B.SC 6TH SEMESTER
FISH AND FISHERIES
PAPER CODE: ZOO-HE-6026

TOPIC: GILLS AND GAS EXCHANGE

Richa Sharma
Assistant Professor
Department of Zoology, PKC

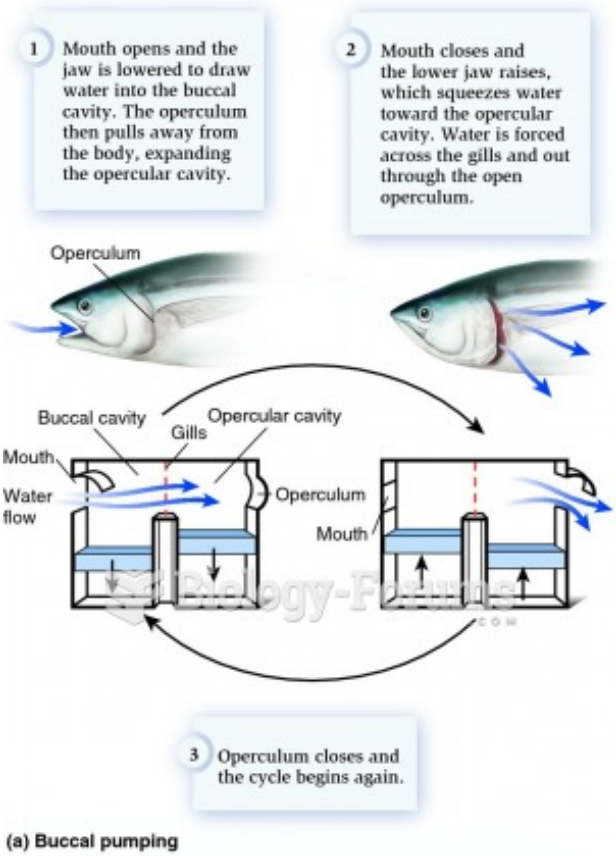
RESPIRATION: Intake of Oxygen for metabolism/energy production and release of Carbon dioxide into the environment as an end product of metabolism.

External respiration: The gaseous exchange of O2 and CO2 taking place between blood and water (or air) through the medium of respiratory organs.

Internal respiration: The essential transfer of gases between blood and tissues/cells of the body and brings about the release of energy.

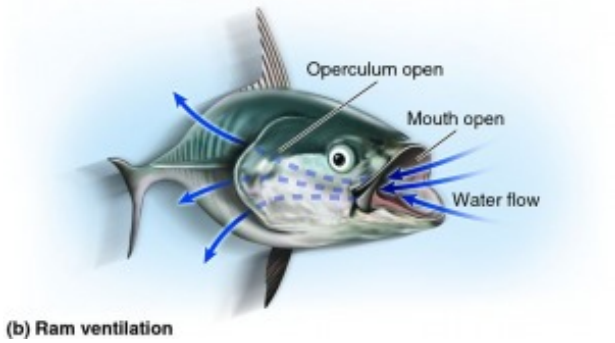
MECHANISM OF RESPIRATION

- For respiration, a continuous current of water is maintained through the bucco-pharyngeal cavity.
- For this, water is sucked into the buccal cavity and expelled through the external branchial aperture. In the beginning, the water enters the mouth by expansion of the buccal cavity. The water is then accelerated over the gill by the simultaneous contraction of buccal cavity and cavity contracts, expelling the water out through the opercular opening, the cycle begins again.
- By inhalation and exhalation of water in the buccal cavity causes the purification of blood.
- Fishes use two different methods for keeping a continuous supply of new water available:



(a) Buccal pumping

(a)Double pump system/Buccal pumping: Unidirectional system, water always moves one way: in through the mouth, across gills and out the operculum. There is no mixing of fresh and respired water, maintaining as high a P_{O2} at the gill surface as possible. When they are moving slowly or resting in water, fish can breathe by synchronously expanding and contracting the buccal cavity (the mouth and throat) and the opercular cavity or an elaborate system of passing water over the gills while the fish stays stationary. Eg. the majority of teleosts.



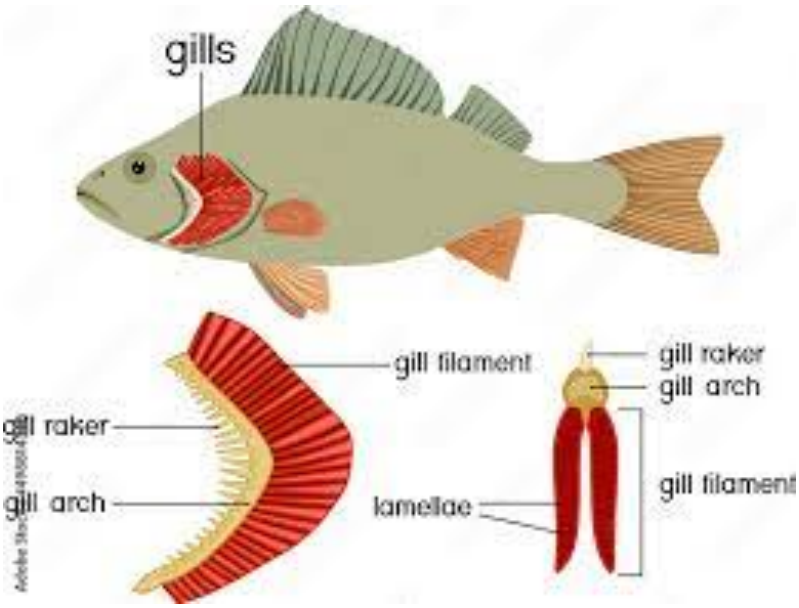
(b) Ram ventilation

(b) Ram ventilation: Fast swimming fishes and fishes of hill streams, may leave their mouth and opercular aperture wide open so that gills are bathed by a continuous current of water produced by swimming. Eg. tuna, swordfish, shark.

Structure of the gill

- Respiration in fish takes place with the help of gills. Fish gills are intricate respiratory organs that allow them to extract oxygen from water.
- Gills are formed by filamentous outgrowth from the anterior and posterior wall of each gill slit.
- Most fish possess gills, 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 (5-7 in number)) and
  - in bony fishes, only one large opening is covered by a bony plate called the Operculum (a flap, that covers and protects the fish gills)

- **Parts of a gill**:
  1. Gill Arch
  2. Gill Raker
  3. Gill filament or Primary gill lamellae
  4. Secondary gill lamellae

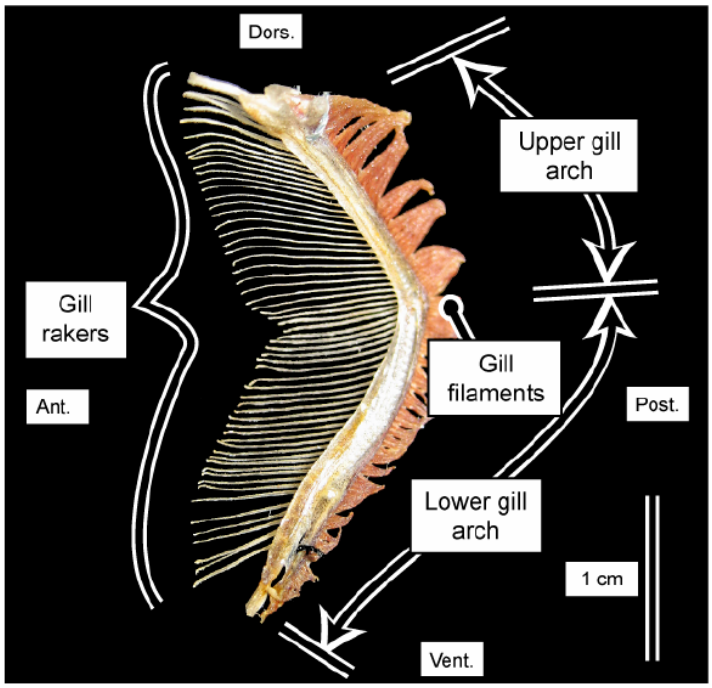


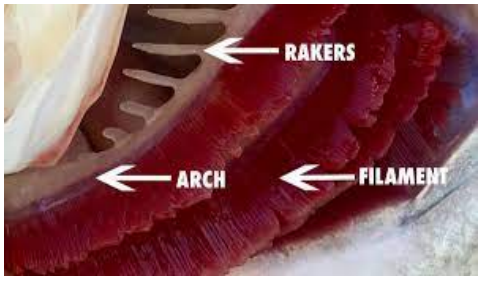
1. Gill Arch:

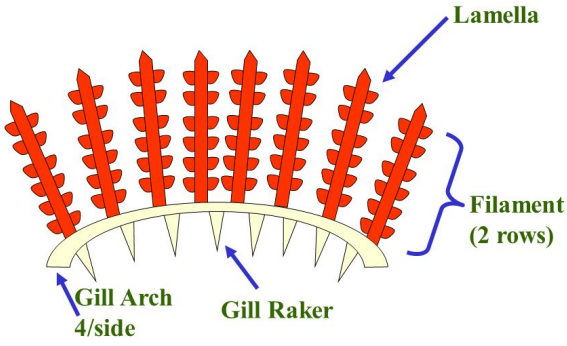
- Branchial arches or Gill arches are a series of bony "loops" present in fish that support the gills.
- Bony fishes have 4 pairs of arches, cartilaginous fishes have 5-7 pairs and primitive jawless fishes have 7 pairs.

2. Gill Raker:

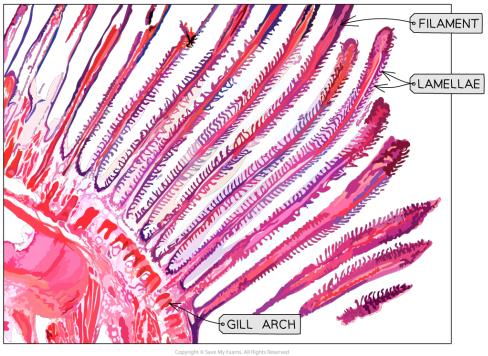
- It occurs in two rows on the inner margin of each gill arch. Each gill arch is a short stumpy structure supported by bony elements
- Gill rakers in fish are bony or cartilaginous processes that project from the branchial arch (gill arch) and are involved with suspension-feeding tiny prey.
- The gill arch projects across the pharyngeal opening. They are modified in relation to food and feeding habits.







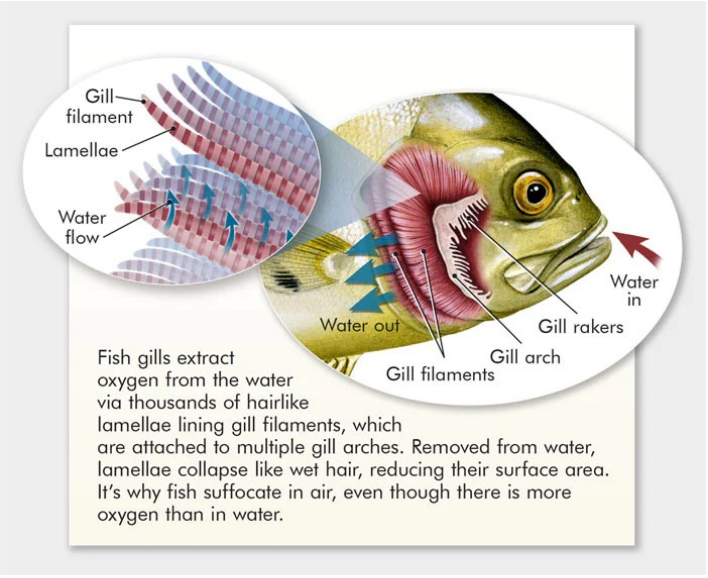
3. Gill Filaments/Primary Gill Lamellae:



- Each gill arch bears two rows of feathery filamentous structures called gill filaments (V shape). They provide a large surface area for gas exchange.
- Each filament comprises lamellae, which are flat, leaf-like structures that increase the surface area for gas exchange. A large surface area is crucial for gas exchange in aquatic organisms as water contains very little amount of dissolved oxygen.
- Lamellae have a rich supply of blood capillaries. Thus the barrier between the blood capillaries and the water is only a few cells thick.

4. Secondary lamellae:

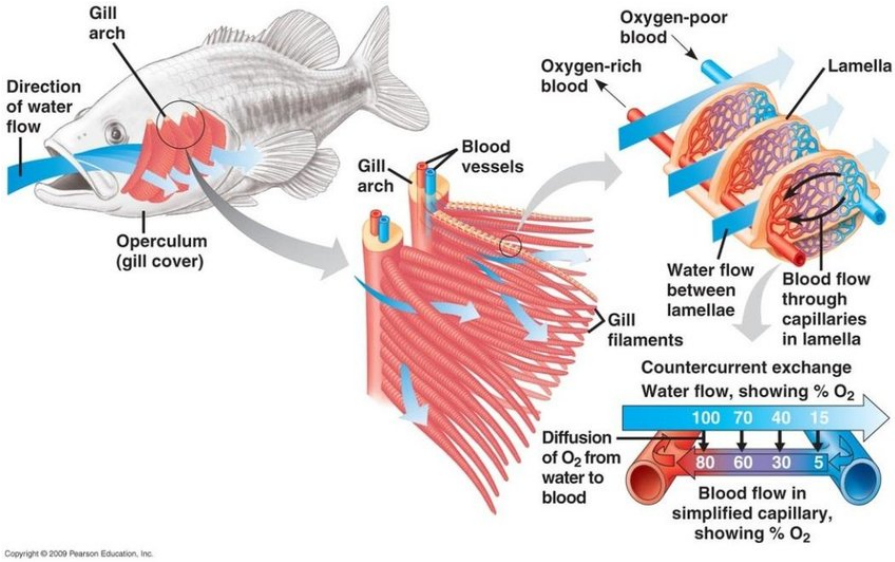
- Each gill filament (primary lamellae) bears a large number of secondary lamellae on both its sides.
- Gill lamellae are used to increase the surface area between the surface area in contact with the environment to maximize gas exchange (both to attain oxygen and to expel carbon dioxide) between the water and the blood.
- These are flat, leaf-like structures.
- Main seats of gaseous exchange.



Water enters the fish through the mouth and passes over the gills, while the gill filaments extract oxygen from the water and release carbon dioxide.

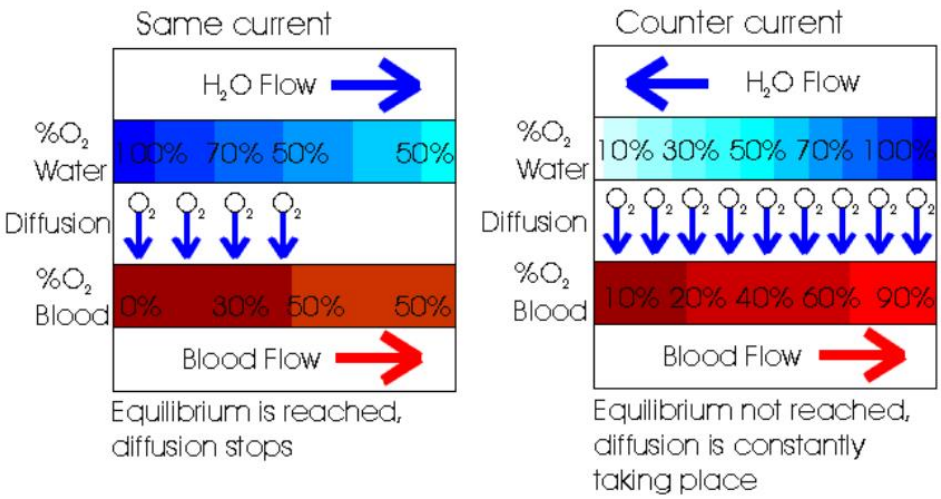
GAS EXCHANGE AT GILLS

- Fish gills use a design called **'counter-current oxygen exchange'.**
- The stream of water flowing over the gill and the stream of blood running within the gill flow in opposite directions to each other and this will help for the effective removal of oxygen and this is called **counter-current flow.**
- 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.
- This flow pattern ensures that as the blood progresses through the gills and gains oxygen from the water, it encounters increasingly fresh water with a higher oxygen concentration that can continuously offload oxygen into the blood.
- Oxygen in water flowing over the gill will diffuse from an area of high pressure into the blood, an area of low pressure until the oxygen content of both water and blood is equal. A countercurrent system places the water with the highest oxygen content in contact with the blood with the highest oxygen content and as blood and water flow through lamellae exchange occurs over the entire respiratory surface. This maintains the greatest pressure gradient possible over the entire blood/water interface maximizing the flow of oxygen into the blood.



- Counter-current oxygen exchange allows the blood to pick up 90% of the oxygen in the water.

Concurrent vs. Countercurrent



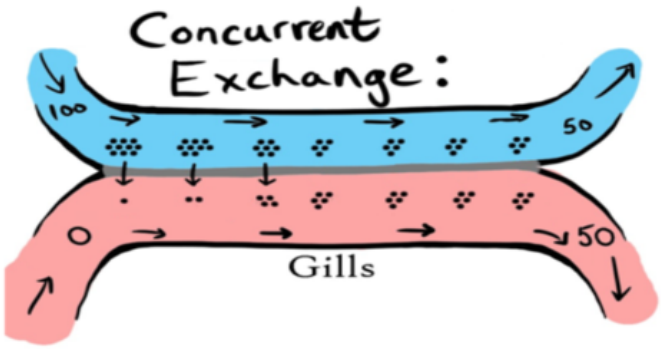
Even though the difference between the % of O2 in the oxygenated blood in the capillaries in the lamellae is never steep, the concentration of oxygen is always higher in the water, meaning that the oxygen will continue to diffuse into the blood capillaries across the whole of the gill

• **Concurrent vs Counter-current?**

Fish utilise a counter-current system to maximise the amount of oxygen that can extracted from water. Water has a much lower oxygen content than air and as such fish need a much more efficient system that can extract a much higher proportion of oxygen from the surrounding water.

CONCURRENT EXCHANGE:

If blood flowed through the lamellae in the same direction as the water passing over the gills, only 50% (maximum) of the available oxygen could be utilised. Oxygen would diffuse down its concentration gradient from an area of higher concentration (the water) to an area of lower concentration (the blood). However, as the water and blood continue to flow across the gas exchange surface an equilibrium would be reached with roughly equal concentrations of oxygen on either side of the gas exchange surface. At this point, there would be no net movement of oxygen as there is no longer a concentration gradient.



COUNTER CURRENT EXCHANGE:

In reality, the blood flowing through lamellae travels in the opposite direction to the water passing over the gills. This ensures that a concentration gradient is maintained across the entire gas exchange surface. Oxygen-deficient blood entering the gills is exposed to oxygen-poor water that is about to leave the gills. Because this water still has slightly more oxygen than the neighbouring blood oxygen diffuses into the blood. As blood flows through the gills it continues to 'pick up' oxygen. As the blood oxygen concentration increases the blood also continues to encounter water with an even higher concentration of oxygen and thus a concentration gradient is maintained. Oxygen-rich blood that is about to leave the gills (to go to respiring body cells) encounters the most oxygen-rich water (water that has just entered the gills). This is much more efficient and allows a much higher proportion of the dissolved oxygen in water to be absorbed.