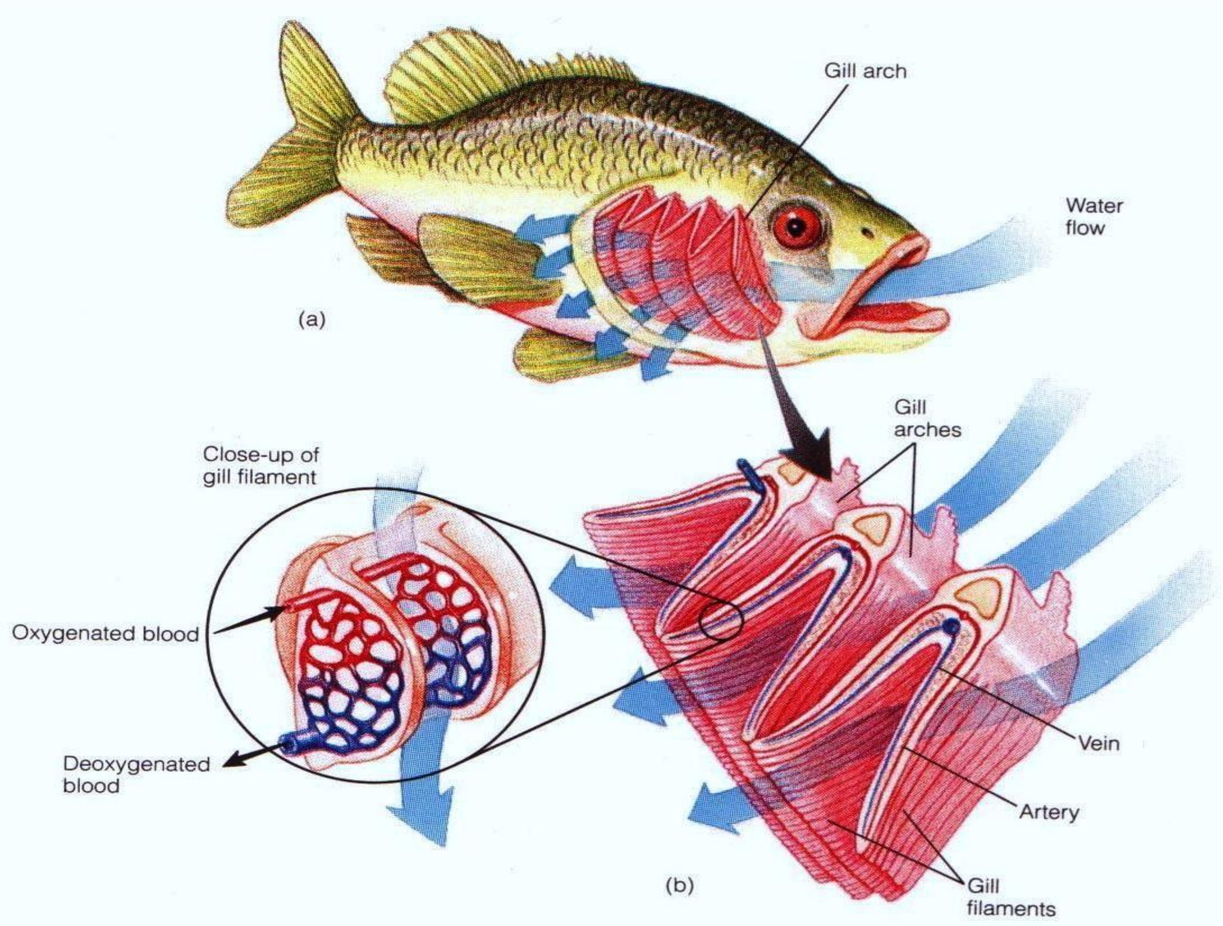
Respiratory System in Finfishes



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 **Intake** of oxygen (O_2) for metabolism/energy production and **release** of carbon-di-oxide (CO_2) into the environment as a end product of metabolism

Aerobic Respiration

$$C_6H_{12}O_6 + 60_2 = 6CO_2 + 6H_2O + 32\ ATP$$

Anaerobic Respiration

Alcohol Fermentation

$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2 + 2\ ATP$$

Lactic Acid Fermentation

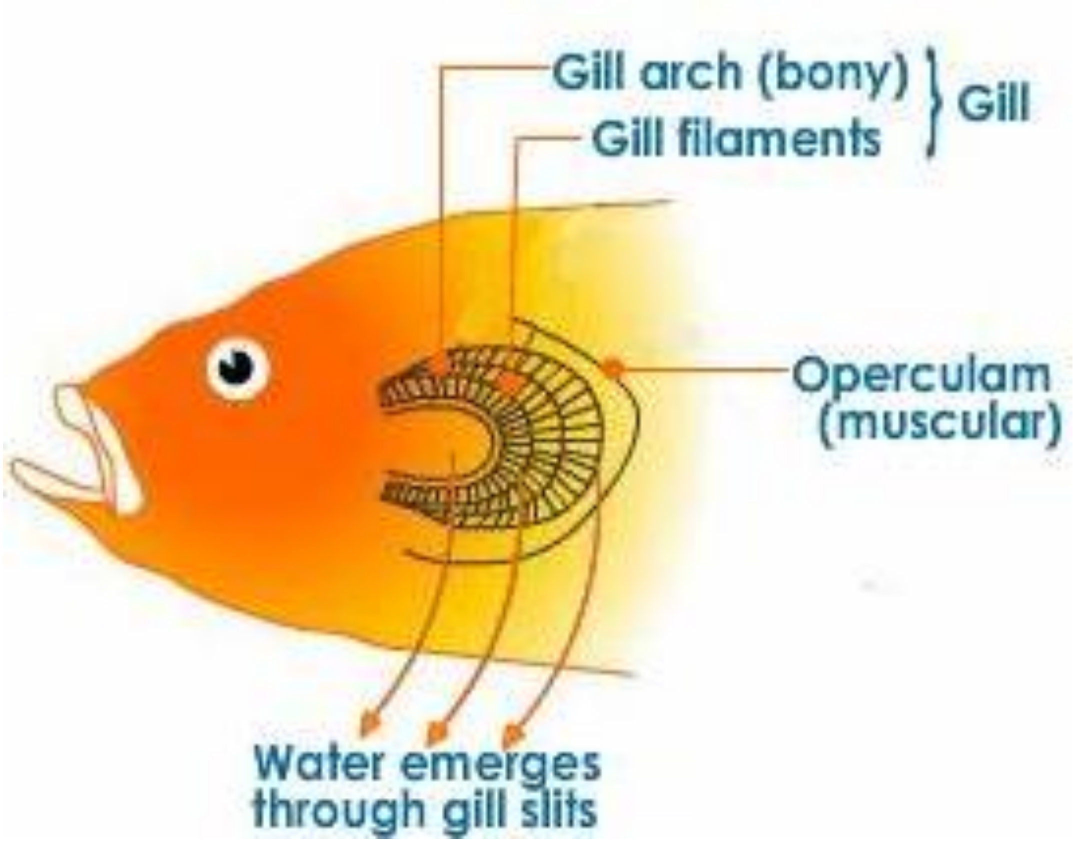
$$C_6H_{12}O_6 \rightarrow C_3H_6O_3 + 2\ ATP$$

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.



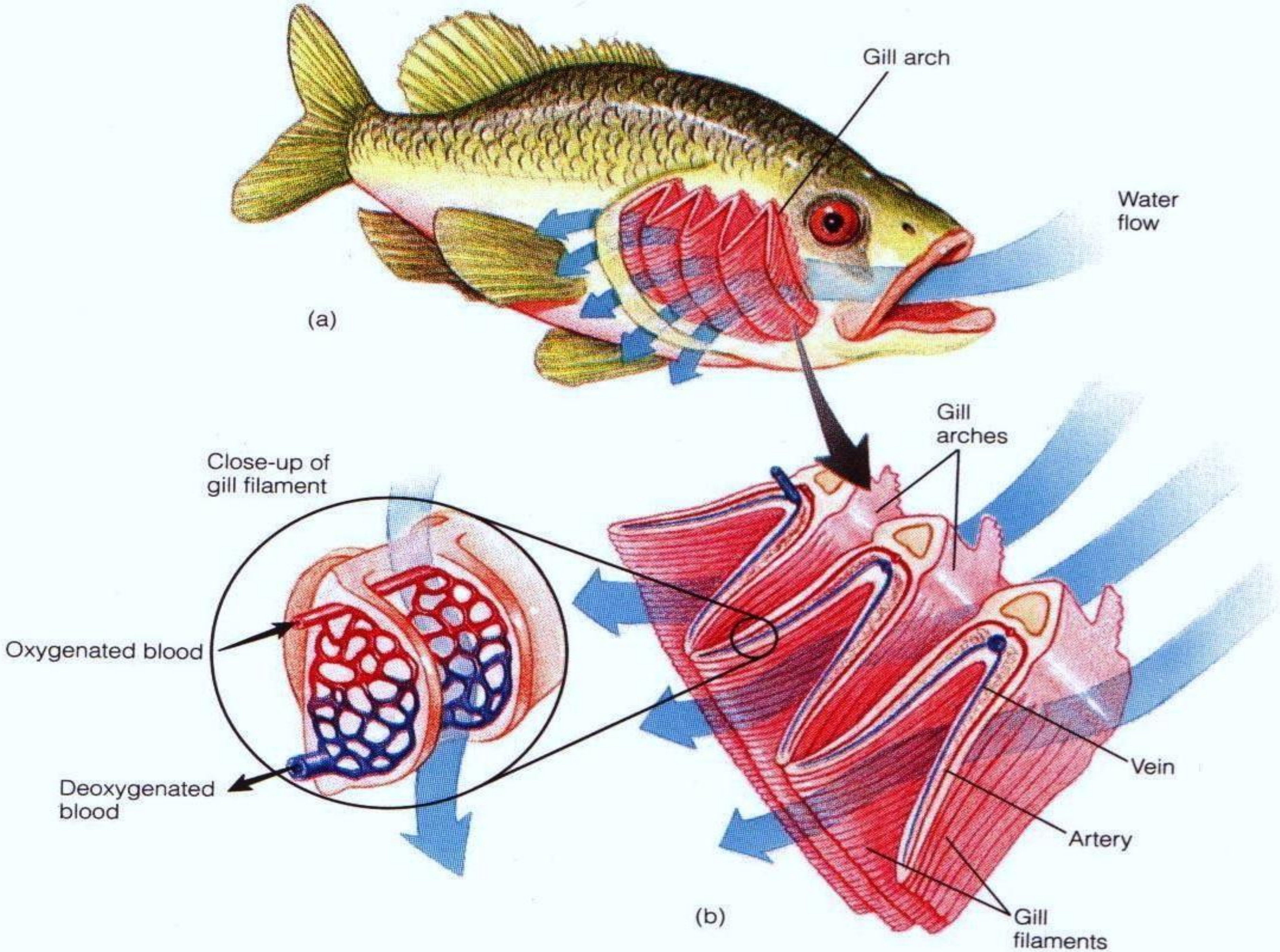
- ✓**Gills are formed by filamentous outgrowth from the anterior and posterior wall of each gill silt**

- ✓**Gill arch bears two rows of gill filaments (V shape) forms a complete gill or holobranch. Individual row is called hemibranch**

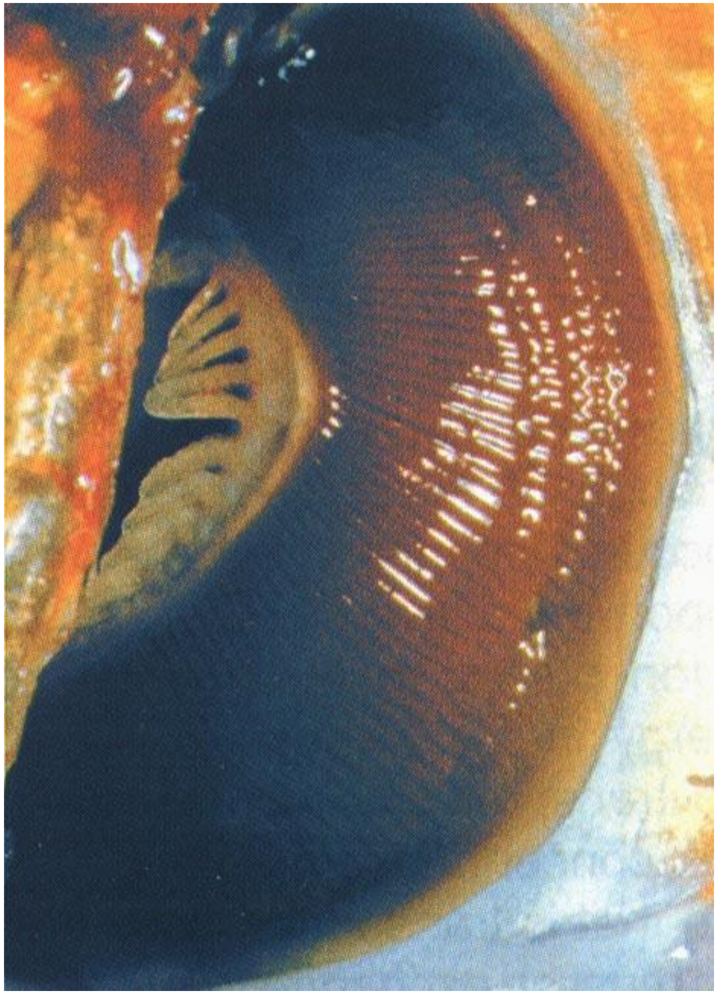
- ✓**Most teleost have four holobranches (8 hemibranches) on each side while elasmobranchs have five holbranchs (10 hemibranches) on each side**

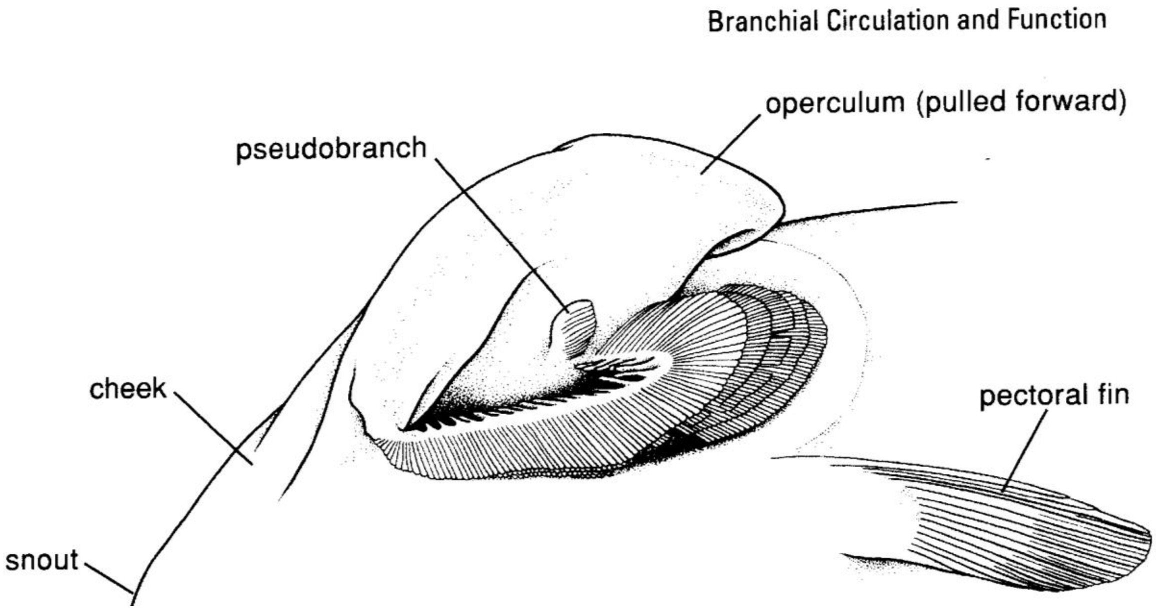
- ✓**Gill arch bears gill rakers towards the inner (buccal) side and gill filaments towards the outer (opercular) side**

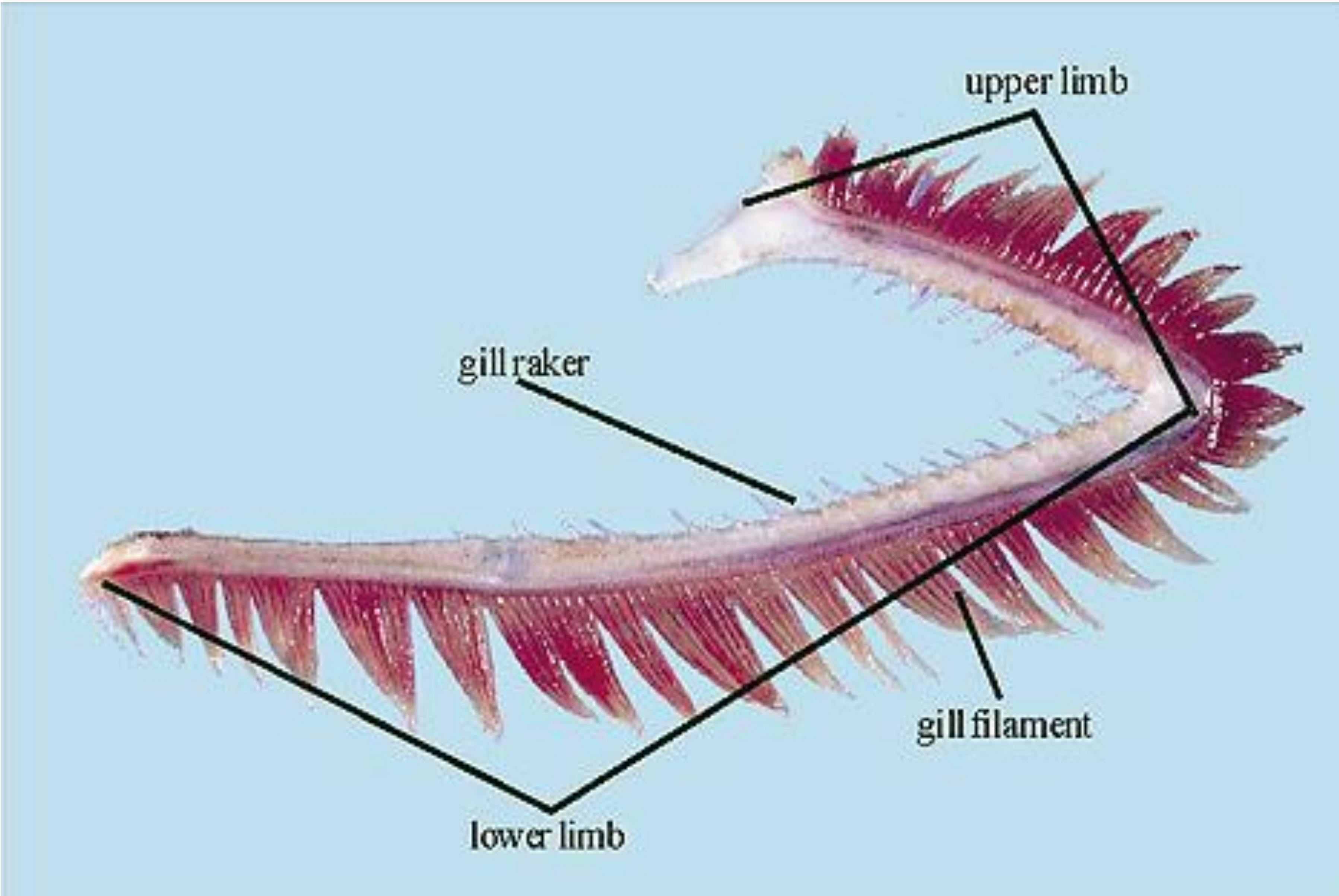
- ✓**Gill rakers are covered by an epithelial layer bearing taste buds and mucus secreting cells**


Gill arch
Water flow
(a)
Gill arches
Close-up of gill filament
Oxygenated blood
Deoxygenated blood
Vein
Artery
Gill filaments
(b)

Teleost gill structure







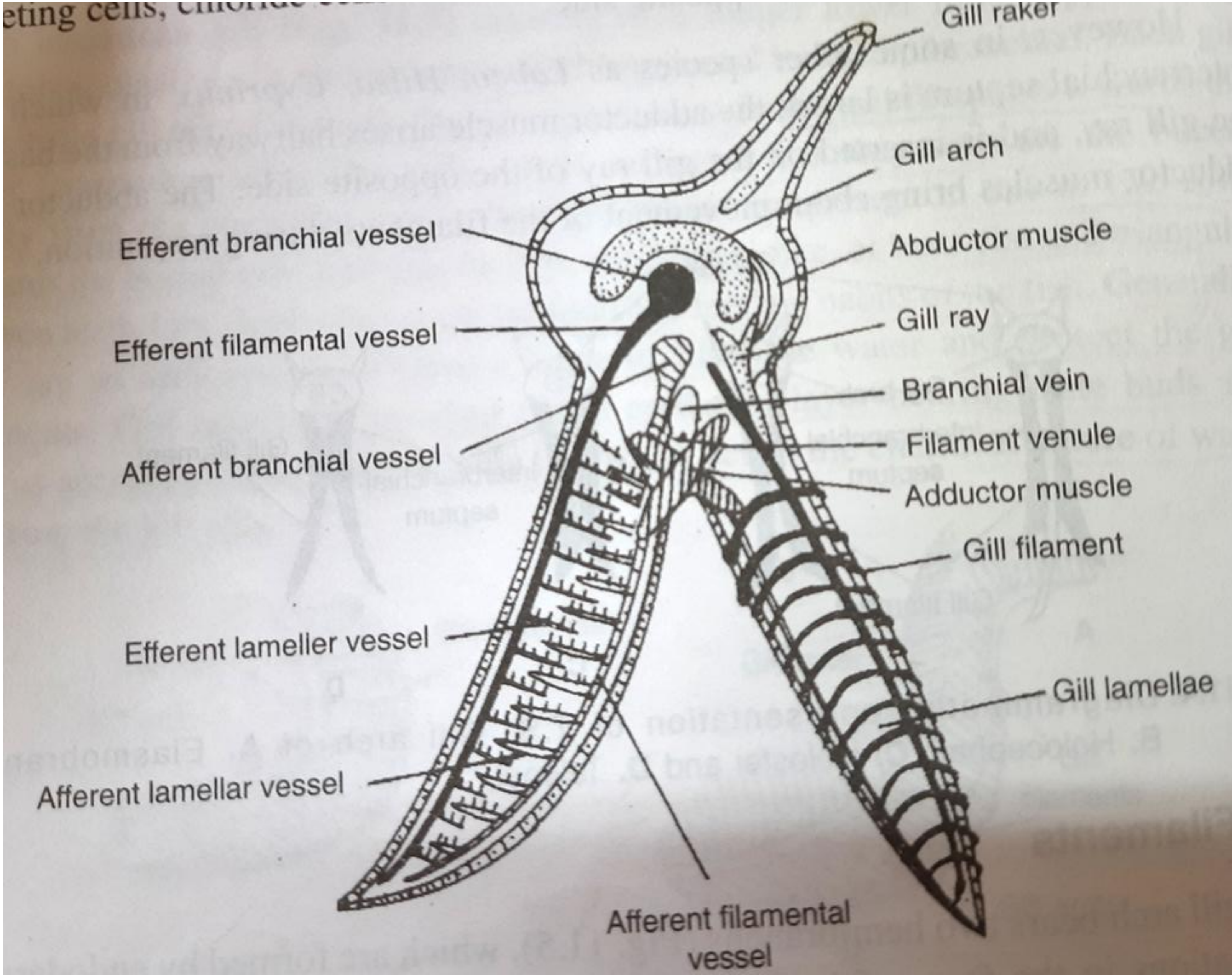
upper limb
gill raker
gill filament
lower limb

Anatomy of Teleost Gill

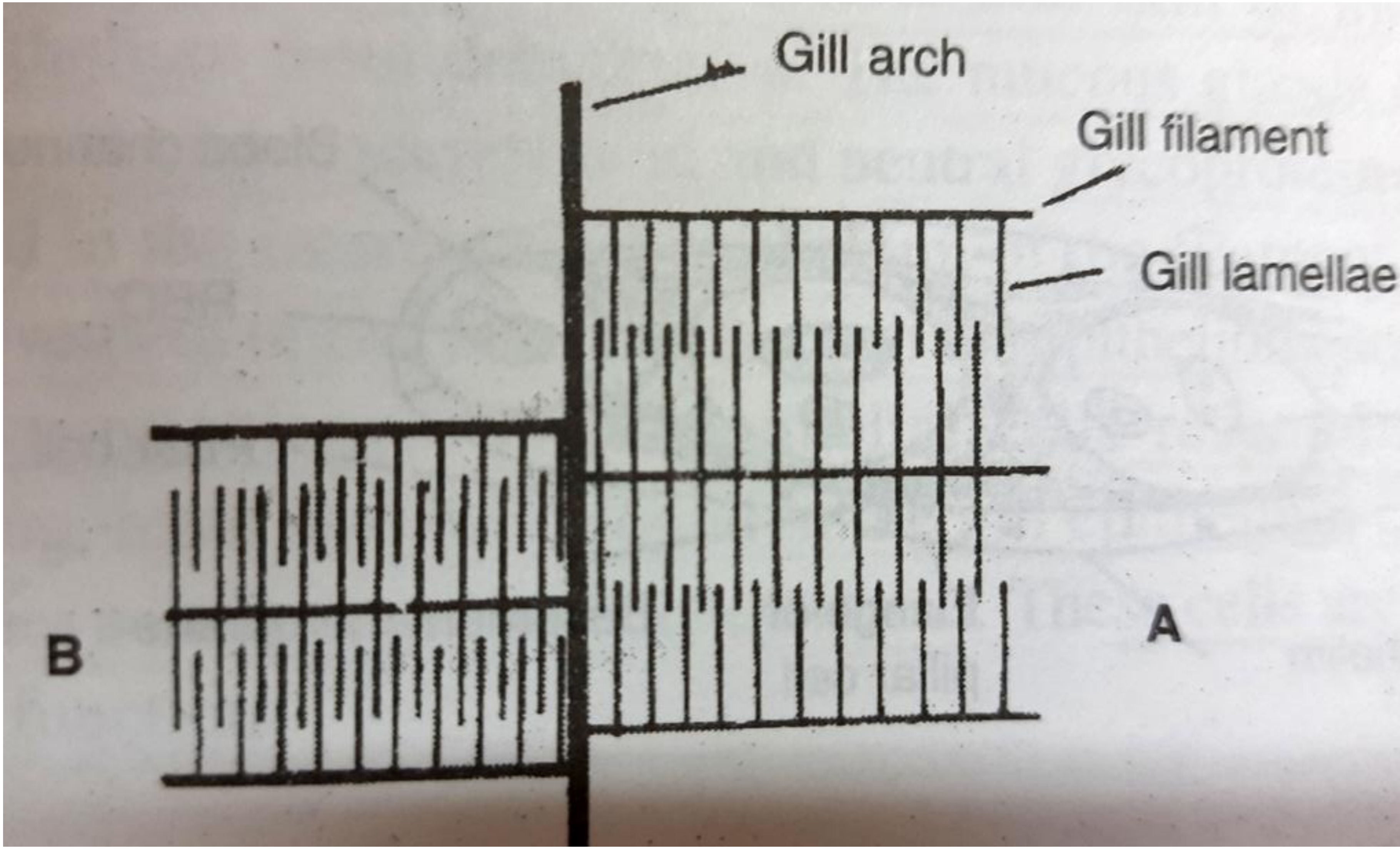
T. S. Gill of a teleost

Arrangement of Gill filaments and lamellae

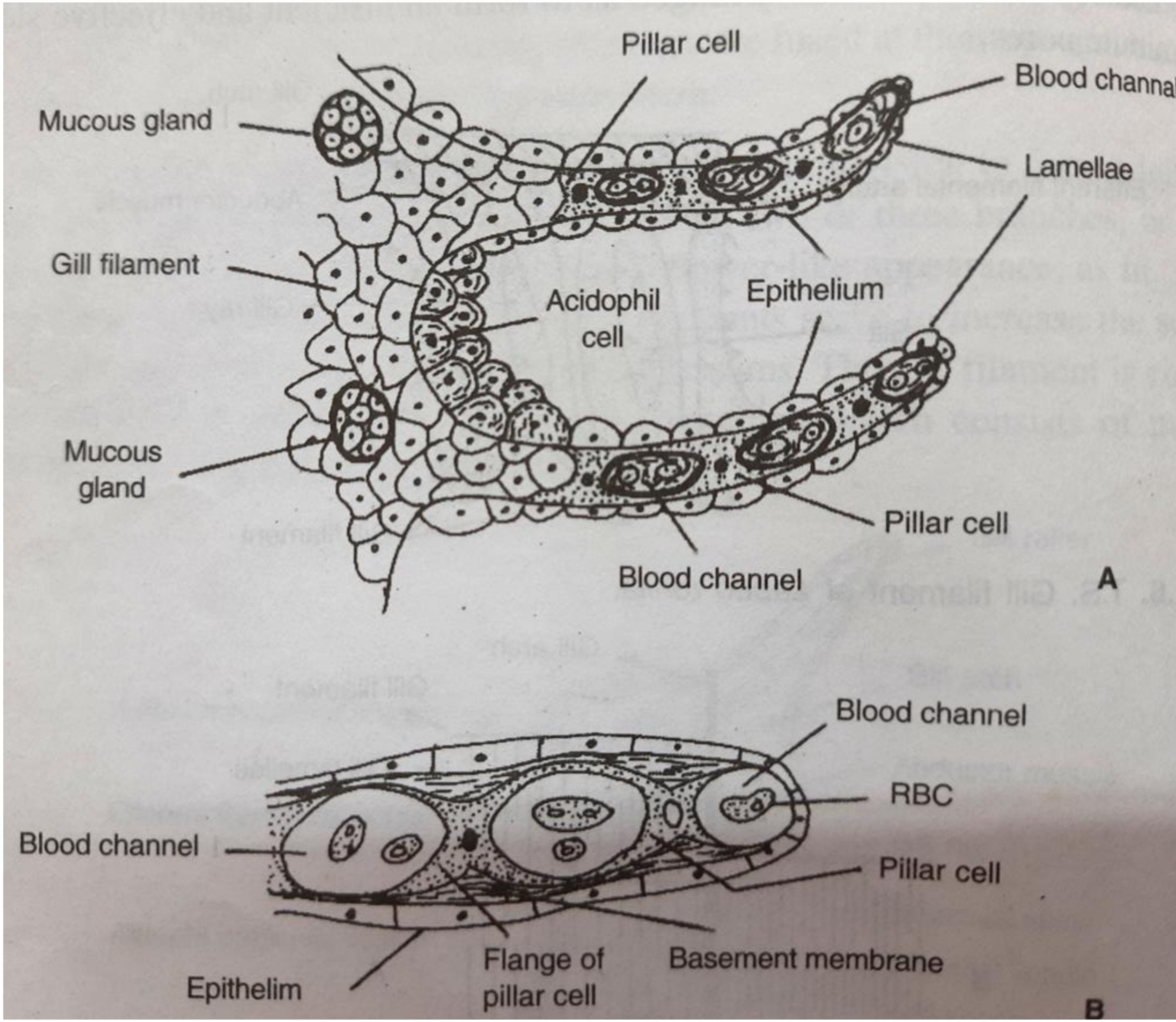
Structure of gill lamellae (pillar cells)



T. S. Gill of a teleost

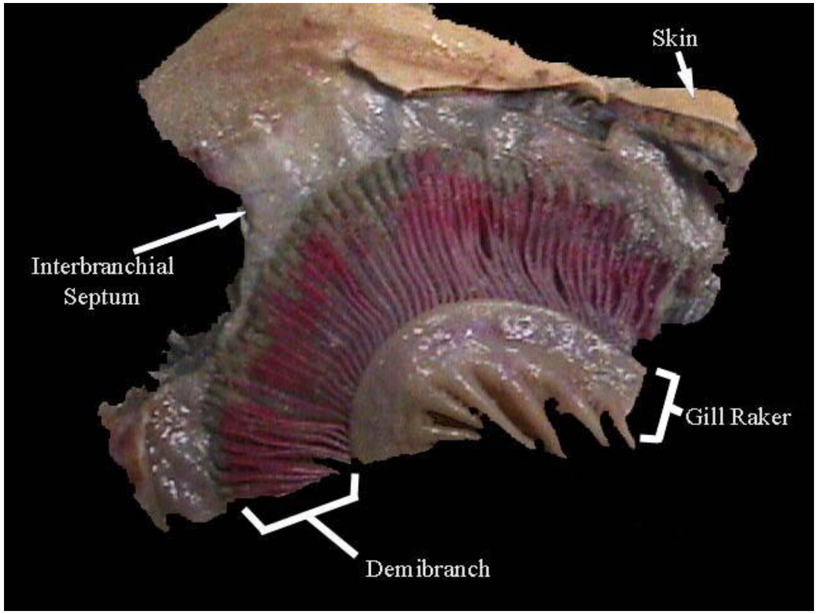


Arrangement of Gill filaments and lamellae



Structure of gill lamellae (pillar cells)

Shark gill structure



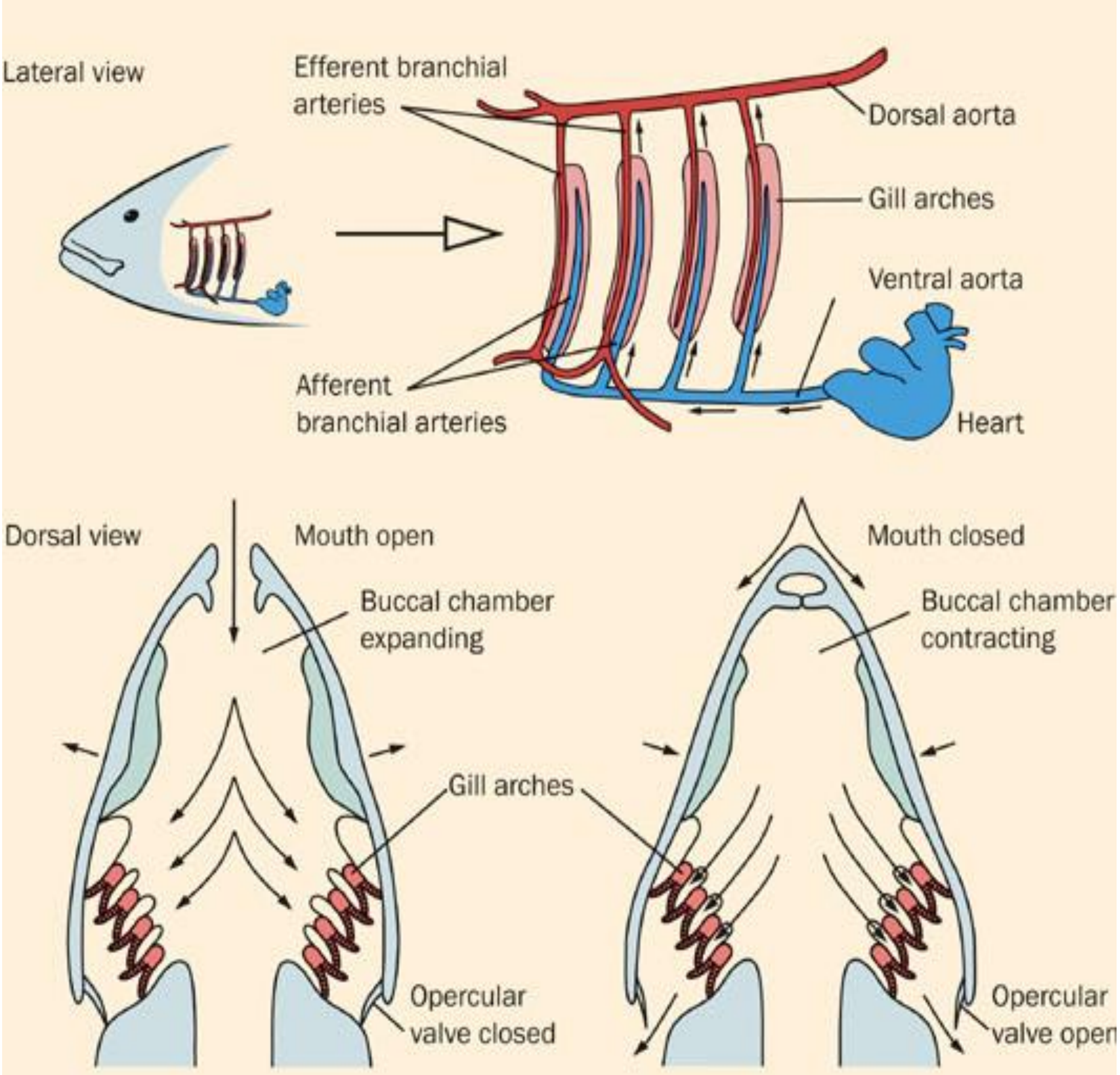
Five pairs of holobranches

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_{O2} at gill surface

Respiratory Pump in Fish



Dual Pump

<u>Phase I</u>

Expansion of buccal and opercular cavities while opercula are closed

<u>Phase II</u>

Mouth closes, opercula open, forcing water across gills

Counter Current Exchange

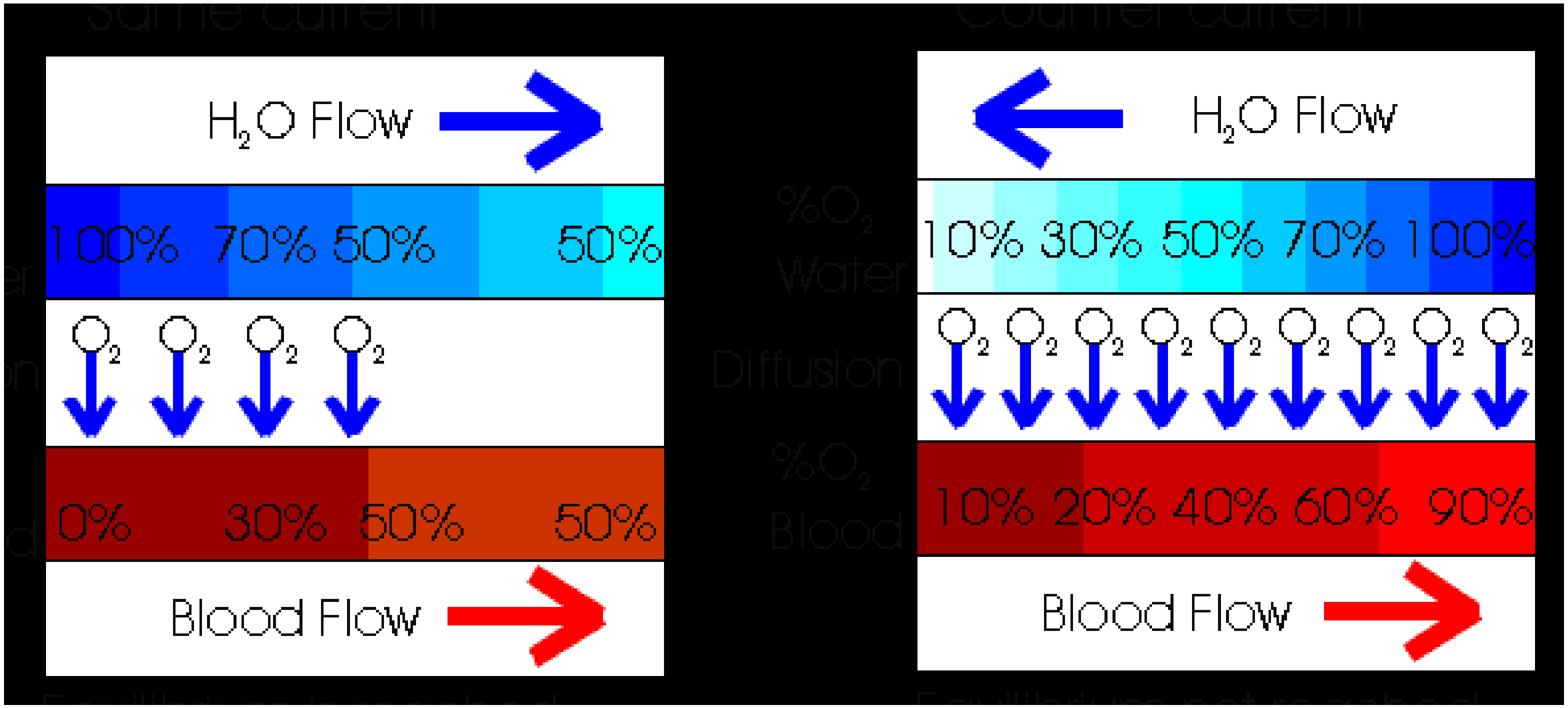
The gills of fish utilize counter-current flow, a very effective mechanism for removing the maximum amount of oxygen from the water flowing over them

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 deoxygnated 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 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 molecule in most teleost fishes
- ✓Agnathans (lampreys & Hag fishes) posses monomeric hemoglobin
- ✓Antartic 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