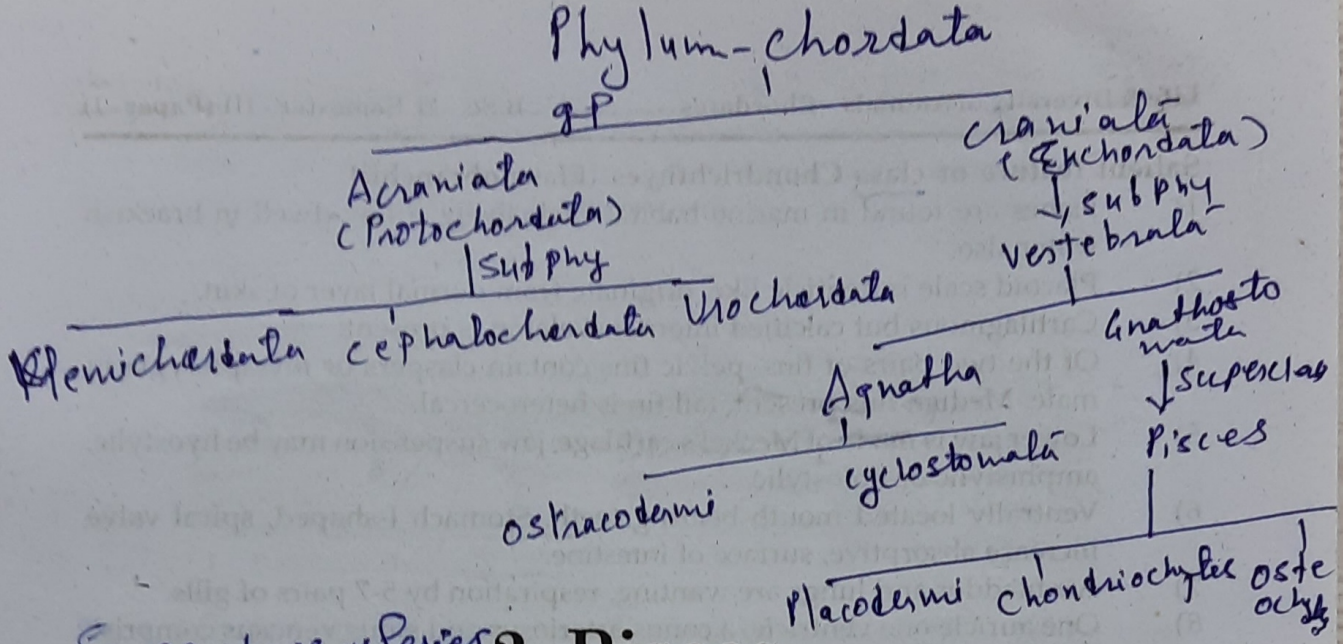

Superclass or Series 2. Pisces

2.1 SALIENT FEATURES OF CHONDRICHTHYES AND OSTEICHTHYES

The superclass Pisces comprise of fishes exhibiting varied shapes, colour, etc. They are adapted for aquatic life and live in fresh, marine and estuarine water's of the world. According to one estimation approximately 40,000 species are described by Zoologists.

General characters :-

1) They are aquatic cold blooded (ectotherm) with stream lined body and spindle shape. Some show dorsoventrally flattened body.
2) Appendages are paired pectoral and pelvic fins, supported by skeletal fin rays.
3) Median fins are one or two dorsal, an anal and a caudal.
4) Dermal scales, bony plates serve as protective exoskeleton on skin.
5) Mouth bear true jaws and teeth.
6) Internal bony skeleton or cartilaginous skeleton present.
7) Blood flows through body, occur in a single circuit. Heart with one auricle and one ventricle. Sinus venosus and renal-portal system are present.
8) Operculum may or may not be present covering the gill slits which are 5-7 in number bearing gills which function as respiratory organs.
9) Excretion by mesonephric kidneys.
10) Internal ears, is the only balancing organs.
11) Lateral line system is present.
12) Sexes are separate, fertilization is external and internal. Direct development, some forms display little metamorphosis.

Salient feature of class Chondrichthyes (Elasmobranchii)

1) Fishes are found in marine habitat exclusively, a few dwell in brackish water also.
2) Placoid scale is denticle like, originate from dermal layer of skin.
3) Cartilaginous but calcified internal skeleton is present.
4) Of the two pairs of fins, pelvic fins contain claspers or myxipterygia in male. Median fins present, tail fin is heterocercal.
5) Lower jaw is made of Meckel's cartilage jaw suspension may be hyostylic, amphistylic or holostylic.
6) Ventrally located mouth bearing teeth. Stomach J-shaped, spiral valve increase absorptive, surface of intestine.
7) Air bladder and lungs are wanting, respiration by 5-7 pairs of gills.
8) One auricle one ventricle, a conus arteriosus and sinus venosus comprise the circulatory system.
9) Opisthonephric kidneys excrete urea, cloaca is present.
10) Large cerebellum and olfactory lobes present. 10 pairs of nerves arise from brain.
11) Membranous labyrinth shows 3 semicircular canals in internal ear.
12) Gonads and gonoducts paired in male and female. Sex cells conveyed to cloaca.
13) Internal fertilization of large yolky eggs is characteristic of life cycle. Show direct development, oviparous or ovoviviparous forms includes sharks, rays, skates and Chimaeras. (Fig.1)

General characters of class Osteichthyes (Bony fishes)

1) Fresh and marine dwelling forms with streamlined, spindle shaped body, skin is mucous covered.
2) Ganoid, cycloid or ctenoid scales present on skin, some forms without scales.
3) Internal skeleton of bone, pelvic girdle small or absent.
4) Jaws terminating into a terminal or sub-terminal mouth bearing teeth, anus present, no cloaca.
5) Operculum cover 4 pairs of gills, an air (swim) bladder is present and may bear or may not bear duct which join with the pharynx. Air bladder is lung like in Dipnoi.
6) Two chambered heart with sinus venosus and conus arteriosus.
7) Olfactory lobes smaller than cerebrum. Cerebellum and optic lobes well formed. 10 Pairs of cranial nerves.
8) Lateral line system present. 3 semicircular canals in inner ear.
9) Male and female develop paired gonads, fertilization is external. Majority produce eggs, some are viviparous. Direct development, rarely metamorphosis is observed. (Fig. 2)

Major carps like catla, rohu, mrigal, catfishes like Clarias and Wallago, etc. and minor carps, snakeheaded fishes, eels, etc., are bony fishes.

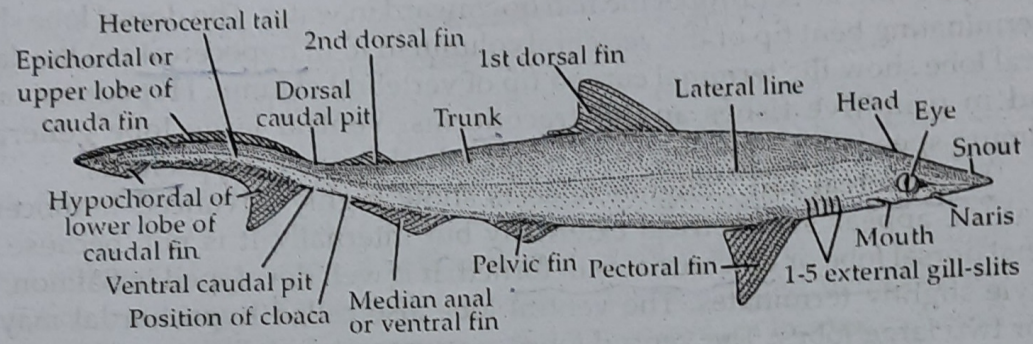

Fig. 1: Female Indian dogfish shark (Scoliodon sorrakowah) in lateral view. Origin of paired fins in fishes.

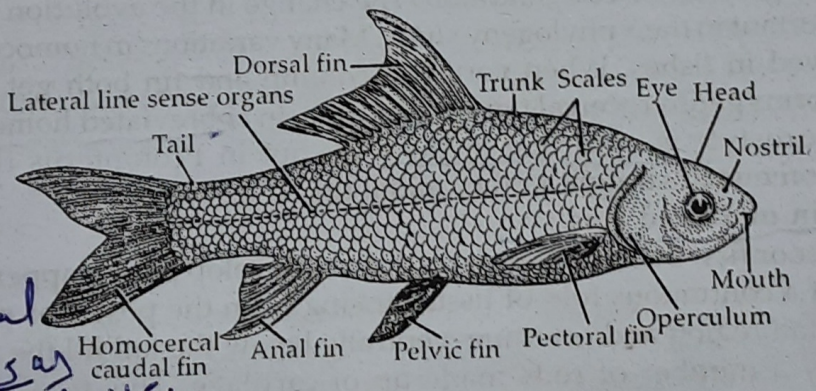

Fig. 2: Labeo rohita. External features in side view.

All types of fishes do not posses a well developed tail. The prehensile tail of Hippocampus and the tail of eel are reduced. In the sting rays caudal fin is absent. Some Zoologist classify caudal fin in to three, whereas some others into four types.

1) **Diphycercal tail :** It means double and is the earliest most type of tail not observed in living fishes. It is also called protocercal, means the first evolved tail, also regarded as secondarily formed modified tail in some fishes . At the tip of the tail the vertebral column show two lobes, one is called the ventral or hypochordal and the other as dorsal or epichordal. Both lobes are equal in size and shape. Eg. Cyclostomes, Primitive sharks, Chimaeras, living lung fishes, many larval teleost fishes, etc.

The caudal fin is three lobed in Latimeria and extinct Coelocanths. Here median lobe is prominent. Elongated and symmetrical tail are observed in deep sea fishes it is of isocercal type.

2) **Heterocercal tail :** Its lobes are asymmetrical, one big the other small a feature of Elasmobranch fishes, extinct Osteolepids and Dipterus, living Acipenser and Polyodon. These fishes have ventral mouth, and are bottom dwellers. The dorsal lobe being larger propel the fish downward in water. The dorsal lobe show the terminating bent tip of the vertebral column in it. In hypocercal tail the large ventral lobe show the terminal curved tip of vertebral column. Hypocercal tail is found in primitive fishes and Ostracoderms. Ventral large lobe generates maximum speed while gliding from water into the air. eg. Cypselurus.

3) **Homocercal tail :** Higher teleosts show highly advanced homocercal caudal fin, appear symmetrical externally but internally it is not, because the original dorsal lobe or epichordal is ill forned. It is well developed in Salmon, the urostyle slightly terminates. The ventral lobe also called hypochordal may be one or two large lobes. The ventral lobes are symmetrical. Fishes with terminal mouth show this tail and use it for forward propulsion in water. If one studies the embryology of fish the following trend is clearly observed in teleost development of tail from diphycercal primitive – heterocercal intermediate and homocercal highly advanced condition. The change in the evolution of these tail types is important in their phylogeny study. Many variations in homocercal caudal fin is observed in fishes. When vertebral column and fin both get reduced or vestigial it forms gephyrocercal tail eg. Fieraspis. In abbreviated homocercal type (Amia) the urostyle is upturned in the lobe, but in Protopterus the urostyle terminates somewhat straight in the caudal fin. (Fig. 5)

2.1 Origin of Paired fins :

Earlier or first evolved chordates did not develop paired appendages. It is believed that a continuous fold of tissue arising from the posterior part of head spread upto tail region and continue ventrally below the tail till the anus and is supported by a number of rods made up of cartilage. This tissue fold is the precursor of unpaired median fins in fishes. During evolution each supporting skeletal cartilaginous rod is separated by dividing to form a basal lower piece submerged in tissues of body wall. While the top or upper radial piece got accommodated in the skin fold which formed the fin. Theories of origin of fins proposed by various Zoologists are mentioned below. (Fig. 3, 5)

1) **Gegenbaur's Theory (19 th century) :** The girdles which supported the paired fins were formed from the gill bars. The skeletal elements of last gill arches and the fold of skin around it formed the paired fins and fin skeleton by undergoing modification during development. Theory is untenable because morphological and embryological studies do not support it.

2) Graham Kerr's external gill theory is also not much believed. In larval forms of fishes external gills are observed and are supposed to give rise to paired fins and their supporting skeletal structures.

3) **Balfour – Thatcher's fin – fold Theory :** In some ancestral Pisces or fishes distinct dorsal, anal, caudal, pectoral and pelvic fins originated simply by several divisions of the continuous median and lateral skin or body walls. Various

evidences support this theory. A common mode of origin of the skeletal elements of paired and unpaired fins in fishes have been proposed. Early stages of embryonic development in cartilaginous fishes show that bands of muscles developed in a serial manner, those which form unpaired and paired fins remain, but remaining ones disappear or are absorbed. Palaentologists haven't discovered any primitive fish fossil possessing continuous fin folds. Thus, the explanation of origin of pectoral and pelavic fins in extinct Cladoselache is not favoured by many Zoologists. Moreover, these paired fins of Cladoselache were supported by parallel rods of cartilage called pterygiophores. These fins were broad and lacked notches at its bases. Another view is, that a double row of small extra spiny fins between the pectoral and pelvic fins originated from the fin folds. These extra spine like fins are remains of the the fin folds in extinct Acanthodian sharks. Wiedersheim, Parker and Goodrich supported this theory.

4) **Ostracoderm theory** : The pectoral fin's developed from lateral fleshy lobes of body in some Ostracoderms. In Acanthodian extra fins on the ventro-dorsal aspect of body were present, which was also exhibited by some other Ostracoderms. These extra fins were spines developed from dermal layer of skin. From these Ostracoderm ancestors probably paired fins and limbs originated by retention of origin of paired fins in fishes. Some dermal spines were retained in the pectoral and pelvic regions. The remaining dermal spines were lost due to degeneration.

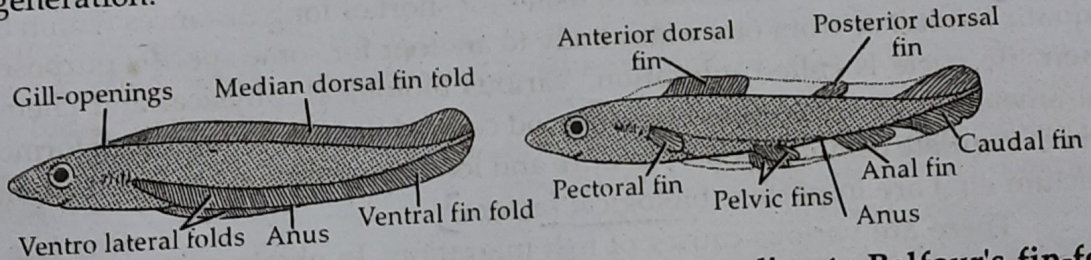

Fig. 3: Diagrams illustrating the origin of fins according to Balfour's fin-fold theory.

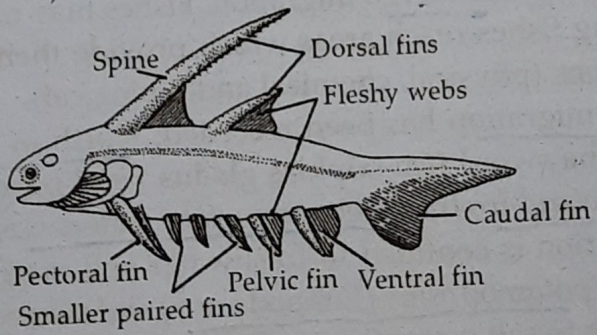

Fig. 4: Schematic derivation of fins according to the fin- spines theory.

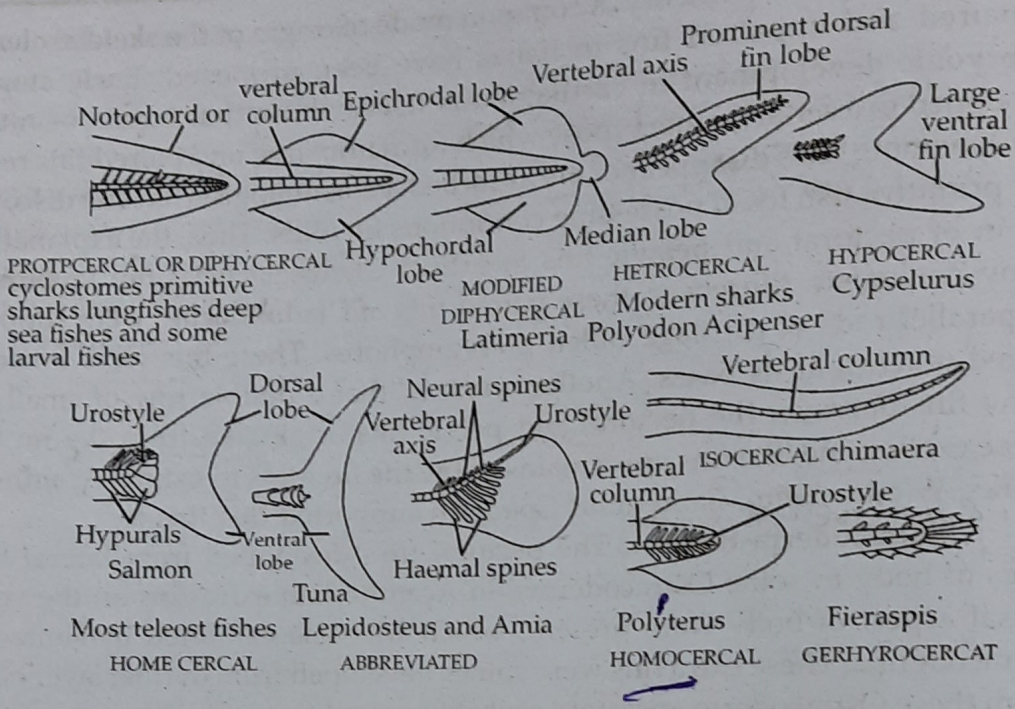

Fig. 5: Different types of caudal fins or tails in fishes.

2.2. MIGRATION IN FISHES

Movement or locomotion of fishes for short or long distances within their aquatic habitat or from one water body to another for some specific purposes in their life cycle is called migration. Various biological, physical and chemical parameters at certain defined time-period compel the fish to migrate. Hormones which regulate osmotic blood pressure and ion concentrations in blood (sodium, calcium etc.) are important biological factors.

There are various causes of fish migration. To obtain optimum quantity of food for survival and tide over extremes of environmental conditions. Similarly, to ensure increase in their population (reproductive success) and to colonize a given aquatic area, fishes undergo migration. Fishes may migrate for any one of these reason. Young fishes reach areas which provide them plenty of food and favourable conditions (physical, chemical and biological).

1. Latitudinal migration has been recorded, North in spring and South in autumn season in the sword fish (xiphias gladus) and Barracudas (Sphyraena).
2. Vertical migration to and fro from deep to surface waters is characteristic of some fishes.
3. When migration is confined to freshwater and marine water within the same area it is called potamodromy (Limnodromy) and oceanodromy respectively.
4. Migration from fresh to salt water (sea) is defined as catadromous, it is for laying eggs (spawning). Migration from sea to fresh water is called anadramous, it is

also for spawning. Catadromous and anadromous migration comes und diadromous migration (sea to water).

5 Amphidromous a type of diadromy is free movement of fishes, swimming for purposes other than breeding. Ex. Chanos.

Catadromous, migration: The common species of eels like, European eel (Anguilla rostrata) and American eel (Anguilla vulgaris) live a considerable part of their lives in fresh water. Change in colour yellow to metallic silver with onset of autumn, indicate that they will stop feeding activity and travel about 4500 kms in West direction from Europe or in East direction from America to their breeding marine habitat in Sargasso sea.[2] Some morphological changes observed are enlarged eyes, snout is sharper (pointed), and lips assume thinner consistency.[3] Internally gonads grow large due to thousands of mature eggs ready to be laid in sea, after this the male and female die.[4] Leptocephali larvae have small head, size is smaller than 6 mm, flat leaf like body, mouth with needle like teeth and large eyes. These transparent, pelagic larvae hatch out from the eggs about 50 m under the water and develop in to glass eels during return journey from sea to fresh water. The males dont ascend the streams and rivers with females. Females first ascend the rivers at the age of 3 yrs or more, now feed and grow rapidly to transform into yellow eels in some years. They mature and become silvery in appearance and migrate again to sea for breeding.

Anadromous migration:[1] With the start of winter mature fishes of both sexes of Atlantic salmon (Salmon salar) and 5 species of Pacific salmon (Onchorhyncus) migrate from sea to fresh water after travelling great distances.[2] They become exhausted due to stress and strain and due to cessation of feeding. They assume a light red-brown colour from their previous silver colour and now spawn in the circular depression in the bottom of the nest prepared for this event.[3] Many die, some may live to migrate back to sea for further spawning later in life. Larvae feed and grow in stream and reach ocean to feed voraciously and grow rapidly. While migrating they detect odours of stream water and chemicals utilizing their sense of olfaction. (smell).

Other catadromous migratory fishes are Salvelinus and Hilsa they migrate long distance to arrive at feeding station in the ocean. The brown trout (S. trutta) and cut throat trout (S. clarki) travel short distances. While migrating fishes may passively drift using water currents in the direction of water flow. Random locomotion may disperse the fish or concentrate them.

1) Thyroid hormones, prolactin, corticotrophin, growth hormone, etc. control migration by way of their physiological effects on fish.[2] Salinity of water, temperature, light variation (dull and strong) position of sun, photoperiod, turbidity, pH, smell and water taste are some physical and chemical factors controlling regulation and causing migration.[3] Memory, lack of predators, biological clock, etc. are few biological factors related to migration. (Fig. 8)

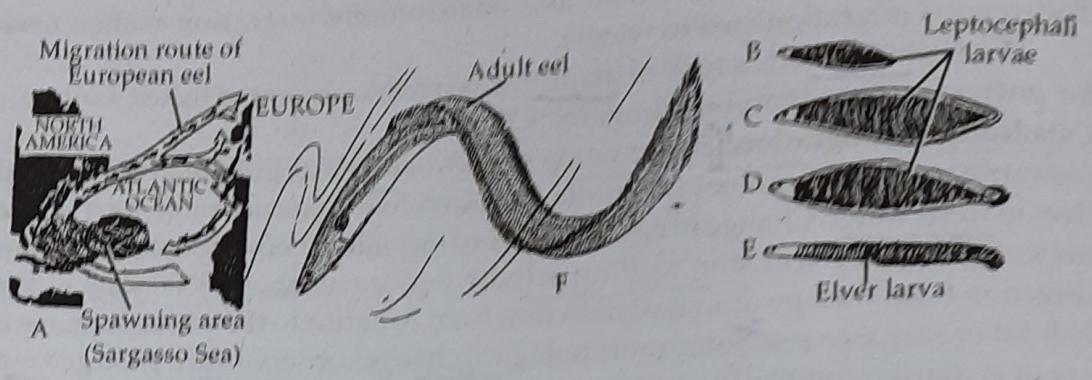

Fig. 1: Migration of fresh water eel. Anguilla. A Migration route and breeding place. B.C.D. Leptocephali larvae. E- Elver or glass eel. F- Adult eel.

ACCESSORY RESPIRATORY ORGANS IN FISHES

The gills are of prime importance in fishes to obtain oxygen for respiration while they are in aquatic habitat. Special structure or extra structures has been described in more than 140 species of fishes which live in tropical regions. This extra structures for breathing is utilized apart from the gills, when fishes come out of water or when the water level decreases. These special structures are referred to as accessory respiratory organs in fishes and are found in the families Cobitidae, Claridae, Anabantidae, Gobidae, Channidae, Notopteridae, etc.

The various types of accessory respiratory organs in teleost fishes are the skin, epithelium of buccopharynx, outgrowth (diverticulas) of pharynx, opercular or branchial chamber, outgrowth of opercular chamber, and a part of the alimentary canal modified as air bladder. (Fig. 1, 2 and 3)

1) **Skin :** The integument becomes highly vascular to absorb oxygen when fish is not in water. Moist skin suck oxygen from air when fish migrate through the damp vegetation. Eg, Anguilla anguilla and Amphipnous cuchia. Until the development of gills in embryos and larva of fishes, the thin, moist skin help in aquatic breathing.

2) **Buccopharynx epithelium:** In Electrophorus, Amphipnous, Boleopthalmus, etc., epithelium contain dense capillary network to absorb oxygen when fish is in water or outside water. Epithelium of these regions may be folded or simple.

3) **Pharyngeal diverticulum :** Just above the gills, two saccular outgrowths hang from the roof of pharynx, they are invested by thick epithelial cells containing a network of capillaries. They are folded in Channa, and very small in Periopthalmus fish.

In the eel (Amphipnous cuchia) reduced gills are located on second gill arch, a fleshy highly vascular membrane is located on the third gill arch. Folds or ridges are observed in the laterally placed pharyngeal diverticula, are two in

number, bear inspiratory and expiratory openings. Islets on respiratory epithelium show many papillae or rosettes which help in respiration when on land during the summer months (aestivation).

4) **Opercular chamber :** In Periopthalmus and Boleopthalmus air enter through mouth (when fishes are out of water or come out periodically out of water surface) passes through slits of gills into the chamber of lateral protective folds of gill called operculum. After sometime opercular chamber expand, at this time the fine vascular inner membrane bring about exchanges of oxygen and carbon dioxide.

5) **Diverticula of opercular chamber :** It is also known as opercular lungs it has advanced in evolution contain special structures or organs. Eg. Anabas, Clarias , Heteropneustes, etc.

a) **Heteropneustes fossilis :** Gill filaments on four pairs of gills are very poorly formed, instead they are expanded fan like gill plates developed on these gills arches. A pair of tubular sacs from the suprabranchial chamber originate and continue through the muscles uptill the middle of caudal region. Its supplied with blood by afferent respiratory vessel of the 4 th afferent branchial vessel. Inner lining of sac bear vascular and nonvascular portions. Lamellae arranged in two rows grow out to form respiratory islets in vascular portion and are concerned with respiration.

Pathway of entry of air : Inhalant opening → suprabranchial chamber → airsac posterior tubular region.

b) **Anabas testudineus :** In each of the two large suprabranchial cavities (outgrowth from dorsal gill chambers) the first epibranchial bones undergo modification to become highly folded concentric bony plate like structure having a vascular epithelium for performing respiration when fish is out of water.

Pathway of entry of air : Mouth air → suprabranchial chambers → exit through opercular openings.

c) **Dendrite (tree like) organs in Clarias :** Above the gills on each side the suprabranchial chambers lodges rosettes or arborescent (tree) organs which are two in number (Total 4 in two chambers) develop on epibranchials of second and fourth branchial arches. First dendritic organ is smaller than second one. Each dendritic organ have terminal knobs, each knob is formed by union of eight gill filaments. There are four gill plates or fans on which non vascular and vascular areas containing islets are present. Four fans on each suprabranchial chambers are developed. Vascular areas with islets and nonvascular areas are scattered on inner layer of suprabranchial cavities.

Path of entry of air : Mouth air → pharynx → inhalant opening → suprabranchial chambers → opercular cavities → exterior. Again mouth opens because a vacuum is created in the buccopharynx.

6. **Part of alimentary canal:** The muscle layers are greatly reduced and inner layer of stomach and intestine function as respiratory epithelium because of network of blood capillaries in it. Intestinal respiration is seen in loaches. Rectal respiration in Callichthyes. Air is held in the alimentary canal for sometime and later expelled through anus.

7. **Air bladder :** This organ in Dipnoi and ganoid fishes functions as lungs or modified respiratory organs. Internal sacculations bear alveoli which is highly vascular. One air bladder is dorsal in position in Amia and Lepidosiren whose duct open dorsally in pharynx. A dorsal air bladder and its duct open ventrally into pharynx in Neoceratodus. Two lungs ventrally located open ventrally through duct in pharynx it is characteristic of Protopterus and Lepidosiren. Air bladder is an adaptation to compensate for ill developed gills and respiration.

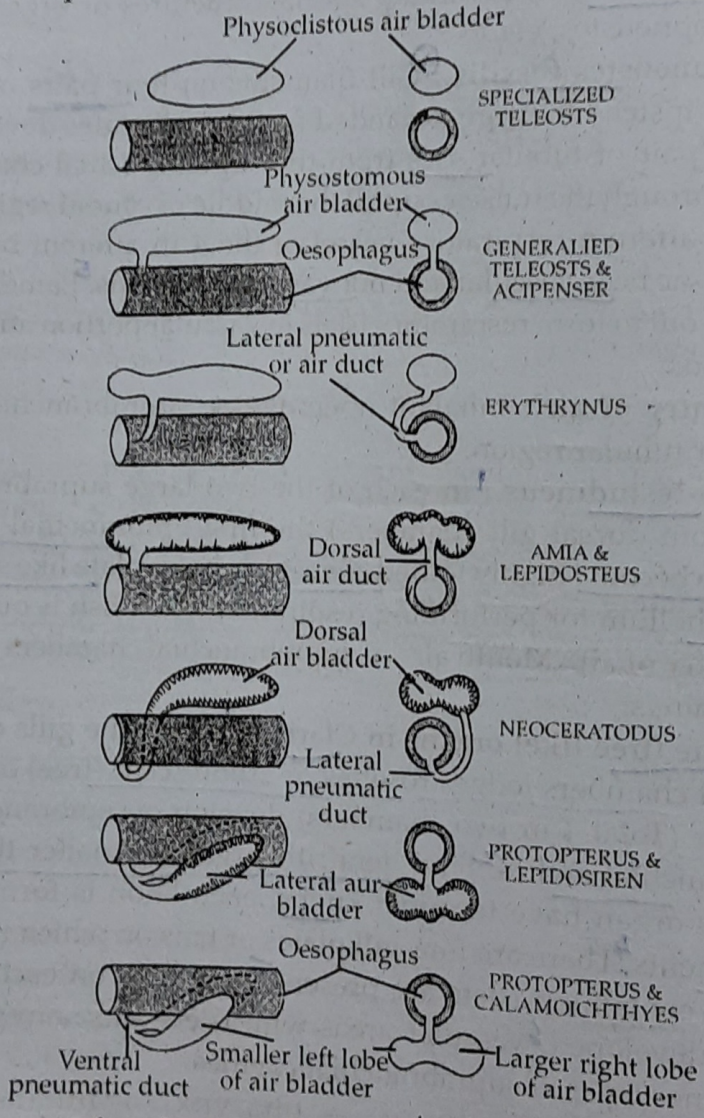

Fig. 2: Various types of swim bladders and lungs in fishes shown in L.S. (Left side) and R.S. (right side).

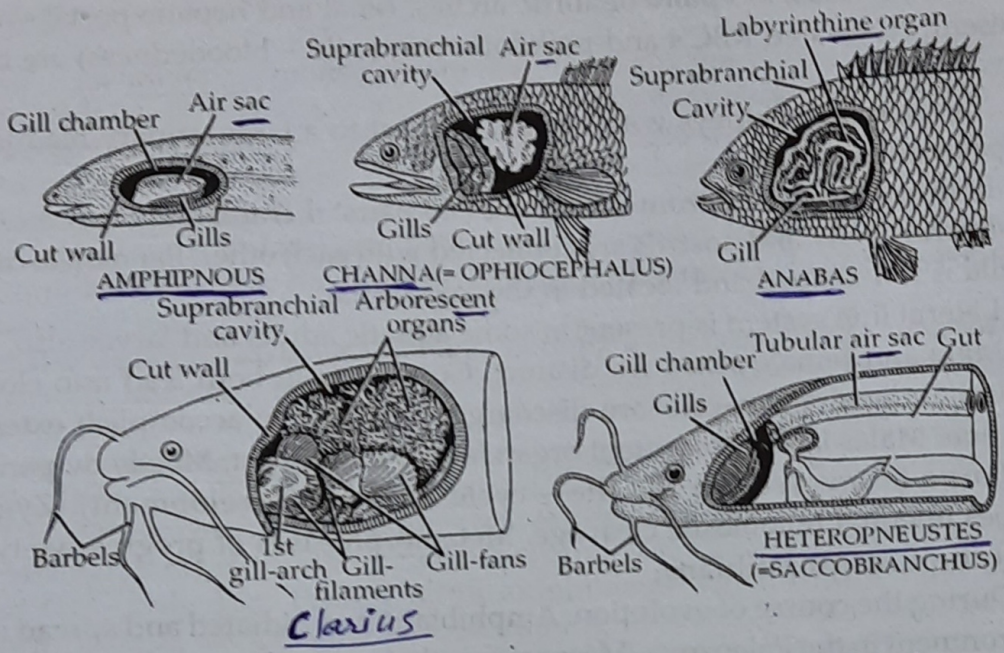

Fig. 3: Accessory respiratory organs dissected on the left side in some air-breathing teleost fishes.

2.3 AMPHIBIA

Amphibians are animals adapted to live on land and also in water. They show body structure on one hand of the fish and on the other hand of the reptiles to survive both on water and land respectively.

General characters of class Amphibia.

1) They are aquatic and semi-aquatic in habitat, utilize skin to perform cutaneous respiration. Show pulmonary respiration on land. Larva bear gills for respiration.

2) Body with a well defined head, and an elongated trunk region. Some forms have neck and tail.

3) They are tetrapod with well developed fore and hind limbs. Toes are 4 to 5 a condition called pentdactyly or some forms contain less toes. If present the median fins are without fin rays.

4) Body without exoskeleton, skin is moist with mucous secreted by gland cells. Chromatophores are cells with pigments embedded in the soft skin.

5) Skin in some forms contain hidden scales called dermal scales.

6) Large mouth bearing homodont teeth either on upper and lower jaws. Tongue is extensible from mouth. Digestive system with oesophagous, stomach, intestine and anus which open into a chamber called cloaca.