SECTION-A (Multiple choice questions)

Q. 1-Answer

(i) **d** (ii) **c** **(iii) c** **(iv) d** **(v) a** (vi) **b** **(vii) b**

(viii) c **(ix) b** **(x) c**

SECTION –B (Descriptive type questions)

Q. 2- Answer

Transport of CO_2 and O_2

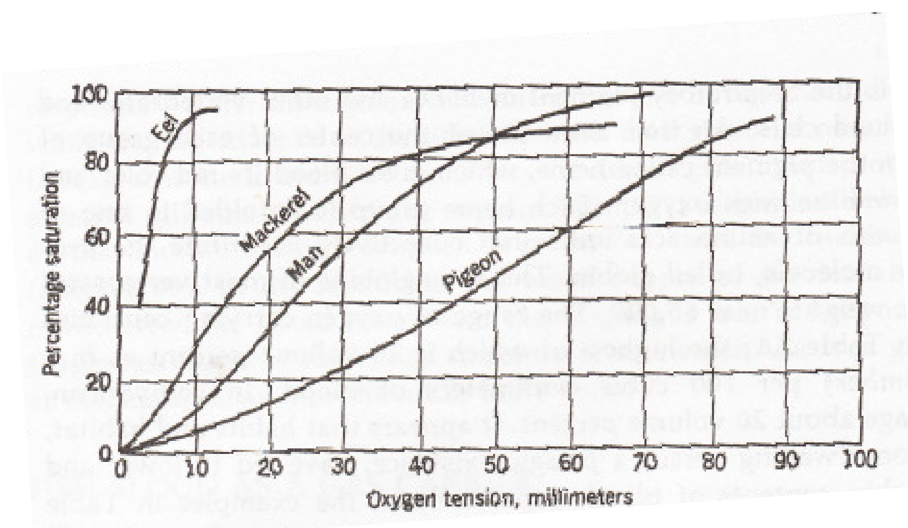
Oxygen diffuses very slowly from one liquid into another. Thus fishes have evolved in their red blood cells a gas-carrying device of high efficiency. The red blood cells account for 99percent of oxygen uptake; the volume of oxygen carried in plasma amounts to less than 1percent of the total.

Hemoglobin is the respiratory pigment of fishes and is in red blood cells. An iron atom lies at the centre of each group of the atom that form the pigment called heme, which gives blood its red colour its ability to combine with oxygen. Each heme group is enfolded in one of two or four chains of amino acid units that collectively constitute the protein part of the molecule, called globin. The hemoglobins of most vertebrates have molecular weights near 65,000. It appears that habits and habitat, such as a bottom-dwelling versus pelagic existence, have led to lower and higher hemoglobin contents of blood respectively.

Loading and unloading of Oxygen

In as much as oxygen is taken up, transported, and released by the red blood cells, we may speak of the process of loading and unloading oxygen and of the respective tensions at which these processes occur. To have adequate measures for comparison, two stages are chosen: (1) T_{sat} - the loading tension of blood; that partial pressure of O_2 at which hemoglobin of a particular species is 95 percent saturated with oxygen;(2) $T_{1/2sat}$ - the unloading tension of blood; that partial pressure of O_2 at which the hemoglobin is 50 percent saturated, or, in other words, the oxygen tension at which half the hemoglobin of the blood is in the oxygenated state and half is in the unoxygenated state. The half-saturation tension is a measure of the affinity of hemoglobin for oxygen. If hemoglobin has a low $T_{1/2sat}$ it has a high affinity and vice versa.

The oxygen dissociation curve describes the equilibrium of oxygen with hemoglobin. The shape of the equilibrium curve is influenced by the degree of interaction of the four polypeptide chains and their heme groups. The three-dimensional structure of the chains determines which amino acid residues will be at the surface of the molecule and available for subunit aggregation. Lack of interaction between hemes leads to hyperbolic curve, whereas with cooperativity between hemes the curve tends to be sigmoidal. A hyperbolic curve with high oxygen affinity is characteristic of fish that can live in water with a low oxygen concentration. The difference between the T_{sat} and the $T_{1/2sat}$ determines the total amount or oxygen delivered to the tissues. Blood described by a sigmoid curve is able to deliver more oxygen to the tissues than when described by a hyperbolic curve.



As the partial pressure of CO_2 increases, higher O^2 tension is required to reach T_{sat} and the $T_{1/2sat}$ is raised accordingly. This phenomenon, called, after its discoverer, the Bohr effect, is more pronounced in fishes and facilitates the unloading of oxygen to tissue cells where the CO_2 tension is relatively high.

Diffusion of O_2 and CO_2 is quantified by Fick equation

$$M_{gas}=\Delta P_{gas}.K_{gas}\ SA/T$$

Where M_{gas}=Rate of gas diffusion

ΔP_{gas}=Partial Pressure

Kgas=Permeation constant

SA=Lamellar surface area

T=Lamellar thickness

CO_2 is considerably more soluble in water than water than O_2. Thus low amount of free CO_2 in natural waters favors waste gas elimination at the gills by diffusion. CO_2 in the venous blood of fishes is carried primarily as bicarbonates but also solution in plasma. The change in bicarbonates into CO_2 and water is catalyzed by the enzyme carbonic anhydrase, found in the acidophil cells of the gills, in red blood cells, and in other tissues.

Q. 3-Answer

Accessory Respiratory Organs-

- In fishes accessory respiratory organs are present in addition to gills.
- Such structures develop in response to exceptional environmental conditions which include life in foul water or life out of water for short periods.
- Air breathing organ enable fish to tolerate oxygen depletion in water or to live out of water for short periods.

1- Skin as a respiratory organ-

- In the eel Anguilla, Amphipnous etc. the skin is highly vascular and serves for exchange of gases.
- These fishes habitually leave the water and migrate from one place to other. During this period, the moist skin serves as an imp. organ of respiration.

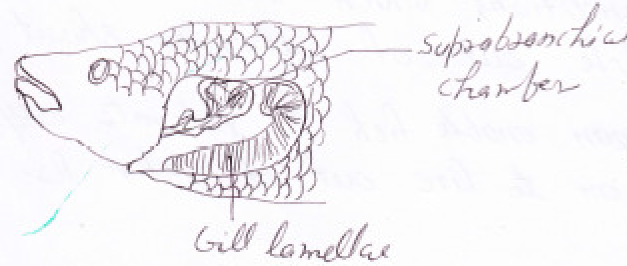
2- Buccopharyngeal Epithelium-

- In some fishes buccopharyngeal epithelium is supplied by a large number of capillaries to make it highly vascular.
- It may remain simple or may develop folds, pleats or tongues projecting into the buccal cavity. eg- Amphipnous, Electrophorus etc.

3- Pharyngeal diverticulum-

- In Channa sp. suprabranchial cavities are developed in the wall of the pharynx.

- Gill lamellae present on gill arches are reduced and that on fourth arch are considerably reduced.
- Cartilagenous processes arise from first gill arch. These processes are covered over by a thin vascular respiratory membrane which becomes highly folded called labyrinthine or dendritic organ.



Accessory respiratory organ of Channa marulius.

First gill arch of C. marulius

4- Opercular chamber modified for aerial respiration -

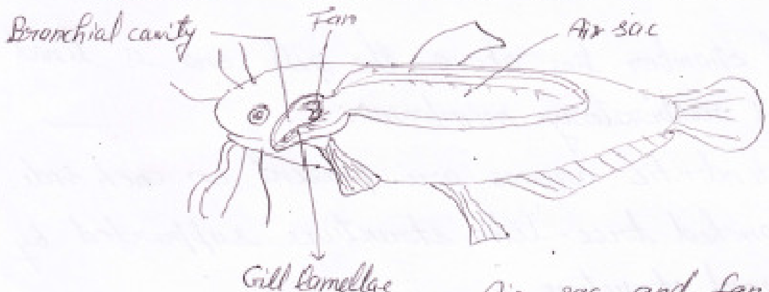
- In some species, inhaled air is stored in opercular chamber for sometime.
- The opercular chamber becomes bulged out in form of balloon
- Membranous lining becomes thin and highly vascular to allow exchange of gases.

5- Development of diverticula from opercular chamber -

- In more specialized air breathing fishes, sac-like diverticula develop from dorsal surface of opercular chamber.
- These air chambers or "opercular lungs" lie above the gills and may contain labyrinthine organs or rosettes

a) Heteropneustes fossilis

- Accessory respiratory organs are
  i) the 'fans' or expanded gill plates
  ii) the air sac, and
  iii) the respiratory membrane
- Four pairs of gills are present but gill lamellae are reduced in size. Four pair of 'fans' develop on these gill arches.
- Besides these fans, a pair of simple sac-like structure extend posteriorly from suprabranchial chamber up to the middle of caudal region.
- Sac's wall is thin and highly vascular
- The air sac recieves blood from the fourth afferent branchial vessel of its own side.

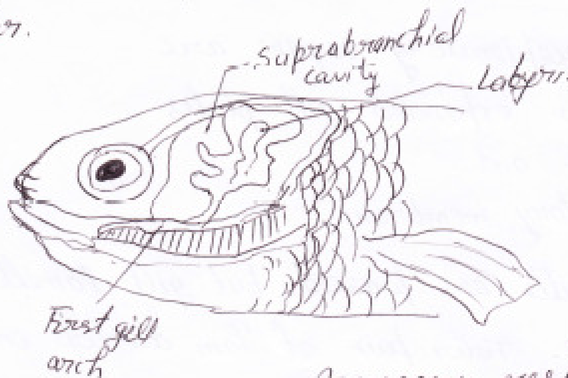


Air sac and fan in Heteropneustes fossilis

b) Anabas testudineus

- Air breathing organ consists of a spacious air chamber on either side of the skull lying between the first gill arch and the hyomandibular.
- The air-chamber communicates freely with the bucco-pharyngeal cavity as well as the opercular cavity.

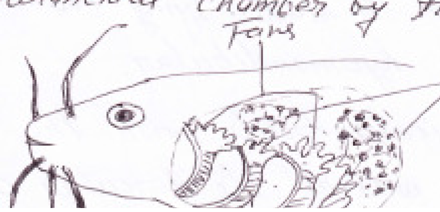
A characteristic labyrinthine organ is lodged in the air chamber.



Accessory respiratory organs of Anabas

Clarias batrachus

- Accessory respiratory organs consist of
  - i - the supra branchial chamber
  - ii - two beautiful 'rosettes' or air-trees
  - iii - the fans and
  - iv - the respiratory membrane
- The supra branchial chamber lies above the gill and is lined by a highly vascular respiratory membrane.
- Two rosettes or dendritic organs are present on each side.
- Each is highly branched tree-like structure supported by cartilagenous internal structure.
- Some of primary gill lamellae of each gill arch are fused so to form a 'fan' or gill plate.
- When air enters the opercular cavity, it is directed into the suprabranchial chamber by the action of fans.



Accessory respiratory

(5)

6- Part of Alimentary canal modified for aerial respiration-

- In some fishes, either stomach or intestine is specially modified to serve for aerial breathing.
- In these fishes inhaled air is swallowed and forced back into alimentary canal and is stored for sometime.

After respiratory exchange, used up air is either passed out to the exterior through the anus or is expelled through mouth.

7- Air bladder modified as respiratory organ-

- Air bladder of some fishes is modified for aerial respiration.
- The swim bladder of Notopterus has a wide pneumatic duct and acts as an accessory respiratory organ.

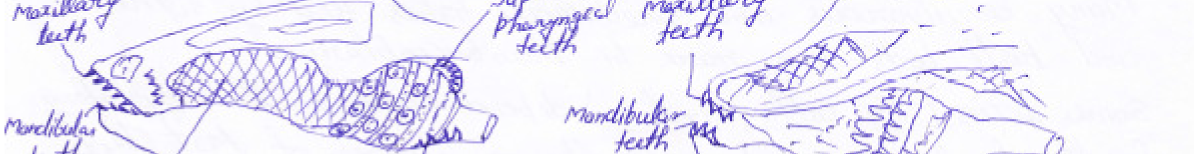
Q. 4- Answer

Alimentary canal and its modification

- Fishes have become adapted to a wide variety of food.
- Some feed exclusively on plants, others feed on animals, while a large number are omnivorous.
- The structure of the buccal cavity, pharynx and the gut of teleosts varies in different species in relation to food and feeding habits.

Buccopharynx

- Buccopharynx in fishes perform two important functions a) respiration and b) catching of food and conveying it to oesophagus.
- In carnivorous and predatory fishes as Wallago, Mystus, Channa, Notopterus, Harpodon etc. the buccopharynx is armed with strong teeth and even gill rakers are tooth-like.
- Teeth are borne by premaxilla, maxilla, vomers, palatine and dentaries.
- In some species (Notopterus) teeth are present on the tongue also.
- Teeth may be villiform, incisiform, canine like, molariform or as blunt knobs.
- Teeth are generally sharp, pointing backward and help to prevent the escape of the prey from mouth.



- In herbivorous fishes as Labeo, teeth are completely absent from the jaws and palate but well developed inferior teeth are present. These teeth are used for crushing the prey.

Gill Rakers -

- In carnivorous species, gill rakers are generally long, hard and teeth-like forming rasping organs as in Wallago, Mystus, Notopterus, Harpodon etc.
- In omnivorous fishes like Tor, Puntius, they are short and stumpy.
- In herbivorous forms like Labeo, Cirrhina gill rackers form a broad sieve-like structure for filtering the water in order to retain the food.
- There is a remarkable correlation between the structure of the gill rakers and feeding habit of fish.
- The filtering efficiency increases considerably from carnivorous to omnivorous fishes and is maximum in herbivores.

Taste buds and mucus secreting cells -

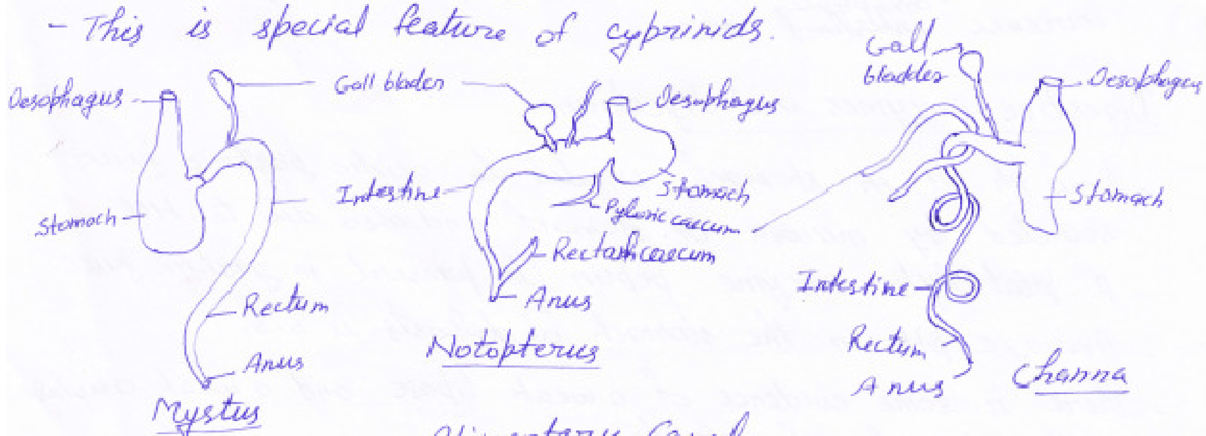
- It appears that presence or absence of taste buds depends on the mode of feeding of fishes.
- Many carnivorous and predaceous fishes feed by sight and taste buds are rare in their buccopharynx.
- Some species (Tor, Catla, Cirrhina) depend more on their gustatory faculty for feeding and posses large number of taste buds

Oesophagus -

- It is a short and narrow tube in a number of herbivorous and omnivarous fishes.
- Carnivarous and predatory fishes that feed on prey of large size possess a longer and distensible oesophagus.

Stomach -

- The stomach is generally sac-like and thick walled in carnivarous and predatory species as in Wallago, Mystus, Harpodon, Notopterus etc.
- In some species as Hilsa, Gadusia etc., the stomach is reduced in size, but is greatly thickened to become gizzard-like.
- In some fishes stomach is absent and anterior part of intestine is swollen to form a sac behind oesophagus. This swollen structure is known as intestinal bulb as in Labeo, Catla, Tor, Cirhina, Puntius etc.
- This is special feature of cyprinids.



Alimentary Canal

Intestine -

- Generally, intestine is short and nearly straight in carnivorous fishes, but long, thin walled and highly coiled in herbivores.
- It is difficult to generalize on the length of gut and nature of the diet due to omnivorous habit of a large number of fishes.
- More than one factors might be responsible for determining the relative length of the gut.
- The length of the gut also depends on the average mucosal area and a short gut may be compensated by longer mucosal folds.

Pyloric or Intestinal ceaca-

- Number of finger-like outgrowths develop from the pylorus or anterior part of intestine and are called pyloric or intestinal ceaca.
- They may serve as accessory food ~~reservoir~~ reservoir.
- Histologically they resemble intestine and probably serve to increase ~~intestinal~~ absorptive area.

Q.5- Answer

Digestive enzymes and digestion-

- Low ~~ph~~ pH in stomach is due to acidic gastric juice secreted by mucosa of stomach and also due to HCl.
- A proteolytic enzyme, pepsin, is present in gastric juice.
- Average pH in the stomach of teleosts is 5.6.
- There is some evidence of a weak lipase and a weak amylase in the stomach of teleosts.
- In the stomachless fishes such as Labeo, Cirrhina and Catla pepsin and hydrochloric acid are absent.

- Digestion of proteins continues in the intestine also, and they are broken down in the alkaline medium by the action of trypsin, secreted by the pancreatic tissue.

- The source of enzymes in intestine is not clear
- It appears that the trypsinogen is formed in the pancrease and erepsin and enterokinase are secreted by intestine.
- Digestion of carbohydrates and lipids also takes place in the intestine.
- Amylase is produced in pancrease. However, amylase has also been reported from extracts of intestinal mucosa and pyloric caeca.

- Maltose and lipase is also present
- Pancreatic amylase hydrolyzes the α-1,4 linkages producing straight-chain oligosaccharides (maltodextrins)
- Amylase does not hydrolyse α-1,6 linkages and so isomaltose is also produced.

Carbohydrate —Amylase→ Maltodextrins + Isomaltose

Maltodextrins —maltase→ Glucose

Isomaltose —Isomaltase→ Glucose

- Proteins are hydrolyzed by endoproteases and peptidases
- Endoproteases (pepsin, chymosin, trypsin, chymotripsin, elastases and collgenases) are secreted in inactive zymogen form.
- Endoproteases hydrolyses internal peptide bonds but leave terminal ones.
- Peptidases cleave terminal peptide bonds

- Lipids are hydrolyzed by lipases. Lipids are first emulsified by bile salts to provide the surface area for lipase hydrolysis.
- Pancreas is the major source of lipase.

Q. 6- Answer

(a) Bony Ridge Scale

The cycloid and ctenoid scales are also known as the bony ridge scales. They are present in majority of the teleostean fishes and are thin, flexible, transparent structures due to the absence of the first and the middle layers of other types. These scales exhibit characteristic ridges alternating with grooves and generally the ridges are in the form of concentric rings. The central part of the scale is called the focus and is the first part to develop. In many species, oblique grooves or radii run from the focus towards the margin of the scale.

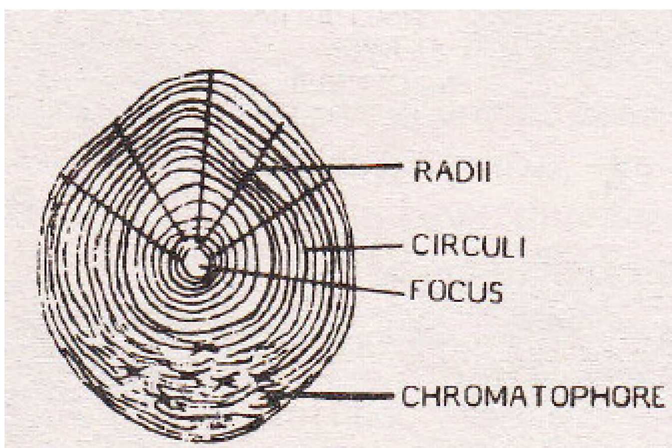


Fig. Cycloid scale

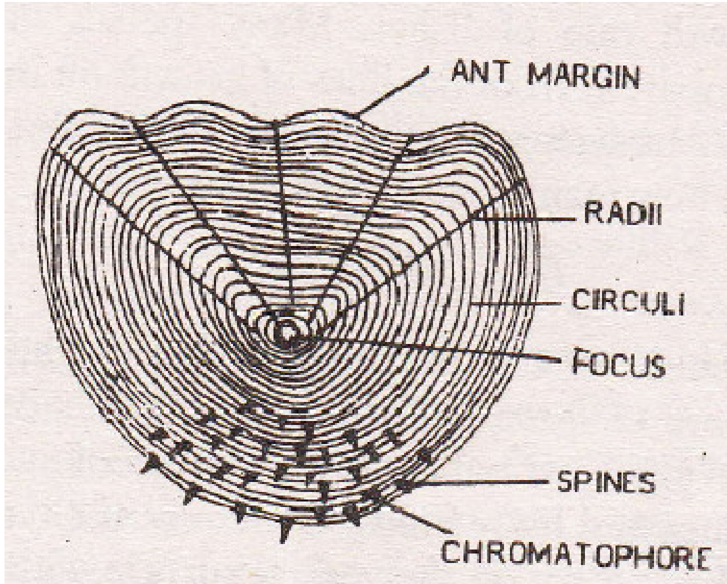


Fig. Ctenoid scale

The origin and development of both these types of scales are similar. The cycloid scales are thin and roughly, rounded in shape, being thicker in the centre and thining out towards the margin. They are found in a large number of teleostean fishes having soft rayed fins. They form a protective covering over the skin and project diagonally in an imbricating pattern. The ctenoid scales are also circular and can be distinguished from the cycloid by having a more or less serrated free edge. Moreover, several spines are present on the surface of the posterior area of the scale. These scales are found in a large number of fishes with spiny rayed fins.

(b) Iridocytes

- Large number of teleostean fishes are brightly and brilliantly coloured.
- Colouration in fishes is primarily due to skin pigments
- Background colour is due to ~~body~~ underlying tissues, body fluids or gut content.

Source of Colouration-

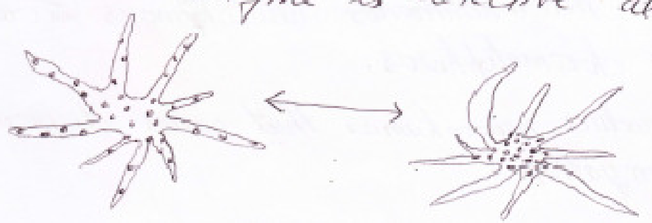
- Colouration is due to presence of two types of special cells called the chromatophores and iridocytes.

- The iridocytes contain a crystalline substance guanin which is opaque, whitish or silvery. It is waste product and is deposited in the form of granules or rounded, polygonal or stellate bodies, or in the form of plates.
- Iridocytes are also called mirror cells as they contain great reflection power. They give white or silvery appearence to the fish.

(c)

Melanophores -

- Contain eumelanin, black or brown.
- Pigment is packaged in vesicle called melanosomes.
- ~~Smu~~ Eumelanin is generated from tyrosine.
- Enzyme involved is tyrosinase
- when this enzyme is defective albinism occurs



Fish melanophores are cells that ~~contain~~ can change colour by dispersing or aggregating pigment-containing bodies.

Q. 7- Answer

Blood Supply in swim bladder

The swim bladder receives its blood from branches of the coeliaco-mesenteric artery or directly from the posterior branches of the dorsal aorta. The venous blood is then drained into a vessel that joins the hepatic portal system, while in some species the air bladder vein joins the posterior cardinal vein. The gas bladder also shows differences in its degree of vascularity in various teleosts and in the formation of 'red bodies' or 'red glands'. In some species (Clupeidae and Salmonidae), the capillaries are uniformly distributed all over the surface of the bladder and do not form a 'retia mirabila', while in other Physostomes as carps (Cyprinus, Labeo, Tor tor) the blood vessels are arranged in a fan-like manner and are concentrated at one or more points on the inner surface of the bladder, forming red masses of various shapes called the 'red bodies'. These are essentially retia mirabilia consisting of numerous arterial and venous capillaries, running parallel to one another and carrying blood to and from the gas gland. They constitute the wonder net of capillaries which do not communicate until they rich the epithelium of the gas bladder. In the physostomous fishes, this structure is more primitive, being covered with a simple flat epithelium and is called red body. In the Physoclistous fishes, the capillaries are covered with a thick glandular folded epithelium and it is called the red gland.

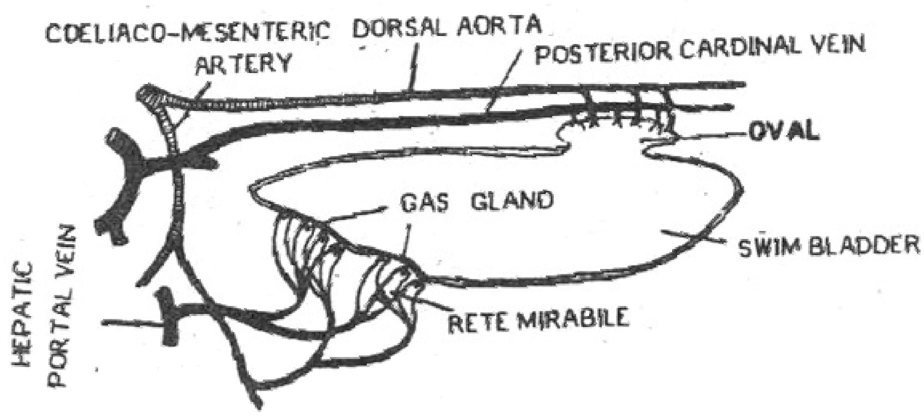


Fig: Blood Supply of the swim bladder of a Physoclistous teleost.

Gas Supply in swim bladder

The anterior part of the swim bladder, whether open or closed, is specialized for gas secretion, while absorption of gas into the blood takes place in the posterior region of the physoclistous forms. In more specialised physoclisti, such as the Mugil, Balistes and gadus, the posterior region becomes converted into an 'oval' whose opening is guarded sphincter and dilated by muscles. A small area in the anterior region becomes specialized for secreting gas and is called the red body or red gland.

In several species belonging to the Syngnathidae, Gadiidae, Labridae and Triglidae, the gas bladder is closed and divided into two chambers by a constriction. In these fishes gas gland for secreting gas is found in the anterior chamber, while the posterior chamber becomes thin walled for gas diffusion. But in the Cyprinidae, the gas bladder is divided into two chambers and has pneumatic duct. Here, the gas gland is confined to the posterior chamber.

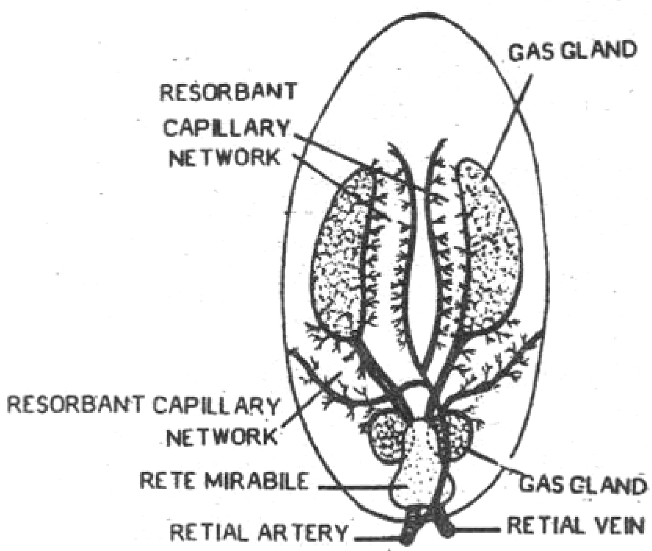


Fig: Swim bladder of a deep sea fish showing gas secreting complex.

Q. 8- Answer

Closed circulatory systems have the blood closed at all times within vessels of different size and wall thickness. In this type of system, blood is pumped by a heart through vessels, and does not normally fill body cavities. Example: Vertebrates, and a few invertebrates, have a closed circulatory system.

The open circulatory system is common to molluscs and arthropods. Open circulatory systems (evolved in crustaceans, insects, mollusks and other invertebrates) pump blood into a hemocoel with the blood diffusing back to the circulatory system between cells. Blood is pumped by a heart into the body cavities, where tissues are surrounded by the blood.

Working of heart in Teleost:

The venous blood flowing continuously towards heart reaches the sinuses and passes into auricle by pushing apart the semilunar valves. During this, the pockets of the valves also become full of the blood and pressure due to contraction of the auricle cause the valves to swell and adhere with each other, thus preventing the backward flow of blood. The blood now flows from auricle to ventricle by pushing apart the four auriculo-ventriculer valves. As soon as the ventricular cavity is full, the valves also received the blood, so that they bulge out and adhere with each other so as to effectively close the opening and thus, prevent the backward flow of the blood. The blood, now, pushes aside the ventriculo bulber valves, to enter the bulbus. Here again, the increased pressure inside the bulbus causes the valves to swell and close the passage, preventing backward flow of the blood, which passes forward into the ventral aorta. A schematic diagram of heart of a carp (Tor tor) showing blood flow is given below:

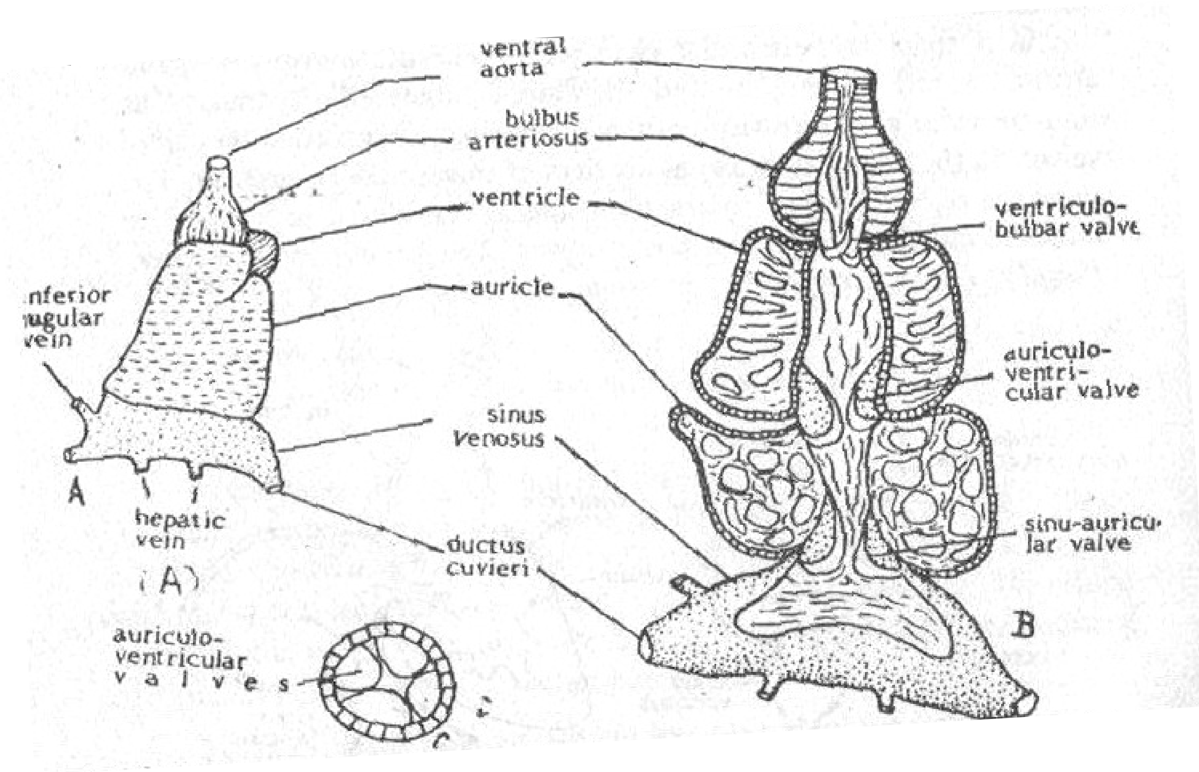


Fig: (A) Heart of a carp (Tor tor) (B) The same dissected to show internal structure and working of heart.