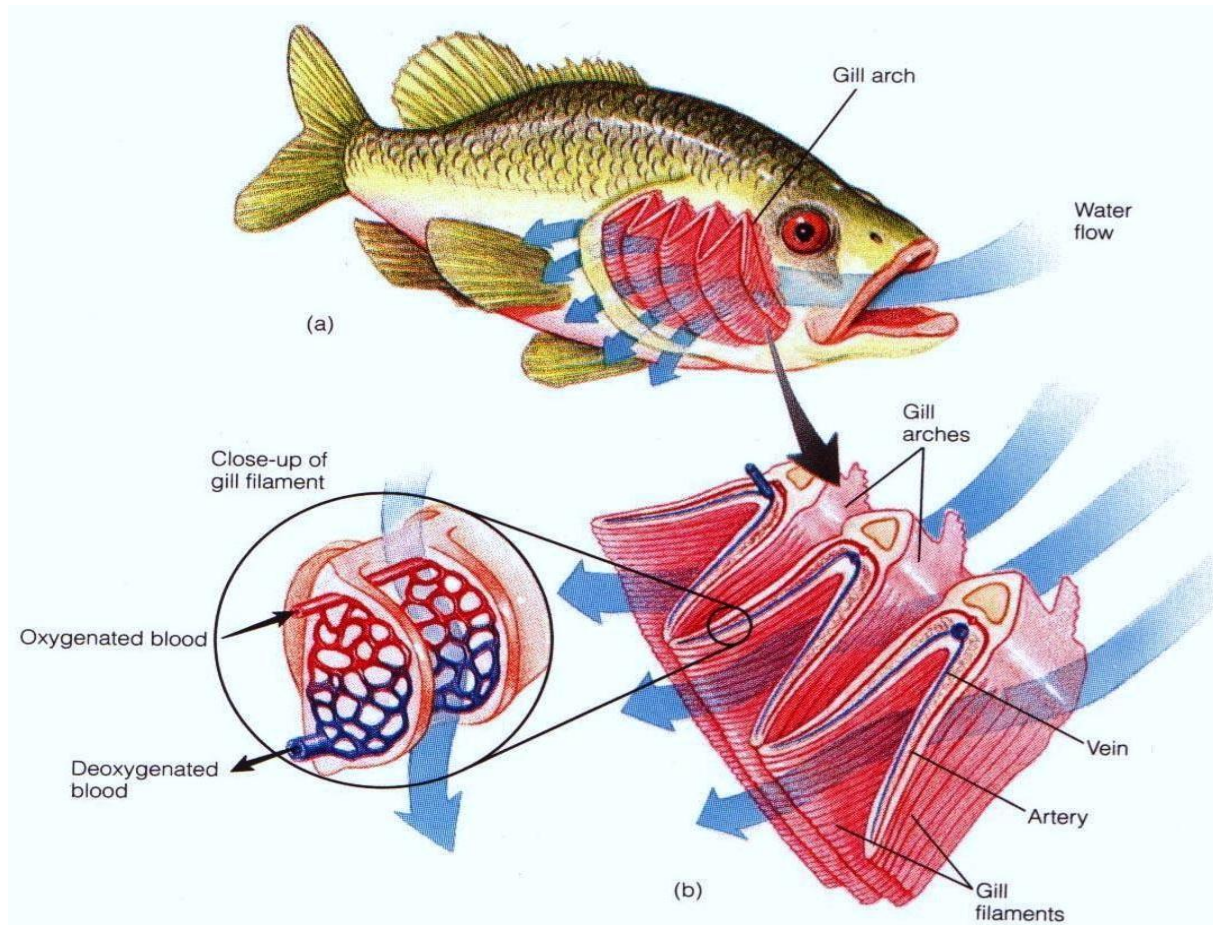


Respiratory System in Finfishes



Gas Exchange The transfer of oxygen (O₂), carbon-di-oxide (CO₂) and to a lesser extend, ammonia (NH₃) between the environment and the cell/tissue site of use or production

Respiration Intake of oxygen (O₂) for metabolism/energy production and **release** of carbon-di-oxide (CO₂) into the environment as a end product of metabolism

Aerobic Respiration



Anaerobic Respiration

Alcohol Fermentation



Lactic Acid Fermentation

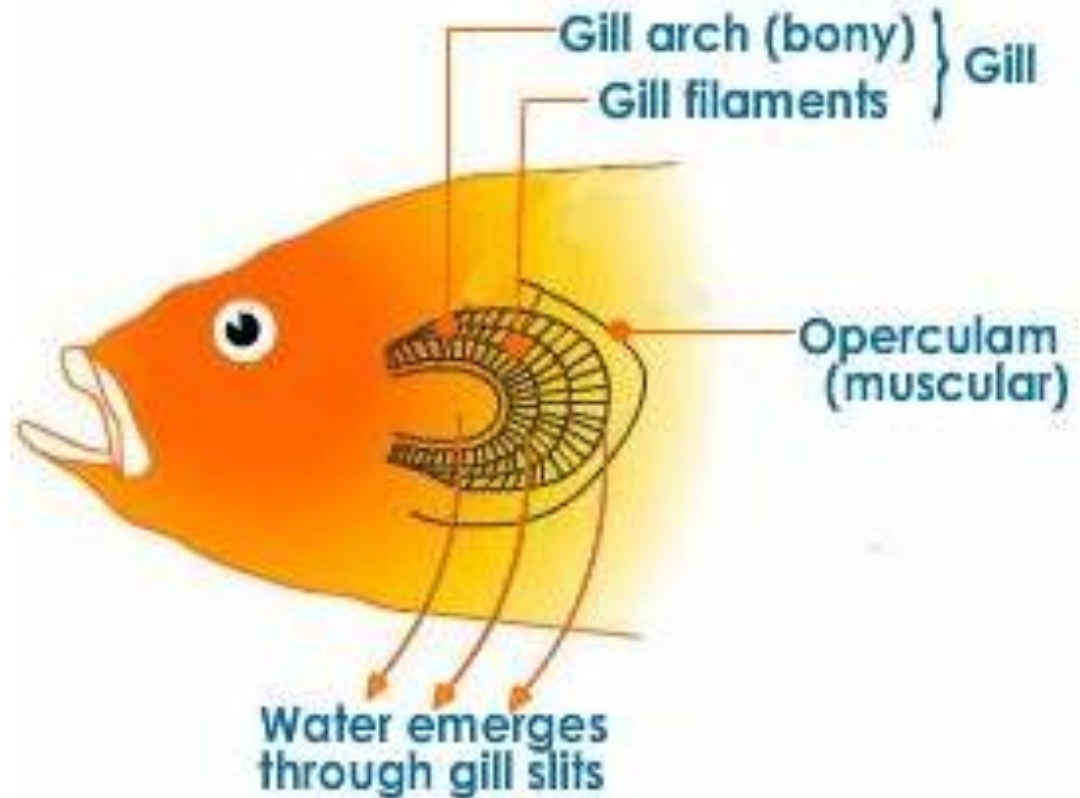


Respiratory Organs in Fishes

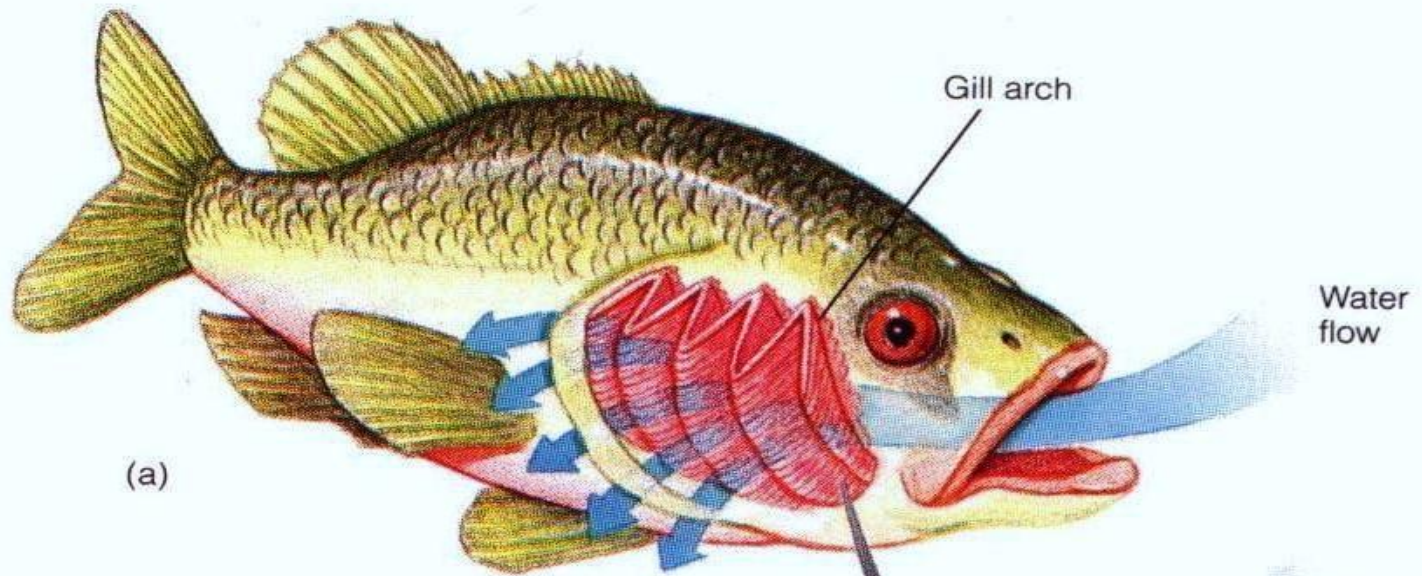
- ✓ **The gills are the main organ by which gases are exchanged between the fish and the surrounding water**
- ✓ **Through the gills, fish are able to absorb oxygen and give off carbon dioxide**
- ✓ **Like the lungs, the gills have a large area for gaseous exchange**
- ✓ **Some species have altered gills and other organs so that they can take atmospheric air and extract the oxygen like skin, air bladder etc**

Structure of Bony fish gill

The region between the buccal cavity (mouth) and the oesophagus is called the pharynx. In the pharyngeal region, the wall on either side shows slits which open to the exterior. These slits are called the gill slits. The gill slits are separated by a tissue called the gill arch or the branchial arch.



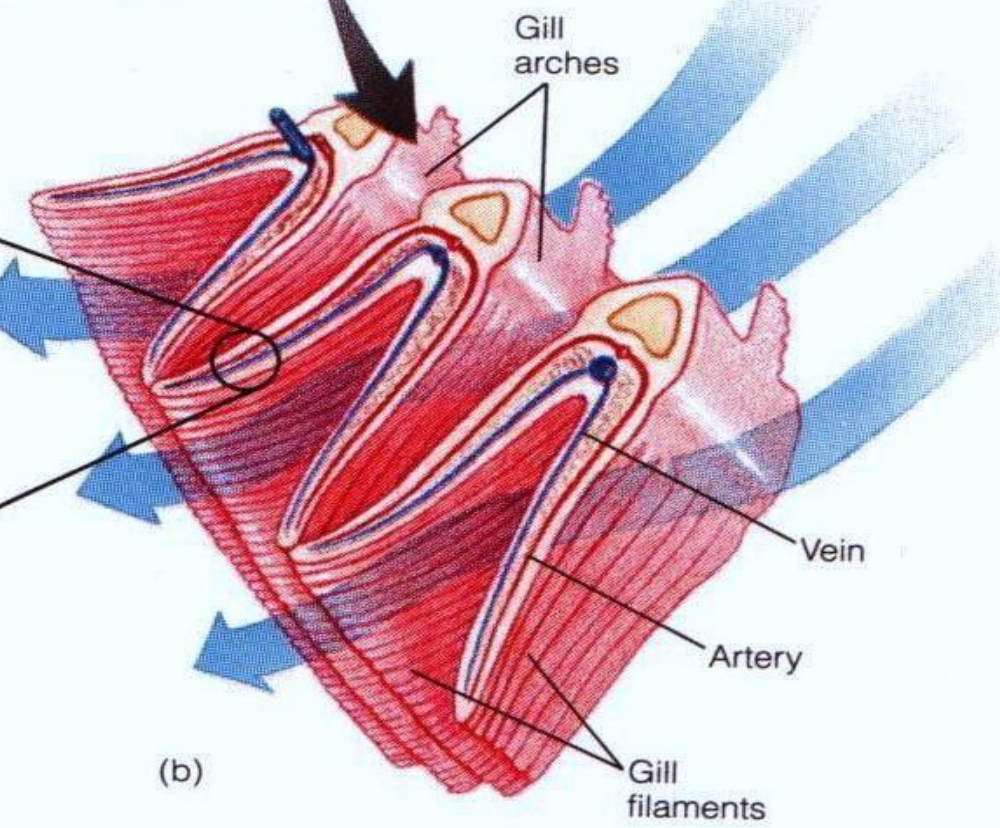
- ✓ **Gills are formed by filamentous outgrowth from the anterior and posterior wall of each gill slit**
- ✓ **Gill arch bears two rows of gill filaments (V shape) forms a complete gill or holobranch. Individual row is called hemibranch**
- ✓ **Most teleost have four holobranches (8 hemibranches) on 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**



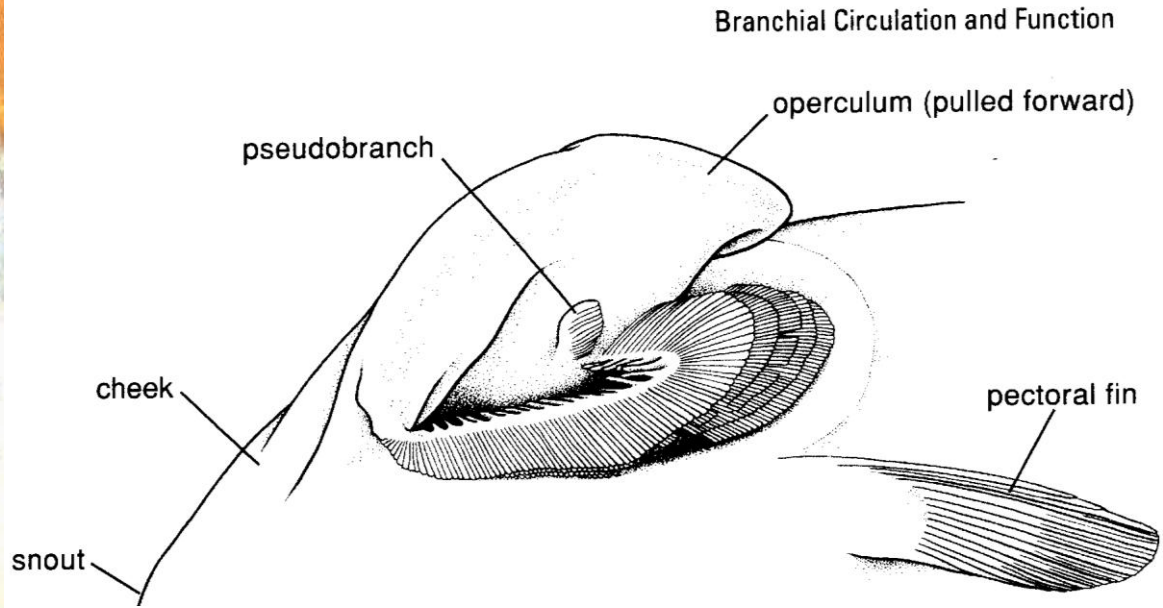
Close-up of gill filament

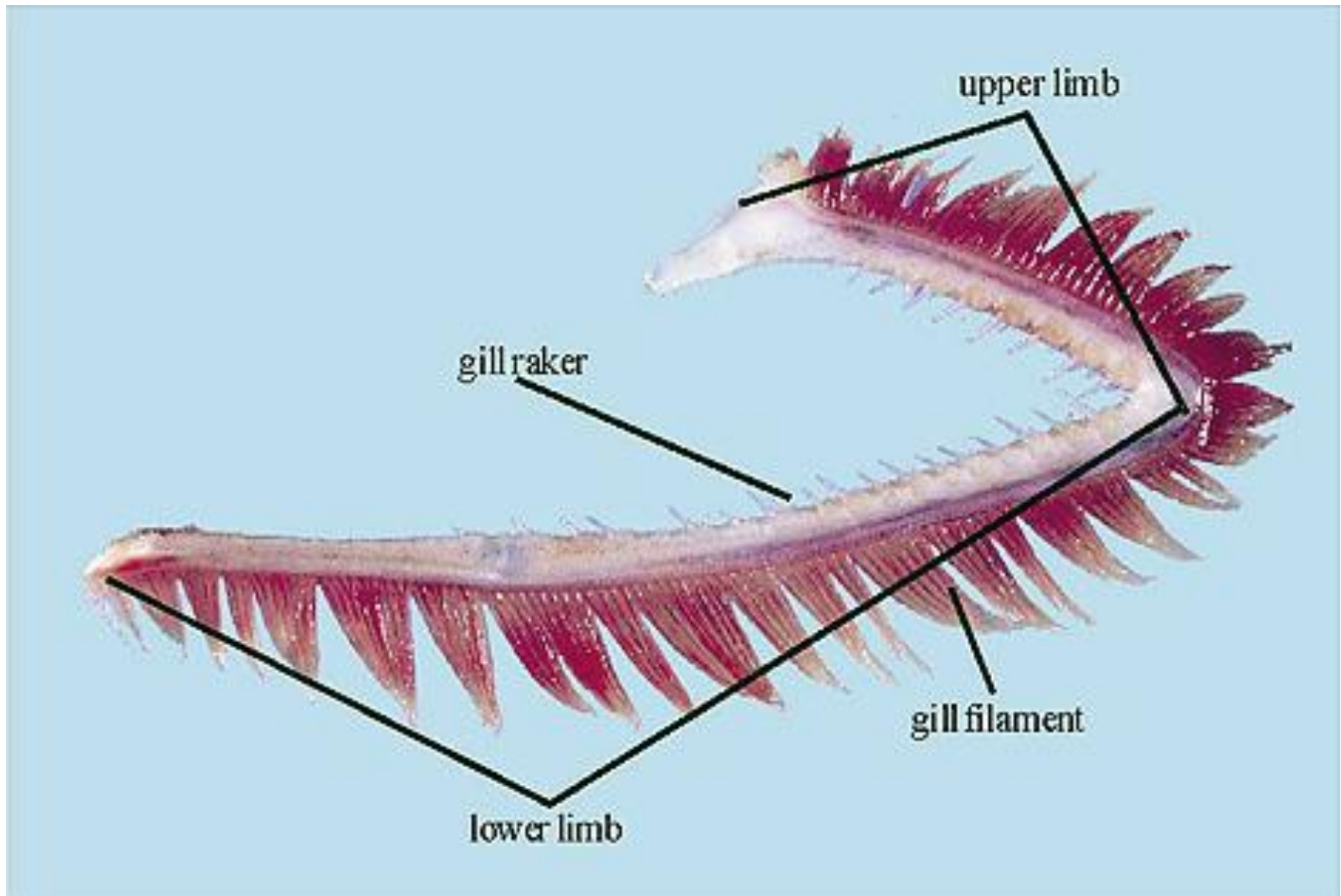
Oxygenated blood

Deoxygenated blood



Teleost gill structure



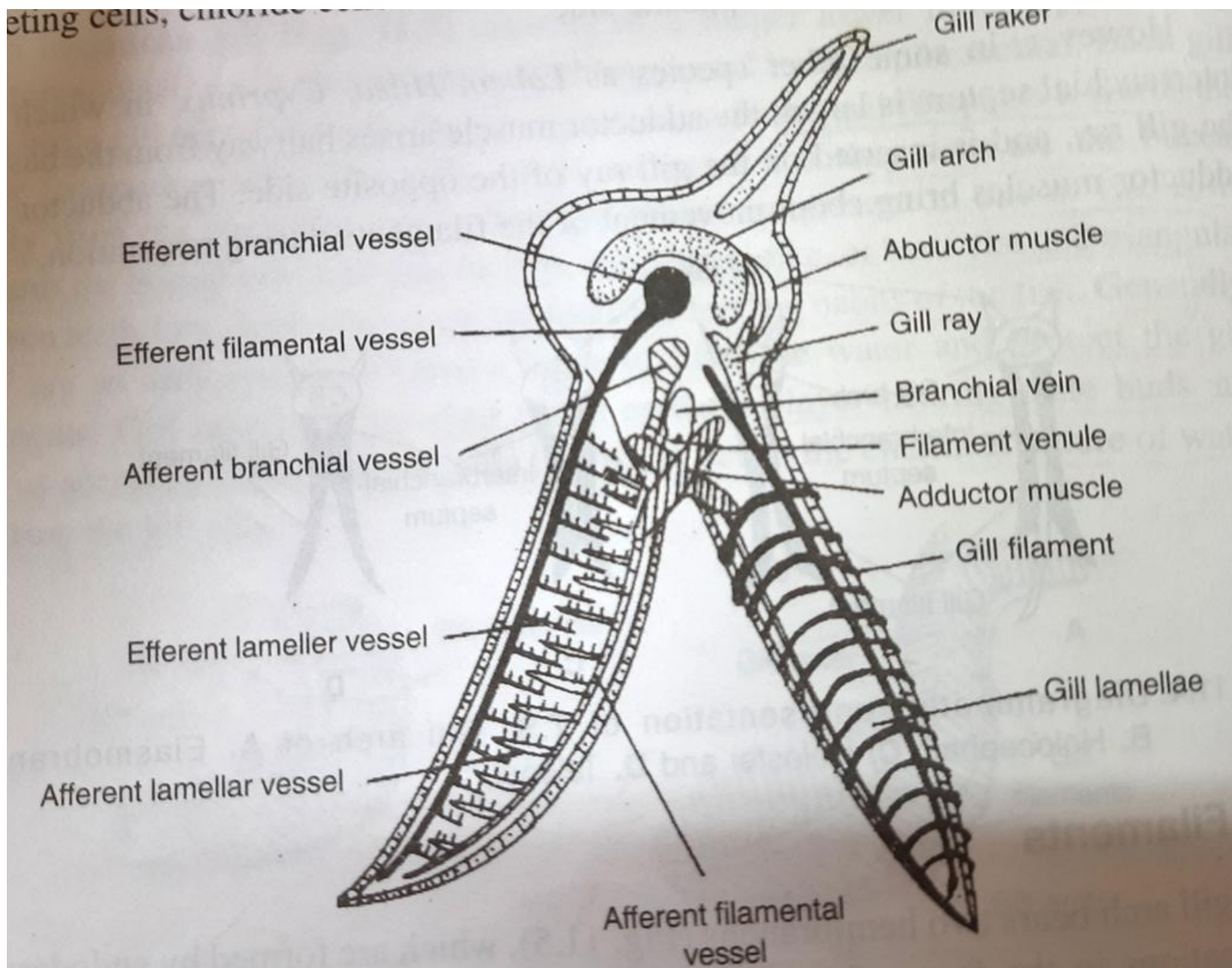


Anatomy of Teleost Gill

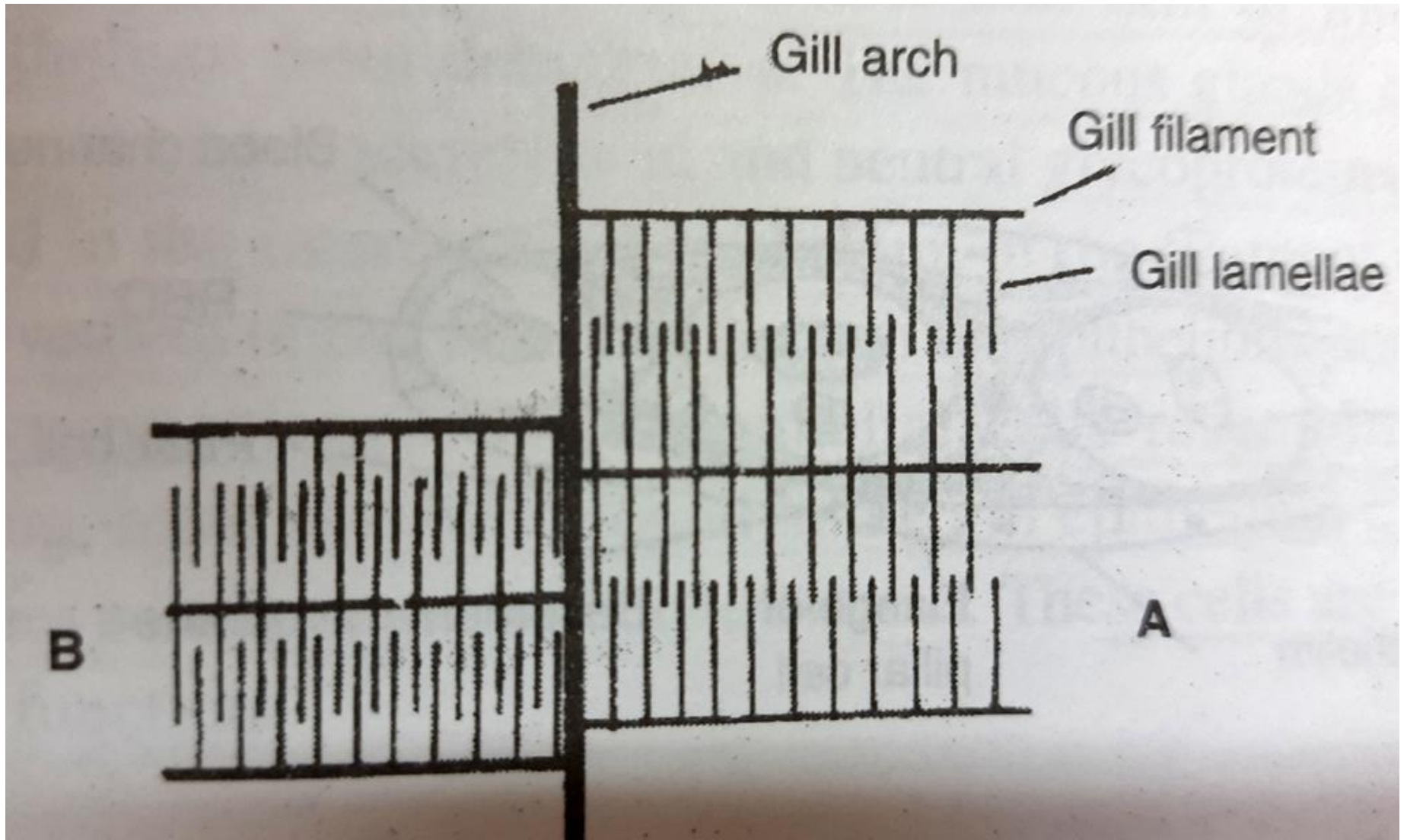
T. S. Gill of a teleost

Arrangement of Gill filaments and lamellae

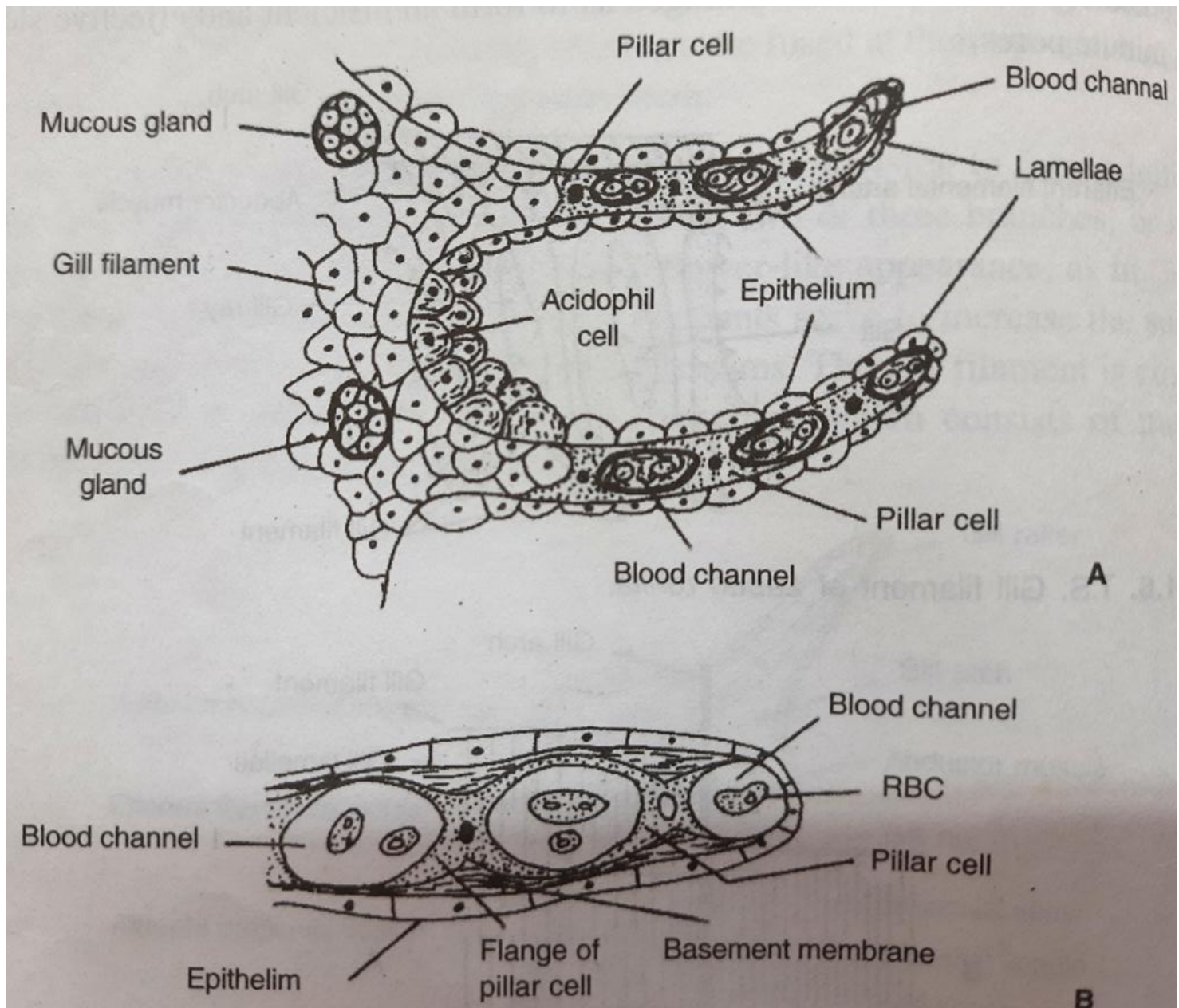
Structure of gill lamellae (pillar cells)



T. S. Gill of a teleost

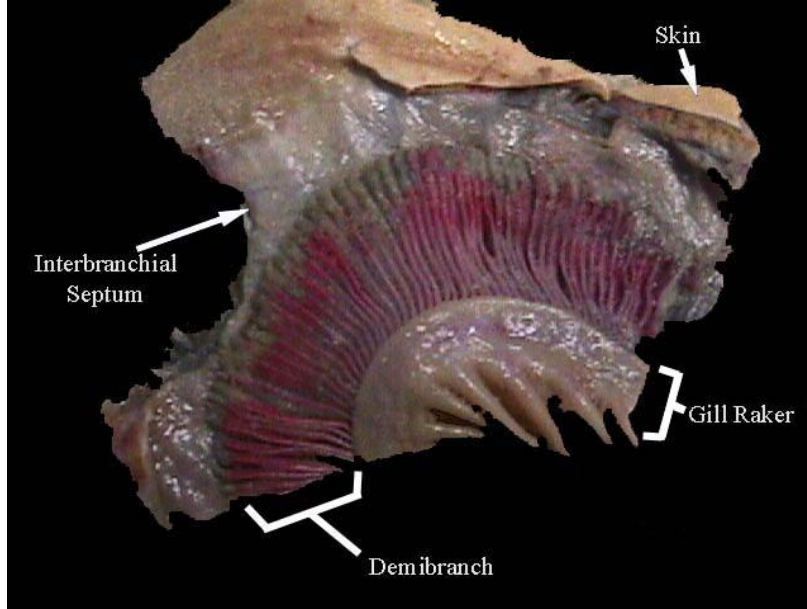


Arrangement of Gill filaments and lamellae



Structure of gill lamellae (pillar cells)

Shark gill structure



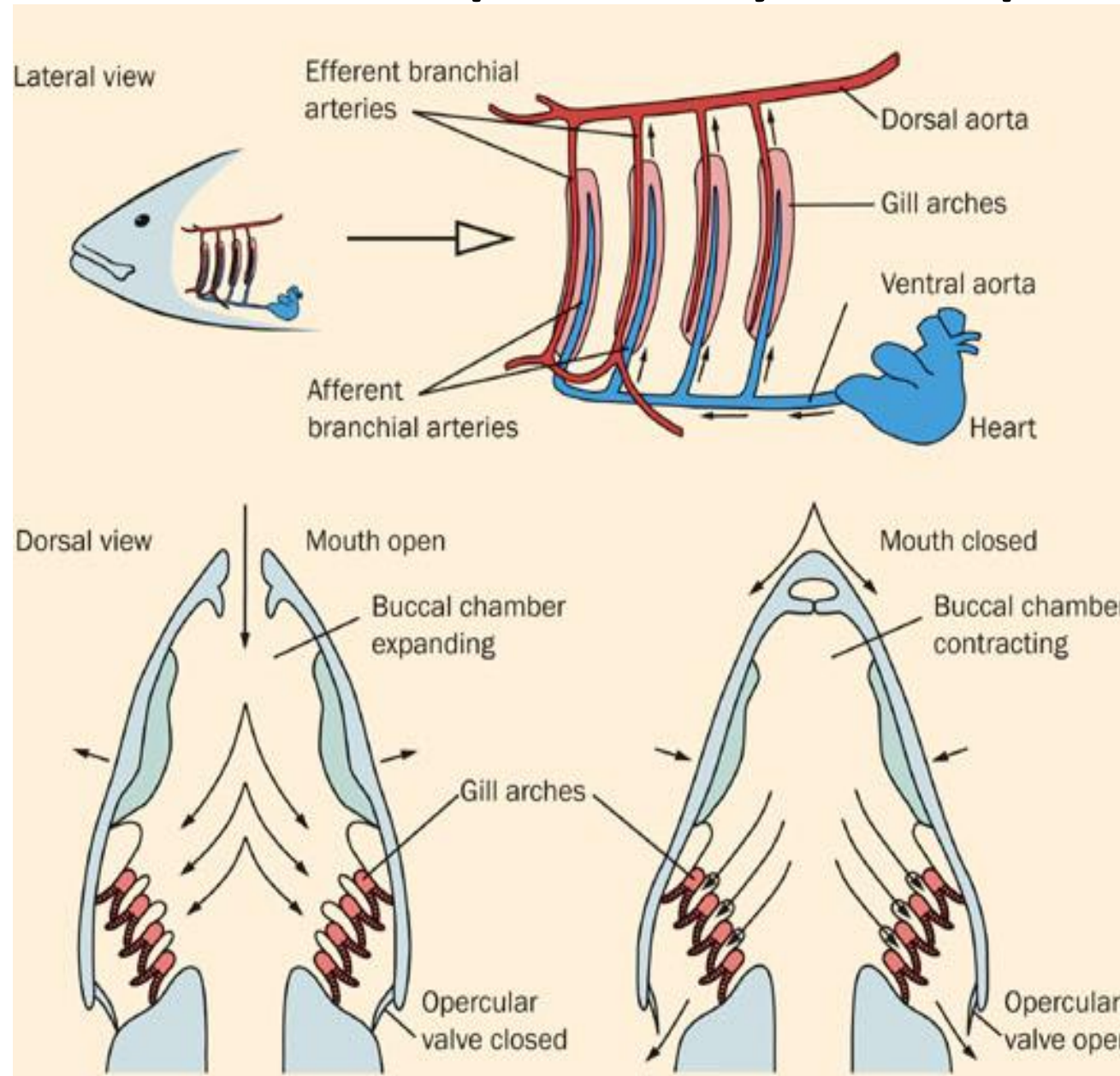
**Five pairs of
holobranches**

Respiratory Pump in Fish

Fish need a more efficient method than terrestrial animals

- + Unidirectional system, water always moves one way across gills and out operculum
- + No mixing of fresh and respired water maintaining highest possible P_{O_2} at gill surface

Respiratory Pump in Fish



Dual Pump

Phase I

Expansion of buccal and opercular cavities while opercula are closed

Phase II

Mouth closes, opercula open, forcing water across gills

Counter Current Exchange

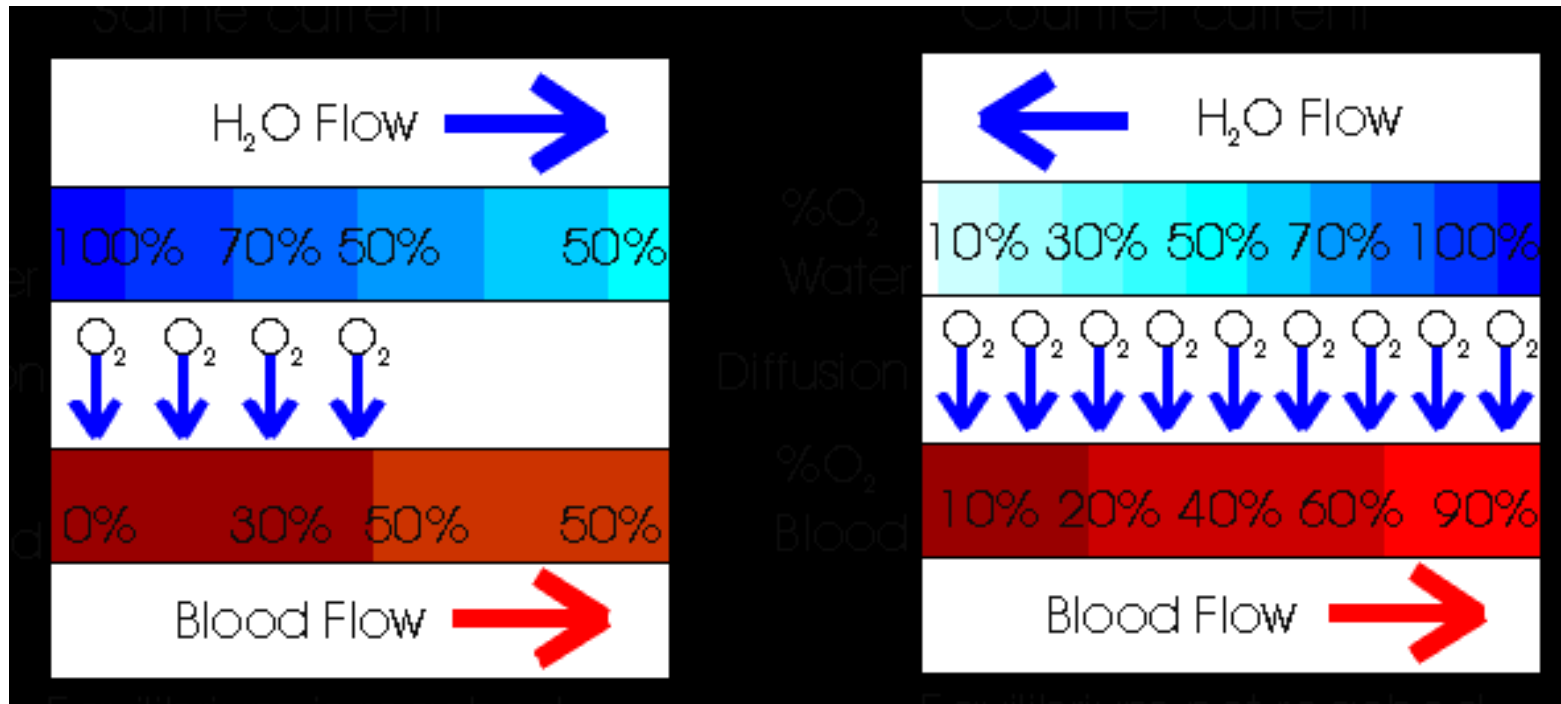
The gills of fish utilize counter-current flow, a very effective mechanism for removing the maximum amount of oxygen from the water flowing over them

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)

Counter Current Exchange



Blood flows through gill tissue in the opposite direction of water

If blood flow were in same direction then blood would only be able to get half of available oxygen

With blood flow opposite the gradient is always such that oxygen will pass to the blood

This gives fish 80 – 90% efficiency in acquiring oxygen

✓ Blood flows across each lamella within a dense network of capillaries. Within each lamella, counter-current flow enhances diffusion by maintaining a concentration gradient of oxygen between the water (which is relatively high in oxygen) and the blood (lower in oxygen). Water is deflected over the lamellae in a direction opposite the flow of blood in the capillaries.

✓ Counter-current flow is so effective that some fish extract 85% of the oxygen from the water that flows over their gills.

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

Efferent branchial vessel collect oxygenated blood

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 O₂ and to remove the CO₂ produced by cellular metabolism**
- **Blood carries O₂ to the tissue and remove CO₂ 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 O₂ carrying capacity of blood up to 20 folds in comparison to physically dissolved O₂**
- **H⁺ binding capacity of Hemoglobin also help in transportation of CO₂**

Hemoglobin

- ✓ Hemoglobin is a **tetrameric** molecule in most teleost fishes
- ✓ Agnathans (lampreys & Hag fishes) possess **monomeric** hemoglobin
- ✓ Antarctic fishes (Ice fish) **do not have hemoglobin**



Teleost



Hag Fish



Ice Fish

Hemoglobin

- ✓ Tetrameric hemoglobin has two α and two β chain
- ✓ O_2 bind in reversible and cooperative fashion to four heme group while H^+ and CO_2 bind to specific amino acid residues in the globin chains
- ✓ But in fishes, due to acetylation of α amino group only β chain available in bind to CO_2

