Gills in Vertebrates

Gills: Gills are specialized organs of respiration in aquatic animals. They are adapted to absorb dissolved oxygen from water. Gills consist of numerous thin walled, highly vascular rods or plates called gill filaments or gill lamellae that provide a large surface for respiratory exchange of gases.

There are two types of gills:

(a) Internal gills
(b) External gills

(a) **Internal gills:** Internal gills are made up of plate like structure called gill lamellae or rod-like structures called gill filaments. The gills that are formed of gill lamellae are called lamelliformes gills and in them the interbranchial septum extends beyond the gill lamellae. eg - in case of elasmobranchs. The gills that are formed of gill filaments are called filiform gills and in them the interbranchial septum is highly reduced eg in teleosts. Gill lamellae or filaments are generally present on both sides of the interbranchial septum (ie one on anterior side and the other on the posterior side) and less often on one side. Lamellae or filaments present on one side of the interbranchial septum form half gill or hemibranch where as two hemibranchs with their interbranchial septum constitute a complete gill or holobranch. A branchial cleft is, thus bound by two hemibranchs, belonging to different holobranchs.

For respiration with internal gills, water containing O_2 generally passes via mouth, buccal

Cavity, pharynx, internal gill slits into branchial or gill clefts and then over the gill lamellae or filaments. Here the lamellae or filaments absorb oxygen from H_2O and release CO_2 into it. The deoxygenated water then passes out through the external gill slits.

Internal gills in Cyclostomes:

In adult Lamprey, the pharynx, lies beneath the oesophagus and is closed from behind and has a curtain-like fold called velum on its anterior side. The lateral walls of the pharynx consist of 7 pairs of internal gill slits. These gill slits open into 7 pairs of gill clefts, and these gill clefts open outside by 7 pair of external gill slits.

Each cleft is bound by hemibranchs belonging to different holobranch (The interbranchial septum ~~has~~ contains lamellae generally on both sides. The lamella on one side forms the hemibranch + both the lamellae along with the interbranchial septum form the holobranch.

So, in case of lamprey, there are 6 holobranchs and 2 hemibranchs. One hemibranch is present on the anterior side of the pharynx and other present on the posterior side of the pharynx.

The lamprey draws fresh water into the gill cleft through external gill slits; water then passes over the gill lamellae, where exchange of gases takes place and the water containing CO_2 moves out through external gill slits.

Water does not enter through mouth

Internal gills in Fishes:

In fishes, the Ist gill cleft lies between the mandibular arch (i.e the Ist visceral arch) and the hyoid arch (IInd visceral arch). and is called hyomandibular cleft. It is either reduced or closed altogether and is called spiracle or oval pit. In Scoliodon, an elasmobranch, the oval pit or spiracle has no gill lamellae and no external opening and is closed. Thus it is regarded as a vestigeal gill cleft where as in other elasmobranchs, the spiracle has a rudimentary gill lamellae and also opens to the exterior and is thus called false gill or pseudobranch. These lamellae recieve oxygenated blood and are non respiratory i.e do not take part in exchange of gases & hence the name false gill is assigned to them. Thus, in fishes (Elasmobranchs or in teleosts) the Ist functional gills occur in the gill clefts between the hyoid arch and the Ist branchial arch (i.e the 3rd visceral arch).

(1) Cartilagenous fishes – In cartilagenous fishes eg Scoliodon, the gills are lamellliformes. The external gill slits are uncovered i.e without any operculum. The interbranchial septum are well developed and extend beyond their gill lamellae to form flaps which guard both the gills as well as the external gill slits. Generally, the elasmobranchs have 5 pairs of gill cleft in addition to the spiracles, one pair of hemibranch (i.e lamellae is present only on one side of the interbranchial septum) on the posterior side of the hyoid arch and 4 pairs of holobranchs on the

Ist, IInd, 3rd and 4th branchial arch.
In some elasmobranchs have 6 and 7 pairs of gill clefts in addition to the spiracles eg. Hexanchus has 6 pairs and Heptanchus has 7 pairs of gill clefts. Chimaera has only 4 pairs of gill clefts.

From the visceral arches, cartilagenous gill rays extend into the interbranchial septum that support the septum. From the visceral arches also often project stiff, comblike gill rakers that check the entry of food particles or foreign bodies into the gill clefts.

Breathing Mechanism: The process involves intake of water and its elimination alternatively.

(1) Intake of Water: Here, the mouth is opened, buccal floor is depressed and pharyngeal floor lowered by the simultaneous contraction of the coracomandibular (lower jaw muscles), coracohyoid (present anterior to the basihyal) and coracobranchial (present in the branchial arches) muscles. At the same time, the external branchial apertures or external gill slits are closed by the contraction of the horizontal muscle of the interbranchial septum. (The horizontal muscles lie along the length of the septum and their contraction pulls the septum and closes the external gill slits).
Because of the reduced pressure in the enlarged buccal + pharyngeal cavities, water rushes in through the mouth into these cavities.

(2) Elimination of Water: The mouth is closed by the contraction of the adductor mandibular muscle (it extends between the upper + lower jaw), the external gill slits are

opened by the relaxation of the horizontal muscles of the interbranchial septum. The buccal and pharyngeal cavities are reduced by the contraction of constrictor muscles (found inner to the visceral arches of the ~~outer~~ interbranchial septum. This increases the internal pressure and forces the water through the internal gill slits into gill clefts. The water then passes over the gill lamellae where exchange of gases takes place and then the water moves out of the body through external gill slits. During the breathing movements, the oesophagus is kept closed by the contraction of its muscles to check the entry of water into it.

Exchange of gases: The fresh water containing dissolved O_2 enters through the mouth into the pharynx and then into the gill clefts.

The water then passes over the gill lamellae. The lamellae contain extensive system of capillaries that contain the blood. The blood is deoxygenated and has been received from the various body parts. The O_2 from the water passes by diffusion through the walls of the capillaries into the blood present in them. At the same time CO_2 from the deoxygenated blood passes out by diffusion into the outgoing water current.

This water now moves out through the external gill slits. Whereas the oxygenated blood is distributed to the body through the dorsal aorta.

[The deoxygenated blood ~~is recieved~~ enters into the capillaries of the lamellae via afferent branchial arteries.].

[In case the students find the topic lengthy, they can omit intake of water + Elimination of water part. But do write Exchange of Gases.]

Gills in bony fishes or teleosts: In bony fishes, mouth is anterior. Buccal cavity has (just inside the mouth) a pair of oral valves. These valves permit the water to enter but not to leave the cavity. External gill slits are covered by a flap, the operculum. The operculum actually grows backward from the hyoid arch, enclosing between itself and the body wall, a branchial or opercular chamber which opens out (in front of the pectoral fin) by a large crescent opening, the branchial or opercular aperture. The operculum is supported by several thin opercular bones. A branchiostegal membrane is attached to the posterior margin of the operculum. This membrane acts as a one way valve, allowing water to leave but not to enter the gill chamber. The branchiostegal membrane is supported by bony branchiostegal rays. The Gills in teleosts are filiform. The interbranchial septum are greatly reduced so that the gill filaments hang freely in the opercular chamber. The interbranchial septa are supported by visceral arches. From the inner border of the visceral arches project sharp, pointed gill rakers that protect the gills from hard particles and check food from entering into the gill clefts.

In teleosts, generally, there are present 5 pairs of gill clefts and 4 pairs of holobranchs. The holobranchs are borne on Ist, IInd, IIIrd + IVth branchial arches. The hyoid arch (i.e. the 2nd visceral arch) is 'abranch and so is the Vth branchial arch. (abranch means without hemibranch or holobranch).

Spiracles are generally closed.

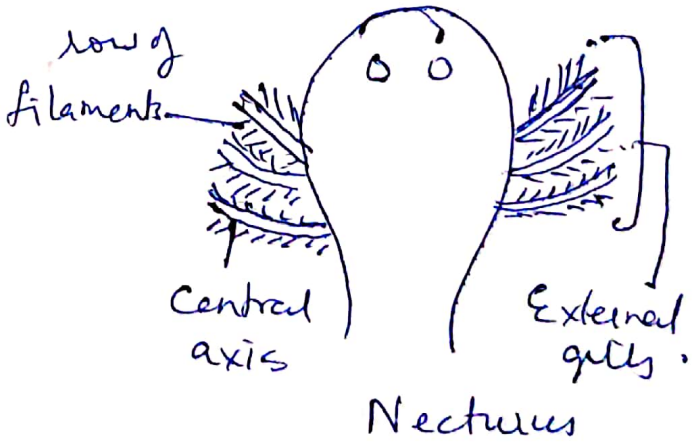
Mechanism of breathing: Breathing movements occur in 2 steps, gill chambers working as suction pumps.

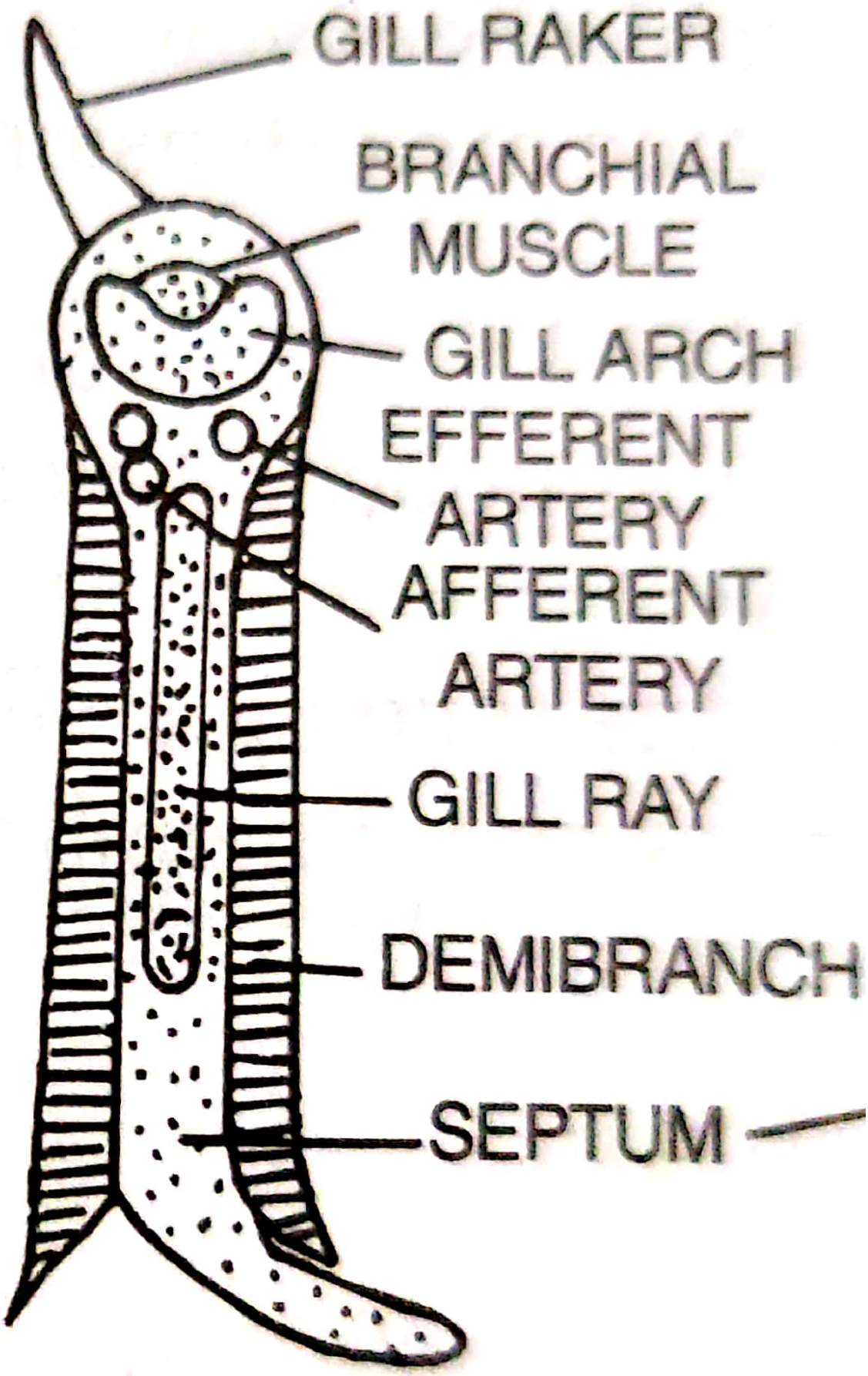
(1) Inspiration: During inspiration, opercula and branchiostegal membranes press against the body keeping the two external branchial apertures tightly closed. The opercula are then raised, enlarging the branchial chambers. The branchial chambers act as suction pumps so that the oral valves open and as a result the mouth also opens and the water flows from outside through the mouth into the buccal cavity + pharynx and then to the opercular chambers.

Expiration: Now, the operculum comes back to its original position and the pressure is exerted on the internal water. The backflow of H_2O is prevented by the closure of the mouth by the oral valves. The opercular aperture opens and the water is then forced through the gill slits, over the gill filaments and then into the branchial chamber from where it leaves the body through branchial aperture. The blood flowing in the capillaries of the gill filaments gives up its CO_2 and absorbs O_2 from the water flowing over them by diffusion through their thin epithelium. During the process the oesophagus is kept closed by the oesophageal valve to check the entry of water into it.

The deoxygenated blood is supplied to ~~each~~ to the capillaries of the lamellae via afferent branchial arteries and the oxygenated blood is taken to the various body parts through the dorsal aorta.

External gills: They are branching processes hanging freely on the sides of the head. They are formed in larvae of some fishes such as Polypterus and Protopterus - all larval amphibians and some adult tailed amphibians such as Necturus, Proteus and Siren. Polypterus larva has a single pair of external gills whereas protopterus has 4 pairs of ext. gills. Necturus is 3 pairs of ext. gills. Each gill consists of a narrow central axis which bears a row of filaments on either side. The external gills are in direct contact with water containing dissolved O_2 and the exchange of gases occurs in them without any effort on the part of the animal.

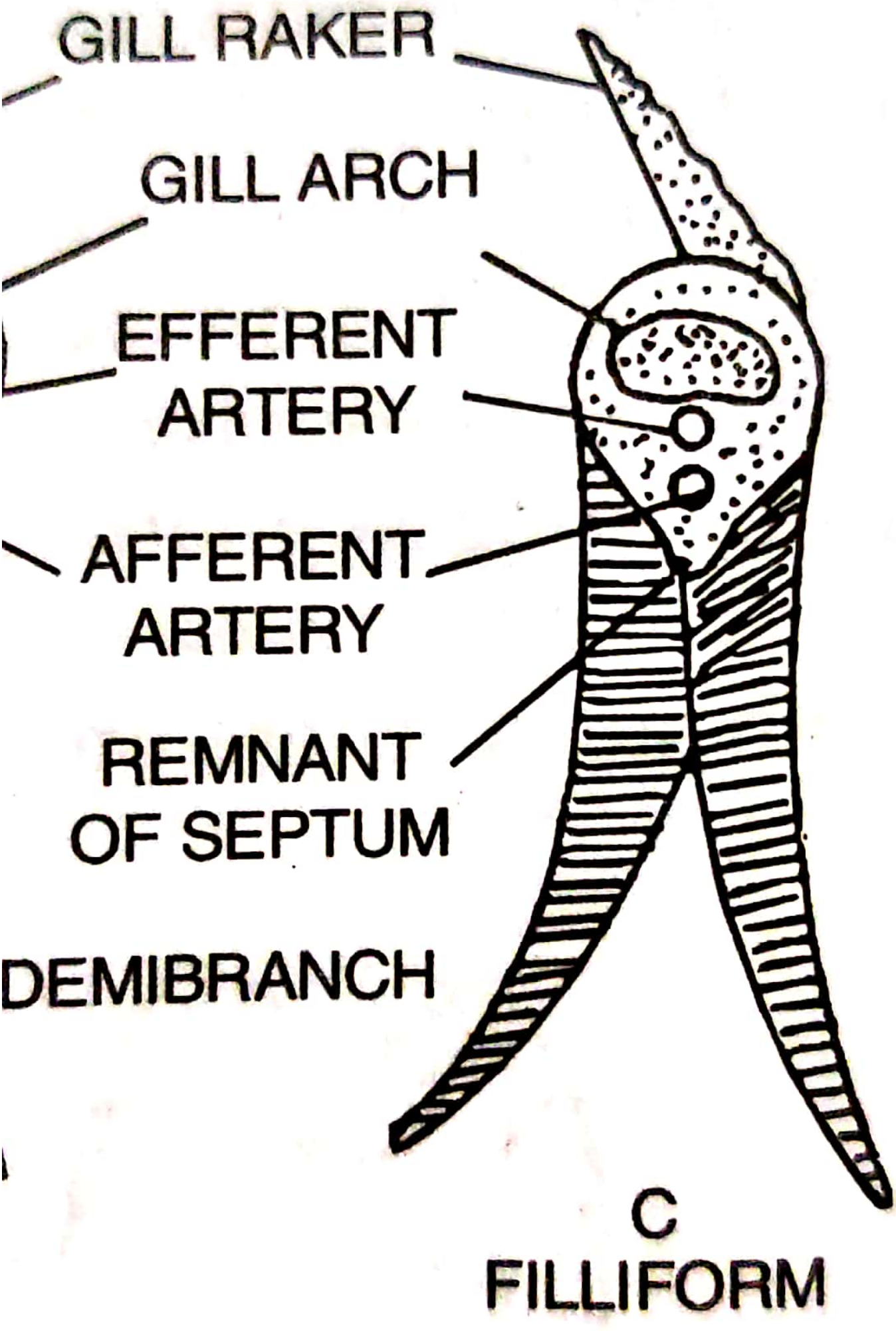




A

LAMELLIFORM

INT



C
FILLIFORM

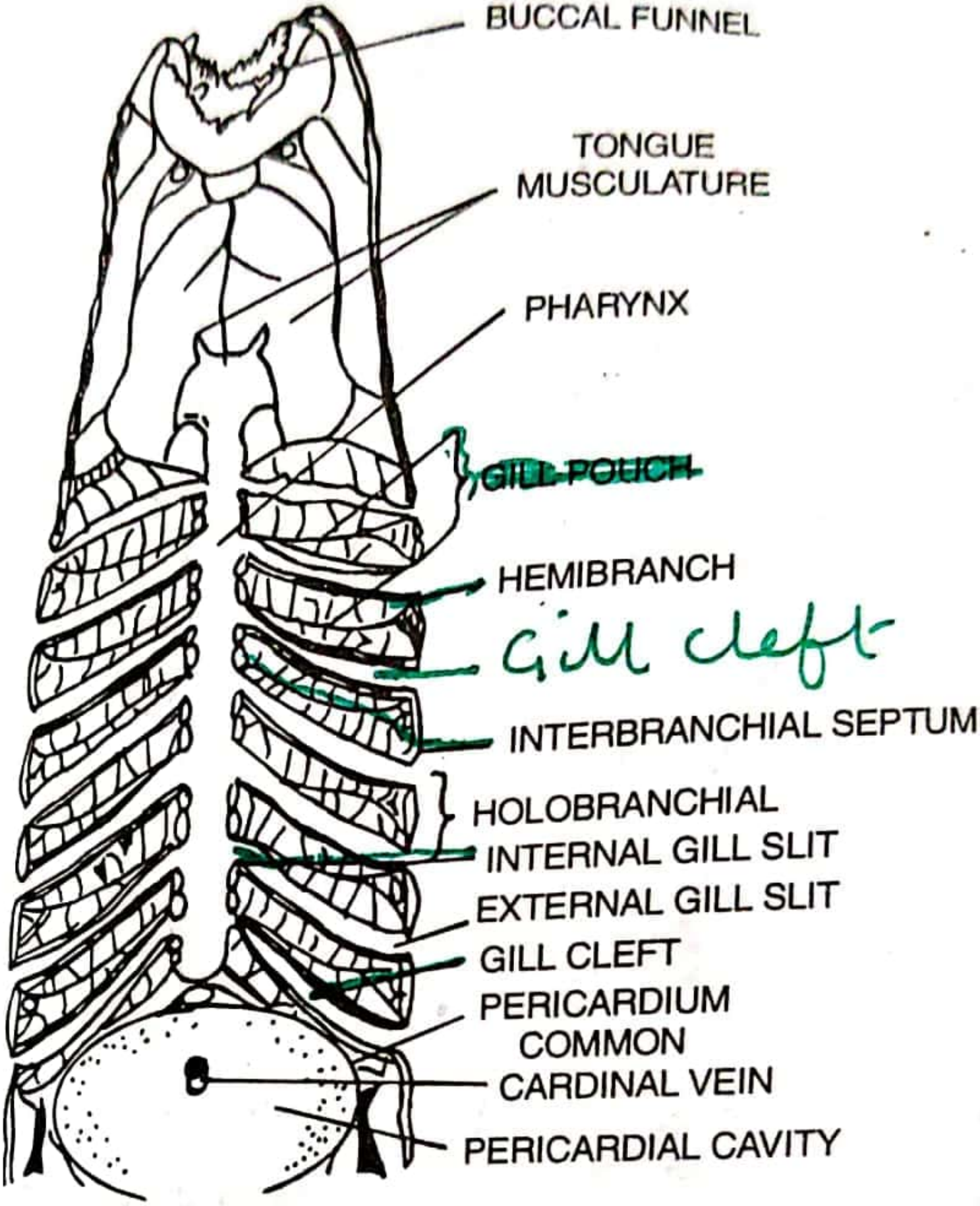


Fig. 4. Frontal section of anterior end of *Petromyzon* showing gills.

(lamprey)

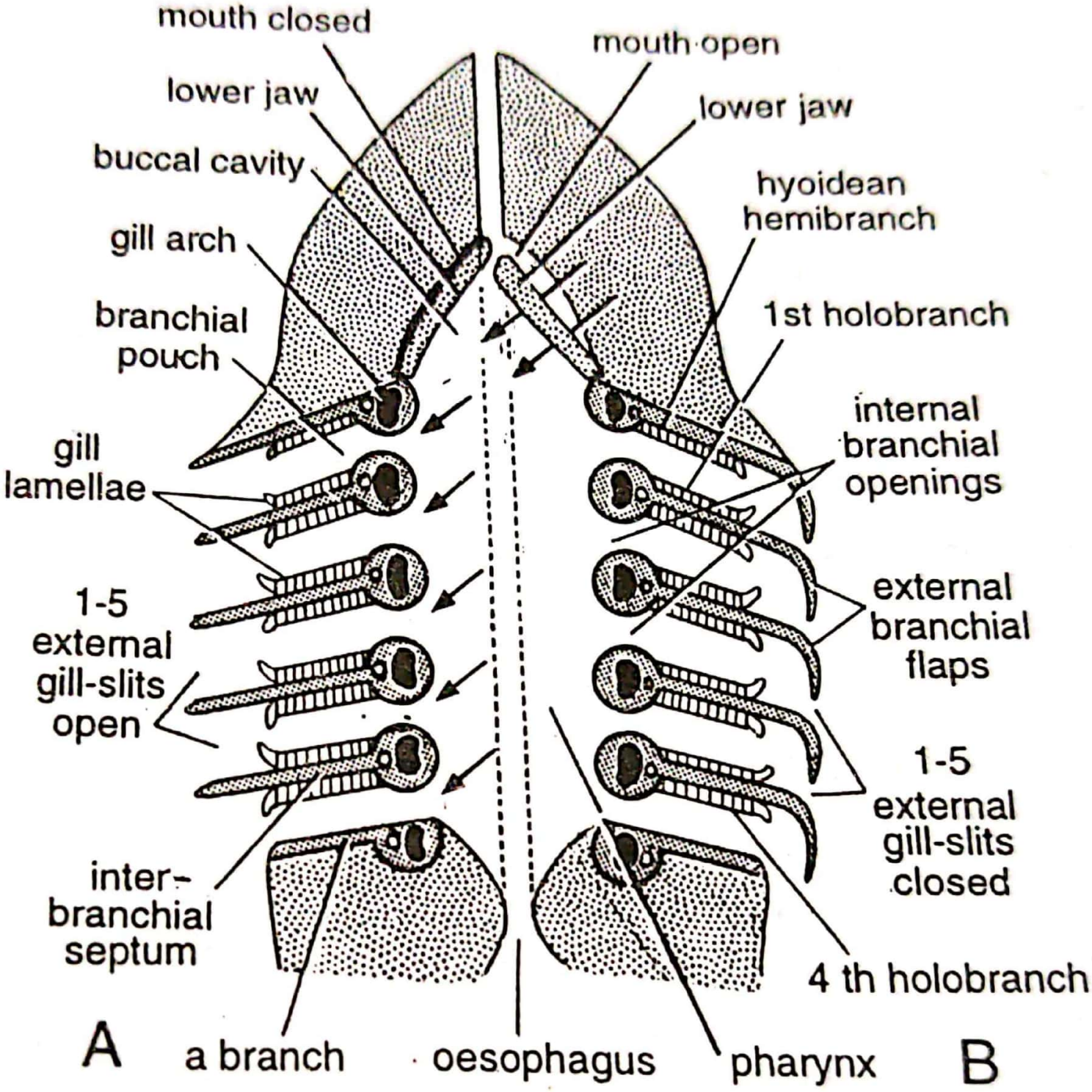


Fig. 15. *Scoliodon*. Breathing mechanism. A — Expiration. B — Inspiration.

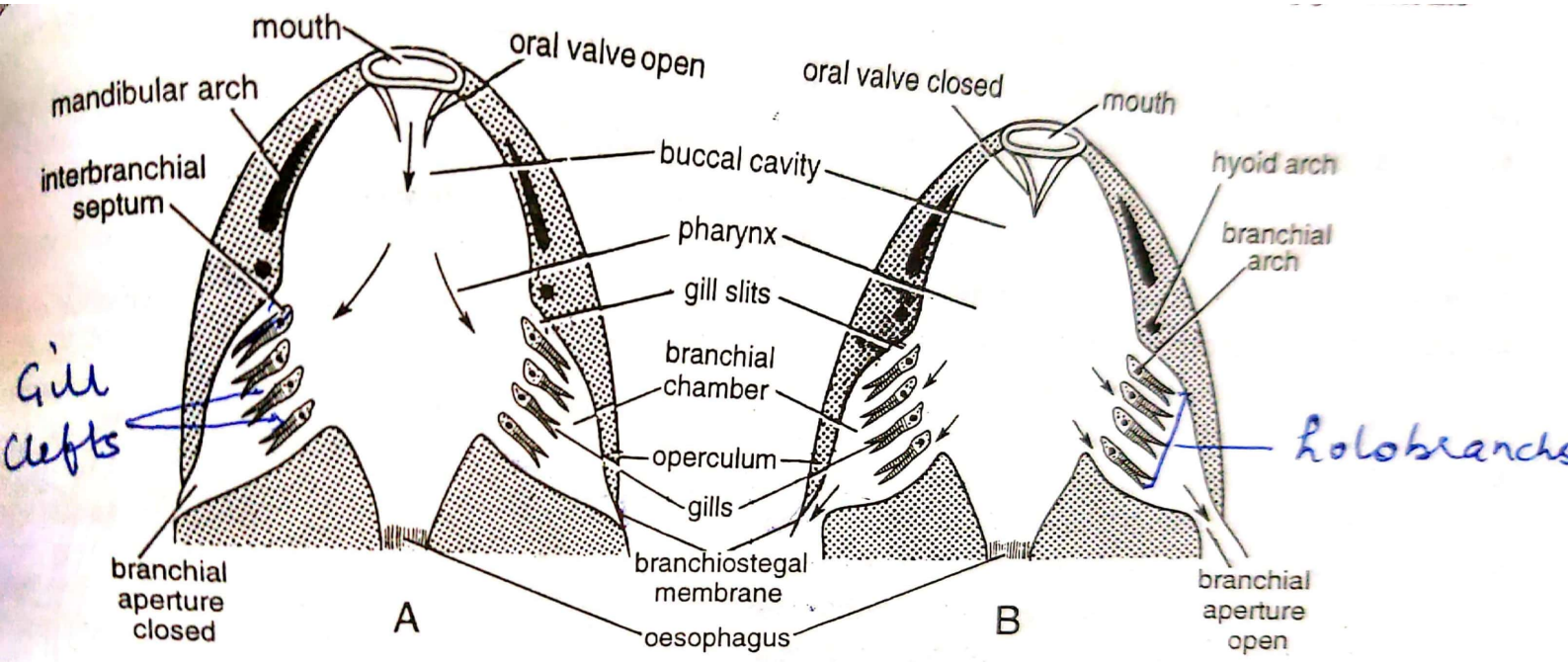


Fig. 5. Respiratory mechanism of a bony fish. Arrows show direction of respiratory water currents. A—Inspiration. B—Expiration.