SECTION-A (Multiple choice questions)

Q. 1-Answer

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

(viii) d **(ix) a** **(x) c**

SECTION –B (Descriptive type questions)

Q. 2- Answer

The skin forms the external covering of the body and performs a number of important functions in fishes. Besides protecting the body against injury and infection, the skin has respiratory, excretory and osmoregulatory functions. The derivatives of skin play an important part in the metabolic activities of body. Special structures of some species like the electric organs, poison glands, and phosphorescent organs are also the integumentary derivatives.

Structure

The skin of a fish is composed of two layers, an outer epidermis and an inner dermis. The epidermis is ectodermal in origin and consists of several layers of flattened cells (stratified epithelium), of which the deepest layers are made up of columnar cells forming the stratum germinativum in which cells are always multiplying by mitotic division to replace the outer worn cells. A superficial layer of dead horny cells, forming the stratum corneum in terrestrial vertebrates, is not present in fishes.

The dermis is mesodermal in origin and is composed of connective tissue, brood vessels, nerves and cutaneou, sense organs. The thin upper layer of loose connective tissue is called the stratum spongiosum and the thicker dense lower layer, the stratum compactum. Numerous tubular or flask shaped mucous cells are scattered among the epidermal cells and may even extend into the dermis. The cells secrete mucin, a glycoprotein, which mixes with water to form thick, slimy mucus covering the whole body. Mucous cells develop from stratum germinativum and migrate to the surface. They vary in number, kind and size in different species of fishes. In general, fishes having poorly, developed scales or no scales, possess a larger number of mucous cells.

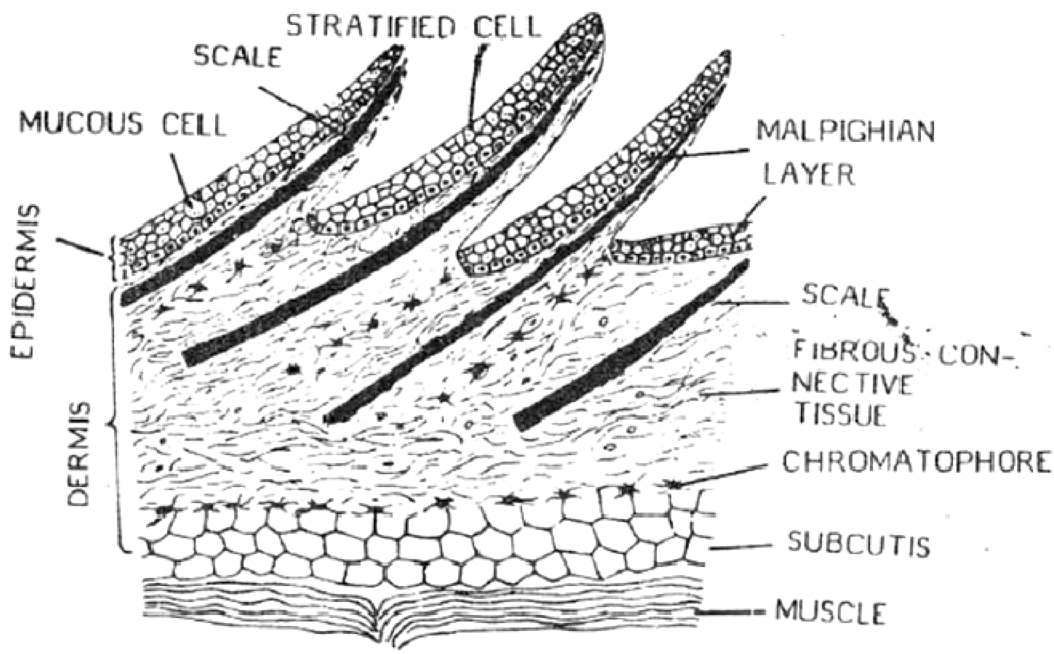


Fig. V. S. Skin of a Teleost

Chromatophores of various kinds, present in the dermis, give beautiful colour patterns to the body, making it conspicuous or inconspicuous. Exoskeleton in the form of scales, plates or denticles are important derivatives of the skin which provide protection to the body. The skin has also the power to absorb dissolved nutritive substances from the surrounding water.

In most of the fishes, the skin is covered with an exoskeleton in form of scales and only a few are naked having no scale on the body. According to mode of their origin, there are two types of scales: (I) those which are formed due to secretory activity of both epidermis and dermis, as the placoid scales of sharks, and (II) non-placoid scales that are derived from the dermis only as the scales of teleosts. Structurally the scales are classified as cosmoid, ganoid or rhomboid cycloid and ctenoid; the last two are also called as the bony ridge scales.

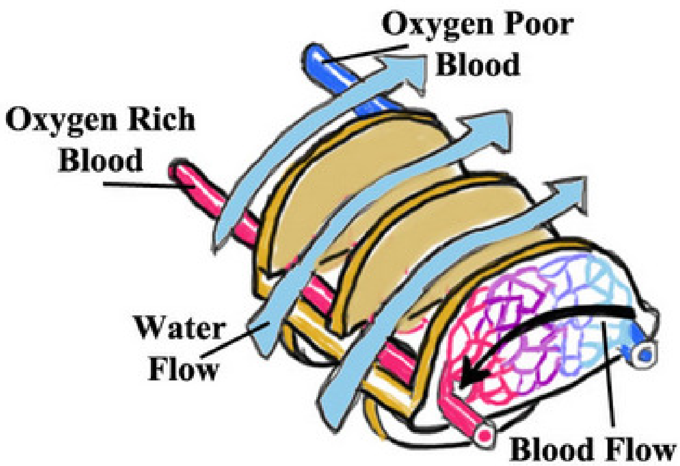
Q. 3-Answer

Counter current exchange in aquatic respiration (fish)

The efficiency of fish gills stems from a simple adaptation known as **countercurrent exchange**: The blood in the capillaries flows in the opposite direction from the water in the adjacent channels. Dissolved gases diffuse faster between fluids with a large difference in gas concentration (a high concentration gradient) than between fluids with only a small difference.

In the fish gill, low-oxygen blood enters the capillaries, encountering water at the end of its travel through the gills, which is thus relatively low in oxygen. As blood travels in the direction opposite to the water, it encounters "fresher" water with ever-higher oxygen concentrations. Thus, along the capillary, a steep diffusion gradient favors transfer of oxygen into the blood.

Gill efficiency is further increased by **ventilation**, the increase in flow of the respiratory medium over the respiratory surface. Fish ventilate by swimming and by opening and closing the flaps that cover the gills, the **opercula**. This draws fresh water into their mouths to pass over their gills and out their gill slits.



Counter current exchange in aquatic respiration (fish)

Water flow across the gills:

Gills are very efficient at collecting free oxygen from water, they have to be because water typically contains only a fraction of free oxygen of that found in air.

The gills are composed of a gill arch (which gives the gill rigid support), gill filaments (always paired), and secondary lamellae (where gas exchange takes place). In brief, the gills themselves consist of a series of gill arches which have gill filaments on one side and gill rakers on the other. It is the **gill filaments** which are used for respiration. The gill arches are covered from the outside by the fishes operculum which acts as a protector and is used to pump the water over the gills in branchial respiration. Each branchial arch in the teleost is elaborated into multiple filaments, which are further subdivided into thousands of lamellae and this is where gas exchange occurs. The water flows in the opposite direction to the blood so that maximum exchange can take place.

Fish must pass new water over their gills continuously to keep a supply of oxygenated water available for diffusion. Fishes use two different methods for keeping a continuous supply of new water available, one is very simple and the other complex.

Ram Ventilation: Swim through the water and open their mouth (such as a shark would), but the fish must swim continuously in order to breathe.

Normal Ventilation: Occurs by the fish taking in water through the mouth. The mouth closes, forcing the water back over the gill filaments and out through the gill slits.

In brief, some fish such as sharks and tuna use **ram ventilation** because they cannot pump water through their gills and they must keep moving with their mouth open so that water enters their mouth and flows over the fill filaments in order to be able to breathe. The vast majority of fishes breathe by **branchial pump** where water is actively pumped over their gills regardless of whether the fish are in motion. Using this method means that the fish can rest and not suffocate but because this method uses energy it also means that 10 to 15% of the oxygen extracted from the water is used simply to pump the gills when the fish is completely resting.

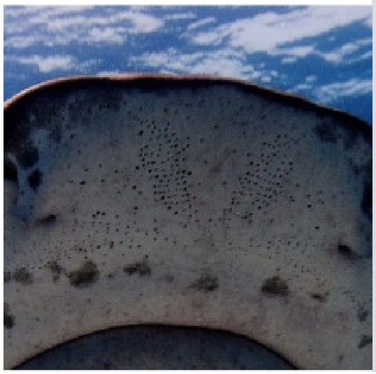
Q. 4-Answer

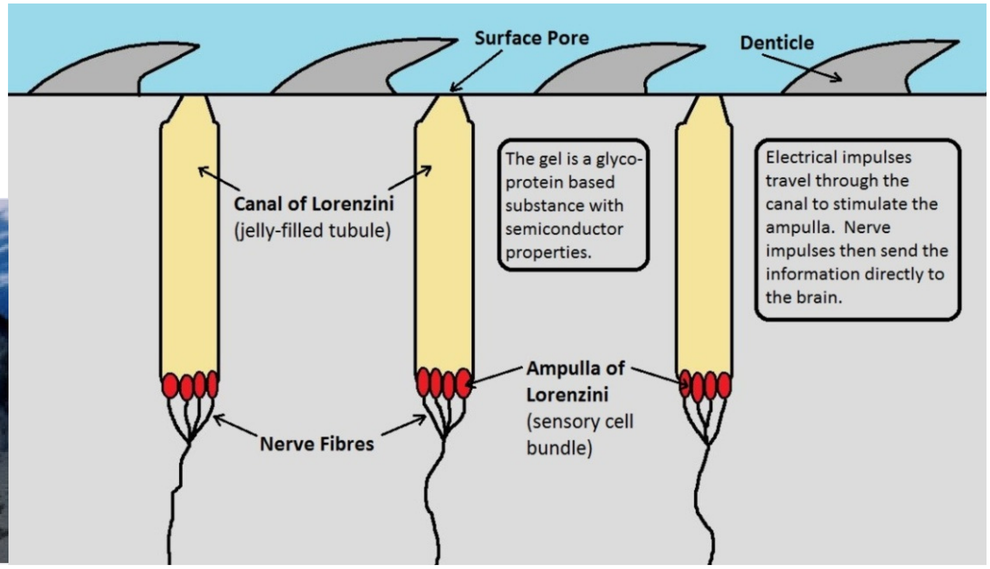
A **chemoreceptor** is a sensory receptor that transduces a chemical signal into an action potential. Chemoreception plays a major role in the lives of fishes. Nearly all aspects of life — feeding, prey detection, predator avoidance, species and sex recognition, sexual behavior, parental behavior, migration, etc. — are affected or mediated by the ability to detect water - born chemicals and to react appropriately to these stimuli. Chemoreception can be conveniently divided into two basic types that, while essentially different, show some degree of overlap in their sensitivity to particular substances: olfaction (smell) and gustation (taste).

Similar to other vertebrates, fish have discrete taste and smell systems; however, since they live in water, the taste system is not confined to the oral cavity. For example, taste buds occur on the lips, the flanks, and the caudal (tail) fins of some species, as well as on the barbels of catfish. Regardless of where the taste buds occur on the body, they are connected to neurons in the same three cranial nerves (facial, glossopharyngeal, and vagus) as the taste buds in the oral cavity. In addition to the taste buds, isolated (solitary) chemoreceptor cells are scattered over the surface of fish. These cells have a similar structure to that of individual taste receptor cells, but their connections to the brain or spinal cord arise from the nerves' providing innervations for the particular part of the body in which the cells occur.

Electroreceptor:

In all fish and amphibians, the electroreceptors are a secondary cell system (such as in the eye and ear), where a specialized receptor hair cell responds to a stimulus by producing a receptor potential, which then activates a primary sensory neuron. However, there are differences between different groups, e.g. with respect to receptor type and the nature of the stimulating signals. Most fish and amphibians possess cathodally sensitive ampullary receptors (known as "Ampullae of Lorenzini" in elasmobranchs). They consist of a jelly-filled canal, which opens to the surface by a pore in the skin, and are excited by negative pulses and inhibited by positive ones. In contrast, the electroreceptive teleosts have evolved anodally sensitive ampullary electroreceptors as well as tuberous receptors. Tuberous receptors are not connected to the surface and able to respond to the discharges of the electric organs of these electric fish.





Ampullae of Lorenzini in shark:

1. The ampullae of Lorenzini form a complex and extensive sensory system around a shark's head.

2. External pores cover the surface of a shark's head. Each pore leads to a jelly-filled canal that leads to a membranous sac called an ampulla. In the wall of the ampulla are sensory cells innervated by several nerve fibers.

3. The ampullae detect weak electrical fields at short ranges. All living animals produce electric fields.

4. Ampullae of Lorenzini are effective only within inches, as they sense bioelectrical fields in the final stages of prey capture.

5. Mainly considered electroreceptors, it is possible that the ampullae of Lorenzini may also detect temperature, salinity, changes in water pressure, mechanical stimuli, and magnetic fields.

Q. 5- Answer

The mouth exhibits a variety of fascinating adaptations for capturing, holding and sorting food, ratcheting it into the oesophagus and otherwise manipulating it prior to entry into the stomach.

In milkfish (Chanos), the gill cavity contains epibranchial (suprabranchia) organs dorsally on each side, consisting either of simple blind sacs or elaborate, spirally-coiled ducts. The organs occur in several relatively unrelated families of lower teleosts and apparently relate to the kind of food eaten. Those fish with simple ducts all eat macro-plankton and those with the larger ducts microplankton. Although their function is unknown, concentrating the plankton has been suggested as a possibility.

The common carp provides an excellent example of non-mandibular teeth being used as the primary chewing apparatus. Pharyngeal teeth occur in the most fully developed forms of the Cyprinidae and Cobitidae, although many other groups also show some degree of abrading or triturating ability with some part of the gill bars. In carp, the lower ends of the gill bars have a well developed musculature which operates two sets of interdigitating teeth so as to grind plants into small pieces before swallowing them. The grinding presumably increases the rather small proportion of plant cells which can otherwise be successfully attached by digestive enzymes.

Many fish which chew their food have some ability to secrete mucus at the same time and place. This would have some apparent benefit when ingesting abrasive food. Although one might be tempted to equate such secretions with saliva, enzyme activity in the mucus does not appear to have been demonstrated, so the mucus is only partly comparable to saliva.

The oesophagus, in most cases, is a short, broad, muscular passageway between the mouth and the stomach. Taste buds are usually present along with additional mucus cells. Freshwater fishes are reputed to have longer (stronger?) oesophageal muscles than marine fish, presumably because of the osmoregulatory advantage to be gained by squeezing out the greatest possible amount of water from their food (i.e., marine fish would be drinking seawater in addition to that ingested with their food and freshwater fish would have to excrete any excess water).

The oesophagus of eels (Anguilla) is an exception to this general pattern. It is relatively long, narrow, and serves during seawater residence to dilute ingested seawater before it reaches the stomach.

Fish stomachs may be classified into four general configurations. These include (a) a straight stomach with an enlarged lumen, as in Esox, (b) a U-shaped stomach with enlarged lumen as in Salmo, Coregonus, Clupea, (c) a stomach shaped like a Y on its side, i.e., the stem of the Y forms a caudally-directed caecum, as in Alosa, Anguilla, the true cods, and ocean perch, and (d) the absence of a stomach as in cyprinids, gobidids, cyprinodonts gobies, blennies, scarids and many others, some families of which only one genus lacks a stomach.

The particular advantage of any configuration seems to rest primarily with the stomach having a shape convenient for containing food in the shape in which it is ingested. Fish which eat mud or other small particles more or less continuously have need for only a small stomach, if any at all. The Y-shaped stomach, at the other extreme, seems particularly suited for holding large prey and can readily stretch posteriorly as needed with little disturbance to the attachments of mesenteries or other organs. Regardless of configuration, all stomachs probably function similarly by producing hydrochloric acid and the enzyme, pepsin.

The transport of food from the stomach into the midgut is controlled by a muscular sphincter, the pylorus. The control of the pylorus has not been demonstrated in fish, but the best guess at this time is that it resembles that in higher vertebrates. The pylorus is developed to various degrees in different species for unknown reasons, in some species even being absent. In the latter case, the nearby muscles of the stomach wall take over this function, which may also include a grinding function by the roughened internal lining. In fish which lack a stomach, the pylorus is absent and the oesophageal sphincter serves to prevent regress of food from the intestine, i.e., in fish lacking a stomach and pylorus, the midgut attaches directly to the oesophagus.

The digestive processes of the midgut have not been studied extensively, except histo-chemically, but so far as known resemble the higher vertebrates. The midgut is mildly alkaline and contains enzymes from the pancreas and the intestinal wall, as well as bile from the liver. These enzymes attack all three classes of foods - proteins, lipids, and carbohydrates - although predators such as salmonids may be largely deficient in carbohydrases. The pyloric caecae attached to the anterior part of the midgut have attracted considerable attention because of their elaborate anatomy and their taxonomic significance. Histological examination has proved them to have the same structure and enzyme content as the upper midgut. Another suggestion was that pyloric caecae might contain bacteria which produce B-vitamins as in the rodent caecum. When tested, this hypothesis had no factual basis either. Pyloric caecae apparently represent a way to increase the surface area of the midgut and nothing more. This still leaves an interesting question of how food is moved into and out of the blind sacs which are often rather lone and slim: e.g., in salmonids.

The demarcation between midgut and hindgut is often minimal in terms of gross anatomy, but more readily differentiated histologically - most secretory cells are lacking in the hindgut except for mucus cells. The blood supply to the hindgut is usually comparable to that in the posterior midgut, so presumably absorption is continuing similarly as in the midgut. Formation of faeces and other hindgut functions appear to have been studied minimally, except histologically.

Q. 6- Answer

Generally, the gas bladder or swim bladder opens into the oesophagus by a duct called penumaticus duct which is short and wide in the lower teleosts (Chondrostei and Holstei) but longer and narrow in others. The pneumatic duct is present in the form of an open tube in several orders of teleosts as Cluppeiformes, Esociformes, Anguiliformes and Cyprininformes, but absent in Gasterosteiformes, Mugiliformes, Notacanthiformes and the Acanthopterygii. Hence, the teleosts were formerly divided into the **Physostomi** with an open duct and **Physoclisti** with a closed bladder.

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.

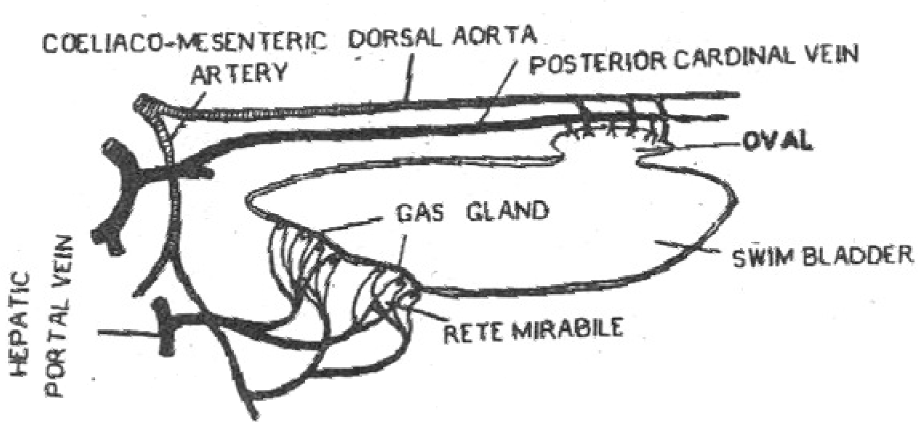


Fig: Blood Supply of the swim bladder of a Physoclistous teleost.

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.

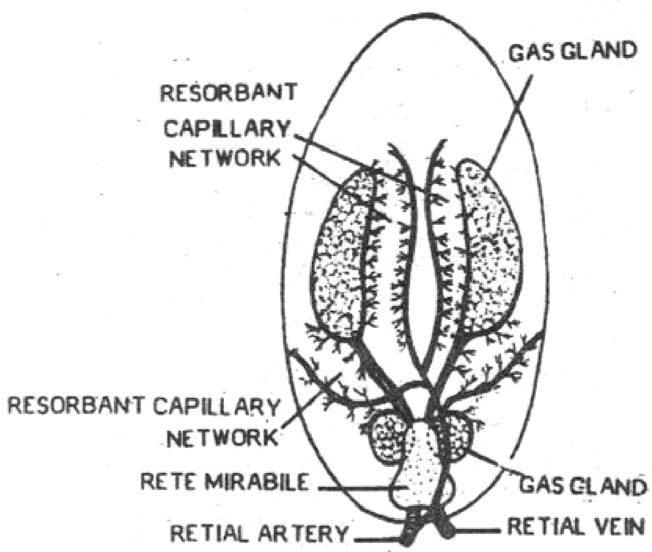


Fig: Swim bladder of a deep sea fish showing gas secreting complex.

Q. 7- Answer

Venous system in *Tor tor:*

The blood from the head is collected by external and internal jugular which unite to form an anterior cardinal vein on each side. The internal jugular vein receives blood from the premaxillary, nasal and optic regions while the external jugular collects the blood from the maxillary and mandibular regions. The anterior cardinals also receive opercular vein and the subclavian vein before opening into the ductus Cuvieri. A single inferior jugular vein collects blood from the ventral surface of the pharynx and opens into the sinus venosus.

Only one posterior cardinal vein is present in this fish and run through the substance of the right kidney. Renal vein from both the kidneys opens into the posterior cardinal which forwards and opens into the sinus venosus. The blood from the tail is collected by the caudal vein which after receiving several segmental vein, discharge into the kidney.

The hepatic portal vein collects blood from different regions of the alimentary canal, spleen, air bladder and the gonads and empties into the liver. From the liver, two hepatic veins arises and carry the blood to the sinus venosus.

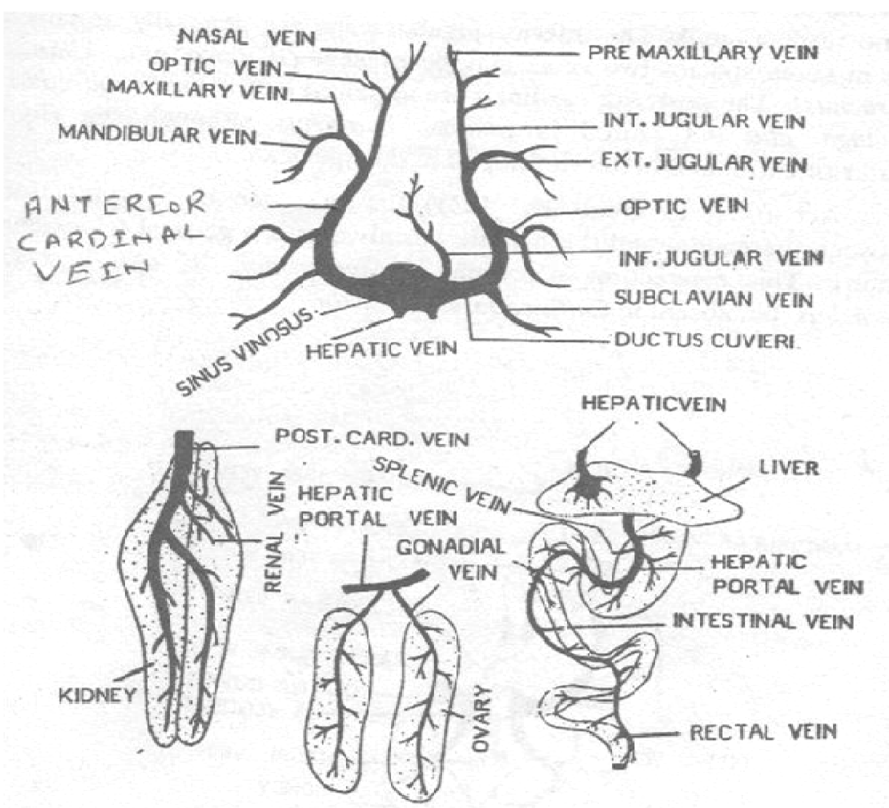


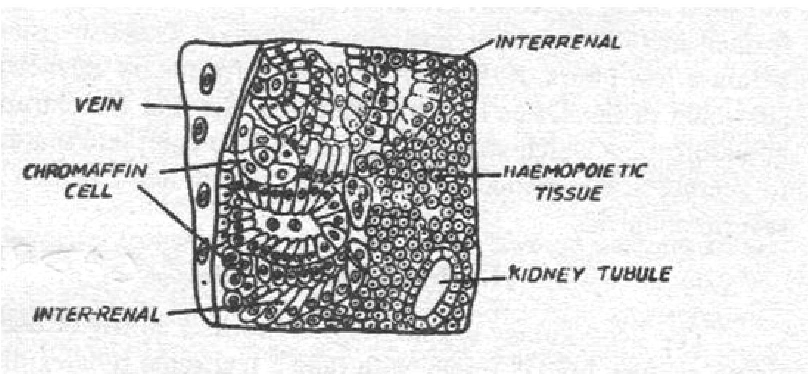
Fig: Venous system in *Tor tor*

Q. 8- Answer

Adrenal gland:

There is no true adrenal gland present in most fish (exception is sculpins). The adrenal cortical tissue in most fish is represented by the interrenal cells. These cells are pale eosinophilic cuboidal cells associated with major blood vessels in the anterior kidney. Both glucocorticoid and mineralocorticoid are secreted.

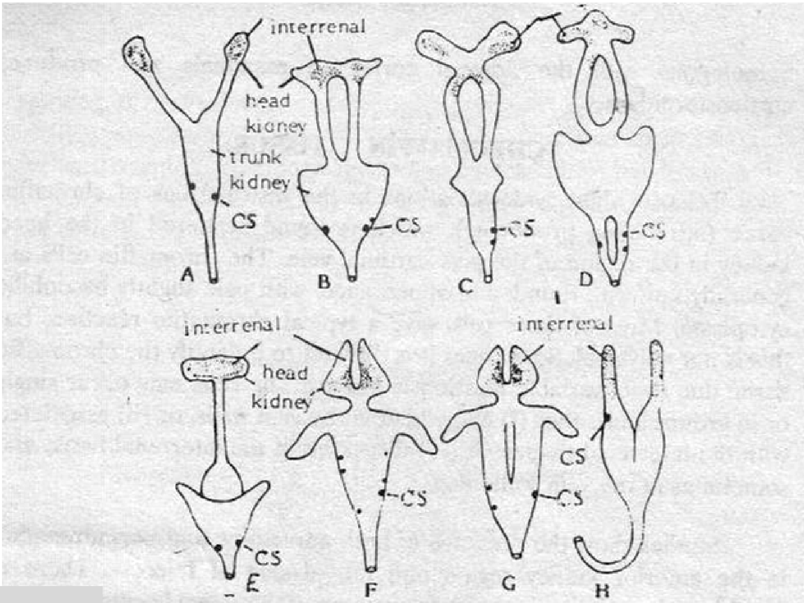
The adrenal medullary cells (chromaffin cells) may vary in location. These cells are usually found with the sympathetic ganglia in clumps between the anterior kidney and spine or in the interrenal tissue.



T. S. head kidney of *Channa* showing interrenal and chromaffin cell.

Corpuscles of Stannius:

These are islands of eosinophilic granular cells located in paired organs on the ventral surface of the kidney. This organ secretes a protein called hypocalcin (teleocalcin) that acts with calcitonin to regulate calcium metabolism.



Distribution of Corpuscles of Stannius (CS) and interrenal tissue of the kidneys of :

(a) Channa punctatus (b) Labeo (c) Catla catla (d) Cirrhina mrigala (e) Mystus vittalus (f) Clarias batrachus (g) H. fossilis (h) Notopterus notopterus (After Belsare 1973).