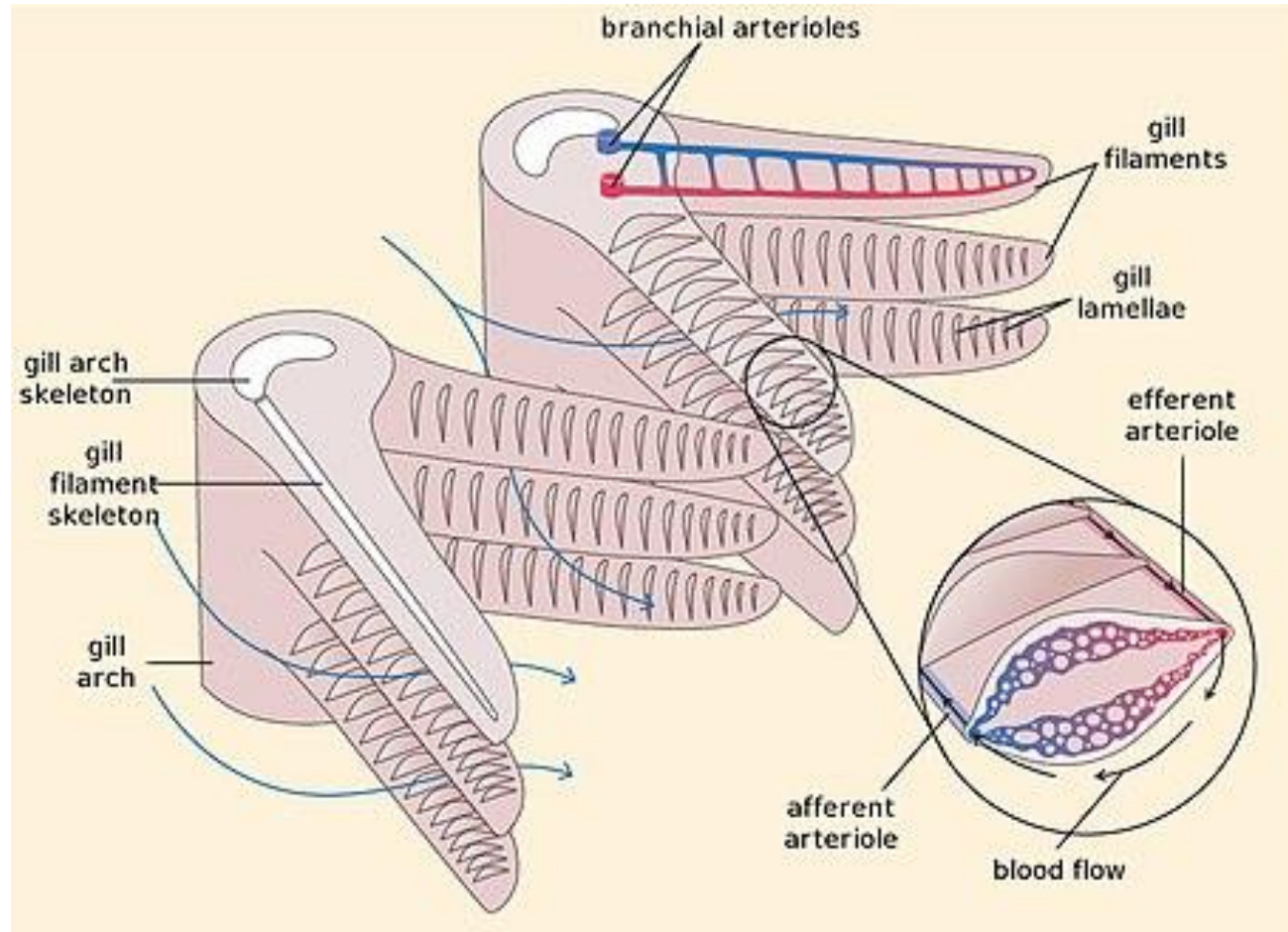
- ❖ Gills are situated in the gill chambers on either side of the head of the fish.
- ❖ The gill chamber opens outside to the water through **gill-slits** in the case of **Elasmobranchs** (Shark and Rays (5 in number)) and by Bony fishes only one large opening covered by a bony plate called the **Operculum** (a flap, that covers and protects the fish gills) in the case of **Bony fishes**.
- ❖ Gill arch bears two rows of gill filaments (V shape) forms a **complete gill** or **holobranch**. Individual row is called **hemibranch**



- ❖ Most teleost have **four holobranches** (8 hemibranches) on each side while elasmobranchs have **five holobranches** (10 hemibranches) on each side
- ❖ Gill arch bears gill rakers towards the inner (buccal) side and gill filaments towards the outer (opercular) side
- ❖ Gill rakers are covered by an epithelial layer bearing taste buds and mucus secreting cells
- ❖ From each gill arch arise two rows of gill filaments, which are arranged in a **V-shaped** manner.
- ❖ Each gill filament bears a large number of tiny folds on both the sides. these flat leaf like structures are called the lamellae and serve to further increase the surface area of filament



- ❑ Lamellae have a rich supply of blood capillaries. Thus the barrier between the blood capillaries and the water is only few cells thick.

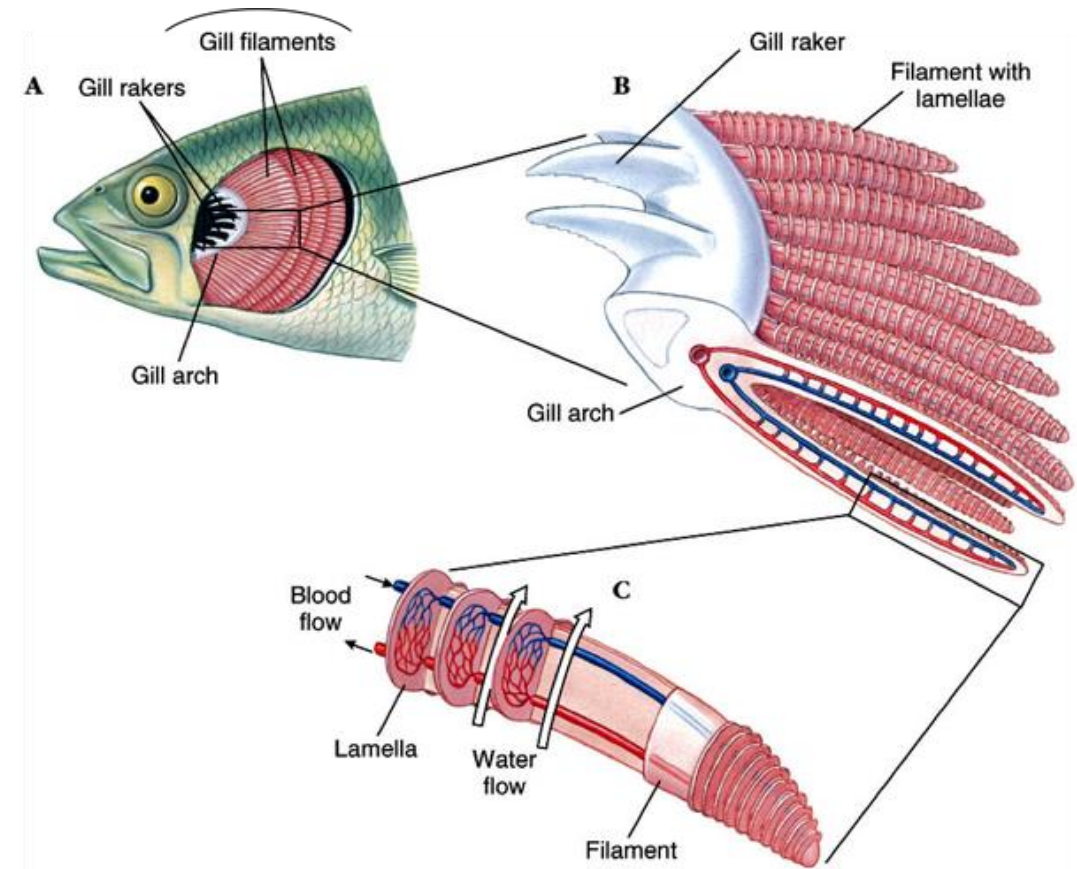


GILL AREA AND DIFFUSION CAPACITY

- ❖ The gill area of a fish depends on the number and size of the gill filaments and gill lamellae.
- ❖ It has been shown that fast swimming and active fishes possess more gill area and higher number of gill lamellae/mm of gill filament as compared to sedentary species.
- ❖ Air breathing fishes, mainly have accessory respiratory organs, in gill area reported to be $\frac{1}{2}$ of the area of fishes that depends on aquatic respiration.
- ❖ The total gill area increases with the increase in body weight as the fish grows.



- ❖ The efficiency of the gill as a respiratory organ depends on its **oxygen diffusion capacity** in water, which is inversely proportional to the **blood water barrier** (diffusion distance) i.e., the barrier through which the exchange of gases takes place between blood and water.
- ❖ This barrier is formed by the **lamellar epithelium**, **basement membrane** and the flange of the **pillar cells**. (The pillar cells or pilaster cell are a characteristic feature of the teleost gill and serve as pillars to keep the 2 epithelial layers of the lamella separate and prevent them from collapsing).
- ❖ The thickness of the barrier is less in species depending on water for respiration than in air breathing fishes.
- ❖ The teleostean gill is capable of diffusing 60-80% of oxygen from water to blood at the gills.



MECHANISM OF RESPIRATION OR VENTILATION OF GILLS

- For respiration, a continuous current of water is maintained through the buccopharyngeal cavity.
- For this, water is sucked into the buccal cavity and expelled through the external branchial aperture.
- By inhalation and exhalation of water in the buccal cavity causes purification of blood.
- Fishes use two different methods for keeping a continuous supply of new water available
 1. Double pump system which is complex and
 2. Ram ventilation is very simple.



DOUBLE PUMP SYSTEM

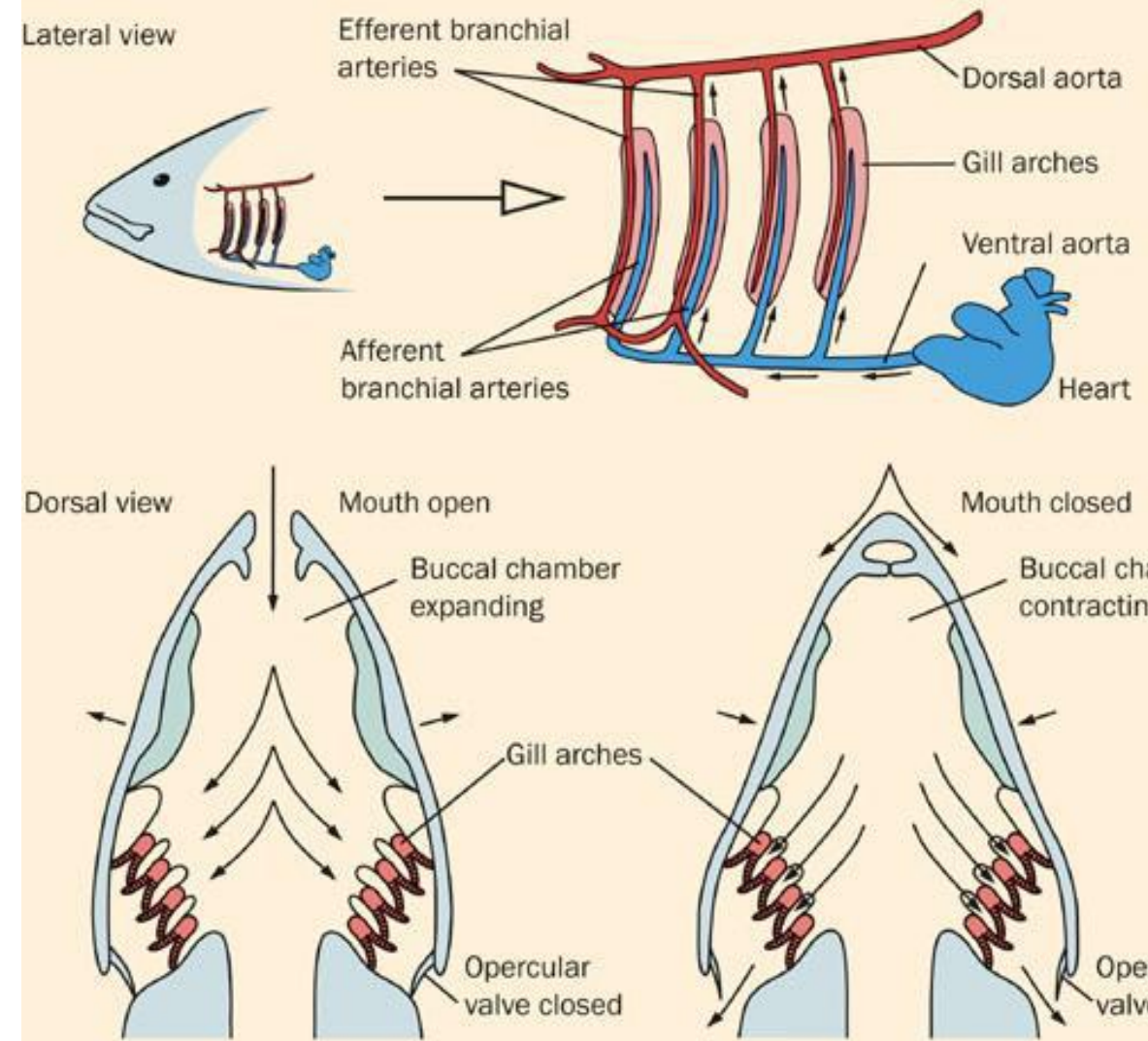
- Unidirectional system, water always moves one way across gills and out operculum
- In majority of teleosts, **2 respiratory pumps**, buccal and opercular function in co-ordination with each other, to propel water through the gills.

Phase I

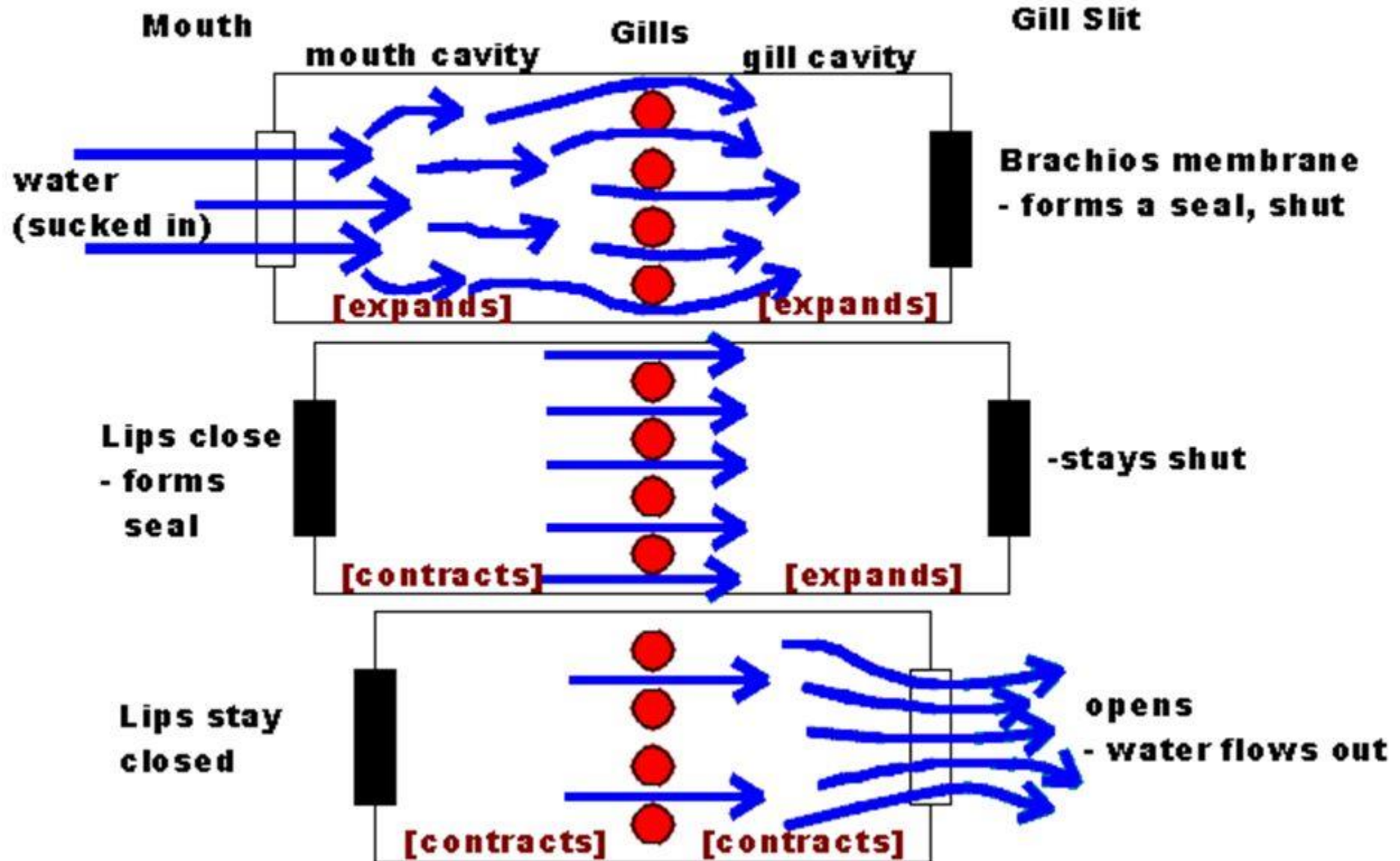
- Expansion of buccal and opercular cavities while opercula are closed

Phase II

- Mouth closes, opercula open, forcing water across gills



Double Pump System: An elaborate system of passing water over the gills while the fish stays stationary. There is no moment throughout the cycle when the water stops flowing.



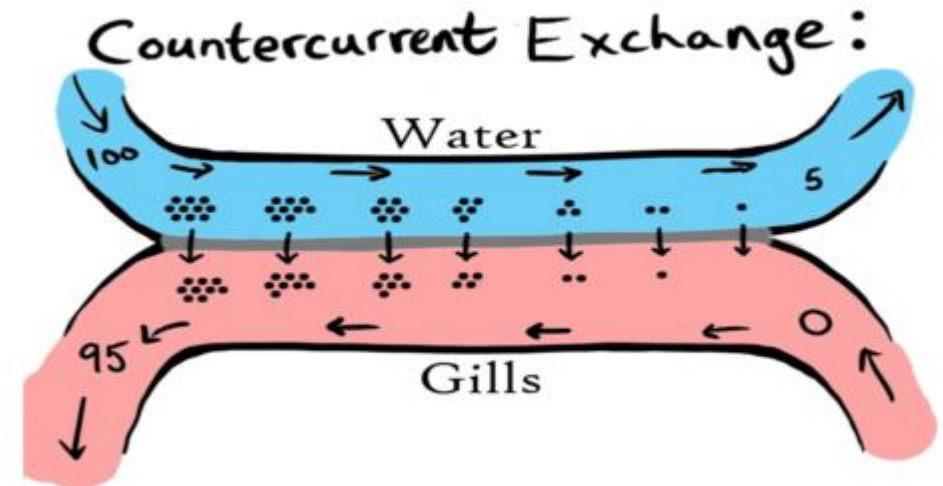
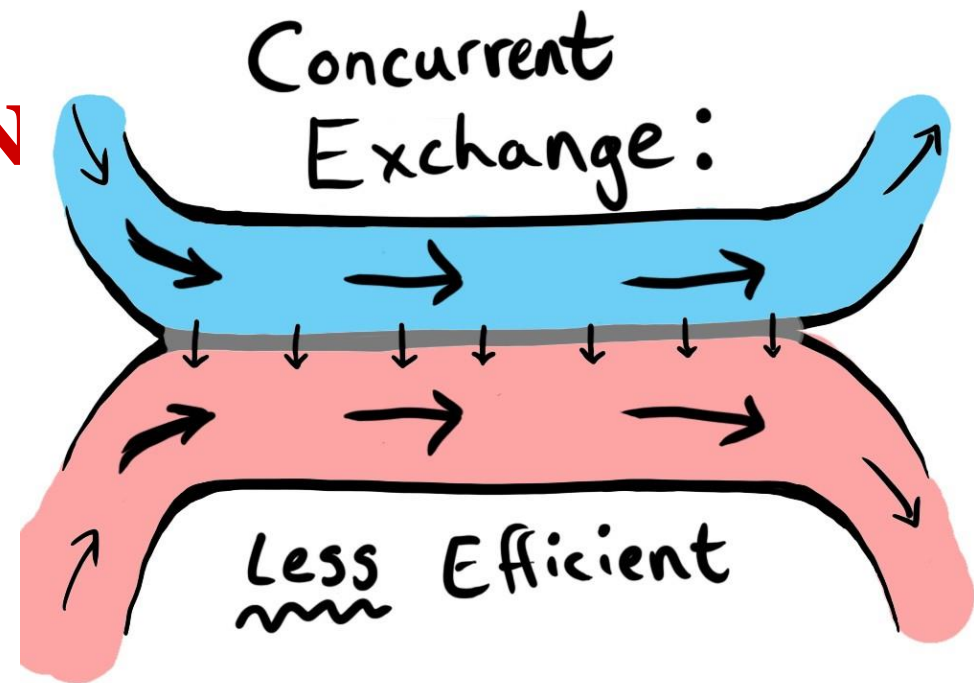
RAM VENTILATION

- In tuna which is fast moving in nature has immobile gill cover and it require high water flow over the gill by taking water into the mantle cavity, and by ejecting the water by jet propulsion.
- Fast moving fishes have largest gill area than the slow movers.
- This help to desire more oxygen for its activity.
- Fast swimming fishes may leave their mouth and opercular aperture wide open
- So that gills are bathed by a continuous current of water produced by swimming.
- This is called ‘ram ventilation’
- The rhythmic movement of operculum is controlled by a respiratory centres which is located in the area of medulla oblongata.

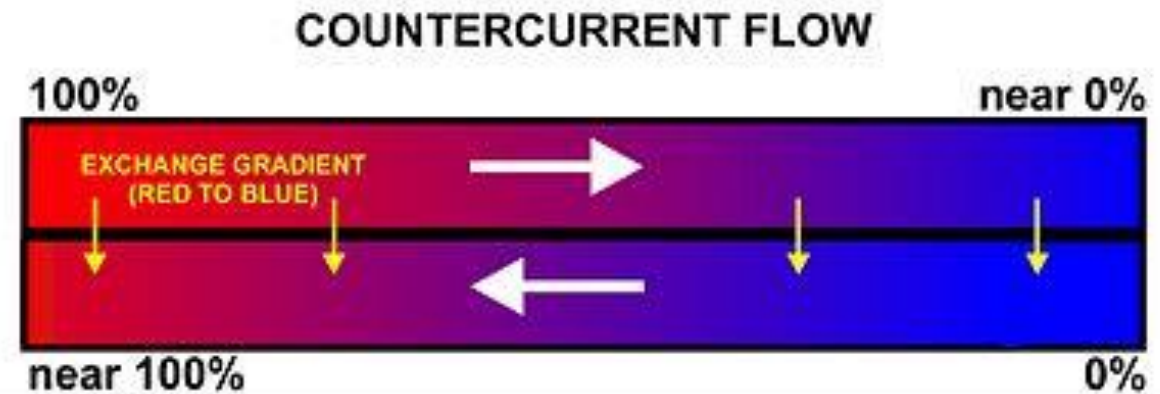
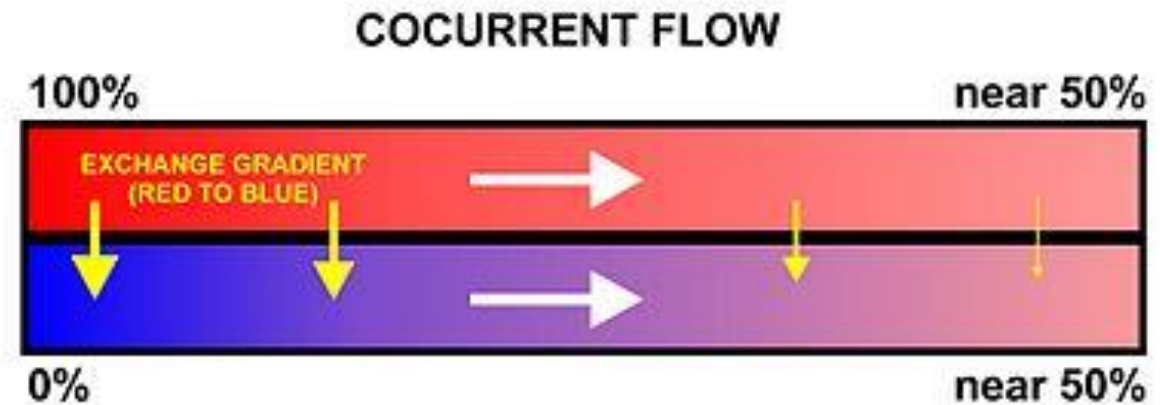


COUNTER FLOW MECHAN

- 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.
- The gills of fish utilize counter current flow, a very effective mechanism for removing the maximum amount of oxygen from the water flowing over them



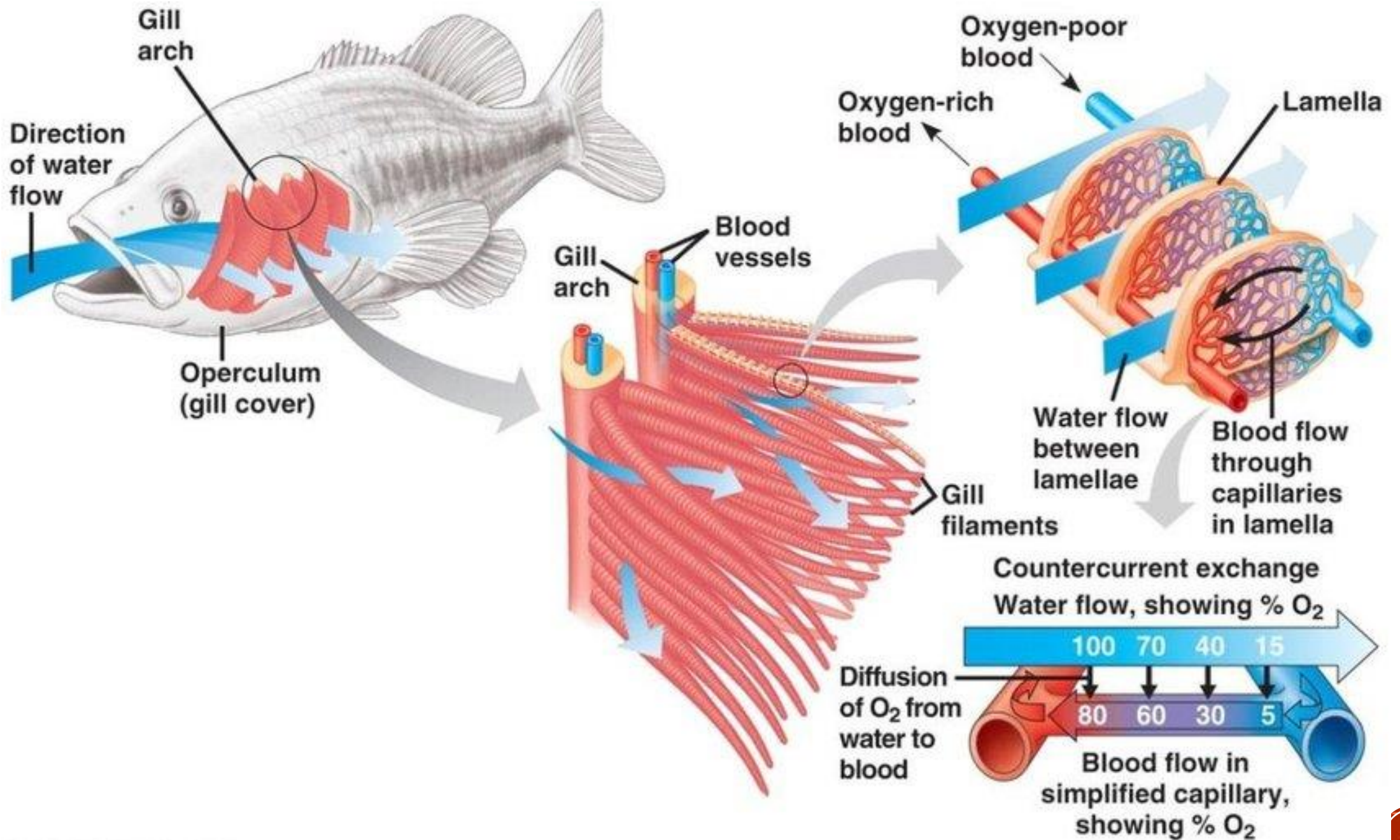
- During counter-current flow, two types of fluids (in this case blood and water) with different concentrations of one or more dissolved substances flow in opposite directions past one another
- These fluids are separated by thin membranes
- Counter-current flow promotes diffusion of a substance (such as oxygen) down its concentration gradient from one fluid (water) to the other (blood)
- The water may leave the gill having lost as much as 80 -90% of its initial oxygen content.



CIRCULATION OF BLOOD THROUGH GILL FILAMENT AND LAMELLAE

- Teleost gills generally have one afferent unit and one efferent unit
- Afferent branchial vessel brings deoxygenated blood to gill
- Efferent branchial vessel collect oxygenated blood from gill





TRANSPORTATION OF RESPIRATORY GASES IN THE BLOOD

- The essential function of the gas exchange system is to meet the metabolic requirements of the cells for O_2 and to remove the CO_2 produced by cellular metabolism
- Blood carries O_2 to the tissue and remove CO_2 from respiring tissues to the gas exchange surface
- The main adaptation of blood for gas transport is the presence of the respiratory pigment hemoglobin (Hb) within the RBCs
- Hemoglobin increase the O_2 carrying capacity of blood up to 20 folds in comparison to physically dissolved O_2
- H^+ binding capacity of Hemoglobin also help in transportation of CO_2



HEMOGLOBIN

- Hemoglobin is a **tetrameric** (4 polypeptide chain and 4 heme group) molecule in most teleost fishes
- Agnathans (lampreys & Hag fishes) possess **monomeric** hemoglobin
- Antarctic fishes (Ice fish) **do not have hemoglobin**

