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INTRODUCTION TO FISH BIOLOGY AND ECOLOGY

1.1. FISH BIOLOGY- INTRODUCTION:

Fish have great significance in the life of mankind, being an important natural source of protein and providing certain other useful products as well as economic sustenance to many nations. The gradual erosion of commercial fish stocks due to over -exploitation and alteration of the habitat is one reason why the science fish biology came into existence (Royce, 1972).

It is a well known fact that the knowledge on fish biology particularly on morphometry, length-weight relationship, condition factor, reproduction, food and feeding habit, etc. is of utmost important not only to fill up the lacuna of our present day academic knowledge but also in the utility of the knowledge in increasing the technological efficiencies of the fishery entrepreneurs for evolving judicious pisciculture management.

For developing fishery, it is necessary to understand their population dynamics- how fast they grow and reproduce, the size and age at which they spawn; their mortality rates and its causes, on what they prey upon along with other biological processes.

There are many isolated disciplines in fish biology, of which the study of morphology is inseparably related to study of the mode of life of the organism. It fact, the size and shape are fundamental to the analysis of variation in living organisms (Grant and Spain, 1977) and morphological variations even in the same species most often related to the varied environmental factors.

1.1. General characters of a fish

Fishes are the first vertebrates with Jaws. They are cold-blooded animals that breath by means of gills, live in water and move with the help of fins. There are about 36,000 species, which represent the 40% of the total vertebrates present. Fishes have evolved during Ordovician period and widely distributed during Devonian period, which is known as 'Golden age of fishes'. The study of fishes is known as Ichthyology. Fishes differ from each other in size, shape, habits and habitats. The smallest fish is the Phifippine goby, *Mistichthys lozerensis* which measures about 1.2 cm. and the largest fish is the whale shark, *Rhinodon* which grows up to 20 meters. They live in all the seas, rivers, lakes, reservoirs, canals, tanks etc. They are economically a very important group of animals. They are used as food throughout the world and the fish liver is the main source of liver oil containing vitamin A and D. Body oils of fishes are externally used in soap industry and tanneries. Beautiful coloured fishes are the present craze to have them in Aquariums. The general characters of fishes are:

1. Fishes are aquatic. found in all types of waters. They are found in freshwater (*Labeo*), marine (*Stromateus*), brackishwaters (*Chanos*) and cold waters ('*Salmo*).
2. **Symmetry**: These are bilaterally symmetrical
3. **Coelome**: Fishes are eucoelomates and enterocoelomates
4. These are triploblastic animals
5. **Segmentation** : Fishes are segmented and segmentation is internal
6. **Shape** : Most of the fishes are spindle shaped some are dorso-ventrally depressed (*Narcine*), some are laterally compressed (*Notopterus*), some are snake like (*Mastacembelus*) , some are globe like (*Tetradon*)
7. **Colour**: Different colours are found in fishes. Aquarium fishes are extremely beautiful with glittering colours
8. **Size**: Size of fishes also varies from 1.25 cm *(Mystichthys lozerensis*) to 20 meters (*Rhynodo*) in length.
9. **Exoskeleton** : Fish body is covered with scales and bony plates. Due to their various functions, scales are known as identity card of fish. Scales are mesodermal in origin. Scales are absent in siluriformis fishes (cat fishes). Scales are absent on head region in few fishes (major carps). Bony rings are found in syngnathifromis fishes (*Hippocampus*).

Scales are of different types. These are cosmoid (extinct fishes), ganoid (Dipnoi fishes), placoid (Elasmobranch fishes), cycloid (Cypriniformis fishes) and ctenoid (perciformis fishes) scales. Some fishes have spines on body (*Clarias*)

10 **Fins:** Fins are useful for swimmmg and balancing Fins are supported by rays known as fin rays Fins have both spiny and soft rays. Fins without fin rays are known as adipose fins (*Mystus)* Fins are mainly two types — paired and unpaired fins. Paired fins are pectoral and pelvicdor ventrals. Unpaired fins are dorsal, anal and caudal fins. Fins are mostly normal or modified in few fishes.

11 **Body farm** : Fish body can be divided into head, abdomen and tail

12 **Tail** :Tail is useful for changing the direction during swimming. Tail consists of fin known as caudal fin Tails are of different types — diphycercal (Dipnoifishes), hypocercal (extinct fishes), heterocercal (cartilagenious fishes and homocercal (teleost fishes). Caudal fin is either forked or round or confluent with dorsal and anal.

13. **Endoskeleton**: Mostly autostylic skull, Amphicoelous verterbrae. Appendicular skeleton is poorly developed

14. **Digestive system**: Complete alimentary canal: Mouth is large in carnivorousfishes, small in other fishes. Mouth is terminal (many fishes), upturned (Catla), subterminal (Labeo) and ventral (cartilaginous fishes). Teeth are well developed in carnivorous fishes. Stomach is absent in many fishes. An intestinal bulb is present. Scroll valve is present in cartilaginous fishes. useful for food absorption. Cloaea is present in cartilaginous fishes. Pancrease is well developed. Inter cellular digestion.

15. **Respiratory system** : Branchial respiration by gills. Gills are located in branchial chamber. 5-7 gills are found in cartilaginous fishes and 3-5 gill are found in teleosts. Each gill is supported by gill arch, gaseous exchange takes place in gill lamellae, gill rackers are well developed in plankton feeding fishes, where these are useful as sieve. Open type of branchial system is found in cartilaginous fishes, whereas closed branchial system is observed in bony fishes. Operculum is present only in bony fishes. In cartilaginous fishes more than one pair of external branchial openings are found, where as only one pair of opening are seen in bony fishes. Haemoglobin is respiratory pigment. Accessory respiratory organs are found in few fishes like *Clarias* (respiratory trees), *Channa* (labyrinthin organ), *Heteropneustes* (air sac), dipnoi

fishes (lungs), etc, which are useful to live for some time out side water.

16. **Circulatory system**: Closed type of circulatory system is found in fishes. Heart is two chambered, venous, tubular and with either conus or bulbus arteriosus. RBC are biconvex in nature.
17. **Nervous system**: Cerebrum is not much developed Olfactory lobes are well developed, especially in sharks. 10 pairs of cranial nerves are found.
18. **Sensory organs** : Laternal line system is very well developed in fishes. Neuromast cells are found in lateral line system, which are useful to detect water currents. External and middle ears are absent. Internal ear is present in the form of membranous labyrinth. Olfactory organs are well developed with olfactory lamellae. Ampullae of Lorenzini are thermoreceptors found in cartilagerious fishes. Barbles are very well developed in catfishes.
19. **Excretory system** : Mesonephric kidneys are found, ammnotelic animals. Marine fishes retain urea in their blood to maintain isotonic condition with seawater.
20. **Reproductive system** : Monosexuals, sexual dimorphism is found. In Few fishes are Coupulatory organs. Claspers in cartilagenous fishes and gonopodium in poecilidae family fishes are coupulatory organs. Gonads exhibit sesonal variations. Oviparous, except sharks and poecilidae fishes. External fertilisation, except in above fishes Megalecithal eggs. Cleavage is holoblastic, determinate. Direct development except in Anguilla, which consists of elever or leptocephalus larval form. Parental care is fond in fishes eg. *Oreochromis* is mouth brooder. Brood pouch is found in *Hippocampus*. Some fishes are nest builders eg *sunfishes.*
21. Electric organs are found in few fishes, which produce current eg. *Tarpedo, Electrphorus*
22. Few fishes exhibit bioluminescence eg, *Blepherodon*
23. Fishes like *Anguilla* and *Salmon* exhibits diadromous migration.

1.2. General characters of prawns

Prawns and shrimps are decapode crustaceans. They are aquatic, and respire with gills. Prawns are freshwater and shrimps are marine crustaceans.

1. Prawns are freshwater animals eg. *Macrobrachium resenbergii*, *molcolmsonii*. Shrimps are found in both sea and brackishwater eg.

Penaeus monodon, P. indicus, Metpenaeus dobsoni

2. **Symmetry** : These are bilaterally symmetrical.
3. **Coelome** : There are eucoelomates and schizcoelic animals. The coelome is known as haemocoel due to the presence of blood in the coelome.
4. These are triploblastic animals.
5. **Segmentation** : Segmentation is heteronomous and external.
6. **Shape** : Body is elongated, more or less spindle shaped. Abdomen region is in cama (,) shaped
7. **Size** : The size of adults varies from species to species. The largest prawn (32 cm) is gainst freshwater prawn, *Macrobrachium rosernbergii*. Largest shrimp is *penaeus monodon.*
8. **Body farm** : The body is divided into cephalothrax and abdomen. Cephalothorax is the fusion of head and thorax and consists of 13 segments. Abdomen consists of 6 segments.
9. **Exoskeleton** : Body is covered by a hard protective calcareous plates, known as sclerites. Sclerites are made up of chitinous cuticle. Adjacent sclerites are connected by thin arthroidal membrane, making the movements feasible.
10. **Rostrum** : The sclerites of dorsal (terga) and lateral (pleura) form a laterally compressed and serrated rostrum. The separations of rotram are called denticles which play a major role in identification of species. The denticles are found both dorsally and ventrally as in *Penaeus*_sp or only dorsally as in *Metapenaeus* sp.
11. **Appendages** : Each prawn has 19 pairs of joined appendages, each pair attached to a segment. Cephalic region consists of 5 pairs of appendages, thorax consists of 8 pairs and abdomen consists of 6 pairs of appendages. The cephalic appendages are antennule, antenna, mandible, maxillulae and maxilla. The thoracic appendages are 3 pairs of maxillepedes or foot-jaws and 5 pairs of paraopods or walking legs. The abdominal appendages are 5 pairs of pleopods or swimmerets and a pair of uropods, all useful for swimming. All the appendages are biramus and each appendage is with a common base or protopodite, bearing 2 rami or branches, an inner endopodite and outer exopodite. Both the rami comprise of many segments or podomeres.
12. **Telson** : Last abdominal segment consists of an elongated sharp spine known as Telson.

13. **Integument** : The integument Consists of outer epicuticle, inner endocuticle, epidermis and dermis composed of connective tissue layer with muscle strands and many tegumental glands.
14. **Endoskeleton** : It is absent in prawns.
15. **Digestive system** : Complete alimentary canal, mouth is large and slit-like, stomach is thin-walled and double-chambered, consisting of cardiac and pyloric stomachs. Intestine is a long and narrow tube. Hepatopancrease is a large, bilobed and produce digestive enzymes. Prawns are deteritivores, feed on debris of bottom, phyto —. and zooplankton. Intercellular digestion.
16. **Respiratory system**: Branchial respiration by gills. Respiratory system is well developed and consists of 8 pairs of gills, 3 pairs of epipoodites and lining of branchiostegites or gill covers, found in gill chambers in thorax region. Scaphognathites or balars are useful for pumping of water into gill chamber.
17. **Blood vascular system** : Open or lacunar type of blood vascular system. Blood capillaries are absent and blood flows through the lacunae or sinuses .Heart is neurogenic muscular and triangular in shape. Blood is colourless with leucoçytes and without erythtocytes. The respiratory pigment is haemocyanin Prawn blood has remarkable clotting properties.
18. **Excretory system** : The excretory organs are antennary or green glands, renal or nephroperitoneal sac and integument. Prawns are ammonotelic animals.
19. **Nervous system** : Brain is in the form of supra-oesophageal ganglia. Ventral thoracic mass is found in cephalothorax and a ventral nerve cord is found, sympathetic nervous system is in the form of ganglia and nerves.
20. **Sense organs** : Compound eyes, statocysts, tangoreceptors, chemoreceptors and proprioreceptors are sense organs found in prawns. Eyes are located on ommatophore. Mosaic vision and apposition image are found in prawns.
21. **Endocrine system** : The sinus gland of eye stalk produce growth or moulting inhibitory hormone
22. **Reproductive system** : Prawns are dioecious and sexual dimorphism is well marked. Males are bigger than females. Second chelate legs of males are longer, stronger, stouter and more spiny than in female.

Second pleopods of males bear appendix masculine. Gonads are paired. Fertilization is external. The fertilized eggs are placed in thelcum and prawn with fertilized eggs are known as berried prawn. Indirect development, first larval farm is naupleus, second larval form is protozoa, third larval farm is mysis, which developed into post larvae.

23. **Moulting** : Prawns undergo the moulting or ecdysis. During this process, the growth of prawn takesplace.
24. **Migration** : Prawns exhibit breading and feeding migration. Freshwater prawns exhibit breeding migration, migrate from freshwater to brackishwater and back to freshwater. Marine shrimps exhibit feeding migration, migrate from sea to brackishwater.

1.1.2 Classification of fishes and prawns

1.1.2.1 Classification of fishes

The super class pisces is divided into three classes
1. Placodermi 2. Chondricnthyes 3. Osteicnthyes

1.1.2.2 Class Placodermi

These are extinct animals, Fossil evidences reveal that they lived in Silurian, Devonian and Carboniferous periods of Paleozoic era. Endoskeleton and exoskeleton was made up of bony-armor Jaws were primitive

Eg. *Climatius, Palaeospondylus.*

1.1.2.3 Class Chondrihcthyes or Elasmobronchii

(Gr. Chondros = Cartilage; icthyos =fish)

I) All are marine animals
2) Endoskeleton is made up of cartilage
3) First gill slit is spiracle
4) Scales are placoid type and are minute
5) Fins are without rays. Tail is heterocercal
6) Mouth is ventral
7) Spiral valve is present along the internal well of the large intestine. Cloaca is present

8) Paired nostrils are present at the ventral side of rostrum
9) Air bladder is absent
10) 5 to 7 pairs of Gills. GilL slits are present and are not covered by operculurn
11) In the heart, sinus venosus, auricle, ventricle and conus arteriosus with valves are present.
12) These are ureotelie animals and store high levels of urea and trimethylamine oxide (TMO) in their blood and body fluids.
13) A pair of claspers are present in males on either side of cloaca.
14) Eggs are macrolecithal (high amount of yolk) and cleavage is meroblastic
15) Fertilization is internal and many species are viviparous. Development takes place inside the oviduct and in oviparous forms development occurs outside the body.

1.1.2.4. Class Osteichthyes (Bony fishes)

(Gr. Osteos = bone; ichthiyes fish)

1) Endoskeleton is made up of bone
2) Inhabits both freshwater as well as marine.
3) Skin is covered by cycloid, ctenoid or gonoid scales
4) Mouth is usually terminal or sub-terminal
5) 4 pairs of gills are present on either side of the pharynx. Their openings are covered by operculum or gill cover.
6) Tail is homocercal, diphycercal or heterocercal
7) Claspers, cloaca and nasobuccal grooves are absent. Separate Oval and urinogenital apertures are present.
8) Heart is two charmbered with an auricle and a ventricle. Conus arteriosus is absent. Lung fishes have an incompletely divided auricle and a ventricle. Pulmonary artery and pulmonary vein are present in lung fishes.
9) These are ammonotelic animals
10) Air bladder is present in many species
11) Bony fishes are usually oviparous. Few are viviparous. (eg. *Gambusia*, *Labestis*)

Class osteichthyes is divided into two sub-classes.

1. Crossopterygii (Lobe — finned fishes) 2. Actinopterygii (Ray finned fishes)

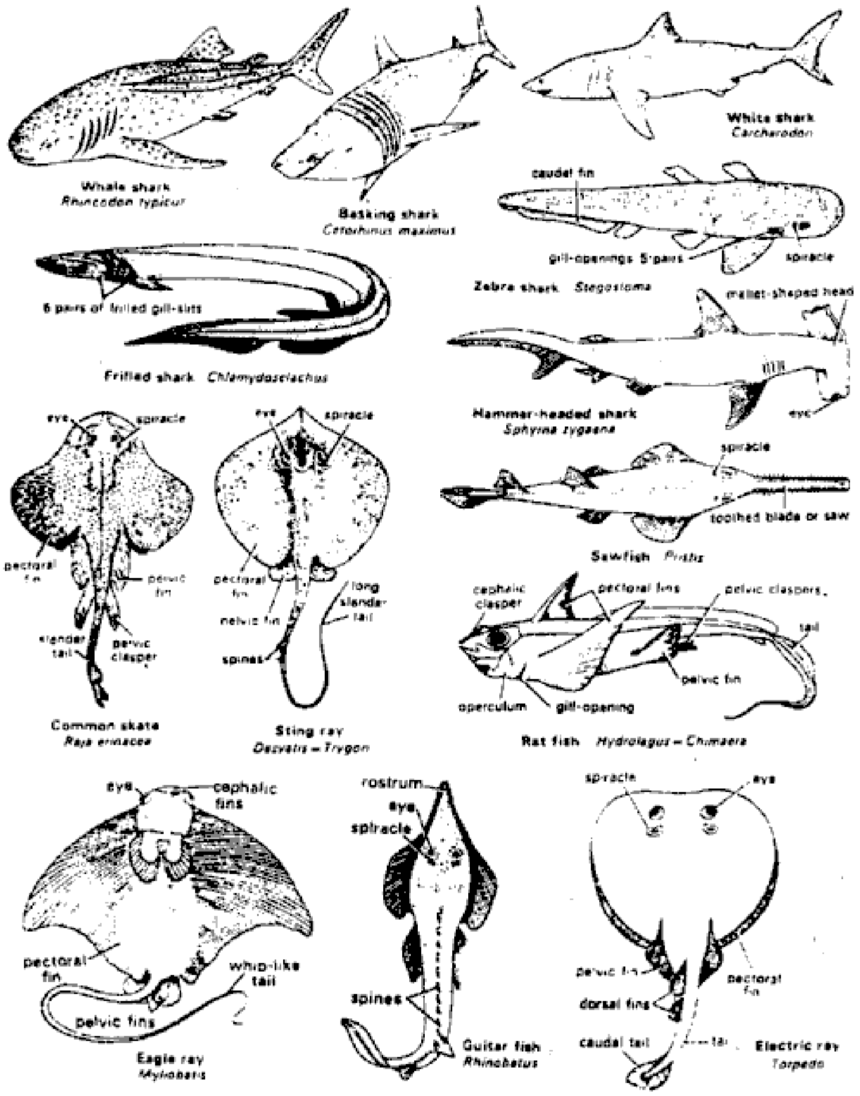


Fig 1.1 Cartilagenous fishes

Eg. *Scoliodon* (shark), *Pristis* (saw fish), *Sphyrna* (Hammer-head shark) *Torpedo* (Electric ray)

1.2.4.1. Sub class Crossopterygii

1. First vertebrate animals in which nasal passage connects the mouth cavity to the out side (Osteolepids and lung fishes)
2. Each paired fin is provided with large median lobe and dermal finrays arising on either side of an axis in a pinnate fashion.
3. Caudal fin is diphycercal. Fins are paired and having a scale covered lobe.
4. Lungs are formed by the vertral evaginations of the pharynx.

   Sub class crossopterygii is divided into two order.

1.2.4.1.1. Order Rhipidistia

1. These are marine animals
2. Pectoral and pelvic fins are lobed and paddle-like
3. Skin is covered by cycloird scales
4. Spiral valve intestine is absent
5. Includes extinct Osteolepids which had internal nostrils and considered to be ancestors of amphibia and the living fossil fishes coelacanths, eg. *Latimeria chalumnae.*

1.1.2.4.2. Order Dipnoi (Lung Fishes)

1. These are fresh water anima1s
2. Body is long and slender
3. Jaws are short, teeth form a pair of plates
4. Pectoral and pelvic fins are slender
5. Skin is covered by cycloid scales
6. Spiral valve in Intestine in present
7. Internal nostrils and one or two lungs and pulmonary arteries and veins are present

Eg. Protopterus, Lepidosiren, Neoceratodus.

1.1.2.4.2. Sub class Actinopterygii

1. Internal nostrils are absent
2. Paired fins are supported by

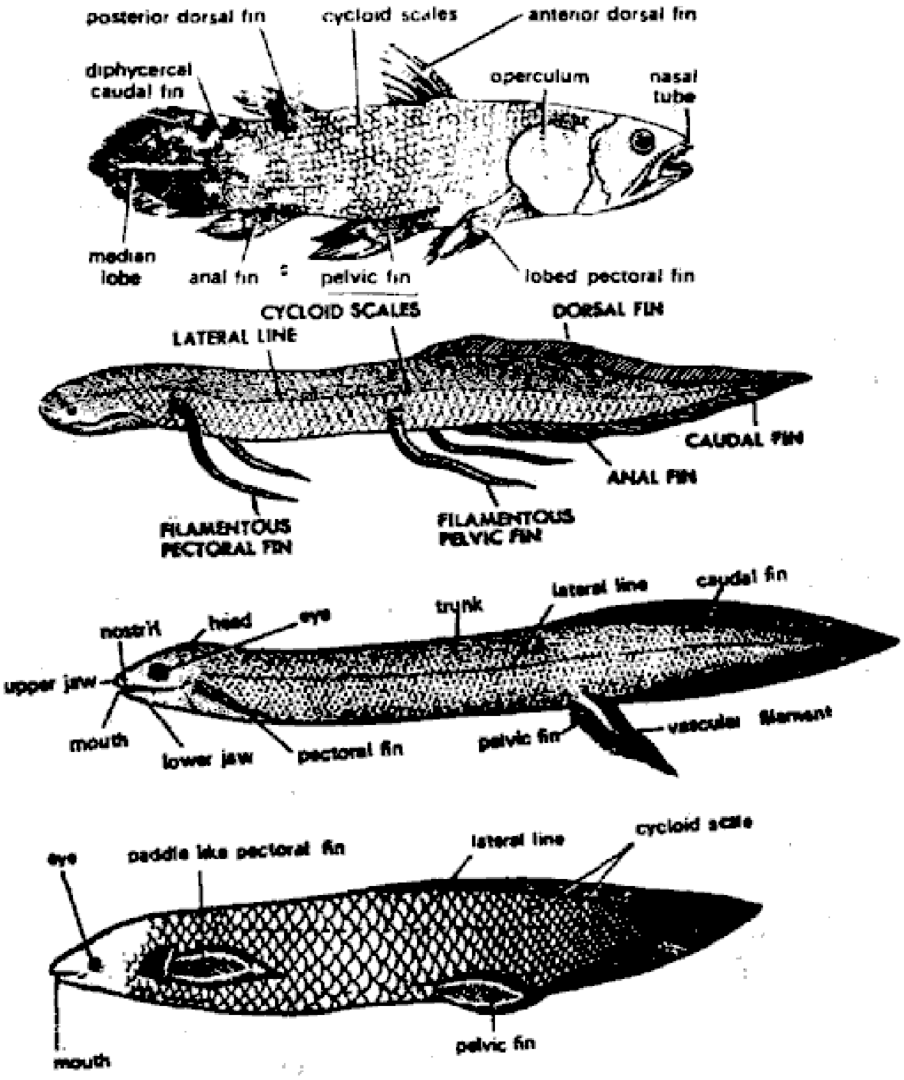
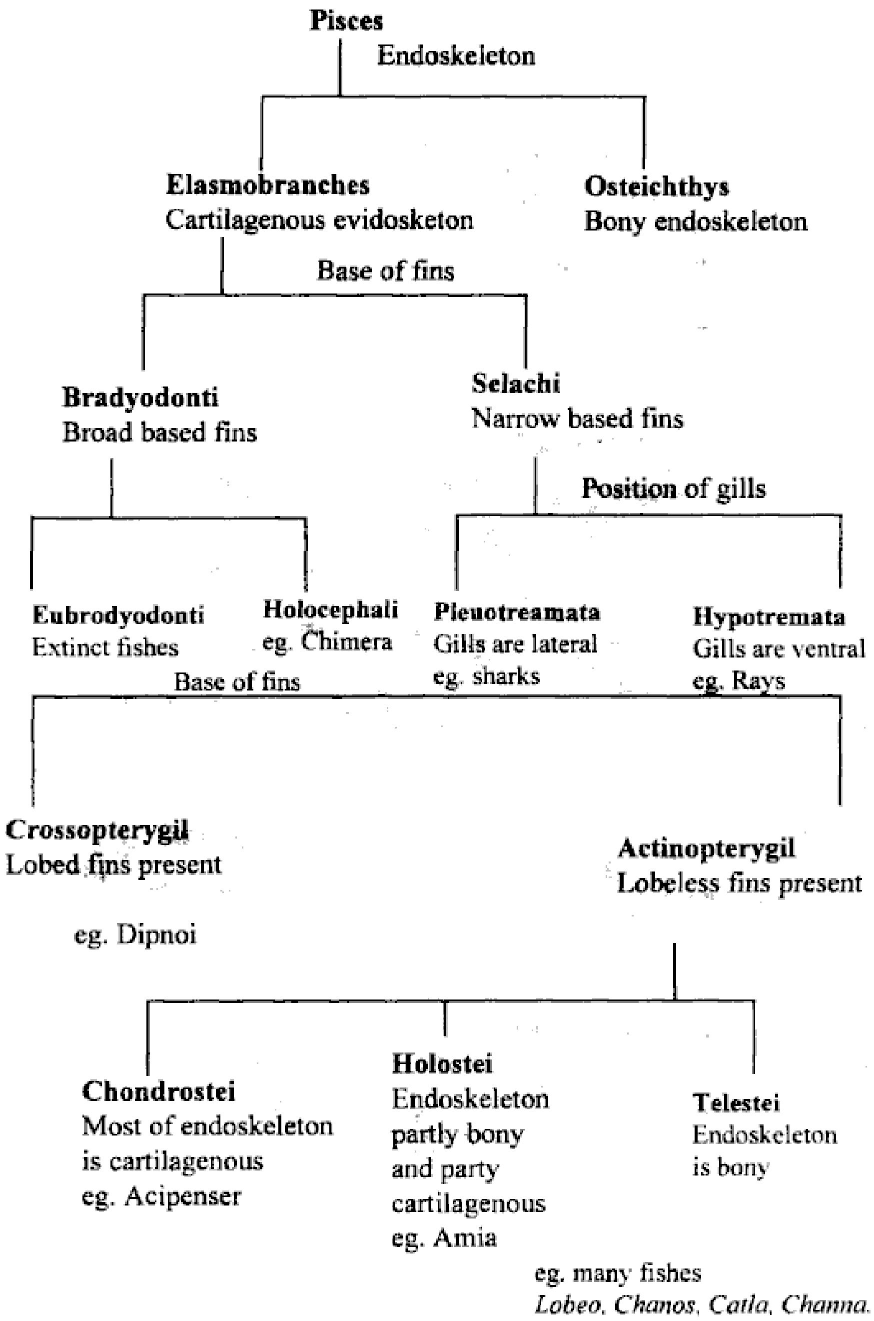


Fig. 1.2 Lobed fin fishes

a. Latimeria. b. Protopterus. c. Lepidosiren d. Neoceratodus

CLASSIFICATION OF FISHES



fin-rays arranged in a palmate fashion

3. Caudal fin is homocercal
4. Lungs are absent. An air bladder or swim bladder or gas bladder is presen which is hydrostatic in function

Sub class Actinopterygii is divided into the three superorders

1. Chondrostei 2. Holostei 3. Teleostei

1.1.2.4.2.1. Super order Chondrostei

1. These are fresh water fishes
2. Weak jaws without teeth
3. Endoskeleton is cartilagenous
4. Exoskeleton consists of bony plates covering the body.
5. Tail is heterocercal
6. Spiral valve is present in the intestine
7. Air bladder with duct is present

Eg. *Acipenser* (Sturgeon), *Polyodon*.

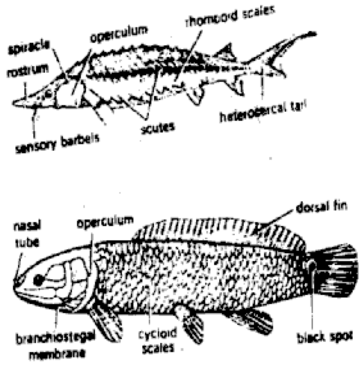


Fig. 1.3 Primitive actinopterygian fishes, a. Acipensor, b. Amia

1.1.2.4.2.2. Super order Holostei

(Gr. Holo- complete; osteo=bone)

1. These are known as bow fins
2. There are found in fresh water of America
3. Endoskeleton is bony
4. An air bladder is present above the oesophagus
5. Spiral valve is present in the intestine
6. Air bladder is present with a duct

Eg. *Amia, Lepidosteus*

1.1.2.4.2.3.Super order Teleostei

(Gr. Teleo = entire, osteo=bone)

1. Includes a large number of modern bony fishes. Skeleton is fully ossified
2. These are occur in fresh water as well as in sea

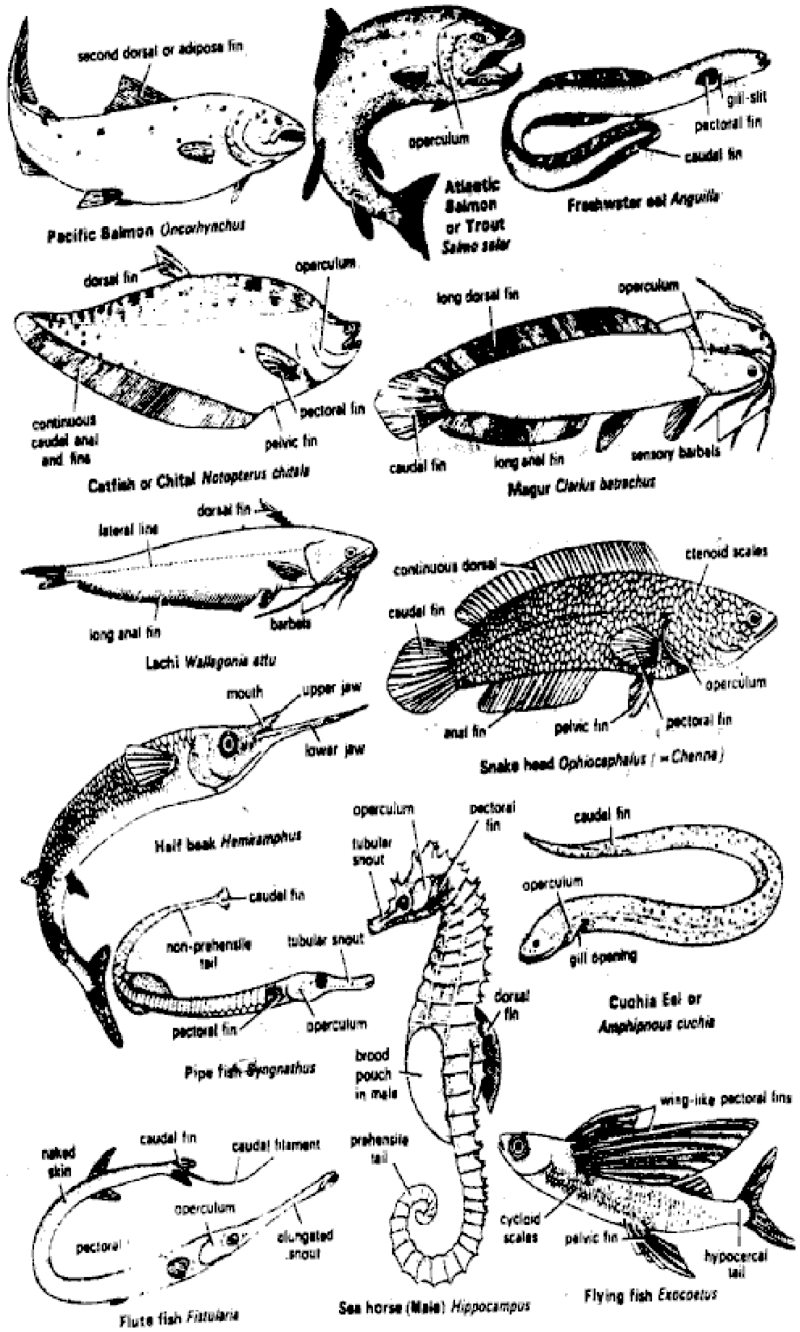


Fig. 1.4 Teleost Fishes

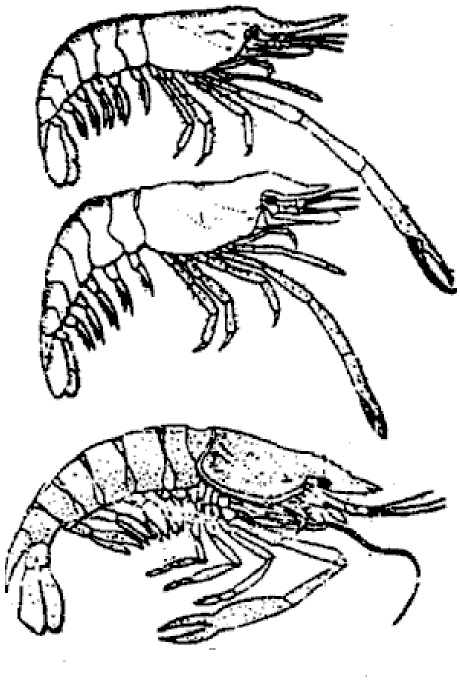


Fig. 1.5a. Freshwater prawns

a) Macrobrachium rosenbergii
b) M.molcolmsonii
c) Palaemon tenuipes

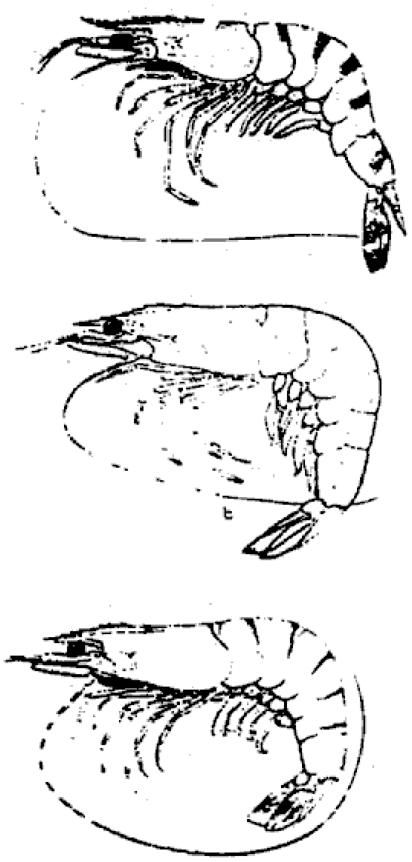
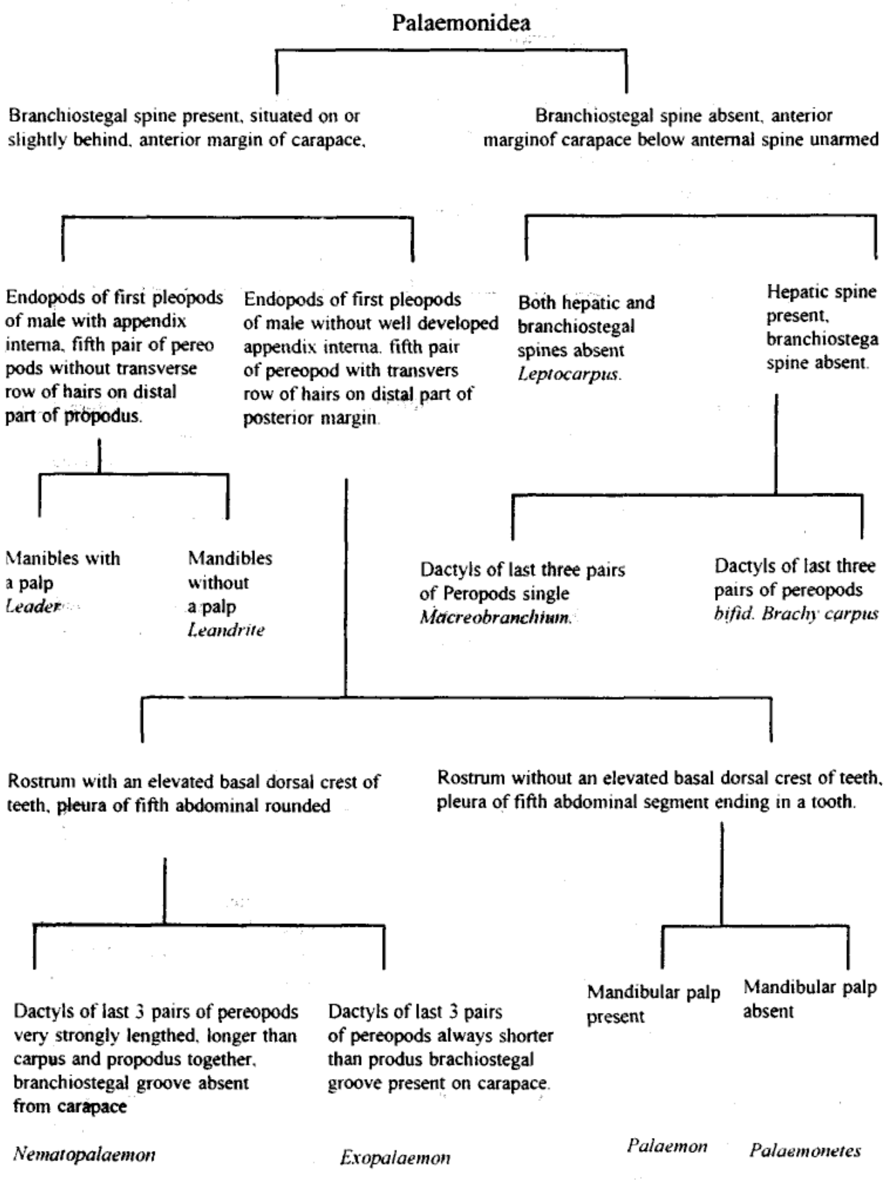


Fig. 1.5b. Brackishwater prawns

a) Penaeus monodon
b) P.indicus
c) P.semisulcatus

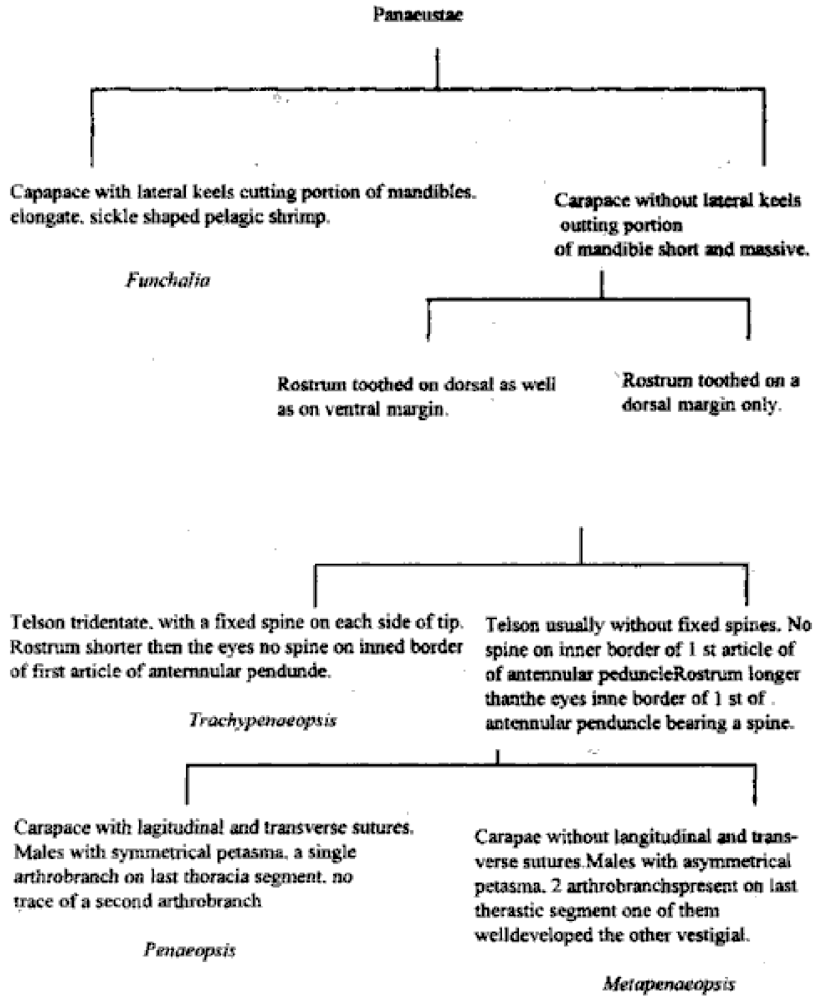
1.2 Classification of Prawns

1.2.1 Key to the identification of genera from family palaemonidea



1.2.2 Key to the identification of different generaiof family penaeudae.

- Rostrum tooth are well developed
- carapace without postorbital spine and with a short carvical groove ending well below dorsal midline.
- Last two pairs of pereopods well developed.
- Third two pairs of pereopods well developed.
- Endopods of second pair of pleopods in males bearing appendix masaulina only (lacking of appendix interna and muscular projection)
- Last three pleurae are keeled dorsally
- Telson sharply pointed.



3. Exhibits great diversity in their structure and shape
4. Skin in covered by cycloid or cteniod scales
5. Mouth in small. Tail is symmetrical or homocercal
6. Four pairs of gill slits are present. Spiracle is absent
7. Air bladder is present, having hydrostatic function
8. They are ammonotelic animals
9. Spiral valve is absent in intestine
10. Heart has bulbous arteriosus in place of conus arteriosus

Super order Teleoslei is commonly known as advanced ray finned fishes. They are modern fishes. Teleostei is divided in to 30 orders. Some important orders and their examples are listed below.

1. Anguilliformes : eg. *Anguilla* (Eel)
2. Siluriformes : eg. *Wallago attu* (cat fish)
3. Cypriniformes : eg. *Labeo rohita* (Ruhu)
4. Syngnathiformes : eg. *Hippocampus* (Sea horse)
5. Beloniformes : eg. *Exocoetus* (Flying fish)
6. Perciformes : eg. *Anabas* (Climbing perch)
7. Tetradontiformes : eg. *Diodon* (Porcupine fish)
8. Lophiiformes : eg. *Lophius* (Angler or fishing frog)
9. Pleuronectiformes : eg. *Solea* (Flat fish)
10. Channiformes : eg. *Channa* (Murrel)
11. Clupeiformis : eg. *Chanos* (Milk fish)

1.3 INTRODUCTION TO ECOLOGY

Ecology is a branch of science, which deals with the study of organisms and their environment, which is as much as complex and dynamic, but also interdependent, mutually reactive and interrelated to various disciplines of science

The term ‘ecology’ was coind by Ernst Haeckle in 1869, which is the combination of two Greek words, Oikos meaning ‘house, kitchen or dwelling place’ and logos meaning the study of to denote the relationships between organisms and their environment. Thus, literally, ecology is the study of organisms ‘at home’. Ecology has been defined in various ways by different authors. Warming (1895, 1905), who actually employed this science for the study plants, defined Oikologie as "the study of organisms in relation to their environment". Woodbury (1954) treated ecology as a science which investigates organisms in relation to their environment. Taylor (1936) defined ecology as "the science of all the relations of all organisms to all their environments"

However, the recent development in the study of ecology has been recognized the fact that, the biotic (living) and abiotic (non-living) components function in an orderly manner as a definite system. Biotic factors are the organisms encountered, whether of the same or different species. Abiotic factors are the physical and chemical conditions such as temparature, moisture, respiratory gases and substrate. Odum (1969) with such an approach put forth a new defination of ecology as the study of interrelationships between organisms and environment. Krebs (1985) defined ecology in a simple modern way as ecology is the scientific study of the interactions that determine the distribution and abundance of organisms.

1.3.1 SCOPE OF ECOLOGY

Tayler (1936) once described ecology as the science of all the relations of all the organisms to all their environments. During the recent years, ecology has assumed greater importance due to its relation with mankind through environment. The various aspects of environment such as environmental pollution and its control, conservations of natural resources and proper monitoring on the consumers and decomposers have a direct influence on the betterment of the mankind. In fact, there exists a balance in the nature between various biotie organisms with regard to the environmental factors and if by any natural or artificial means this balance is disturbed, it leads to the harmful results for mankind as a whole.

Ecological principles provide a background for further investigation into fundamental relationships of the natural community and also into sciences dealing with these environments like soil, forest, ocean or inland waters. There are many practical applications of ecology in agriculture, biological surveys, game management, pest control, fishery biology and forestry. Knowledge of ecology is essential for the intelligent conservation of these ecosystem and proper maintenance in relation to forest wildlife, water supply and fishery resources.

Human ecology is quite important for man himself as it provides a background for the understanding of human relations to the environment. In 1972, different scientists of the world at the international conference, held in Sweden emphasized the need for the check up of environmental pollution (resulting from high pace of industrialization and urtanization). I esides it, ecological studies of the organisms are very useful in determining the heredity and evolutionary phenomena. In brief, the scope of ecological studies involves:

1) Determination of population of different niches.
2) Evolution and origin of species as a result of speciation and natural selection.
3) Study of the composition and ecological processes of habitats so as to determine their utility for the mankind.
4) Monitoring of environmental pollution by testing various ingradients of the biosphere, and
5) Proper maintenance of natural resources.

1.3.2 BASIC CONCEPTS OF ECOLOGY

Like other sciences ecology too has its own principles and basic concepts, which are as follows:

All living organisms and their environment are naturally reactive, effectively each other in various ways. Animal population, flora and vegetatiation are inter dependent through the environment and are mutually reactive. Environment which is actually a complex of several interrelated function and is much dynamic,works as sieve to select organisms.

It is not only the environment which influences the life of organisms, even organisms too modify their environment as a result of their growth, dispersal, reproduction, death, decay, etc. Thus the environment is subjected to change due to organisms activities. The environment and organisms make a new platform for the development of different kinds of other new indivuduals through a process known as succession. The process continues till the development of community which more or less stable and is now able to keep itself adjusted in equilibrium with the environment.

According to Clement and Shelford (1939), under similar climatic condition, there may be simultaneously develop more than one communities, some reaching to climax stage, others under different stages of succession.

1.3.3. SUB DIVISIONS

Being a vast and complex subject, the field of ecology can be sub divided in to various ways such as based on taxonomic affinities, habitat, levels of organization etc. However the important subdivisions based on levels of organisation are

1) Autecology
2) synecology

1.3.1.1 AUTECOLOGY

This is also known as ecology of individuals where we study the relation of individual species to its environment. In autecology one studies the factors which influence the growth and life of a particular organisms. With an autecological approach, individual species are the units of study.

1.3.1.2. SYNECOLOGY

Under natural conditions, however, organisms-plants, animals, microbes, ect, live together as a natural group affecting each other life in several ways.

Thus more complex situations exist. Such an approach where units of study are groups of organisms is called synecological approach. Depending upon. the conditions syncology may deal with population, community ecology, biome ecology and ecosystem ecology.

1.3.4. BRANCHES OF ECOLOGY

The specialized disciplines of ecology are as follows -

1. **Oceanograhy** - It is the study of marine habitat and organisms.

2. **Limnology** - It is the study of freshwater bodies like lakes, ponds and their organisms,
3. **Terrestrial ecology** - It is the study of biomes and the organisms distributed therein. It can further be differentiated into (I) forest ecology, (ii) cropland ecology and (iii) grassland ecology
4. **Pedology** - It deals with the study of soils, in particular their acidity, alkalinity, humus-content,mineral contents, soil types etc., and their influence on the plant and animals life.
5. **Community ecology** - It is the study of distribution of animals in various habitats.
6. **Population ecology** - It includes the study of population, its growth, competition, means of dispersal etc.
7. **Geographic ecology or Ecogeography** - It includes the study of geographical distribution of organisms.
8. **Ecosystem ecology** - It is the relation and interaction of both plant and animal communities of organisms.
9. **Animal ecology** - It is the interpretation of animal behaviour under natural conditions.
10. **Cytoecology** - It deals with the cytological details in a species in relation to populations in different enviromnental conditions.
11. **Palaeoecology** - It deals with the organisms and their environment in geoecological past.
12. **Insect ecology** - It is the ecology of insects.
13. **Mammalian ecology** - Ecology of mammals.
14. **Avian ecology** - Ecology of birds.
15. **Production ecology and Ecological energetics** - This branch of ecology deal with the mechanisms and quantity of energy conversion and energy flow through different trophic levels in a food chain and rate of increase in organic weight of the organisms in space and time. The productivity is measured both in gross and net values. The total organic production is called the gross production, and the actual gain i.e the gross production minus the loss in resporation is termed as the net production. It includes the proper management of different ecosystems so that the maximum yield can be obtained. This includes agriculture and horticulture.
16. **Applied ecology** - The wild life management, range management, forest conservation, biological control, animal husbandry, pollution control,

are the various aspects dealt within the applied ecology.

17. **Radiation ecology**- It deals with the gross effect of radiation of radioactive substances over the environment and living organisms.
18. **Space ecoloy** - It is the modern subdivision of ecology. It is concerned with the development of those ecosystem which support life of man during space flight or during extended exploration of extraterrestrial environment.

SUMMARY

Fishes are aquatic organisms, respire with gills and move with the help of fins. The golden age of fishes is Devonian period. Fishes are cold blooded animals. The body is covered with scales. Fishes consist of paired pectoral and pelvic fins) and unpaired (dorsal, anal and caudal fins) fin; the tail is useful for changing directions, gaseous exchange takes place in gill lamella and accessory respiratory organs are found in few fishes. Two chambered venous heart is found in fishes. Mesonephric kidney is responsible for excreting ammonia. Sexes are separate and direct development.

Prawns are decapode crustaceans live in all types of water. The bod s divided into cephalothorax and abdomen 13 pairs of cephalic, throcic and 6pairs of abdominal appendages are found in prawn. Uropods and pleopod are useful for swimming Head prolonged into the rostrum. Branchial respiration is found in prawns. Naupleus, zoeae mysis larval farms are found in the life cycle of prawns.

Fishes are classified into elasmobranches and osteichthys mainly based on nature of endoskeleton. Sharks and rays are included in elasmobranches. Based on the lobed or lobeleses fins. Osthichthys are classified into crossopterygii and actinopterygii. Lungfishes and coelocanth fishes are included in crossopterygii. Most of the bony fishese included in teleosti.

Freshwater prawns are included in family palaemoidae and marine shrimps are included in penaedae. Macrobracium is included in palaemonidae. Tigar shrimp. Penaeus monodon is included in penaedae.

The two natural components of ecology are organisms and environment. The term ecology was coined by Ernst Haeckel in 1869. The simplest defination of ecology is “The study cfltructure and function of nature”. Biotic factors are the other organisms whether of the same or different species. Abiotic factors are the physical and chemical conditions such as tempatature, moisture, respiratory gases, and substratum. The international problem of enviromnental pollution needs ecological assistance. “Ecology is the science if all the relations of all organisms to all their environments”. Ecology plays an important role in management of pest control, fishery biology, grasslands, conservation of forest, soil etc. Fauna, flora, and regulation are interdependent through the environment and are mutually reactive. The study of individual species in relation to environment is called autecology. The study of group of organisms as a community in relation to environment is called synecology.

Questions:

1. Describe the general characters of fishes.
2. Discuss the general characters of prawns.
3. Give the detailed account of classification of fishes.
4. Write down the classification of bony fishes.
5. Discuss the classification of actinopterygii fishes.
6. Give the classification of prawns.
7. What is ecology? Give an account of its scope and basic concepts.
8. What are the different sub-divisions of ecology and explain in brief.
9. Describe the branches of Ecology.
10. Discuss the environment and the medium.
11. What are the approaches adopted to study the ecosystem. Explain?

2

MORPHOLOGY OF PRAWN AND FISH

2.1. Morphology of prawn

2.1.1. Shape and size and colouration

Body is elongatd. more or less spindle-shaped and bilatarally symmetrical. It offers least resistance in swimming. Size of adult varies from species to species. *Macrobrachium malcomsonii*, found in Central India and Tamil Nadu. measures 25 to 40 cm in length. The giant prawn *P. carcinus* from Kerala is upto 90 cm long. While the dwarf prawn *P. lamarrei,* found almost throughout India, is 25 to 5 cm long. Young stages are translucent and white, but the adults are differently tinted according to the species. Usual colour is dull pale-blue or greenish with brown orange-red patches. Preserved specimens become deep orange-red.

2. 1.2. Segmentation and body divisions

Body of adult prawn is distinctly divided into 1 9 segments or somites, all bearing jointed appendages. The segments are arranged into two main regions : an anterior cephalothorax (fused head-thorax) and a posterior abdomen.

2.1.2.1. Cephalothorax

Cephalothorax is large, rigid. unjointed and more or less cylindrical in shape. It consists of 13 segments. The joints between segments are obliterated. Cephalothorax is formed by the union of two regions: (i) head and (ii) abdomen. Head consists of 5 segments. while thorax includes 8 segments, all bearing jointed appendages.

2.1.2.2. Abdomen

Well-developed abdomen is jointed, unlike cephalothorax. It is composed of 6 distinct movable segments, and a terminal conical piece. the tail-plate or telson. which is not considered a segment because of post-segmental origin. Abdominal segments are dorsally rounded, laterally compressed and normally bent under the cephalothorax, so that the animal looks like a comma (,) in shape. The abdomen looks almost circular in a cross section. Each abdominal segment carries a pair of jointed appendages, called pleopods or swimmerets.

2.1.3. External apertures

The slit—like mouth opens mid-ventrally at the anterior end of cephalothorax. Anus is a longitudinal aperture lying ventrally at the base of telson. Paired renal apertures open on raised papillae on the inner surface of coxa of antenne. Paired female genital apertures in females are on the inner surface of coxae of the third pair of walking legs. Paired male genital apertures in the male are situated on the inner surface of coxae of the fifth pair of walking legs. There are two minute openings of statocysts, one lying in a deep depression dorsally on the basal segment (precoxa) of each antennule.

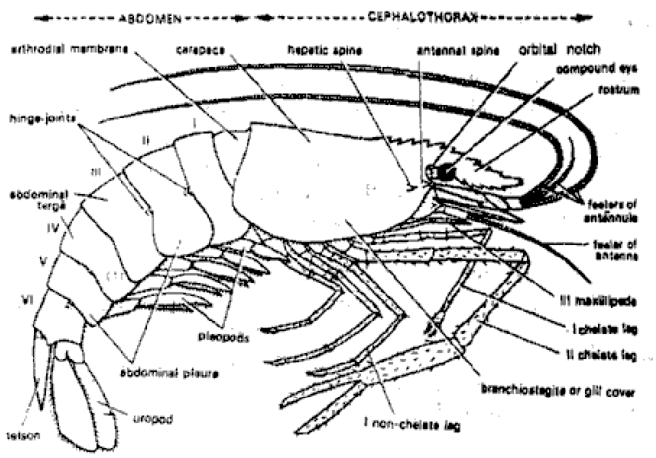


Fig.2. 1. External features of prawn

2.1.4. Exoskeleton

Body and appendages are covered by a hard protective calcareous shell or exoskeleton. It is composed of chitinous cuticle which becomes variously tinted by the deposition of lime salts and sclerotin. The exoskeleton comprises several hardened plates, called sclerites. Adjacent sclerites are connected by thin, soft, uncalcified cuticle or the arthroidal membranes, making the movements feasible.

2.1.4.1. Cephalothoracic sclerites

All the sclerites of dorsl and lateral sides of cephalothorax unite to form a single, large and continuous dorsal shield. The anterior and somewhat triangular region of dorsal shield is termed dorsal plate. It extends forward over the head as a laterally compressed and serrated vertical process, called rostrum. At the base of rostrum, on either side, is an orbital notch, which accommodates a stalked, jointed and movable compound eye. Just behind and below each orbital notch are two spine-like outgrowths, the anterior antennal spine and the posterior hepatic spine. The posterior region of dorsal shield is termed carapace. On either side of thorax, it hangs down freely as branchiostegite or gill-cover which encloses a gill-chamber housing the gills.

2.1.4.2. Abdominal sclerites

The sclerite of each abdominal segment is separate, ring-like and articulates with the adjacent sclerites by thin, flexible. uncalcified athrodial membranes providing movable joints. In each abdominal sclerite, its dorsal broad plate is called as tergum, the ventral narrow transverse bar-like plate as sternum, and the two lateral flap-like plate as pleura. An appendage is connected with the pleuron of its side by a small plate the epimeron.

Tergum and pleura of an abdominal segment slightly cover the corresponding parts of the succeeding segment. This overlapping is known as the imbricate arrangement of terga and pleura. However, the pleura of second abdominal segment are much developed and overlap the pleura of both the first and third segments, thus disturbing the imbricate arrangement. Pleura of sixth abdominal segment are greatly reduced.

Two adjacent abdominal segments articulate with each other by means of a pair of hinge joints, one on either side. A hinge joint consists of a small round peg, fitting into a socket on the succeeding segment. However, the. hinge joints are lacking between the third and fourth segments. Abdominal segments can move upon each other only in a vertical plane due to presence of arthrodial membranes and hinge.

2.2. Morphology of fish (eg *Labeo*)

The body of Labeo is elongated, laterally compressed, spindle shaped tapering at either end. The colour of the body is dark gray and the back and sides are pale yellow or white below. The fish grows about a metre and weights about ten kilograms. The body is divisible into head, trunk and tail.

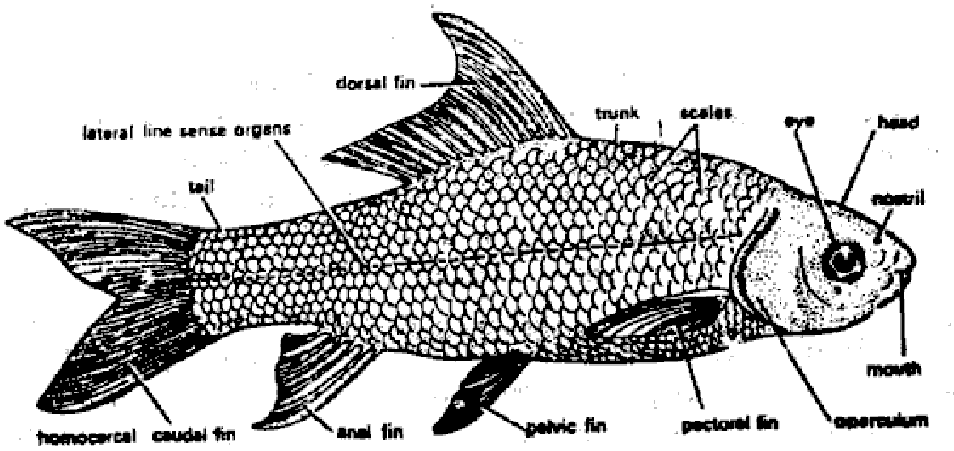


Fig. 2.2 External features of Labeo

2.2.1. Head

The head is depressed and is produced anteriorly as short, obtuse, depressed and swollen snout. This makes the mouth sub-terminal instead of terminal. It is large transverse aperture bounded by thick and fleshy lips. There is a pair of short, thread like, tapering, sensory processes on the snout, one on the either side, just above the mouth. These are the maxillary barbels. The jaws are without teeth, instead, there are three rows of teeth in the pharynx. The paired eyes are large, without eyelids but a transparent membrane covers the cornea. The pupil is rounded. There are two nostrils situated dorsally in front of eyes. They open internally into the olfactory sacs. There is a large, bony flap below and behind each eye. This is the operculum which is also called the gill cover. Between the gill-slits and the operculum lies a spaceous branchial cavity or opercular chamber, which communicates with the exterior by a single aperture, which is crescentic and can be shortened and widened by the branchio-stegal fold that borders the opening. There is no operculum in sharks. The mechanism of breathing and gill structure of rohu is quite different from that of the sharks.

2.2.2. Trunk

It extends from the posterior border of the operculum to the anal aperture It is the thickest part of the body and is compressed laterally. On either side of trunk and tail is a lateral line. The trunk is covered by the dermal cycloid scales which are rounded with free edges and not spiny. They are arranged lengthwise and differ from those of sharks in being true bony, not provided with enamel. The trunk bear five fins including paired and unpaired fins. The fins are supported by bony fin rays. The single dorsal fin is some what rhomboidal and is supported by 12-13 jointed bony fin rays. The anal fin, lying just posterior to the anus and has eight fin rays. The caudal fin arises from the hind end of the tail and is deeply forked into two similar lobes. The epicaudal and hypocaudal lobes are roughly equal. It seems that in rohu and other bony fishes with similar homocercal tails. There are nearly nineteen fin rays in the tail fin of rahu. The movement of this fin pushes the fish to move forward. Amongst the paired fins, the pectoral fins are found ventro-laterally behind the operculum. The pectoral fin bears 19 fin rays each. The pelvic fins are found more or less in the middle of the body, lying ventro-laterally, and have nine fin rays each.

There are three apertures in the trunk region. These include the anal, urinary and genital apertures. The anal aperture is the posterior opening of alimentary canal and lies on the ventral side just in front of the anal fin. The urinary aperture is present behind the anal aperture. The genital aperture lies between the anal and urinary openings.

2.2.3. Tail

The tail forms about one third of the body. It is laterally compressed and narrower behind. It bears tail fin. The tail makes the principal locomotory organs. Tail is also covered over by cycloid scales like the trunk.

2.3.1. Appendages and locomotion of prawn

2.3.1.1 Appendages in prawn

Each segment of body bears a pair of jointed appendages. Thus, there are 19 pairs of appendages in prawns. They show considerable variations, depending on the functions they perform. However, they all are of a biramous type, as they are built on the same fundamental biramous plan.

Each appendage consists of a common base or protopodite, bearing two ramit or branches, an inner or median endopodite and an outer or lateral exopodite. Any appendage composed of two branches is called biramous (bi, two + ramus, branch). Typically, the basal protopodite is composed of two segments, a proximal coxa for attachment with the body and a distal basis which bears the two ramii, both comprising several segments or podomeres.

With the exception of antennules, which are uniramous, all the appendages of prawns, are homologous structures, regardless of their functions, because they are all biramous and have similar embryologic origin. As they occur in a serial sequence on body, they also illustrate an example of serial homology.

In prawn, there are 19 pairs of appendages, 13 in cephalothoracic region and 6 in abdomen. Cephalothoracis appendages further include 5 pairs of anterior cephalic appendages and 8 pairs of posterior thoracic appendages.

2.3.1.1.1 Cephalic appendages

There are 5 pairs of cephalic or head appendages, beginning from the antennules, antennae, mandibles, maxillulae, and maxillae. Antennules and antennae are pre-oral, while mandibles, maxillulae and maxillae are post-oral.

2.3.1.1.2. Antennules

The antennules are attached, one on either side, below the bases of eye-stalks. The protopodite consists of three segments-a large proximal precoxa, middle coxa and distal basis. Precoxa bears a depression, containing the opening of statocyst on its dorsal side. It also bears a basal spiny lobe called stylocerite and a distal spine on its outer margin. Coxa is short and cylindrical. Basis is elongated and without setae. It carries two long and many jointed, whip-like feeler, which are probably not homologous with the exopodite and endopodite. Outer feeler is further divided into an inner smaller branch and an outer larger branch. The feelers of antennules bear sensory setae and the tactile in function.

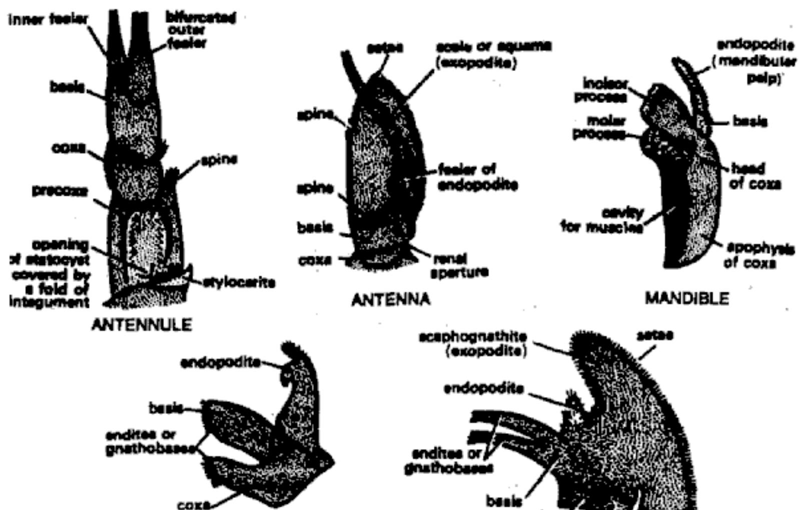


Fig. 2.3 Cephalic appendages of prawn

2.3.1.1.3. Antennae

The antennae lie, one on either side, just below the antennules. The protopodite is greatly swollen due to presence of excretory organ within, which opens by a minute renal aperture on the inner margin of coxa. Basis bears a spine. Endopodite is represented by many-jointed sensory feeler, while exopodite is in the form of a broad and leaf-like plate, the squama or scale. It bears setae along its inner and distal margins, while the outer smooth margin bears a small spine. Squamma probably serves as a balancer during swimming. Thus, the antennae are sensory, excretory and balancing in function.

2.3.1.1.4. Mandibles

The two mandibles are strong calcified bodies, lying one on either side of the mouth. Almost the entire mandible consists of coxa, which is differentiated in to a proximal, triangular and hollow apophysis, and a distal solid head. The head forms two processes, a stout molar process bearing 5 to 6 dental plates, and a plate-like incisor process ending in 3 teeth. Outer margin of head carries a mandibular palp made to 3 segments. The proximal segment represents the basis, while two distal segments represent the endopodite. The exopodite is absent. Mandibles constitute the biting jaws and are masticatory in function.

2.2.1.1.5. Maxillulae

These are small, thin and leaf-like appendages. Free borders of coxa and basis are covered with pointed spines and project inwards as jaws or gnathobases (Gr.. gnathos, jaw). Endopodite forms a curved process bifurcated at the apex. The exopodite is absent. Maxillulae help in the manipulation of food.

2.3.1.1.6. Maxillae

These are also thin and leaf-like mouth appendages. The small coxa is patially divided, while the large basis forms a bifurcated gnathobase internally. Endopodie is quite small, while exopodite forms a large expanded, fan-shaped scaphognathite or baler, the movements of which create a water current passing over the gills. The whole free margin of scaphognathite is beset with setae. Maxillae help in respiration and in the manipulation of food.

2.3.1.2. Thoracic appendages

There are 8 pairs of thoracic appendages. These are differentiated into anterior 3 pairs of maxillipedes (Gr., maxilla, jaw+podos, foot) or foot-jaws, and posterior 5 pairs of paraeopods or walking legs.

2.3.1.2.1. First maxillipedes

These are thin and leaf-like. Inner borders of coxa and basis form endopodites or gnathobases. Outer side of coxa bears a bilobed respiratory primitive gill or epipodite. Endopodite is smaller than exopodte, which gives out a plate-like process from its base. Margins of exopodite and endopodite are fringed with setae.

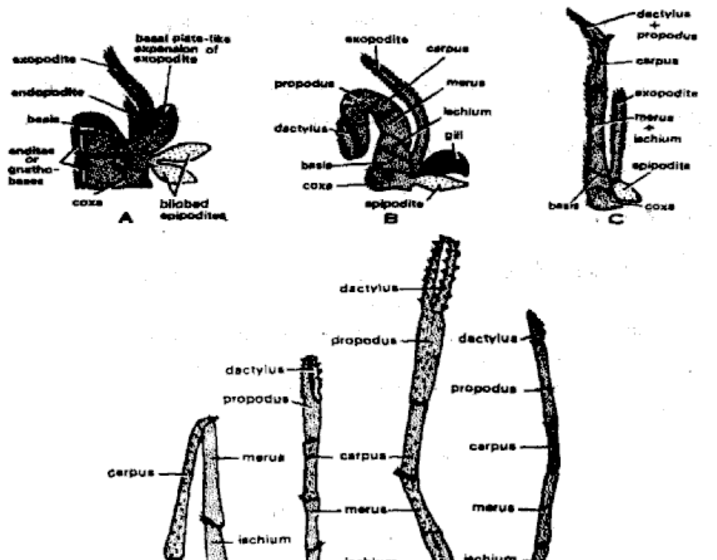


Fig. 2.4 thoracic appendages of prawn. A-First maxillipede. B-Second maxillipede. c-Third maxillipede. D-G-Thoracic legs.

2.3. 1.2.2. Second maxillipedes

Coxa bears an epipodite and a gill (podobranch) on its outer margin. Basis carries a long, slender and unjointed exopodite, covered with setae along its distal half, and 5- segmented endopodite. The segments or podomeres of endopodite are named from the base as ischium, merus, carpus, propodus and dactylus. The last two podomeres are bent backwards and inwards and posses cutting margins.

2.3.1.2.3. Third maxillipedes

These look leg-like in appearance and have the same parts as second maxilipedes. Outer border of coxa bears an epipodite. Basis supports a long, slender and unsegmented exopodite covered with setae and a three- jointed endopodite. Proximal podomere of endopodite represents ischium and merus fused together, the middle podomere is the carpus and the distal podomere represents propodus and dactylus combined together.

The three pairs of maxillipedes take part in feeding and hold the food in position while the mandibles masticate it. They are also helpful in respiration as they bear gills and epipodites.

2.3.1.2.4. Walking legs

The 5 pairs of walking legs differ from maxillipedes in their greater size and in the absence of exopodite and epipodites. A typical walking leg, like the fourth, consists of a two-jointed protopodite and a five-jointed endopodite. All the seven podomeres, namely the coxa, basis, ischium, merus, carpus, propodus and dactylus are arrange in a linear series and are movably hinged together.

In the first and second pairs of legs, propodus is prolonged beyond its articulation with dactylus, so that the two podomeres work one against the other like the blades of a pair of forceps and form a chela or pincer. Such legs are termed chelipeds or chelate legs. They are used to grasp food and pass it on to the mouth. They also serve as organs of offence and defence. The second chelate legs in male are larger and more powerful than in female.

The third, fourth and fifth pair of legs are non-chelate and typical. In female, each third leg bears a female reproductive aperture on the inner side of the coax. While in male, each fifth leg bears a male genitl aperture on the arthrodial membrane between the leg and thorax.

2.3.1.3. Abdominal appendages

Abdomen bears 6 pairs of abdominal appendages, one pair in each of its segments. First 5pairs, are the swimming pleopods or swimmerets, used as paddles, while the 6th pair are the uropod which, along with the post-segmental telsoñ, form the tail fin. All these appendages are of simple biramous type.

2.3.1.3.1. Typical abdominal appendages

In a typical appendage, like the 3rd, 4th or 5th, the cylindrical basis. The basis. The basis bears flattened leaf-like smaller endopodite, and larger exopodite. From the inner basal margin of endopodite arises a small rod-like structure, the appendix interna, with a knob-like head bearing many hook-like processes. In fema1e, during breeding seasons, the appendix internae of opposite appendages articulate with each other forming a series of bridge which serve to carry eggs Outer surface of basis and the margins of endopodite and exopodite are beset with numerous setae. The remaining pairs of abdominal appendages slightly differ from this typical structure.

2.3:1.3.2. First abdominal appendages

Appendix interna is absent and endopodite is greatly reduced in size. Rest of the structure is typical.

2.3.1.3.3. Second abdominal appendages of male

Second pleopod of female is typical. But, in the second pleopod of male, there is an additional rod-Iike and setae-bearing process, the appendix masculine, lying in between the appendix interna and endopodite. The rest of the structure is typical.

2.3.1.3.4. Uropods

The 6th pair of abdominal appendages are called uropods. These are large and lie one on either side of the telson. Together with telson, they form a tail-fin which enables the prawn to take backward spring in water. In each uropod, coxax and basis fuse together to form a triangular sympod, bearing the oar-shaped endopodite and exopodite. Exopodite is bigger than the endopodite and incompletely divided in the middle by a transverse- suture. Their margins, except the outer border of exopodite, are fringed with numerous setae.

2.1.2. Locomotion in prawns

The prawn crawls at the bottom of the river or pond by means of its walking legs. It can swim forward in a leisurely manner by beating its swimmerets or the abdominal appendages. It may take a quick backward spring by sudden contraction of the muscles which pulls the uropods and telson ventrally with a powerfully stroke.

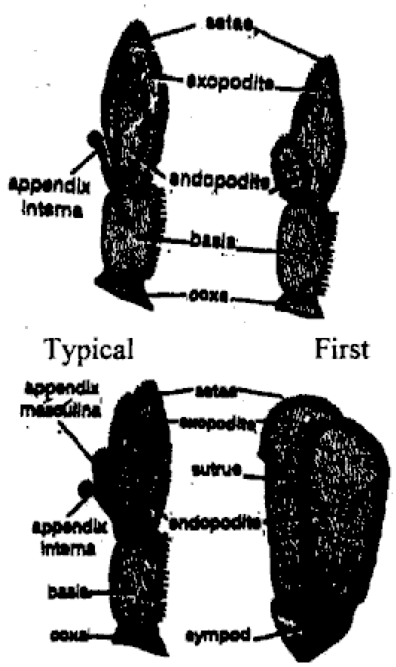


Fig. 2.5. Abdominal appendages of prawn

Fins and locomotion in fishes

2.4.1. Fins in fishes

Fins are broaden appendages present on the body of fishes and are the chief locomotory organs. There are two types of fins; unpaired or median and paired fins. The median fins include a dorsal on the mid axis of the body, an anal on the mid ventral side behind the vent and caudal at the end of the tail. Pectorals and pelvics are the paired fins corresponding to the fore and hind limbs of the terrestrial tetrapod vertebrates. Fins are supported by skeletal rods called the radials and dermal fin rays. In teleosts the fin rays are branched and jointed bony structures and are known as the lepidotrichia. The fins without fin rays called a dipose fins (eg. *Mystus*)

2.4.1.1. Unpaired fins or median fins

Due to the differentiation in a continuous embryonic fin fold the median fins of all fishes will develop. During development a continuous embryonic fold tissue is formed dorsally along the back up to the tip of the tail and is then strength and by a series of cortilagenous rods and this condition is seen in lampreys and represents the primitive stage of the median fin. In higher fishes seperate dorsal, caudal, and anal fins are formed by the concentration of the redials in certain areas and degeneration of the fold in the intervening spaces, between the fins. In the present day bony fishes, the fleshy lobe at the base of the dorsal fins are disappeared and the radials are reduced to nodules of bone or cortilage.

In some fishes (eg. shark) dorsal fin is divided into two or more segments. The first dorsal fin part is more or less *triangular* in shape. The second dorsal fin is small in size. Many bony fishes also have two dorsal fins. In *Channa* a single lengthy dorsal fin is present. Dorsal fin will divides into many small segments in *Polypterus*. The first dorsal fin in *Echins* modify into a adhesive sucker.

The caudal fin of the fish is a vertically expanded structure, lying at the caudal end of the body. It can be differentiated into a dorsal epichordal lobe and a venral hypochordal lobe. The epichordal lobe lies above and the hypochordal below the spinal column. Like median fins, the caudal fin is also supported by skeletal elements. In dorsal lobe the fin rays may connect to a basal pterygiophore or directly to a much reduced neural spine called the hippural bone and in ventral lobe they form connections with modified hemal spines, spoken as hypurals. The internal and external architectural design of caudal fin varies, depending upon the swimming habits of the fish. As such several tail types are observed among the actinopterygians and described by special terms. The nature of the end of spinal column is considered useful in this descriptive grouping. Various tail types of fishes are (fig.).

2.4.1.1.1. Protocercal tail

This type of tail is regarded as the most primitive type. The notochord is straight and extends up to the tip of the tail, dividing the latter into two equal parts. The fin fold continues with the dorsal and the anal fins to form a continuous fold, unsupported by the fin rays. Such a type of fin is found in cyclostomes and the living lung fishes.

2.4.1.1.2. Protoheterocercal

This intermediate tail type is different from above in having separate dorsal, ventral and the caudal fins, which are formed by the interruption of the continuous fold on dorsal, and ventral side of the fish. From this type of tail the heterocercal and diphycercal tails are said to have been derived.

2.4.1.1.3. Heterocercal

In heterocercal tail, the notochord bends upwards at its posterior end, so that the dorsal lobe of the tail is almost lacking or represented by a few spines, while the ventral lobe becomes well developed. The large sized ventral lobe possesses a longer postero-dorsal and a shorter antero-ventral lobe. Consequently the tail becomes asymmetrical, both externally and internally. Such type of tail is mainly found among the elasmobranches.

2.4.1.1.4. Diphycercal

A diphycercal tail as found in dipnoans, *Chimera* and *Protopterus* is very much like the protocercal tails of earlier forms but the palaeontiological and embryological evidences suggest it to be a modified secondary form of heterocercal tail. The notochord is continued straight upto the end of the tail and the fin lobes are disposed symmetrically above and below to it.

2.4.1.1.5. Homocercal

A homocercal tail is a modified form of heterocercal tail. The posterior end of notochord becomes ossified into the urostyle, that provides a rigid support to the dermotrichia. Because the notochord is turned upwards, the dorsal lobe is not apparent in the fin but the ventral lobe is quite well developed. The latter contributes the formation of two equal sized lobes. Tail thus becomes symmetrical externally but remains asymmetrical internally. The homocercal tails are the most common types and characterize the higher bony fishes.

2.4.1.1.6. Isocercal

In an isocercal tail, the spine is drawn out into a long and straight rod like structure. The fin fold develops, both, above and below the rod, in the form of the marginal extensions of the tails and remains supported by the fin rays. Such tails are found in some deep sea fishes and in many fresh water teleosts belonging to Anguilliformes, Notopteridae, Gymnarchidae, Macruridae and Blennidae.

2.4.1.1.7. Gephyrocercal

This type of tail is very much like the isocercal, but the fins are reduced to vestiges. The caudal lobe or peduncle is truncated and the hypurals in the spinal colunm are not found. Such fin types are found in Fierasfer and in Orthagoriscus.

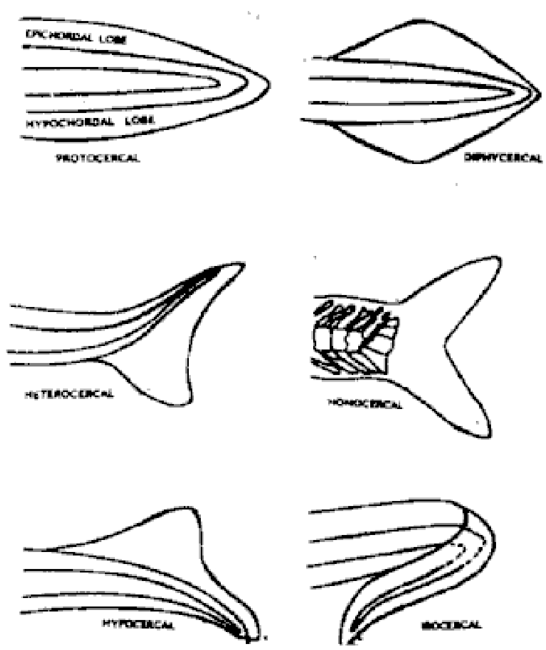


Fig. 2.6. Various kinds of tails in fishes

2.4.1.1.8. Hypocercal

The hypocercal tail type is derived from the heterocercal type by bending of the hinder end of the notochord downwards. The dorsal lobe thus becomes larger than the ventral lobe which is much reduced.

2.4.2.1. Paired fins

Paired apprises were not present in the ancestral vertebrates and were developed during the course of early evolution. The supporting endoskeleton of the paired fins varies greatly in different groups of fishes. The original primitive condition is known as the 'archipterygium' and was provided with an anterior pre-axial and a porterior post-axial series of radials attached to it. The radials were arranged in decreasal manner on either side of the median axis. This is called a biserial arrangement of the radials and known as biserial archipterygim, found in ceratodus and present in the devonian crossopterigii. Various types of paired fin skeleton in the teleosts may be derived from the archiptenygium by shortening of the median axis and reduction in the number of postaxial radials that finally disappear completely, giving rise to pleuroarchic or uniserial type of skeleton found in teleosts

Pectoral fins are present behind the gills and horizontal to the ventro lateral portion. Broad and long pectoral fins acts like the wings of bird in *Exocoetus* and fly in the air. In *Periopthalaus* pectoral fins are useful for walking. In *Trigon, Torpido* they extend laterally from head to tail and modify into leafy structure.

A pair of pelvic fins are present at the ventral side of the body on either side of cloacal aperture. In male sharks a pair of copulatory structures the claspers are present inside the pelvic fins. Generally pelvic fins are small in size. They are modified into suckers in globe fish and helps in fixing with rocks.

SUMMARY

Fishes is in fusiform shape. Its body is covered with scales. Pectoral fins are locatedjust after operculum and pelvic fins behind pectorals. Dorsal and anal fins are located on dorsal surface and behind anus respectively. The tail consists of a caudal fin. Slit like mouth is found at anterior part of head. Branchial region and gills are enclosed by operculum.

The body of the prawn is divided into cephalothorax and abdomen. Cephalothorax is the fusion of 13 segments of cephalic and thoracic region. Caphalothorax is extended anteriosly in the form of rostrum. The abdomen ends with a telson. pairs of cephalic, pairs thoracie and pairs of abdominal appendages are found in prawns.

Nineteen pairs of appendages are found in prawns. The cephalic appendages are antennules, antennae, mandibles, maxillule and maxillae. The thoracic appendages are three pairs of maxilliped or pareopods and five pairs of walking legs. The abdominal appendages are five pairs of pleopods and one pair of uropods. They crawl at the bottom with the help of walking legs. They swim with the help of swimmerets.

The fins and tail are the locomotory organs in fishes. The paired fins are pectorals and pelvics. The median fins are dorsal, anal and caudal fins. The fins are useful for swimming and balancing, whereas tail is useful for changing directions. The myomeres are useful for locomotion in fishes.

Questions:

1. Describe the morphological features of fish.
2. Discuss the morphological characters of prawn.
3. Give an account on appendages in prawns.
4. Explain the structures found on the head of fish.
5. Describe the appendages and locomotion in prawns.
6. Explain the fins and locomotion in fishes.
7. Give an account on cephalic appendages in prawns.
8. Discuss the unpaired fins in fishes.
9. Discuss the locomotion process in fishes.

3

GROWTH IN FISHES AND PRAWNS

Growth has been one of the most intensively studied aspect of fish biology as it indicates the health of the individual and the population. Growth of an organism can be defined as a change in its size (length and weight) over a period of time. As the age of a fish and its growth are closely related, the assessment of age and growth rate are conducted together. Abundant food supply and existence of other favourable conditions result in fast growth rate, whereas slow growth rate indicates the opposite. The rate of growth varies in fishes from species to species, and for the same fish from different localities, as it is influenced by various factors.

3.1. Growth in fishes

3.1.1. Factors affecting growth rate

The growth rate in fishes is highly variable and depends upon a number of environmental factors such as temperature, amount of dissolved oxygen, ammonia, salinity, photoperiod, degree of competition, quality of food taken, age and the state of maturity of the fish. Temperature is one of the most important environmental factors, and along with other factors, influences growth rate. Thus, optimum food consumption for maximum growth is temperature dependent. For example, in the young salmon maximum growth rate is achieved at 15°C.

Dissolved oxygen level depends on temperature, and by itself is also an important factor affecting growth rate of fishes. Possibly, the fish is deprived of 'extra' aerobic energy required for growth and reproduction, if dissoloved oxygen falls below a certain level. Ammonia if present in high concentration, will slow down the growth rate. Growth rate depends on the population density also. Higher densities slow down the growth and lower densities tend to increase it. This way also be due to competition for available food. Competition may, be interspecific as well as intraspecific.

Food availability which depends upon temperature affects growth rate on a seasonal basis. Growth may be rapid during warmer months, when plenty of food is available, and slow during winter. Similarly photoperiod may also affect seasonal growth. Age and maturity are also important factors. Fish typically grow very fast in length in the first few months or years of life until maturation. Later, large amount of energy is diverted for the growth of gonads, hence body growth slows down. Growth rate of mature fish are therefore, much less than those of immature fish. However, mature fish are typically heavier per unit of length than the immature fish, partly due to the large sized gonads. This is shown by their higher Condition factor (K), Condition factor represents the condition of the fish during a certain period, and is the ratio of the length to the weight of the fish, as calculated by the following formula:

$$K = \frac{W}{L^3} X 100$$

where, W is the weight of the fish in grams, and L is the length in cms.

The condition factor is generally used by the biologists as an indication of the health of a fish population. A high value of K shows that plenty of food is available to support both somatic and gonadal development of the fish.

3.1.2. Regulation of growth

Growth of fish is known to be regulated by certain hormones, especially the growth hormone synthesised in the pituitary gland. Hypophysectomy results in the cessation of growth in various species, while injections of mamalian growth hormone brings about increase in growth rate. This may be due to enhancement in the food conversion rate, possibly by stimulating stored fat mobilisation, protein synthesis and insulin secretion. Increase in growth is also achieved by the thyroid hormone, triiodothyronine (T3). Addition of T3 increases growth rate and food consumption in certain species like salmon, and trout. Androgens (testosterone and 11-

Ketotestosterone) are also reported to bring about improvement in food conversion efficiency of common carp, when added to their diet.

3.1.3. Methods of determining age- and growth

Growth rates in fishes can be determined by measuring the changes in size in relation to time. One of the following methods can be used:

3.1.3.1. Rearing the fish in a controlled environment

This is one of the direct methods for determining the growth of fish. A fish or egg or larvae of known age are placed in a tank or in a cage in a river. Its length and body weight is measured at intervals of time for calculating growth rate. This method is specially useful for determining growth of cultured fishes, as feeding rate, temperature and other environmental factors can be kept under control.

3.1.3.2. Tagging

Fishes are marked or tagged, and released after recording initial measurements of length and weight, The fish are recaptured after an interval of a few months and measured again. The growth rate is calculated from the change in size over the time period fish spent in its natural habitat. Marking should be done in such a way that it does not affect the behaviour or feeding rate of the fish, and can be done by clipping the fin rays, colouring the epidermis by spray painting or providing fluorescent rings on scales or bones. Various dyes such as chromium dioxide, Fast Blue, Lead acetate or Latex may be injected, so that the fish can be recognised when caught again.

Tagging is however, more popular. Various types of tag bearing particulars about the fish and date of tagging etc., are attached to the body, so that they remain in position and are not lost. A tag may be a disc made of plastic, aluminium, silver, nickel etc. Tag may be attached to the body by means of a thin wire without actually piercing it. The wire may be tied by encircling the jaw or caudal peduncle. In some cases a thin wire is used to actually pierce the tissue of the body. The wire carries the disc or plate, and the two ends of the wire are twisted after piercing through the tissue, to keep it in place. Another kind of tags are, in the form of straight shaft of metal that is pushed into the tissue. The shaft bears one or more barbs at one end to prevent it from dropping out. The outer end of the shaft carries the disc, bearing details aboutthe fish. Magnetic tags are small metal rods inserted into the body, and can be detected in a magnetic field. The marked or tagged fishes provide more realistic data regarding growth and movements of the fish, but are more difficult to recapture, hence a very large number of fish must be used in this method.

3.1.3.3. Length frequency distribution method

This method is based on the expectation that length-frequency analysis of the individuals of a species of any one age group, collected on the same day, will show variation around the mean length. It is further based on the assumption that when data in a sample of the entire population are plotted, successive ages at successive given lengths will be clumped together, making possible a separation of various age groups.

In this method, lengths of 300-500 fish from a population are measured in a month at suitable predetermined intervals, taking care that the sample is from a catch in which fish of all sizes are included. The data are distributed into frequencies. For example, if the maximum recorded length is 400 mm, the lengths can be tabulated in frequencies of 1-19, 20-39, 40-59, 60- 79 etc. From these the model values are determined for every month, and these plotted on graph paper with the model values on the Y-axis, and the time in equal intervals of months on the other. The modes are then traced from month to month to determine the age and rate of growth. This technique is especially useful for young fish. By comparing the mean length between age classes, one can determine approximate growth rate at various ages.

For a fairly reliable result by the above method, it is necessary that the sample consists of a large number of individuals, collected preferably on a single day, and should include representatives of all sizes and age groups in the population.

3.1.3.4. Rings or annuli on hard substances

In many species, the rate of growth in the diameter of the bones, spines and scales is proportional to the growth of the fish. The hard part that can be studied for age determination are the otoliths, vertebrae centra, scales, dorsal and pectoral spines, opercular bones, coracoids, hyomandibular etc. Of these the most commonly used are the scales and otoliths.

Generally, scales are used for age determination of fish. This is the simplest and most accurate method, and with some experience, annuli on the scales can be easily counted. About 10 scales are taken from the fish, usually from below the origin of the dorsal fin just above the lateral line. These are called ‘key scales’. The scales are cleared in water by scrubbing them. Wet or dry mounts are then prepared. Permanent preparations are made either by cellulose or plastic impression or as a whole mount in glycerine, balsam, or glycerine-gelatin mixture.

The scale is examined under a binocular microscope, or the image may be enlarged by using a microprojector for easy and accurate counting of growth rings. The focus of the scale is the first part to develop and is usually located in the centre. An annulus is usually marked by a clear, narrow streak, encircling the focus. One annulus represents one year, and addition of successive annuli indicates the number of years the fish has attained.

The age of fish is determined by scales on the basis that successive rings are formed as the fish grows in age. During summer and autumn, plenty of food is available and the fish grows at a faster rate so that the rings formed in this period are widely spaced. During winter, the food supply is limited and growth is restricted so that the rings are tightly picked, giving an appearance of alternate rot and dark bands. These two bands are together considered to have been formed in one year and are called the annuli. The number of annuli on the scale gives the age of the fish. Circuli are the actual sites of heavy deposition of bone material, and annuli represent the period of slow growth in a year. Sometimes false annuli also appear in some fishes due to slowing or. fluctuation in temperature, and must be distinguished froze real annuli. Generally a true annulus runs all along the surface of the scale, and is formed at the same time each year. but a false annulus does not run all along the scale and can be formed at any time due to various factors.

It was formerly thought that availability of food was responsible for the formation of rings, and so this method is valid for fish living in temperate

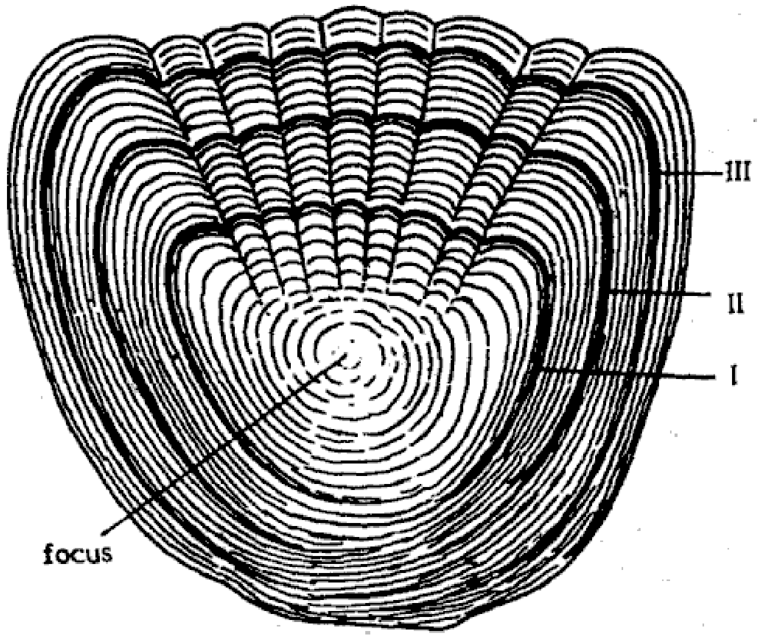


Fig. 3.1 A Scale showing three annuli

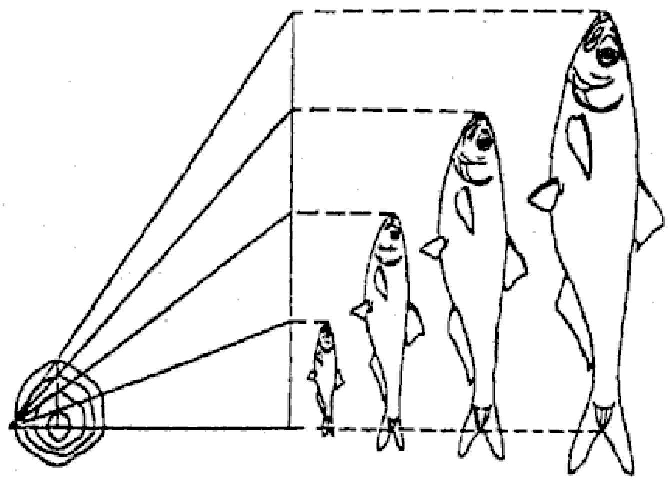


Fig. 3.2 The correlation between the growth rate of fish and that of its scales

Fig 6.2 T

zones, where the amount of food varies with the season, while in tropics where the food is available throughout the year, this method is not reliable. However, it is now believed that food alone is not responsible for the formation of the annuli, and it can be due to cessation of feeding during the process of maturation and spawning. According to Qasim (1973), it is not easy to read the scales in marine fishes as summer and winter are not well marked seasons in tropics.

Thus, age of the fish can be determined by counting the annuli, and fish lengths at each year can be back-calculated by measuring the linear distance (radius) from the focus' of the scale, to each annulus.

For example, the length at n' years can be calculated by using the following formula:

Ln= a + (L-a) (Vn)

where Ln = fish length at n years.

a = a constant that often approximates fish length at time of scale formation.

L = fish length at the time of capture.

V_n scale radius, distance from focus to n^{th} annulus.

V_r scale radius from focus to scale edge.

From these back calculations of length at different years, growth rates can-be calculated. This method has been used in fishes belonging to Cypriniformes, Perciformes and Channiformes.

Otoliths are formed in embryo as soon as the inner ear is formed, and are located on either side of the skull, where the upper arm of the gill arch is attached to the ode bone. Otolith can be seen after removing the muscles of the pro-otic bone, Of the three otoliths (lapillus, asteriscus, and sagitta), on either side of the skull, the sagitta is the largest and is used in age determination. It is roughly oval is shape, thin and flat in some fish, or thick at the tips. The thin otolith can be examined as such, while the thicker ones have to be grounded carefully. They are then examined under a binocular microscope to count the rings starting from the central nucleus. However, it is necessary to check and verify the age determined by the scale or otolith method, by other methods such as random sampling of the population over an extended period, or from direct observation from fish reared in a tank or cage.

3.1.3.5. Radio-carbon uptake method

Fish scales taken from the epidermis of a live fish are incubated in a medium containing the amino acid glycine made radio active by C^{14}. The rate at which the C^{14} - glycine is incorporated into the scale after an incubation of less than four hours, is measured by the level of beta radiations emitted by the scale. Increased incorporation of C^{14} by the scale, as shown by the scintillation counter, means faster growth rate.

3.2. Growth in prawns

Growth in crustaceans is directly and indirectly influenced by two ways: one is internal which ‘includes moulting and nutrition; the other includes external environmental factors such as temperature, dissolved oxygen. salinity, culture. density,. water quality, etc.

3.2.1. Internal factors

3.2.1.1. Moulting

In order to increase in size, crustaceans both marine and fresh water must replace their confining exoskeleton with a larger one and subsequently grow to fill it. This process of shedding the exoskeleton is called moulting or ecdysis and is a normal physiological phenomenon of crustaceans.

3.2.1.1.1. The moult cycle

In crustaceans, the moult cycle can be divided into several stages: early premoult, Moult, postmoult and intermoult stages.

The premoult stage (proecdysis) : During this stage, there is an active preparation for the moult as well as lost limbs and old exoskeleton is regenerated and replaced. Old endocuticle is digested by enzymes secreted from epidermal glands and new epicuticle and exocuticle are synthesized (Brusca and Brusca. 1990).

The moult stage (ecdysis): As soon as the old cuticle is loosened and a new cuticle is formed, the moult occurs. The newly formed soft cuticle includes new epicuticle and two layers of exocuticle.

The postmoult stage (metecdysis): This stage begins a few days after moulting when new cuticle is enlarged and later the animal enters a postmoult period. The noticeable physiological characteristic of this stage is that animal's cuticle becomes harder and more active than during the first two stages.

The intermoult stage (anecdysis): During this stage real tissue growth occurs including growth of epicuticle, exocuticle, endocuticle, membranous layer and epidermis. After its completion, the animal can be said to be in anecdysis (Skinner. 1985).

3.2.1.1.2. Hormonal control of moulting

In crustaceans the moult cycle is controlled by the Y-organ which is located at the base of the antennae or near the mouth part and is the glandular source of a steroidal moulting hormone (MH) or prohormone and ecdysone. On the other hand, the X-organ of crustacean which is located in a region of the eyestalk nerve called medulla terminalis, is a source of neurosecretory peptides and has been shown to have physiological and growth regulatory effects. The moultinhibiting hormone (MIH) and the gonadinhibitinghormone (GIH) are two inhibitory hormones produced by neurosecretory cells of the X-organ. The former inhibits moulting while the latter inhibits gonad activity. During the intermoult period, MIH is produced in the medulla terminalis by neurosecretory neurons in the X-organ. Then it is carried and stored in the sinus gland which is responsible for releasing MIH into the blood. When MIH in the blood reaches a certain level, it will inhibit the synthesis of ecdysteroids by the Y-organ. Certain appropriate internal and external stimuli inhibit the secretion of MIH due to the sensory input in the central nervous system. Because MIH levels are limited in the blood, it ultimately results into the production of ecdysone and the initiation of a new moult cycle. Since

1905 when Zeleny first reported that removal of the eyestalks resulted in a significant acceleration of the moult cycle, there have been many experiments repeated on a number of different crustacean species.

3.2.1.2. Nutrition

When provided with abundant food and given meticulous care, Prawns may have multiple accelerated moults. In addition to being abundant, the food must be of good quality. Although research studies on nutritional aspects of crustaceans are not as advanced as these are for trout and eels, it is now clear that lipids play an important role as a source of energy in the growth of crustaceans and that four highly unsaturated fatty acids (HUFA) are particularly important as dietary ingredients for crustaceans. These are linoleic. l.inolenic eicospentaenoic. and decoshexaenoic acids. Evidences indicate that growth is inhibited if the lipid content of the diet is not enough or lacking in the food.

3.2.2. Externalfactors

3.2.2.1. Temperature

Temperature is the most important external factor affecting the duration of the intermoult. And a general trend is that a rise in temperature significantly shortens the intermoul, a few studies have demonstrated an optimum temperature for the abbreviation of the intermoult. In Panulirus the intermoult shortened at 20-26°C, then lengthened at 29°C. Although the intermoult duration is affected by temperature, it is also important to remember that intermoult also varies with the size of the crustacean.

3.2.2.2. Dissolved oxygen

It is well known that low dissolved oxygen reduces the growth and moulting frequencies in crustaceans. besides causing mortalities in cultured shrimps. This has been demonstrated with some penaeid shrimps, including *Penaeus monodon, P. japonicus.* and *P. vannamei.* There was an interesting observation by Clark in 1986. He observed that *P. semisulcatus* kept at an oxygen level of 2 ppm for 1 7 days did not moult and experienced high mortalities. However, when the oxygen level was increased to 5 ppm. the mortality rate decreased and there were may moults at the same time. It is now well known that the rate of oxygen consumption rises before moulting. Therefore, an aftermath absence of moulting in *P. semisulcatus* during the hypoxic period may cause an inhibition of moulting by the x-organ or death of shrimps in the stages preceding moulting and/or during the stages of ecdysis. However, in order to stimulate growth it is necessary to increase dissolved oxygen to a certain level.

6.2.2.3. Salinity

The effect of salinity on crustacean growth depends on the species. Hartnoll (1982) mentioned that larval duration in Cardisoma guanhumi was unaffected in salinities from 20 to 40 ppt, but it became prolonged when subjected to 15-45 ppt. In *Penaeus monodon* growth tends to occur faster at lower salinity of about 10 to 18 ppt. and when the salinity increases to 35 ppt. the growth rate is only about 70% of the prior growth rate.

SUMMARY

Growth of an organism can be defined as a change in its size over a period of time. Growth is known to be regulated by certain hormones, especially the growth hormone synthesized in the pituitary gland. Age and growth can be determined by rearing the fish in a controlled environment, tagging. length frequency distribution, scales. vertebrae. opercular bone Otoliths. Growth in prawns is influenced by molting, nutrition. environmental factors like temperature. dissolved oxygen, salinity, water quality.

Questions

1. Discuss the growth in fishes.
2. How the age and growth determined in fishes.
3 Discuss the factors influence the growth in prawns.
4. Describe the length frequency method and how is useful to determine the growth.
5. How the scales are useful in detecting age of a fish.

4

SKELETON AND INTEGUMENTARY SYSTEM IN FISHES

Skeleton in Fishes

The endoskeleton in fishes is mainly bony and is well differentiated into axial and appendicular bones. The axial part includes skull, vertebral column and ribs, whereas the appendicular part includes pelvic and pectoral girdles with their related fin skeleton.

4.1. Axial skeleton

4.1.1. Skull

Skull is cartilagenous in the beginning and then after undergoes ossification and turns bony. The skull comprises cranium and visceral skeleton.

4.1.1.1. Cranium

The posterior most part of cranium is the occipital region which is made up of four bones supra occipital, basiocciptal, and two exooccipitals. In addition there are three appertures in the occipital region a small median foramen magnum and two large lateral oval fenestrae characteristic of cyprinoid skulls (Fig.4.l & 4.2). Dorsally supraoccipital is overlapped by the parietals which lie in front. The supraoccipital bears dorsally a median longitudinal vertical occipital spine. Basioccipital is found below the two lateral exocciptals. The dorsal process of ex-occipital meets that of the other side to enclose the foramen magnum dorsally.

The otic region includes four bones namely the protic, the epiotic. the sphenotic and the pterotic. There is no opisthotic in adult *Labeo*. A smaJl beam shaped supratemporal bone is present between pterotic and the posterior process.

The major part of roof of skull is composed of parietals and frontals. There is a pair of parietals above, parasphenoid below and paired alisphenoids on the side. A pair of frontals above, parasphenoid below and paired orbitosphenoids on the sides.

The floor of the skull is composed of parasphenold. There is no bassispheroid. The frontal articulates with the mesethnoid medially. the nasal and the ectoethmoid laterally, supraorbital, anterio laterally and post frontal, postero-laterally.

The orbits are found in the frontal region and are bounded dorsally by frontal ventrally by alisphenoid and orbitosphenoid, anteriorly by ectoethmoid. and posteriorly by sphenotic.

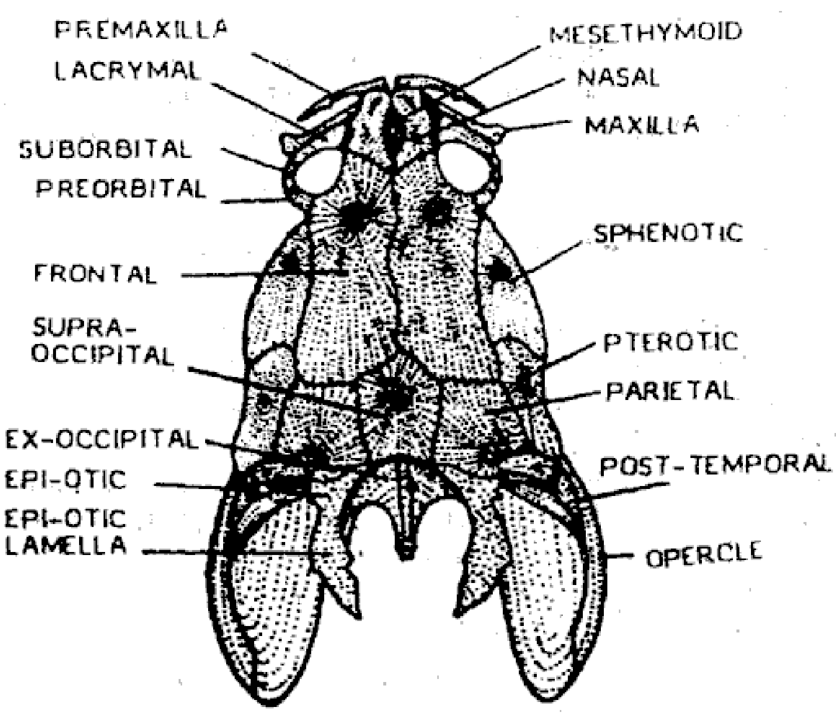


Fig. 4.1. Dorsal view of the skull.

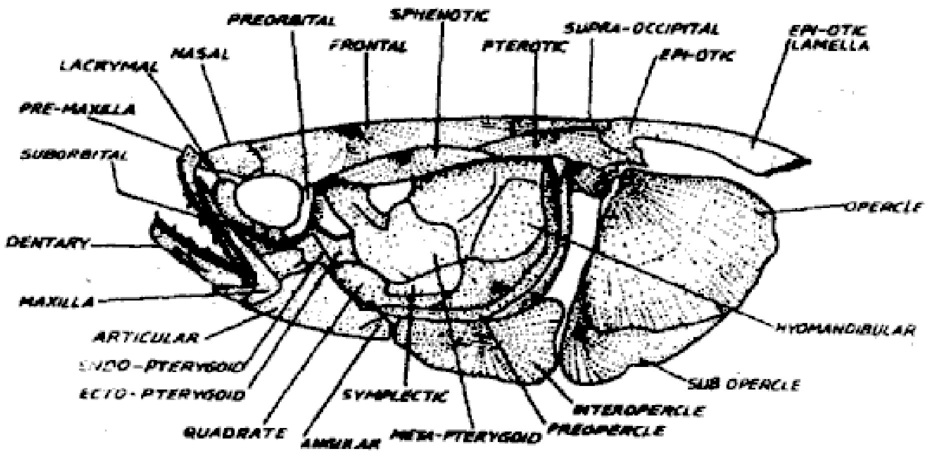


Fig. 4.2. Lateral view of the skull

The nasal or ethmoidal region is composed of nine bones. This region includes paired nasal above the olfactory capsule, median mesethemoid infront of frontal, a median nostral to the anterior concave notches of the mesethmoid and a ventral median vomar lying infront of parasphenoid and beneath the mesethmoid. Ecto-ethmoid and lacrymal bones also belong to this region.

4.1.1.2. Visceral skeleton

The visceral skeleton is made up of several pairs of visceral arches. Among these, first pair is the mandibular, second pair is the hyoid and five branchial arches. The mandibular arch forms the upper and lower jaws. The upperjaw consists of premaxilla, maxilla, palatine. metapterygoid and quadrate. Similarly lower jaw consists of dentary angular and articular bones. Teeth are never developed on these jaw bones in *Labeo*. The hyoid arch is formed of hyomandibular dorsally and the epihyal, the ceratohyale and the hypohyale ventrally. The posterior corner supports the tongue and the floor of mouth cavity. The last five pairs of visceral arches are called the gill or branchial arches. First four branchial arches bear gill lamellae while the last one is without gill lamellae. Typically, each arch is made up of four components; Hypobranchial (ventral), ceratobranchial (ventro lateral), epibranchial (dorso-lateral) and pharyngobranchial.

4.1.1.3. Jaw-suspension in fishes

In the foregoing account, it was made clear that the splanchnocranium comprises various visceral arches of which the mandibular arch forms the upper and the lowerjaws. The first upperjaw skeleton that develops in the embryo is the platoquadrate (pterygoquadrate) cartilage on each side. In bony fishes this cartilage becomes covered by dermal bones. These dermal bones, the premaxillae and maxillae comprise the upper jaw of adult bony fishes and may often bear teeth. Bones called maxillae in teleosts may be toothless, reduced or not in the upper jaw and may not be considered homologous with the maxillae of older fishes and tetrapods.

The lowerjaw in embryos appears as the Meckel's cartilage ventrally to the upperjaw. The cartilages of each side meet ventrally with each other to form the skeleton of the lower jaw. While the upper jaw braces against the chondrocranium the lower jaws gets movably attached with the upper jaw. The hyoid arch also contributes to the bracing of mandibular arch and forms a jaw hyoid complex. Such complexes technically called jawsuspension occur in three different forms in fishes, as described below.

4.1.1.3.1. Amphistylic jaw suspension

Both the platoquadrate and the hyoid arch connect with the basal and the otic processes of the chondrocranium directly, with the help of ligament's. Such an arrangement is regarded as a primitive type and found in ancient acanthodians, crosspterygians and in early sharks (Cestracion. Hexanchus and Heptanchus) (Fig.4.3a). It is believed that the jaws of the primitive types were connected directly to the skull, and it was only later that the hyoid arch became a part of jaw suspension. Various modifications in the evolution of jaw mechanism are said to be closely to the feeding mechanism of fishes.

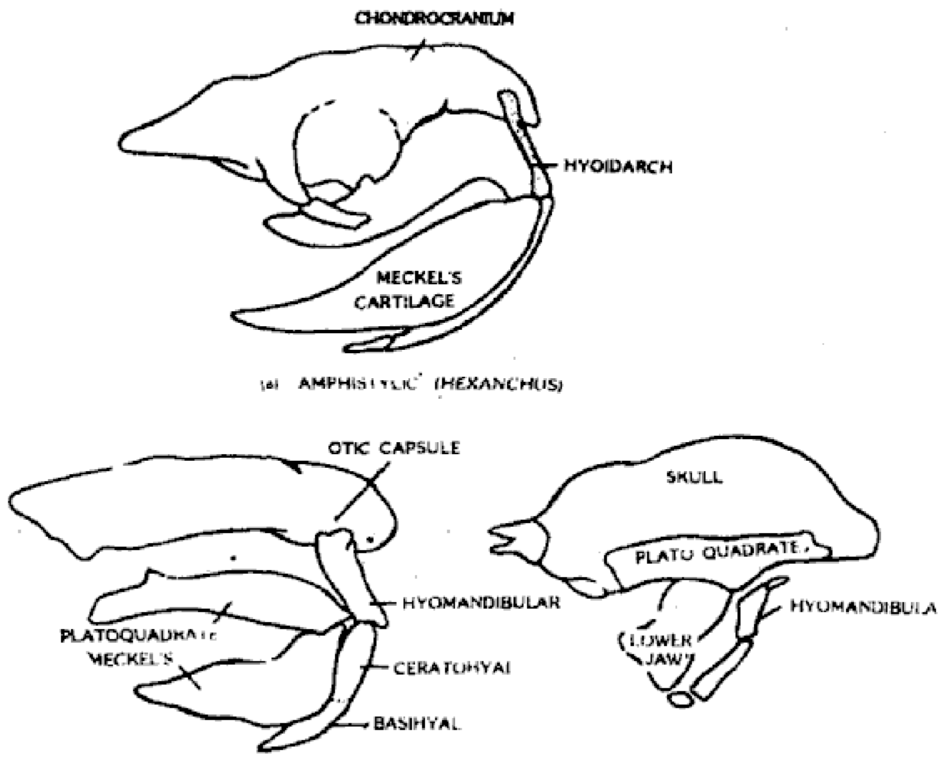


Fig. 4.3 Jaw suspension in fishes

4.1.1.3.2. Hyostylic jaw suspension

The jaws are suspended to hyomandibular by means of ligamentous connection, and only the hyomandibular attaches to the otic region of the skull. Thus a direct articulation of jaw with the cranium is lost. Such a condition is found in all the extant sharks. strugeons and in the actinopterygian fishes. (Fig. 4.3b).

4.1.1.3.3. Autostylic jaw suspension

This type of jaw suspension appears to have been derived from an amphistylic ancestor. The platoqudrate either articulates or fuses with the chondrocranium and hyomandibular plays no role in bracing the jaws. Such a type of self bracing of jaws is found in lung fishes and chimaeras (Fig. 4.3c).

4.1.1.3.4. Holostylic jaw Suspension

This type is a modified kind of autostylic arrangement. The platoquadrate fuses indistinguishably with the chondrocranium. and the Meckeli's cartilage with the basal part (quadrate) of the platoquadrate. Such an arrangement is found in holocephalians. The platoquadrate in placoderms fuses with the dermal armor covering the cheek.

4.1.2. Vertebral column

Vertebral column is comprised of 37 or 38 well ossified amphiceolous vertebrae. The embryonal notochord in adult is replaced by the centra of vertebrae, but in sturgeon it persists primitively unchanged throughout the life of the fish. All the vertebrae of adult form a long and stiffened, rod like vertebral column, that extends from behind the skull of the tip of the tail.

Typically a vertebra (Fig.4.4) consists of a centrum, arches and various processes. The centrum lies immediately under the neural tube. It is concave at both the ends (amphicoelous) and the spaces between them contain the notochordal tissue. A centrum gives rise to a pair of neural arches dorsally, and a long neural spine, and ventrally. The neural arches meet each other dorsally to from a long neural spine, and encloses a space between them the neural canal to lodge the neural tube. Hemal arches similarly meet ventrally and form the hemal spine and the hemal canal. In addition to these arches a centrum may have many other projecting processes called addition to these arches a centrum may have many other projecting processes called the apophyses. Most common of these include the transverse processes extending laterally from the base of neural arches or from the centrum and separating the epaxial and hypaxial muscles. The processes provide for rigidity of the column, prevent excessive torsion and provide surface for the attachment of ribs and muscles.

The vertebral column of cartilagenous fishes are not the typical column of the fishes. The centrum is amphicelous and contains a constricted notochord, traversing through it. The contriction, however, is not seen between the centra. Neural arches consist of cartilagenous basidorsal and the intercalary plates, both completing the enclosure of the neural canal. The basidorsal plate bear the openings for the passage of the ventral root of spinal nerve and inter callary plates are perforated for the passage of dorsal root of the spinal nerve. These roots unite later, but outside the vertebral column to form the spinal nerve. The hemal arches are much reduced in trunk region, being represented by a pair of ventrolateral projections called basopophyses. In tail region they are well developed and form a complete hemal spine. Often the two vertebrae of tail region are formed in association with a single myotome, giving rise to a condition called *edisplospondyly*. In some holocephalans chordal cartilage (Fig.4.5b) converts the notochord into a column consisting of calcified cartilagenous rings, that are much more numerous than the body segments and the notochord does not show constrictions or the expansions.

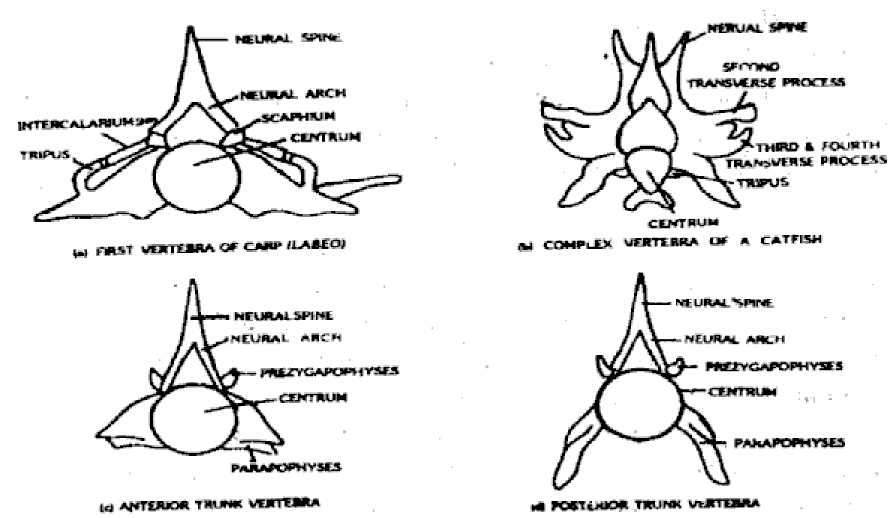


Fig. 4.4. Vertebrae of teleost

Many variations are found in the vertebral columns of the bony fishes. The chondrostean Polyterus, has well developed bony vertebrae. Each vertebra has a well developed centrum, the dorsal and ventral arches. The ventral arches provide surface for articulation of rib in the trunk region and form definite hemal arches in the tail region.

The vertebrae of teleosts are completely ossified with amphicoelous centrum. They often bear a small canal in the centre for a much reduced and compressed notochord. The concavities of centrum are filled with pulpy material derived from the degeneration of notochord. In eels, the centrum tends to becomes flattened at each end (amphiplatyan) and sometimes even bear a convexity in front. From the centrum arises the neural arches, which are differentiated for the first time in bony fishes into an anterior pre-end a posterior post zygapophysis. Hemal arches may similarly be differentiated into anterior and posterior processes. The hemal arches are much reduced (parapophyses) in the trunk region, but provide enough surface for the attachment of ventral ribs. Behind, in tail region the hemal spine is formed in the usual manner.

In many fresh water teleosts, a complex vertebra is formed by the fusion of a anterior vertebrae of the spinal column (Fig. 4.5 a & b). These vertebrae are devoid of parapophyses (lateral projection) and serve to connect to the air bladder with the internal ear. The vertebrae canbe distinguished into an anterior complex vertebra, typical trunk vertebra, precaudal and caudal vertebra, on the basis of modification of various processes arising from the centrum.

4.2. Appendicular skeleton

It includes mainly the bones of pectoral and pelvic girdles. The pectoral girdle lies just behind the last branchial arch. It is made up of two lateral halves. These lateral halves do not meet in the middle. Each half of the girdle consists of a dorsal scapula and a ventral coracoid. The glenoid cavity is developed at their common meeting points. In addition to these two bones, a series of dermal bones are also added to the pectoral girdle in front. These are post-temporal, supra-cleithrum, cleithrum or clavicle and post-cleithrum.

The pectoral fin skeleton includes four radials a pterygiophore and 19 lepidotricha. Thus radials articulate with the girdle at the glenoid facet at one end while their other ends carry dermal fin rays.

The pelvic girdle lies in the ventral abdominal wall anterior to anal fin. Both the halves of the girdle meet in the midventral line. Each half is composed of a large basipterygium or pelvic bone. Its anterior broad part with forked end is connected infront by a ligament to the ribs of the 12th trunk vertebra. The posterior narrow rod like part taper behind into a small cartilage and unites with the fellow of the other side in the mid ventral line.

The pelvic fin skeleton includes three radials, carrying nine dermal fin rays which are long and jointed.

4. 3. The Integumentary system.

The integumentary system compries the skin and its derivatives. The skin or integument forms the external covering of the body and performs a number of important functions in fishes. It protects the body from injury and infections and helps in respiratory, excretory and osmoregulatary functions. The derivatives of the skin play an important role in the metabolic activities of the body. In some species special structures like the electric organs, poisonous glands, phosphorescent organs are also integermentary derivatives.

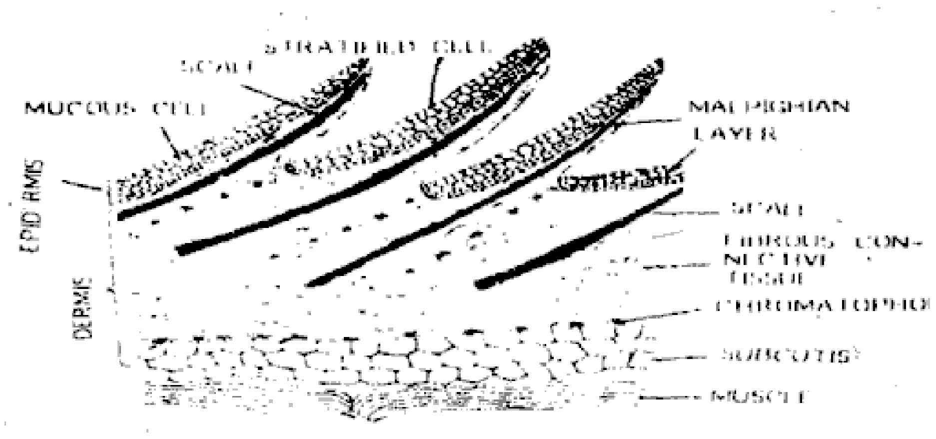


Fig. 4.5. V.S. skin of a teleost.

4.3.1. Structure of Skin

Fish skin is made up of two layers, an outer epidermis and an inner dermis. The epidermis consists of several layers of flattered stratified epitheliurn cells. Epidermis is ectodermal in origin. The deepest layers are made up of columnar cells forms the stratum germinatum where the cells always multiply mitotically to replace the outer worn cells. The stratum corneum which is the superficial layer of dead cells present in terrestrial vertebrates, is absent in fishes.

The dermis consists of connective tissue, blood vessels, nerves and cutaneous sense organs, pigment cells and is mesodermal in origin. The fibres of connective tissue are almost are parallel to the surface. Pigment cells occur only. in the outer part of the dermis. The thin upper layer of loose connective tissue is called the stratum spongeosum and the thicker dense lower layer as stratrum compactum. Number of flask shaped or tubular 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 a thick, slimy mucous, covering the whole body. Mucous cells develop from the stratum germinatum and migrate to the surface. The shape, size and number of mucous cells will vary in different species of fishes. Different types of scales like placoid, cycloid, gonoid will develop depended up the type of fish from the dermis.

4.3.2. Functions

1. The mucous coated skin lubricates the fish to reduce body friction in water at the time of swimming.
2. It protects the body from parasites, fungus, bacteria and other microorganisms.
3. Exoskeleton in the form of scales, plates or denticles are important derivatives of the skin which provide protection to the body.
4. Helps in osmoregulation.
5. It can absorb the dissolved nutritive substances from the surrounding water.

6. It repairs the surface wounds.

7. It acts as respiratory organ in eel and climbing perch due to the highly vascular dermis of their skin.

8. In some species glandular cells modify into poison glands (Scorpion fish, toad fish) and are used for affence and protection..

9. In marine fishes accessory organs like electric organs, which are defence in nature are the skin derivatives

10. Chromatophores of various kinds present in the dermis give beautiful colour patterns to the body.

4.4.1. Scales in fishes

Scales are the skin derivatives which cover and protects the body. Most of the fishes are covered by an exoskeleton madeup of sca1e. Few fishes like catfishes are naked without scales. Some species like *Polyodon* and Acipenser will have scales or plates only at some localized regions.of the body. Placoid scales are the characteristic of the chondrichthyes; ganoid scales are found in primitive bony fishes; cycloid scales and ctenoid scales are found in the higher teleosts. Cycloid and ctenoid scales are helpful in determination of the age and growth rate of fishes.

4.4.1.1. Types of scales

Basing on the structure the scales are classified into cosmoid, ganoid (rhomblood), placoid, cycloid and ctenoid Cycloid and ctenoid scales are also known as bony ridge scales

4.4.1.1.1. Cosmoid scale

The cosmoid scales are found in the extinct crosspterygii and dipnoi fishes. The external layer of the scale is thin and enamel like, It is vitrodentine. The middle layer is made up of hard; non-cellular. dentine like material called the cosmine and contains a large number of branching tabules and chambers.

The inner layer is made up of vascularised bony substance, isopedine. Isopedine material will be added from the bellow and helps in the growth of the scale. Cosmoid scales are not found in living fishes. The living dipnoi possess thin cycloid scales, are have lost the cosmine layer.

4.4.1.1.2. Ganoid scale

The primitive actinopterygians possess ganoid scales and are called as ganoid fishes, these scales have various forms and structure. These are heavy and have an outer layer of inorganic, enamel like material called ganoine. The middle layer is having numerous branching tubules and contains cosmine. The innermost layer is thick and is made up of lamella bone, isopedine. These scales growby the addition of new layers to lower as well as upper surface. These are usually rhomboid in shape and articulate by peg and socket joints.

The ganoid scales are well developed in the chondrostean and holostean fishes. In *Acipenser* they are in the form of large, isolated, bony scutes and are present in five longitudinal rows at places where there is greatest wear and tear. In *Lepidosteus,* the scales are hard, polished, rhomboid plates fitting edge to edge, thus forming a complete armour. The middle cosmine layer is lost in these scales and the thickness or rigidity is reduced. The scales of *Amia* are thinner and do not possess the ganoin layer and resemble typical cycloid scales.

4.4.1.1.3. Placoid scale

Placoid scales are characteristic feature of the sharks. Placoid scales consists of a rhombosidal basal plate and a flat trident spine. The basal plate is fomed of a loose, calcified trabeculae material resembling bone, has a perforation at its center and is firmly anchored in the stratum compactum of the dermis by means of strong connective tissue fibres called the Sharpey's fibes. The spine is largely composed of very hard material, the dentine, which is ramified by five canaliculi and covered by a harden layer vitodentine. The surface of the spine appears to have numerous small plates arranged in transverse rows in an impricate manner. The spine pierce through the stratum laxum and epidermis and partly projects out in water. The spines of the body scales are directed backwards and those of clasper scales are directed forward. The perforation of the basal plate leads to pulp cavity present in the middle of the spine. The pulp cosists of the dentine forming Odontoblasts or scleroblasts a small artery and vein forming a network of capillaries a nerve fibre; and a bit of alueolar tissue. The scales are produced by the mesodermal cells of dermis and can be replaced. The placoid scales are homologous with the vertebrate teeth in the mode of development and nature of dentine.

4.4.1.1.3.1. Development of placoid scale

Placoid scale development begins with the multiplication of dermal cells which accumulate at different points below the stratum germinativum (Malphighian layer). There dermal cells form a papilla which grows upwards pushing the malpighian layer into strongly arched structure. The cells of malphighian layer of this region become columnar and glandular forming enamel organ. The dermal papilla assumes the shape of a basal plate and a spine. The cells at the surface of papilla form a distinct layer and are called odontoblasts. They secrete dentine towards their outer surface to cover the papilla. The central cells of papilla do not calcify and form the pulp. The spine of the scales is gradually pushed towards the surface. Before eruption, the cells of the enamel organ, called a meloblasts, secrete a layer of vitrodentine to form a cap over the spine. The mesenchyme cells of the dermis, surrounding the dermal papilla, secrete a substance like the cement of teeth to form the basal plate of the scale. Thus the placoid scale is partly dermal and partly epidermal in origin.

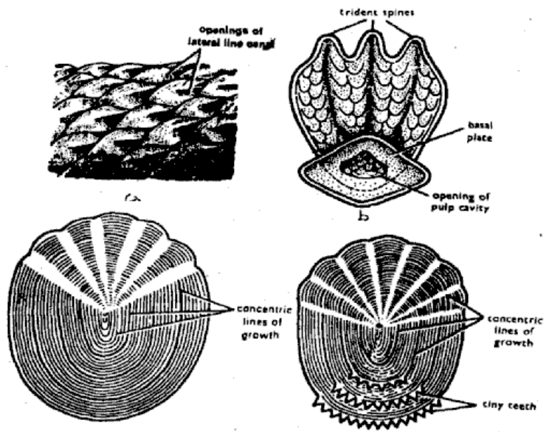


Fig. 4.6. Scales in fishes a. Ganoid, b. Placoid, c. Cycloid d. Ctenoid.

4.4.1.1.1.4 Bony ridge scales or cycloid and ctenoid scale

The cycloid and ctenoid scales are also known as bony ridge scales. Majority of the teleostean fishes possess these scales. They are thin, flexible transperent structures due to the absence of the first and 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 locus and is the first part to develop.

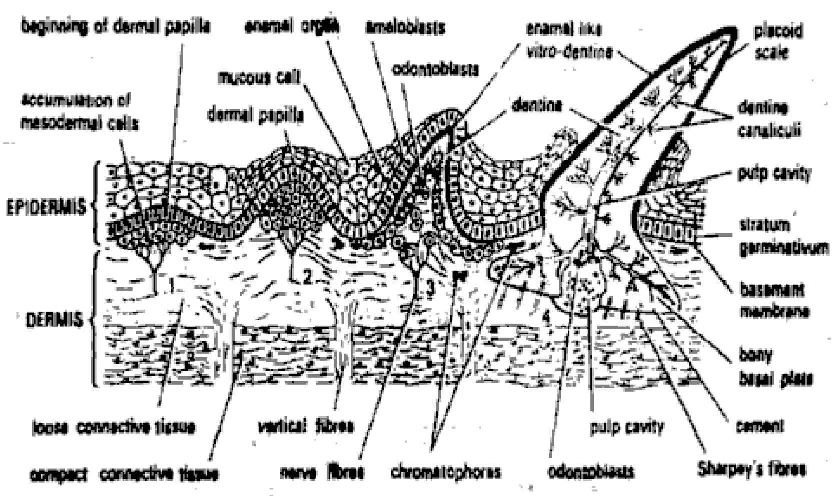


Fig. 4.7. Development of Placoid scale

The origin and development of both the scales are similar. Cycloid scales are thin and roughly rounded in shape being thicker in the center and thinner in the margin. They are found in large number of teleostean fishes (eg. *Labeo, Catla, Barbus, Cirrhina*, etc) They form a projective coverup over the skin and projects diagonally in an imbricating pattern. The anterior area lies embded in the skin. Some times even chromotophores are attached to the exposed portion of the scales.

The ctenoid scales are also circular and can be distinguished from the cycloid by having a more or less secreted free edge. 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 fins. All intermediate types between the cycloid and ctenoid scales are found on different parts of the body. Ctenoid scales are very common in perciformes fishes (eg. *Anabas, Gobius, Perca*, etc.)

The cycloid and ctenoid scales develop in the form of a dermal papilla formed by the multiplication of cells. The epidermis does not take part-in the formation of these scales. The scales are generally formed first at the caudal pedencle then spread to the rest of the body. The papilla first secrete the central part of the scale or focus and then ridges are deposited on the growing scale.

Scales under go several modifications. Jaw teeth of shark, teeth forming the saw of Pristis, sting of sting ray are modified scales. In (Diodon) porcupine fish scales are modified into elongated spines for protection. In the sea horse and the pipe fish scales are fused to form protective bony rings around the body.

4.5. COLURATION :

In fishes the Colouration is well marked. A large number of teleostean fishes are brightly and brilliantly Coloured, while others are of more uniform and sober shade. The pattern of Colouration relates to the life style of the fish and has functional significance. Generally the fishes are darker on their upper surfaces due to sunlight while the ventral and lateral sides are relatively lighter in Colouration.

4.5.1 Source of Colour :

Colouration in fishes has been attributes to the presence of two kinds of special cells. They are I) The Chromatophores and ii) iridoctes.

The Chromatophores are branched connective tissue cells located in the dermis either above or below the scales. Chromatophores contain pigments of various kinds of pigment granules which may be carotenoids (yellow - red), melanin (black), flauines (yellow), purines (white or silvery), pterins, porphyrins and bile pigments. Based upon the Colour of the pigments, the Chromatophores are of the following types.

4.5.1.1 Melanophores:

The pigmentary material of chromatophore is black Coloured, called as 'melanin'. It is formed from an aminoacid tyrosine, which is converted into melanin in the presence of copper containing enzymes tyrosine melanin, so formed, associates with the cytoplasmic organ all called the 'melanosome'. A brown in black pigment called 'eumelanin is also sometimes found within the melanophores.

4.5.1.2. Iridophores :

The pigmentary material in these cells is guanine. Guanine is opaque, whitish or silvery. It is a waste product and is deposited in the form of granules. These granules are opaque and posses great reflecting power, so that the iridocytes may also be called the 'mirror cells'. Tiny crystal of this pigment produce a white or silvery white apperance and against a background of melanophores, impart a blue Colour to the fish.

4.5.1.3 Xanthrophores and erythrophores :

The pigmentary material of these cells include carotenoide and pterins. They are in white, yellow, orange or red Coloured pigments are abundantly found in plants and the fishes being incapable to synthesize them, hence to depend upon the plants for a dietary supply of the pigmentary material. The cellular organelle containing pteridines are known as pterinosome and the ultra microscope vesicles of cells containing carotenoid are called the carotenoid vesicles.

4.5.1.4 Mixed Colouration in fishes :

Colour patterns of a majority of a fishes are due to the combined effects of Chromatophores containing different kinds of pigmentary granules. Thus the black and yellow Chromatophores, together develop green Colour. Likewise, yellow and black and orange and blue may combine separately to rovide or brown appearance to the fish yellow mixed with black gives brown or blackish Colouration in fishes.

4.5.2 Colour change in fishes :

Various species of fish change the pattern of their Colouration in accordance to their surroundings or in relation to the phases of their behaviour. Such an ability may be physiological or the morphological type.

4.5.3 Significance of Colouration :

The Colouration in fishes performers adaptive functions and in useful to the fish in a variety of ways such as camouflage, concealment and disguise, aggressive purpose, courting patterns, warning pattern and Colour patterns.

SUMMARY

The skeleton in fishes can be divided into axial and appendicular skeleton. Axial skeleton consists of skull and vertebrae. Amphicoelous vertebrae are found in fishes. The appendicular skeleton is poorly developed in fishes.

The scales are exoskeletal structures of fish, useful for protection. These are cosmoid. ganoid, placoid, cycloid and ctenoid. Cosmoid scales are with cosmine and were found only in extinct fishes. Ganoid scales are with ganin and are found in dipnoi. chondrostei and holostel fishes. Placoid scales are with a triradiate spine and basal plate and are found only in elasmobranches. Cycloid and ctenoid scales are bony ridge scales found in teleosts. Ctenoid scales can be identified with ctene and are found only in order perciformis. The skin of fish consists outer epidermis and inner dermis. Epidermis consists of stratified and Malpighion layers and dermis consists of spongisum and compactum layers.

Questions

1. Describe the structure and functions of skin.
2. Discuss various types of scales found in fishes.
3. What are bony ridge scales and give their structure.
4. Describe the structure of a typical vertebra.
5. Explain jaw suspension in fishes.
6. Give an account on axial skeleton in fishes.

5

DIGESTIVE SYSTEM OF FISH AND PRAWN

Nutrition deals with the intake of food and water by the organisms. Living animals require food for three main purposes which are as follows:

I) Food provides energy to the body for performing various life activities such as muscle contraction, movements etc;
2) Food is needed for growth and repair of the body.
3) Food is a fuel to supply energy for the maintenance of the body.

The substances required in the food of organisms are carbohydrates, proteins, fats, water, mineral salts and vitamins. The first three are required for energy and building of materials. The next three are useful for building and regulative action. In addition to them, organic substances like choline. sterols, purines and pyrimidnes are also required in the food. Nutrition is an anabolic process. In a majority of animals, it is holozoic type. Animals are heterotrophs.

The process of nutrition includes ingestion, digestion, absorption, as similation and egestion. To perform these activities, vertebrates have developed a system known as Nutritive system or digestive system. Various food materials are converted into simple and soluble substances which can be readily absorbed by blood and lymph. This mechanical and chemical break down of food is called digestion. Digestive system consists of an alimentary canal and associated digestive glands. It is derived from the embryonic endoderm.

5.1 Digestive system of fishes

The digestive system of fish includes the digestive tract and the various glands found associated with it. It is concerned with the ingestion, digestion and absorption of food and with the elimination of undigested wastes. The accessory organs like the tongue, teeth, oral glands, pancreas, liver, gall bladder are also associated with the digestive tract.

The digestive tract or alimentary canal, comprises three major parts- the fore-gut, mid-gut and the hind-gut. Each of these parts undergo further differentiation to include several segments of the gut (Fig.9. I). Foregut differentiates to include the parts like mouth, buccal cavity, pharynx, oesophagus, and stomach. Mid gut differentiates into small intestine and the hindgut into the large intestine and the terminal aperature.

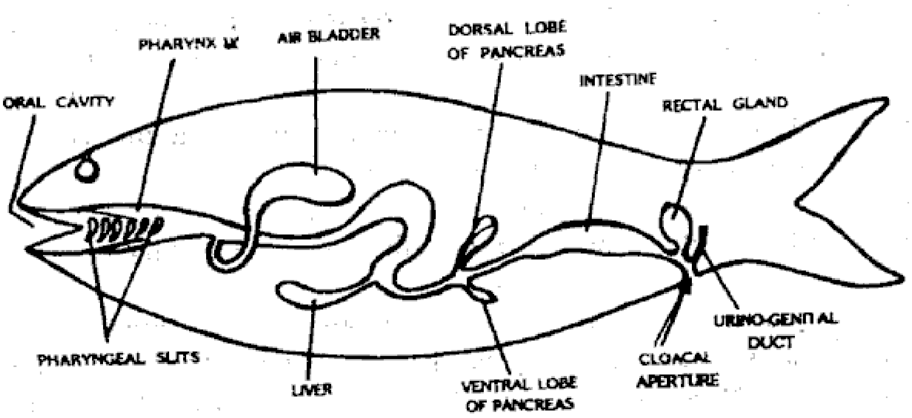


Fig. 5.1 Digestive tract in fish

5.1.1. Digestive tract

5.1.1.1. Mouth

Mouth is a slit like structure in fishes. It is surrounded by lips.

5.1.1.2. Buccal cavity and pharynx

The buccal cavity and pharynx are not clearly marked off from each other. A number of perforations of gill slits are found on each side of the pharyngeal wall. These at their openings into the pharynx are supported by gill rakers which assist in the process of ingestion. Pharynx however is largely a structure for respiration than for digestion. Buccal cavity also consists teeth and tongue.

5.1.1.2.1. Teeth

The teeth of vertebrates in general, may be divided into two main types viz, the epidermal (horny) and the dermal teeth. The former types are derived from the stratum corneum of epidermis and restrict to only the buccal funnel and the tongue of agnathans. The latter type are derived from the dermis and are the only remanent of dermal armour. In most mammals and are seen in many sharks, in which placoid scales show a gradual transition into the teeth, as they gradually approach the edge of a jaw. Like placoid scales, the teeth of fishes are essentially the hollow cones of dentine containing the pulp cavities. They are continuously produced along the inner margins of the jaws in the form of specialized denticles or placoid scales. As the new generations are added from behind the older ones are pushed in front so that when older ones are worn off they are replaced by the newer ones from behind. However, the number, distribution, degree of permanence, shape and mode of attachment of teeth varies among the different species of fishes.

In chondrichthyes the teeth are either found scattered throughout the roof of the buccal cavity or these may be found attached to the cartilagenous jaws with the help of connective tissue (acrodont). They are uniform in appearance (homodont) and can be constantly replaced by the series lying behind (polyphyodont).

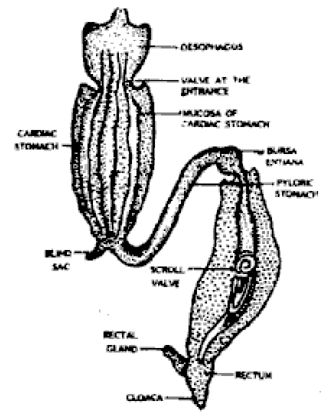


Fig. 5.2 Digestive tract in cartigenous fish.

The teeth of osteichthyes fishes may be divided into three types, on the basis of their position in the oral cavity. Thus the jaw teeth are borne on the premaxillary and the maxillary bone above and on dentine below. Oral teeth or the teeth of mouth are borne on the vomer. palatine and ectopterygoid bone, on the roof and by the tongue on the floor of mouth. The teeth of pharynx represent the third type, and develop from various sources, like as by the modification of lower elements of last gill arch, by modification of gill rakers or by the dermal bones.

The general form of teeth varies according to the feeding habits of the fishes. These may be pointed, spherical, curved, dagger shaped. canine or molariform or fang like in their shape. Occassionally as in dipnoans many of tooth germs fuse to form the compound plate like teeth for crushing the objects of food.

5.1.1.2.2 Tongue

The tongue arises as a fold form the floor of buccal cavity. It is devoid of any muscles, but supported by the hyoid arch that often extends into it. Small papillae, sensory receptors and the teeth are variably found on this structure scarcely called the tongue.

5.1.1.3. Oesophagus

The phazynx opens behind into the oesophagus and the latter in turn passes almost imperceptibly into the stomach. These three parts viz, the pharynx, oesophagus and stomach are not clearly marked off from each other except histologically. Oesophagus commonly bears longitudinal fold to permit a greater distensibility and its mucosal lining comprises largely the squamous cells.

5.1.1.4. Stomach

The stomach, basically is a structure meant for the storage and maceration of food material. Only when its internal lining contain the gastric glands it is properly called a true stomach.

Stomach assumes different shapes according to the availability of space in the body cavities of different fishes. It is usually differentiated into a board anterior part, lying closer to the heart, and called cardiac stomach and into a posterior narrower part called the pyloric stomach. The opening of latter into the mid-gut is usually guarded by a valve.

In elasmobranchs (Fig.5.2) it is typically a “J” shaped structure comprising two parts. The upper longer and broader part represents the cardiac stomach and lower shorter and narrower part represents the pyloric stomach. The junction of the cardiac and pyloric part is marked in many fishes by a circular fold of mucus membrane that forms the pyloric part is marked in many fishes by a circular fold of mucus membrane that forms the pyloric valve. Some forms (Scoliodon) a small thick walled muscular chamber the bursa entiana is found at the end of pyloric stomach. The stomach contains the gastric glands, that are distributed throughout its mucosal membrane.

Stomach of teleosts presents a variety of different shapes (Fig.5.3). In some the entire gut appears as a tube of uniform diameter with no marked differences between the oesophagus and stomach. In others it appears as a round and muscular structure placed at the end of oesophagus, and possesses well formed gastric glands. In a few others the stomach is distinguishable into a cardiac and a pyloric part and possesses a blind sac of variable size, lying between the two. Fishes belonging to family Cyprinidae and Catostornidae, lack a true stomach and the process of digestion is carried out in the intestine by the pancreatic juice. Fishes with and without stomach are found largely in the family Cobitidae.

A constriction is the only demarcation between the oesophagus and the stomach of lung fishes. Stomach of these fishes lack the gastric glands but remain separated from the intestine by a flap like pyloric valve.

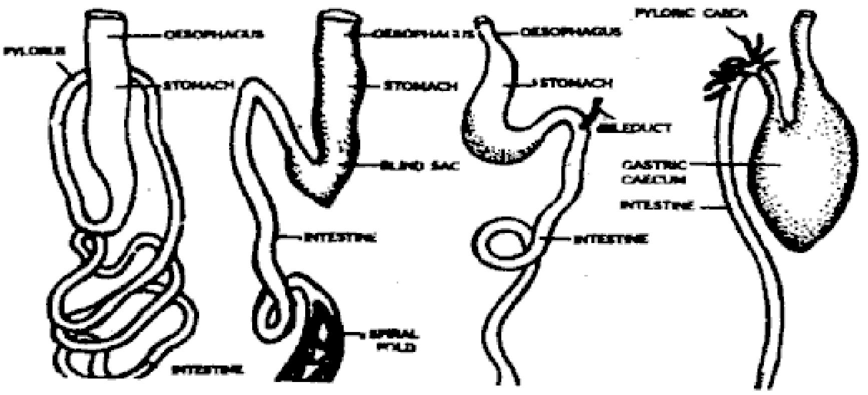


Fig.5.3. Digestive tract in bony fishes.

5.1.1.5. Intestine

The part of digestive tract following the stomach is called the intestine. It is divisible into two main parts, an anterior long but narrower part called the small intestine lying immediately behind the stomach receives ducts from the liver and pancreas and called duodenum while the rest of it is ileum. These various intestinal parts are usually differentiated histologically by only a gradual change in the nature of mucosal layer. Only in certain groups there is a fold marking the posterior region of intestine.

The length of intestine however depends upon the feeding habits of the fishes. It is relatively shorter in carnivorous than in herbivorous fishes. Generally the intestine of the fish is shorter and runs a relatively straight course. The short length is compensated by the development of scroll valve in some fishes. It appears along the inner wall of intestine in the form of an enlogated ridge and grows into the lumen. After reaching the opposite side of the intestinal cavity the ridge rolls up into a scroll. In sharks, it persists in this from in adults, but in many other elasmobranchs a further twisting throws the scroll into a spiral valve. In Scoliodon the spiral takes about fourteen and half turns while many more in some other elesmobranchs. The spiral valve consists of a core of submucosal connective tissue, covered by the mucosal lining of the intestine.

The small intestine of elasmobranchs and chimaeras is shorter than the stomach. It is wide and straight and contains a well developed spiral valve. A circular valve often separates the small intestine from the large intestine. The latter is short and extends straight from small intestine to anus. A long finger like diverticulum called the rectal gland opens into the intestine at the junction of the small and the large intestine. Its gland secretes a highly concentrate solution of sodium chloride to rid off excess salts of blood.

5.1.1.6. Pyloric caeca

Many fishes have pyloric caeca, given off from the portion of the mid-gut, lying immediately behind the pylorus. These caeca may be blind, tubular or sac like diverticulas of uncertain functions. They do not follow any definite arrangement of the organisation and vary in numbers in different fishes. Only a single such caecum is found in *Polypterus* while the number may go upto two hundred in mackerel.

5.1.1.7.Anus

The gut ends with the anus, which is a small opening located at the posterior region of the body.

5.1.1.8. Histology of digestive tract

Typically the digestive tract of fish comprises the fo11owing four layers (Fig.5.4).

5.1.1.8.1. Serosa

This, the outermost serous membrane of visceral layer of peritoneum, is usually absent from the part of oesophagus, that lies outside of the body' cavity.

5.1.1.8.2. Muscle layer

A layer of circular and another of longitudinal muscle fibres lie just under the serosa. In oesophagus the circular muscle layer lies on the outer side of the longitudinal muscle layer, while in the stomach and the intestine the longitudinal layer lies on the outer side of the circular muscle layer.

The layer of circular muscle fibre is comparatively thicker and better developed throughout the gut and the muscle layer as a whole are thicker I the stomach than in the other parts of the gut (Fig. 5.4b).

5.1. 1. 8.3. Submucosa and lamina propia

The layer lies on the innerside of the muscle layer and consists of loosely packed connective tissue, a network of blood capillaries and the nerve plexus. The lamina or tunica proper lies further internally to the sub mucosa and contain muscle fibres and blood vessels in the stomach of fishes.

9.1.1.8.4. Mucosa lining

This layer constitutes the innermost lining of the gut. It is composed f stratified squamous epithelium in many fishes and of columnar epithelium in many others. The mucosa lining contains goblet cells in fairly good numbers to lubricate the passage of food. It also has absorptive cells, that restrict mainly to the intestine. Mucosal lining gets folded to form deep crypts that enclose the opening of multicellular glands, like those of gastric glands in the stomach (Fig.5.4).

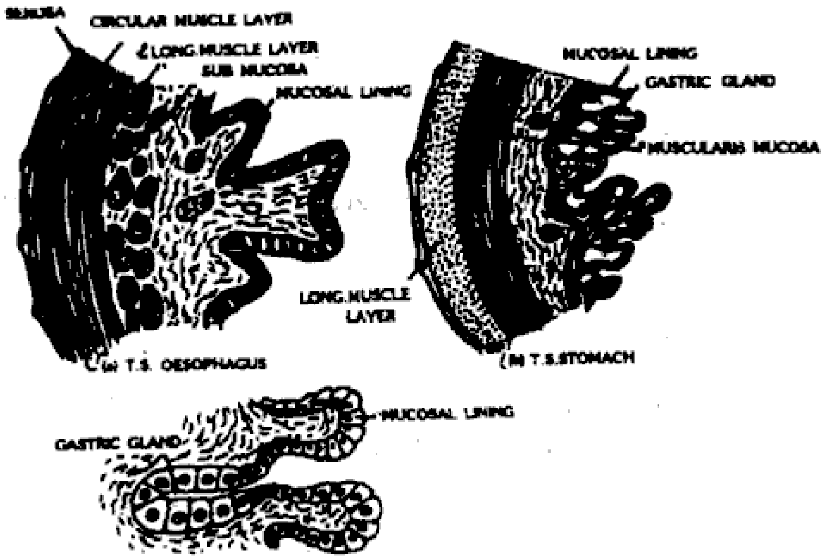


Fig. 5.4. T.S. of digestive tract

5.1.2. Associated glands

5.1.2.1. Liver

Although the liver performs a number of functions, it is primarily a digestive gland. The first rudiment of liver arises as a hollow diverticulum, from the underside of the prospective duodenum (Fig.5.5). The diverticulum soon differentiates into two parts an anterior part, the proliferates to transform into large, glandular mass of liver and its bile ducts and a posterior part which gives rise to the gall bladder and the cystic duct. The paired hepatic ducts, one from each liver lobe join the cystic duct from the gall bladder to form a bile duct, that opens behind into the duodenum (Fig.5.5).

In elasmobranchs, the liver is large and comprises a right and a left liver lobe, both of which are united anteriorly. A gall bladder is almost uniformly present, although lacking only in a few species of sharks.

In teleostomi the large sized liver comprises, two or even three lobes united anteriorly. A gall bladder of large size is uniformly present. Among the dipnoans, the *Protopterus* has a unilobed mass of liver on the right ventral side of the gut, and the gall bladder is large and lies in the left margin of the liver.

5.1.2.2. Pancreas

The pancreas is the second large digestive gland in the body of the fish. It comprises two histologically and functionally different components; an endocrinal portion that secretes hormones and an exocrinal portion secreting the digestive pancreatic juice. The rudiments of pancreas appear in the form of one or more buds, arising from the ventral side of the liver , and another similar bud from the dorsal side of fore-gut. The dorsal and ventral buds give rise to the dorsal and ventral lobes of the pancreas in adults.

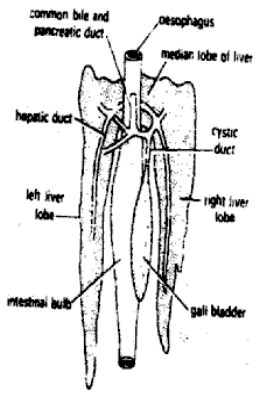


Fig. 5.5 Liver and gall bladder in rohu

In elasmobranchs, the pancreas develops entirely from the dorsal bud of the fore-gut. It comprises a dorsal and a ventral lobe which are often connected by a narrow isthmus. The pancreatic duct enters the intestine to drain the secretion.

The pancreas in adults of teleosts appears as a highly diffused gland. It develops by proliferation of the dorsal bud, given off from the gut. However, in a few teleosts the pancreas of adults is a hepatopancreas, and 1 pancreatic bud arises adjacent to the liver bud and does not separates fiom the latter. The pancreatic tissue becomes diffused and distributed in to mesenteries near the fore-gut of adults. In some other fishes the ndocrinal component lies aloof from the exocrinal component. The pancreas of dipnoans is a distinct diffused structure and lies within the wall of the gut.

5.1.2.3. Gland in digestive tract

The mucosal lining of alimentary canal and the submucosa contain glands of digestive value. Such glands are not found in the buccal cavity of fishes except in certain species of cat fishes, which carry fertilized eggs in their mouth. In these fishes oral epithelium gets temporarily folded during the breeding seasons to form the oral glands. A secretion from these glands nourishes the eggs, till the larvae hatch out of them.

The pharynx is similarly devoid of gland's, but a few teleost (such as *Dorosoma petenense*, a clupeid) have paired tubular outgrowths hanging into pharyngeal cavity from its roof. These glands called supra branchial glands trap planktons from the incoming water.

Glandular structures of stomach mucosa comprise the goblet glands in the cardiac and *pyloric* regions of the stomach. These are simple or branched tubular structures containing juice producing *grandular* cells.

The secretory cells of intestinal mucosa comprise the goblet cells and the *granudlar* cells. The latter have characteristic striated border and bands of granules. In addition to columnar striated cells concerned with the secretory activity there are certain plain type of columnar cells concerned with absorption. Rectum is almost completely devoid of digestive glands in fishes. Rectal glands of elasmobranchs are not the digestive glands, instead they secrete a copious amount of sodium chloride from the blood of marine elasmobranchs.

5.1.3. Food and feeding habits

Fishes consume a variety of different kinds of food. The food and feeding behaviour, therefore varies characteristically in different species of fishes. Nikolskli (1963), recognized four categories of fish food, which are:

Basic food: The basic food is the food which is preferred most by the fish. it is therefore included in large quantities in the diet of the fish.

Secondary food : Occasionally, however, fish consumes small quantities of food items that are liked next to the basic food. This food constitutes the secondary food of the fish.

Incidental food: The articles which only rarely enters the digestive tract of the fish constitute the incidental food.

Obligatory food: The food which is consumed during unfavourable condition of non availability of the basic food comprises the obligatory food of the fishes.

On the basis of the character of the fish food, the fishes can be divided into following three groups.

Plankton feeders: The fishes which feed upon the planktons, both on phyto and zooplankton are included in this category. It is interesting to note that only a few adult fishes live entirely on planktons. Peruvian anchovy (*Engrauls ringens*) and the Atlantic menhaden (Brevoortla) subsist largely on phytoplanktons, are easy to feed upon than the zooplanktons. They are either filtered with the elaborate gill rakers or trapped in the mucus produced by epibranchial glands. Zooplanktons rarely occur in sufficient density to permit this kind of filter feeding. Zooplankton feeders feed them like the larval fishes by snapping up individual zooplankters.

Herbivorous fishes : These fishes feed upon the vegetation comprising flowers, fruits, seeds, leaves and pieces of stem of vascular plants etc. They even scrap algae from the rocks and stones with their broad lipped mouth under the snout. (Table 5.1).

The greatest diversity of herbivores live in the sea and have varied kinds of feeding adaptations. Certain sturgeon fishes (Acanthuridae), rabbit fishes (Siganidae) and parrot fishes (Scaridae) etc. browse and graze the algae growing over rocks, with the help of their closely set cupsed or serrated teeth. Parrot fishes use their beak and rabbit fishes use the incisors set in their jaws to browse off hard surfaces.

Carnivorous fishes: These fishes feed upon the materials of animal origin such as the aquatic invertebrates and vertebrates like the molluscs, crustaceans, fish fry, fingerlings and small fishes, etc. (Table 5.1). Thus the carnivorous often behave like predators.

Omnivorous fishes : These fishes consume food materials of both the animal and the vegetable origin. According to the extent of variation in the selection of food. Nikolskli (1963) recognized following three categories of fishes.

Monophagic fishes: Feed on a single type of food.

Stenophagic fishes: On certain selected kinds of food, and

Euryphagic fishes: Feed on a variety of different kinds of food.

On the basis of trophic niche, which a fish occupies in a water body, they are grouped into following three types.

Surface feeders : These include fishes, which feed along the planktons floating of a water body eg. *Catla catla, Hypoithalamchthys, molitris*.

Column or mid feeders : These include those fishes which feed along the longitudinal column of a water body eg. *Labeo rohita.*

Bottom feeders: These include the fishes feeding at the bottom of water. These fishes, along with the food also happen to take small quantities of mud into their gut. eg. *Cyprinus carpio, Cirrhina mirigala.*

According to the manner of capture and ingestion of food the fishes can be classified into following feeding types.

Grazers or Browsers: These fishes eat away their food either singly or by continual bites made in succession eg. blue gill (*Lepomis inacrochirus*) parrot fish (Scaridae), the butterfly fish (Chaetodontidae) and various bottom feeders.

Strainers : Certain fishes filter a great amount of water by their specially adapted gill rakers. Such device enable them to swallow a large amount of food concentrate in comparatively little time eg. basking shark (Cetrohinus) and the whale shark (Rhincodon). Among the telosts the strainers include *Catla catla, Hilsa ilisha, Godusia chopra* and *Cirrhinus reba*.

SPECIES	FOOD	FEEDING HABITS
Catla catla	Planktonic algae. Plants microscopic plants, aquatic insects and crustaceans	Surface feeder, omnivorous
Labeo rohita	Microscopic plants, vegetables, debris	Column feeder, herbivorous
Labeo calbasu	Microscopic plants, vegetables, debris	Omnivorous
Labeo fimbriatus	Microscopic plants, vegetables, debris	Bottom feeder, herbivorous
Labeo gonius	Microscopic algae, plants, organic detritus and mud	Bottom and column feeder, herbivorous
Labeo bata	Microscopic algae, plants, organic detritus and mud	Bottom feeder herbivorous
Cirrhinusmrigala	Algae, decaying plants and animal matter, detritus and mud	Bottom feeder omnivorous
Cyprinus carpio	Algae, microvegetation, protozoons, insects, rotifers, copepods, crustaceans and the chironomid larvae	Bottom feeder, omnivorous
Tor tor	Aquatic weeds, filamentous, algae, seds macroscopic animals, fish, beetles, crickets shrimps, crabs, molluscs etc.	Bottom feeder, carnivorous
Barbus carnaticus	Filamentous algae, acquatic weeds, insects and other arthropods	Bottom feeder omnivorous
Anabas testudineus	Vegetable debris, insects, water fleas, and fishes	Omnivorous
Wallago attu	Insects, fish, fry, fingerlings, small fishes, other macroscopic organisms	Carnivorous predators
Mystus seenghala	Insects, fish, fry, fingerlings, small fishes, other macroscopic organisms	Carnivorous predaceous
Channa striatus	Insects, fish, fry, fingerlings, small fishes, other macroscopic organisms	Carnivorous predaceous
Channa marulius	Insects, fish, fry, fingerlings, small fishes, other macroscopic organisms	Carnivorous predaceous
Notopteruschitola	Insects, fish, fry, fingerlings, small fishes, other macroscopic organisms	Carnivorous predaceous
Clarias batrachus	Worms, insects, crustaceans, fry and larvae	Bottom feeder carnivorous
Heteropneustes fossilis	Algae, debris, worms, insects and ostracods	Bottom feeder, omnivorous

Table 5.1 The food and feeding habits of common Indian fresh water teleosts.

Parasites: Certain fishes derive their nutrition from other fishes and become variously adapted for such a parasitic life. The common example of such fishes include the lampreys and hag fishes and the angler fish (Ceratles), sucker fish (Echenes), etc.

Suckers : Most fishes suck the food contents into their buccal cavity, by enlarging their bucal and the opercular cavities. The common examples are the golden orfe (Idusidus), the *Anguilla anguilla*, Carassius auratus, *Tilapia mariae* and *Macropodus opercularis* etc.

5.1.4. Adaptive modifications in digestive tract

The modifications in the digestive tract of fishes are mainly due to varied kinds of food and feeding habits of the fishes. Adaptive modifications in different parts of digestive tract will now be discussed separately.

5.1.4.1. Mouth and Jaws

Modifications in the position, shape and the size of the mouth in various species of fishes are correlated with the character of food and the manner in which it is obtained.

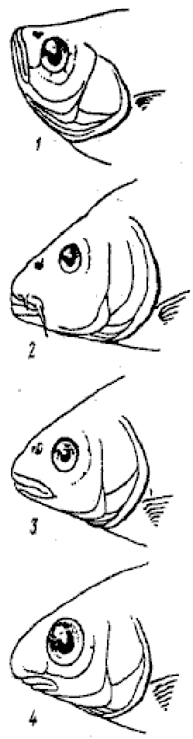


Fig. 5.6 Mouth Position in cyprinoids.
1. dorsal mouth
2. terminal mouth.
3. semiventral mouth
4. ventral mouth

In gnathostomes. the opening of mouth is bordered by jaws which develped for the first time in acanthodian fishes. The necessasity for the development of true jaw is related closely to the change from microscopic to larger units of food.

The position of the mouth varies in different fishes. Generally it is terminal, but in many groups, viz, the Chondrichthyes and Siluroids, it becomes ventral in position. Predatory characinoides and a few hemiramphids have mouth placed on superior position. Generally the bottom feeders have mouth on the ventral side, the surface feeders on dorsal side and the column feeders have them terminally placed (Fig. 5.6)

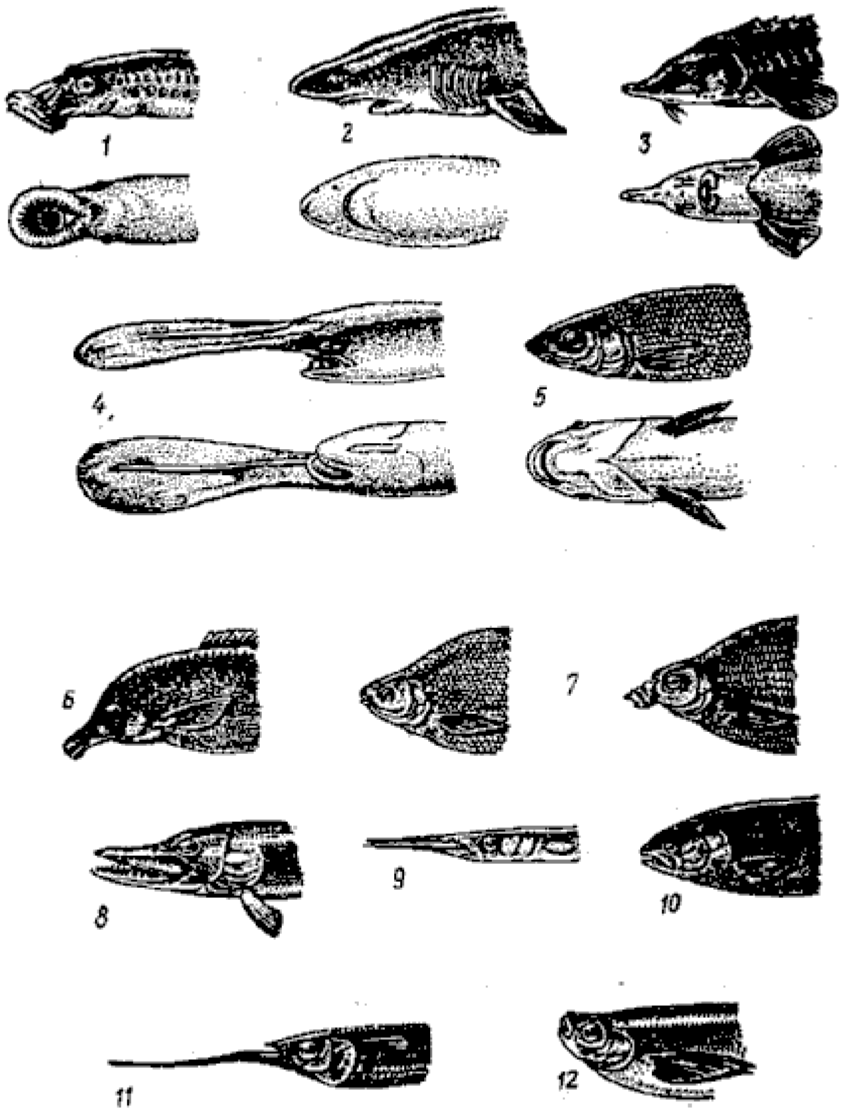


Fig. 5.7 Various types of mouths in fishes. 1 Lamprey; 2 shark; 3, sturgeon; 4; paddlenose; 5, nase (Chondrostoma nasus); 6, Mormyrus; 7, bream; 6, pike; 9, saury pike; 10, salmon; 11, Hyporhamphus sajori; 12, Pelecus cultratus.

With regards to the shape of mouth, a variety of different kinds are seen among the fishes (Fig.5.7). The mouths of grazers and suckers are converted into long flutes by elongation of their jaws. Fistularia *villosa*; the pipe fish Svngnathus, the needle fish, *Xenentodon cancila* and the butterfly *Forcipiger longirostris* have long beak like mouths. The elongated beaks of Fistularia and Syngnathus act like the syringe insucking the objects of food and those of Forcipiger and Xenetodon are equipped with teeth for finding out objects in crevices during their browsing action.

The half beak *Hemiramphus georgu* has only the lower jaw produced into a long bony beak. The upper jaw remains small and forms a triangular expansion. These surface feeders, use their beaks for collection of food and probably for the maintenance of the equilibrium of the body in conjunction with a more posteriorly placed dorsal fin.

Highly protractile mouth of *Nandus nadus* and of various species of *Channa* and the slightly protractile mouth of *Anabas* are the adaptations for increasing the gape of mouth.

5.1.4.2. Lips

The mouth is usually guarded by the lips. These are, fleshy in suctorial fishes like sturgeon, *Labeo*, *Cirrhinus* and *Puntius*, etc. The lips in many fishes form a sort of sucking disc acting like an hold fast organ, as in the sisorid cat fishes *Glyptosternum* and in many armoured cat fishes (*Loricaridae*)of South America.

5.1.4.2. Teeth

A few species of fishes are naturally toothless, e.g. the sturgeons, sea horses, and the pipe fishes. In others a strong correlation between the character of food, feeding habit and the structure of teeth exist. The suckers and most of herbivorous fishes posses pharyngeal teeth, which may be simple comb like, pointed or curved type or have occlusal molariform surface as in Cyprindae. Such teeth are used in grasping, tearing or grinding the objects of food. Among the omnivorous, the plankton feeders and many others are devoid of teeth. They may however be present in different adaptive forms and in greater number of bones in carnivorous and predacious fishes.

The teeth of skates, chimaeras and certain drums (Sciaenidae) have flattened occlusal surfaces (molariform) to grind the food contents, including chiefly the snails, clams and other hard bodied insects and crustaceans. The teeth of most of fresh water carnivores, like bagarid cat fishes and air breathing cat fish are sharply pointed (villiform) and are adapted for grasping, puncturing and holding the prey.

Conical or sub conical teeth adapted for piercing and holding the prey are found in snake heads *Channa* sp. In *Hemiramphus* they are mostly pointed and a few are tricuspid. In *Xenentodon* they are sharp and large and are widely placed.

5.1.4.4. Gill Rakers

The gill rakers of fishes (Fig.5.8) are comb like cartilagenous projections that extend into the pharynx from the inner edges of visceral arches. They are so placed as to overlap the gill clefts when the pharyngeal cavity is not distended and are used to strain the microscopic planktonic food particles from the water.

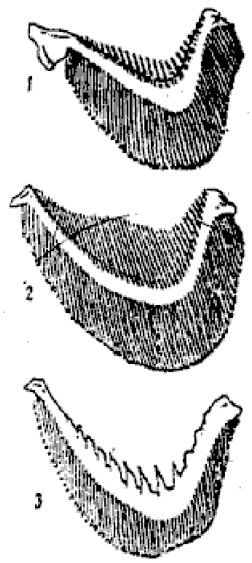


Fig. 5.8 Gill rakers in fishes 1. White fish 2. Coregonous 3. Pikeperch

It can rather be said that the structure of gill raker gives an indication of the types of food the fish consumes. To fish feeders (e.g. *Hippoglossus)* they are indespensable in preventing the prey to escape. They are large in such fishes and provided White fish with a series of small teeth. Polychaete feeders such as lemon sole, Limanda do not need large gill rakers for once the prey enters the mouth it passes on easily into the digestive tract. Gills rakers of strainers are numerous closely set comb or feather like structures, filtering a large amount of food from water and retaining it into the buccopharynx, till it passes on to the alimentary canal. these are therefore best developed in plankton feeders like *Hilsa hilsa*, *Gadusia chapra, Rhincodon*, Cerihinus, etc. The gill rakers of herbivores like *Labeo* or *Cirrhinus* are in the form of broad sieves, placed across their gill slits, and those of carnivores like *Mystus seenghala*, *Notopterus chitala* and *Channa* species, are in the form of hard rasping organs.

5.1.4.5. Barbels and the taste buds

Bottom feeders especially cat fishes (Table 1) generally possess well developed long feelers, because the food taken at the surface has little comparison with that taken at the bottom. In this regard they are selective for their natural foods. Food particles which do not constitute the natural food of fishes are similarly rejected out of the mouth because of gaustatory receptors found in the form of taste buds on the lips and the buccopharynx of many fishes e.g. the *Catla catla*, *Tor. tor*, *Puntius sophore* and *Cirrhinus* mirigala. Such receptors are generally lacking in carnivorous and predaceous fishes like the *Channa striatus*, *C. gachua Mystus Viltatees* and *Harpodon*.

5.1.4.6. Stomach

Various herbivorous species (e.g. *Labeo Xenentodon* and *Hippocampus*) and more commonly the cyprinids lack a true stomach, and their intestine seems to start almost from behind the oesophagus. In *Labeo* the part of the gut which lies behind the oesophagus forms a sort of sac like structure. This structure is devoid of gastric glands and commonly referred to as intestinal bulbs. Here the food is stored so that it can be macerated before the further process of digestion could take place, by the enzymes of pancreatic juice in intestine. The pyloric caeca are usually lacking, thus no possibility for the addition of any digestive enzymes excepting exploring those added by the liver and pancreas. Thus there is no pepsin reaction in the stomach and the pH value range from 6.5 to 7.7.

The Carnivores and predatory species (e.g. *Wallago attu, Mystus seenghala, Channa striatus, Notopterus chitala* and *Clarias batrachus*) usually posses a true stomach, in the form of an elongated sac like structure. Its internal lining contains the tubular gastric glands, secreting a weakly acidic gastric juice (average pH, 5.6 in teleost). Certain carnivores, and plankton feeders (e.g. *Xenentodon* and *Syngnathus*) however, lack a true stomach and the internal lining of oesophagus passes directly into that of intestine. Stomach in many other carnivores exhibit modifications in relation to the size of their food. In swallowers *(Saccopharyngidae)* and gulpers *(Eurypharygidae)* it is a highly distensible structure that allows sized prey. In *Hilsa ilisha*, *Mugil* and *Gadusa chapra*, the stomach is reduced in size but greatly thickened to become a gizzard like grinding structure.

It can thus, be concluded that a adaptive value of stomach does not depend only on the kind of food but also on the availability of various other accessory adaptive features, like the type of teeth required for the grinding of food and the mode of feeding of fish. They are, however, species specific.

5.1.4.7. Intestine

The length of intestine is variable in fishes. It is generally longer in herbivorous than in the carnivorous fishes. The vegetable matter are normally more complex than the animal matter and require a long time for digestion. Longer intestines are therefore, of great advantage to herbivorous fishes, as they retain food for a long period of time to ensure digestion. In fishes, cyprinids, comprising a wide majority of herbivores and in stomachless fishes, the intestine is of relatively greater length. The intestinal bulb of Labeo is about 25 cm, the small intestine about 8 m and the large intestine about a meter in length. There is no clear cut demarcation between the small and the large intestine, as the latter is generally found to contain a large number of zymogen secreting cells, a feature common with small intestine of most other fishes.

The spiral fold in the intestine of chondrichthyans is assumed to be structure compensating for the short length of intestine. A good deal of fresh water fishes commonly off their feed when the cold of December comes and eastern wind prevails in India. The fishes in these season occasionally migrate to deeper water where the temperature is little influenced by the cold winds. Againt with the onset of breeding season, fishes cease of feed and their intestines reduced much during this time (e.g. Onchorhynchus).

5.1.5. Digestion

5.1.5.1. Digestion of proteins

The fishes which possess stomach are generally carnivorous and secrete pepsin enzyme from gastric mucosa. The pepsin is a protease enzyme i.e. it can break down protein. HCI is secreted by the gastric mucosa in carnivorous fishes creating the low pH. Both cholinergic and adrenergic nerves are present in the stomach which stimulate the secretion of gastric juices. The trypsin enzyme is present in the extract of pancreas of some elasmobranchs The trypsin is secreted by exocrine pancreatic and secreted by hepatopancreas. The inactive form of this enzyme trypsinogen is known as zymogen. It is to be converted into active enzyme i.e. trypsin by an enzyme enterokinase. The enterkinase enzyme is exclusively secreted by intestine of fish. In the Cyprinids, stomachless fish, protease compensation is supplemented by some intestinal enzyme known collectively as erypsin. The intestine secretes aminopeptidases. These act on terminal amino acid called as exopeptidases and those act on central bonds are called as endopeptidases. Vitamins are essential constituent of the diet and a large number of vitamin deficient syndrome are noticed in fish

5.1.5.2. Digestion of carbohydrates

The enzymes which break down the carbohydrates in the gut of fishes are carbohydrases. They are amylase, lactase, saccharsases/sucrase and cellulase. The most important enzyme is amalyse which acts on starch, which breakdown to maltose and then to glucose by the process of digestion. The amylase is secreted from the pancreas in carnivorous fishes but in herbivorous fishes, the presence of this enzyme is reported from the whole gastrointestinal tract as well as from pancreas. In tilapia, the herbivorous, the amylase is present throughout the alimentary tract. The starch is digested into glucose by amylase and maltase.

$$\text{Starch} \xrightarrow{\text{Amylase}} \text{Maltose} \xrightarrow{\text{Maltase}} \text{Glucose}$$

In those fishes in which sucrose has been reported the effect as follows:

$$\text{Sucrose} \xrightarrow{\text{Sucrase}} \text{Glucose + Fructose}$$

Blood glucose is converted with the aid of insulin, to muscle glycogen. Although clear details are wanting, but excess of glucose enters the blood from digestive tract, the surplus is converted to glycogen in liver.

The fishes possess endocommensal bacteria containing an enzyme, the cellulase, which breakdown the cellulose plant material instead of passing out through faeces.

5.1.5.3. Fat digestion

The lipids are organic substances insoluble in water but soluble in organic solvents like chloroform, ether and benzene. They form important dietary constituents on account of high caloric value and the fat soluble vitamins and the essential fatty acids contained in them. The main enzyme which act on this lipid is lipase. This enzyme is found in pancreas and mucosa of fishes. Lipase converts the fats into fatty acids and glycerols.

5.1.5.4. Gastrointestinal hormone

In the teleost, the presence of gastrin and cholecystokinin are reported and are secreted by intestinal endocrine cells which are dispersed and are not grouped in clusters. The cholecystokinin affects the oxyntic cells and inhibit further gastric secretion in bony fishes. Somatostatin is present the stomach and pancreas of fishes. They are called as paracrine substances. It differs from hormone because it diffuses locally to the target cells instead of released into the blood. This inhibit other gastrointestinal and pancreatic islet endocrine cells. Pancreas secretes two important hormone i.e. insulin and glucogen, insulin is secreted from -cells while glucogen is secreted by a-cells. Insulin reduce the blood sugar, whereas glucagon increase the blood sugar in fishes.

5.1.5.5. Absorption

Digestive end products are absorbed in to the blood. Inorganic ions uptake in various regions of the alimentary canal in fishes and their subsequent distribution and localization has been reported. The iron (Fe++) ions are absorbed through intestinal columnar cells and then pass into the portal as Fe++ binding protein transfertin. The calcium absorbed by the intestinal submucosal blood vessels. Probably, Ca++ after entering blod vessels in the intestinal region reach finally in the hepatocytes where it is stored in association with vitamin D depending upon Ca binding protein.

5.2. Digestive system of prawns

5.2.1. Alimentary canal

Alimentary canal consists of three distinct regions. (i) Foregut, comprising mouth, buccal cavity, oesophagus and stomach, (ii) midgut including intestine, and (iii) hindgut or rectum. Foregut and hindgut are lined internally by cuticle, called intima, which is shed with the exoskeleton when the animal moults. Midgut is lined internally by endoderm.

5.2.1.1. Mouth

It is a large, slit-like aperture lying mid-ventrally below the anterior end of head. It is bounded in front by the shield-like fleshy labrum, laterally by the plate-like incisor processes of mandibles and behind by the bibbed labium.

5.2.1.2. Buccal cavity

Mouth leads into a short buccal cavity. It is antero-posteriorly compressed and has a thick cuticular lining which is irregularly folded. The molar processes of mandibles lie opposite each other in the buccal cavity to crush the food between them.

5.2.1.3. Oesophagus

The short tubular oesophagus runs vertically upwards from the buccal cavity to the floor of cardiac stomach. Internally the thick muscular wall of oesophagus is thrown into four prominent longitudinal folds, one anterior, one posterior and two lateral.

5.2.1.4. Stomach

Stomach occupies most of the cephalothractic cavity. It remains buried laterally, ventrally and posteriorly in the hepatopancreas. Stomach of prawn is thin-walled and double-chambered, consisting of two parts — (i) a large anterior bag-like cardiac stomach, and (ii) a much smaller posterior pyloric stomach.

5.2.1.4.1. Cardiac stomach

The inner cuticular lining, or intima, of cardiac stomach presents numerous, inconspicuous, longitudinal folds covered by minute bristles. The wall of stomach is supported by some cuticular plates which is supported by some cticular plate which remain embedded in it. Forming the anterior wall of the oesophageal opening is a circular plate. Behind it, on the roof of the stomach, is a lanceolate plate. A large triangular plate is embedded in the mid-ventral floor of cardiac stomach. It is called the hastae plate, because it looks like the head of a spear. Upper surface of hastate plate has a thick growth of delicate setae and carries a distinct median ridge with gradually sloping sides. The posterior tringular part of hastate plate is depressed and fringed with setae along its edge. It forms the anterior border of the cardiopyloric aperture. Eachlateral side of hastate plate is supported beneath by a longitudianal cuticular supporting rod. A narrow lateral groove runs along either lateral border of the hastate plate. Floor of each lateral groove is covered by a cuticular plate which resembles an open drain pipe and is called the groove plate. Each lateral groove is bounded on its inner side by the supporting rod and, on outer side, by a long cuticular ridged plate. Inner border of each rideged plate is fringed all along with a row of delicate bristles, forming a comb-like structure, so that it is also named as a combed plate. The bristles bridge over the lateral groove and partially overlap the lateral margin of the hastate plate, where they constantly keep moving in a living prawn. The two combed plates are united anteriorly thus completely enclosing the hastate plate except that their incurved posterior ends remain separated by the cardio-pyloric aperture. Outside the combed plates on either side, the lateral wall of cardiac stomach is folded inwards to form a prominent lateral longitudinal fold. The two folds are very low anteriorly but gradually increase in height posteriorly and also bend inwards to form the sides of the cardio-pyloric aperture. These folds are also known as the guiding ridges because they guide the food towards the cardio-pyloric aperture.

5.2.1.4.2. Pyloric stomach

Pyloric stomach is a small and narrow chamber lying below the posterior end of cardiac stomach. Its lateral walls are thick, muscular and prominently folded inwards, so that its cavity is imperfectly divided into a big ventral chamber and a small dorsal chamber, both continuous by a narrow vertical passage. Floor of ventral chamber is raised into a median ventral chamber. A median longitudinal ridge, dividing it into two lateral

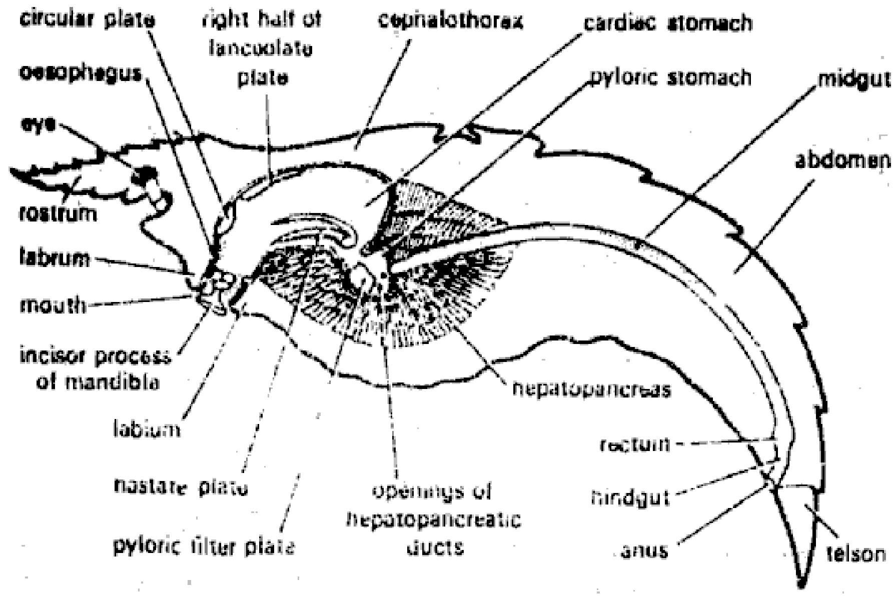


Fig. 5.9 Alimentary canal of prawn

compartments. Floor is covered by a filter plate. It is made of two rectangular surfaces and appears L-shaped in cross section. Each rectangular surface bears a series of alternating longitudinal ridges and grooves. The ridges bear rows of bristles forming a felt-like covering over the grooves. The site walls of ventral, chamber are also covered with closely-set bristles which; together with the filter plate, form an efficient strainer or filter. This pyloric filtering apparatus allows only liquid food to pass through it. The paired the filtering apparatus, just below the junction of the dorsal chamber of pyloric stomach and midgut. These openings are guarded by a group of elongated setae arising from the posterior end of the median ridge of filter plate.

Dorsal chamber gives out a small blind caecum dorsally and then leads behind into midgut. The junction of the two is guarded by one median dorsal and two lateral groups of elongated setae that project backwards into the midgut. These groups of setae strain the food entering the midgut and prevent its regurgitation into the dorsal chamber.

5.2.1.5. Midgut

Midgut or intestine is a long, narrow and straight tube running back along the median line, between the extensor and flexor muscles, upto the 6^{th} i abdominal segment. Its lumen is wide at the anterior end but reduced posteriorly due to the presence of longitudinal folds.

5.2.1.6. Hindgut

It is the shortest portion of the alimentary canal, leading from midgut to anus. Its anterior swollen muscular part, called the intestinal bulb or rectum, bears many internal longitudinal folds. The terminal narrow, tubular part opens to the exterior through anus, which is a sphinctered mid-ventral longitudinal slit-like opening, situated on a raised papilla at the base of telson.

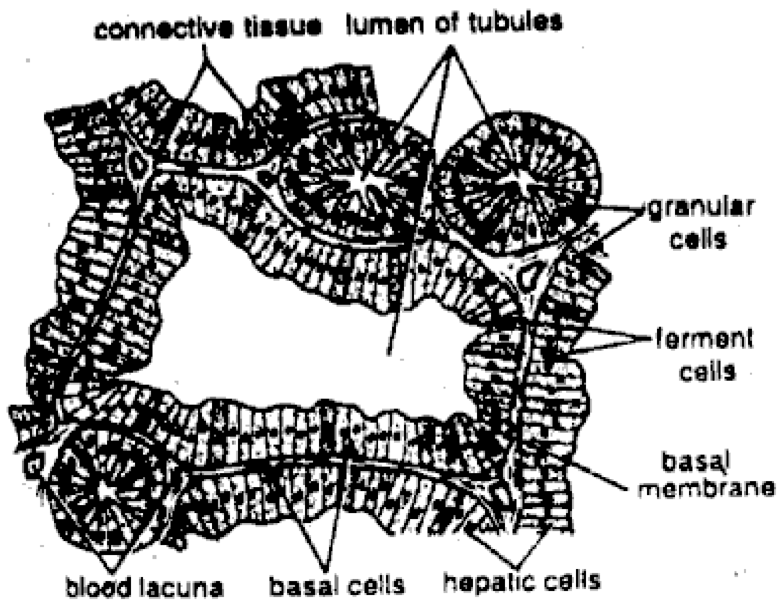


Fig. 5.10 The section of hepatopancreas

5.2.2. Hepatopancreas

It is a large, bilobed, dense and orange glandular mass, which lies below gonads and nearly fills up the cephalothoracic cavity. It surrounds stomach on its lateral, vertral and posterior sides. Hepatopancreas consists of numerous branching tubules completely held together by connective tissue. Wall of tubules consists of a single layer of columnar epithelium which is made up of: (i) granular cells, (ii) ferment cells, (iii) hepatic cells with globules of fat, and (iv) replacing or basal cells. The epithelium rests on a basement membrane. The tubules rejoin to form larger and larger canals, finally forming two large hepatopancreatic ducts, which open into the vertral chamber of pyloric stomach just behind the pyloric filter plate.Hepatopancreas combines in itself the functions of pancrease, small intestine and liver of higher animals. Functioning as pancreas, it secretes digestive enzymes which can digest carbohydrates, proteins and fats. As midgut, it absorbs the digested food material, and as liver it serves as an important storage organ for glycogen, fat and calcium. Some intracellular digestion also seems to take place in hepatopancreas.

5.2.3. Food and feeding

Prawn feeds mainly on algae and other aquatic weeds. It occasionally feeds on small aquatic animals such as insects, snails, tadpoles, fish, and debris of the bottom. It feeds at night, being more active at dawn and dusk than at any other time. Chelate legs, aided by the third maxillipede, capture and convey food to the mouth. Coxae of second maxillipedes hold the food, while incisor processes of mandibles hold the food, while incisorprocesses of maindibles cut it into smaller pieces, which are swallowed with the help of maxillipedes, maxillulae and maxillae. Inside the buccal cavity, molar processes of mandibles masticate the food, which is then conveyed to the cardiac stomach through oesophagus. Passage of food through oesophagus is facilitated by the peristalytic activity of oesophagus and the sucking action of cardiac stomach.

5.2.4. Digestion and absorption

The enzymatic digestive secretion of hepatopancreas flows through the two hepatopancreatic ducts into the ventral chamber of pyloric stomach, from where it reaches the cardiac stomach and mixes with food. Cardiac stomach expands and contracts to effect the churning of food and to facilitate its digestion by the action of digestive enzymes. As food passes over the haste plate, the moving bristle of combed plates cut it into smaller particles. The semi-liquid and semi-digested food is filtered through the bristles of combed plates, into lateral grooves below, where it is carried into the ventral chamber of pyloric stomach through the cárdiopyloric aperture. Here the digested and liquified food is filtered again through the pyloric filtering apparatus. Thus, only the finest food particles enter through heapatopancreatic ducts, into the large digestive gland where they are hydrolysed and absorbed. The residual food, consisting of undigested and coarser particles, ascends up the dorsal pyloric chamber and from there enters the midgut for digestion and absorption. Undigested residual matter passes on to the hindgut. Here water is absorbed from it and the dry faeces thus formed is egested through the sphincter anus.

5.3. Carbohydrate metabolism

Carbohydrates are known as chief energy giving compounds of the body as they simply the major portionof the daily energy requirement of the normal individual. On an ordinary diet more than half of the total daily calories usually come from this source. In addition to being oxidized as a source of energy, they may be transformed to glycogen or to supply the carbon chain for certain amino-acids or to be converted into fats.

In the digestive tract the complex carbohydrates or saccharides contained in the food are subjected to the action of the enzymes present in pancreatic and intestinal juices. These are hydrolyzed to monosaccharides which are soluble in water and are absorbed through the intestinal mucosa into the blood stream. Complete hydrolysis of carbohydrates produces the monosaccharides, gluclose, galactose and fructose which are carried directly to the liver by the portal circulation. In the liver, the three monosacchrides may be converted into one simple sugar, glucose, the primary mnosaccharide of the blood stream and body. In the liver and the muscles the excess of glucose is converted into glycogen. The glycogen in the liver is a reserve material and when necessary it is reconverted by the action of enzyme into glucose which passes into the blood and is transported throughout the body. The glucose content in the blood remains constant (70-100 mg per 100 ml of blood). If the glucose content increases from the normal glucose content of the blood the liver takes up the excess glucose from the blood and converts it to glycogen. All the changes involved in the conversion of glucose into glycogen constitute carhhydrate anabolism. If the glucose content decreases from the normal content of theblood, a part of the liver glycogen is brokendown and liberated into the blood as glucose. In this way fluctuations in the blood glucose level are kept within fairly narrow limits by the layer cells.

The glycogen on its breakdown liberates energy. A particularly large amount of glycogen is brokendown when the muscles are working, the energy liberated is used for mechanical work and as a source of heat. During the process of breakdown of glycogen or glucose (monosaccharides) carbon dioxide and water are formed as by products. They are duly eliminated by lungs and the skin. The destruction changes involved in the breakdown of glucose (monosaccharides) and resulting in the production of energy constitute carbohydrate catabolism.

SUMMARY

The alimentary canal in fishes can be divided in mouth, buccal cavity, pharynx, oesophagus, stomach, intestine and anus, stomach is- absent in cypriniformis fishes. Mouth is modified according to their feeding habits. Liver, pancrease and intestinal glands are useful for digestion. Fishes are herbivores, carnivores and omnivores. Based on their habitat and feeding habits, fishes can be divided into surface, column and bottom feeders. Digestion is intercellular. The enzymes are produced by pancrease, gastric and intestinal glands. The digestion takes place in intestine.

In prawn the gut consists of mouth, buccal cavity, oesophagus, stomach, intestine, rectum and anus. Hepatopancrease is found in the cephalothorax region and combines in itself the functions of pancrease, liver and intestine. Prawns are detritivors, feed on algae, aquatic insects, snails, tadpoles and debris of the bottom. Mouthparts, chelate legs and maxillipedes are useful to get the prey into the mouth. Digestion is intercellular. The digestive enzymes of hepatopancrease are useful for digestion. Digestion takesplace in stomach and intestine and absorbed in intestine.

Questions:

1. Describe the digestive system of fishes.
2. Explain the digestive system of prawns.
3. Discuss the carbohydrate metabolism in fishes.
4. Give an account on food and feeding habits fishes.
5. Write a note on food, feeding and digestion in prawns.

6

RESPIRATORY SYSTEMOF FISH

Respiration is a catabolic process in which the respired oxygen is used in the oxidation of food resulting in the release of energy. This energy is utilized for all the vital activities. Carbohydrates are mainly concerned with release of energy. Oxygen required for this process is obtained from the surrounding medium. Carbon dioxide formed in this process of respiration is expressed as follows:

$$C_6 H_{12} O_6 + 6O_2 \rightarrow 6CO_2, + 6H_2O + \text{energy.}$$

Respiration is the sign of life and index of all biochemical activities taking place in the body. The process of respiration involves the exchange of two gases, namely oxygen and carbon dioxide. Various organs required for the exchange of gases constitute the respiratory system.

On the basis of availability or non-availability of oxygen, respiration is differentiated into two kinds, namely (1) aerobic respiration and (2) anaerobic respiration.

Aerobic respiration involves utilization of oxygen from the environment and liberation of energy into carbon dioxide. This type of respiration takes place in most of the plants and animals. The organisms which exhibit this type of respiration are termed as aerobes.

In anaerobic respiration, glucose is metabolized to lactic acid, without the involvement of oxygen and there is no formation of carbon dioxide. This type of respiration occurs in certain bacteria, parasitic animals etc. Such organisms are known as anaerobes. Life in the absence of oxygen is called anarobiasis.

The fundamental need of fish, like other animals, is to have on adequate supply of oxygen in the tissues so oxidation can occur and provide the necessary energy for life. The respiratory organs of an animal are so constructed as to obtain necessary oxygen for the purpose of intracellular oxidation and the liberation of energy for the maintenance of life and to get rid of carbon dioxide. The gaseous exchange of oxygen and carbon dioxide taking place between blood and water (or air) through the medium of respiratory organs, is called the external respiration to distinguish it from the internal respiration which refers to the essential transfer of gases between blood and tissues or cells of the body and brings about release of energy.

The main respiratory organs in a fish are the gills (fig 6.1). The lateral walls of the pharynx are perforated by means of a series of slit-like apertures, the first of which is called the spiracle, lying between the mandibular and the hyoid arches. The second or the hyoidean cleft lies between the hyoid arch and the first branchial arch, while the rest of the gill slits are situated between the proceeding branchial arches.

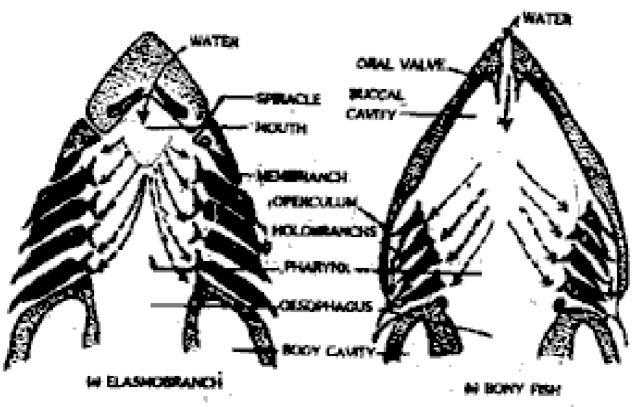


Fig. 6.1. Respiratory region of fishes.

The anterior and the posterior wall of each gill slit is raised in the form of vascular filamentous outgrowths to form the gills where exchange of dissolved oxygen and carbon dioxide takes place. Besides the gills, other structures as the skin, air bladder and accessory organs also function as respiratory structures in some fishes.

6.1. Types of gills

Gills are two types — holobranch and pseudobranch.

6.1.1. Holobranch

A complete gills or a holobranch consists of a gill arch supported by cartilage or bone. Each arch bears gill rakers towards the inner side, and vascular plate-like filaments projecting towards the outside. Each row of these filaments forms a hemibranch or half gill. A holobranch carries two hemibranchs. In elasmobranches, five pairs of branchial clefts are usually present, but only four pairs of gill slits are present in the bony fishes, and the spiracle is also absent. Teleosts have a single external branchial apert you are on each side of thehead due to the development of an operculum covering the gills. The interbranchial septum is reduced in teleosts, and the paired efferent branchial arteries of the elasmobranches are replaced by a single efferent vessel in teleosts.

6.1.2. Pseudobranch

In many actinopterygians, a hyoidean pseudobranch consisting of a series of gill filaments is present anterior to the- first gill, as in *Catla catla.* The pseudobranch may be free or covered with a layer of mucous membrane. It develops quite early in the embryo and have a respiratory function in the embryonic stage but not in the adult. It receives oxygenated blood directly from the dorsal aorta and has a vascular connection withthe internal carotid artery. It may serve to increase the oxygen concentration in the blood going to the brain and the eye through the internal carotid artery. However, the pseudbranch is absent in species like *Wallago attu, Mystus aor, Notopterus* and *Channa.* The pseudobranch may also be useful in the filling of gas bladder and in the regulation of intraocular pressure.

6.2. Structure of a teleostean gill

Typically there are four pairs of gills in teleosts, each of which consists of a larger lower-limb and a shorter upper limb, supported by ceratobranchial and epibranchials respectively. Gill rakers are present in one or two rows on the inner margin of each gill arch. The gill rakers are developed in various degrees and may be soft, thin, thread-like or hard, flat and triangular, or even teeth-like, depending upon the food and feeding habits of the fish. Generally, they form a sieve to filter out the water, and protect the delicate gill filaments from solid particles. Each raker is lined externally by an epithelial layer containing taste buds and mucus- secreting cells. The taste buds help the fish in detecting the chemical nature of the water flowing through the gill slits.

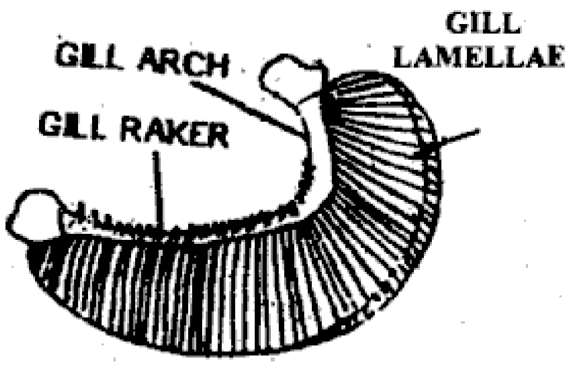


Fig. 6.2. Gilll of Cirrhina

6.2.1. Gill arch

Each gill arch fig.6.3 encloses an afferent and an efferent branch ial vessel and nerves. It is covered over externally by a thick or thin epithelium in which a large number of mucous glands, eosinophilic cells and taste buds are present. The number and distribution of mucous glands, taste buds etc. varies in fishes inhabiting different ecological habitats. Each gill arch has atleast one set of abductor and a set of adductor muscles, which are responsible for the movement of the gill filaments (primary lamellae) during respiration. The abductor muscles are present on the outside of the gill arch connecting it with the proximal ends of the gill rays. The adductor muscles are present in the interbranchial septum and cross each other so as to become inserter on the opposite gill rays. Two arrangements have been described for the adductor muscles. In some teleosts (e.g., *Channa striatus, Rita rita*) the adductor muscle arises from the base of the gill ray of one side, runs obliquely and is inserted on thegill ray of the other side. In some other species (e.g., *Labeo rohita, Hilsa ilisha, Cyprinus carpio*) the muscle arises half way from from the gill ray due to large inter branchial septum, and is attached on the gill ray of the opposite side.

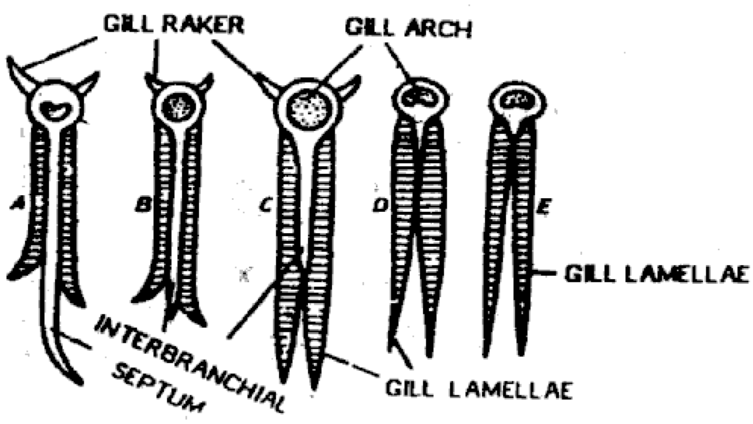


Fig. 6.3. Gill arches of fishes: A. Elasmobranch; B. Holocephali: C. Holostei: D. and E. Teleosts.

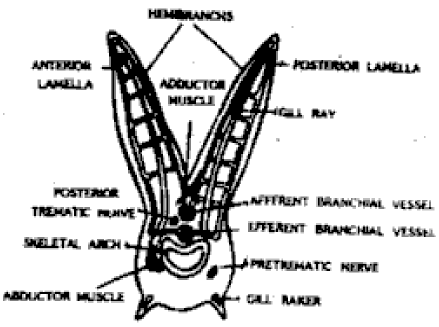


Fig. 6.4. T.S of Gill of a fish

6.2.2. Gill filaments or primary lamellae

Each gill arch bears two rows of gill filaments or primary gill lamellae (fig. 6.4) towards the outside of the buccopharyngeal cavity. In most teleosts, the interbranchial septum between the two rows of lamellae is short so that the lamellae of the two rows are free at their distal ends.

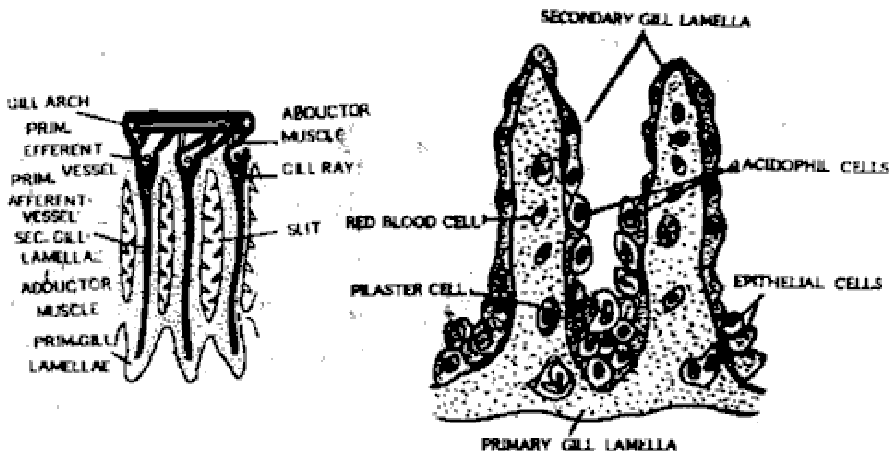


Fig. 6.5. (a) T.S. Primary and (b)Secondary gill lamellae.

However, in *Labeo rohita and Hilsa ilisha,* the septum extends half way down the primary lame'llae. The shape, size and number of the primary lamellae vary in fishes with diverse habits. Species that lead an active life and depend entirely on aquatic respiration (e.g., *Catla catla*, *C.mrigala*, *Wallago attu*, *Mystus seenghala*) have a larger number of long gill filaments, but those which lead a sedentary life or have air-breathing organs, the filaments are fewer in number and shorter in length. The gill lamellae belonging to the two hemibranchs are either alternately arranged with respect to each other (as in *Labeo rohita*), or they may interdigitate (as in *Channa striatus)*. Usually, the gill lamellae of each row are independent of one another, but in *L. rohita,* the neighbouring lamellae are fused at the tips as well as at the bases, so as to leave narrow slit like apertures between them. The primary gill lamellae undergo division to give rise to additional lamellae in several hill stream fishes. The lamellae may bifurcate in the middle or at the base to produce two branches. Sometimes three or four branches are formed of several branches may develop at one point giving a flower-like apperance.

The primary gill lamellae (fig. 6.5) are supported by gill rays which are partly bony and partly cartilaginous and are connected with the gill arch and with each other by fibrous ligaments. Each gill ray is bifurcated at its proximal end to provide a passage for the efferent branchial vessel.

6.2.3. Secondary lamellae

Each primary lamella or gill filament bears a large number of secondary lamellae on both its sides (fig. 6.5). These flat, leaf-like structures are the main sites of gaseous exchange and vary in their shape dimension and density per unit length of the gill filament, in species living in different ecological habitats. Generally, the secondary lamellae are free from each other but may be fused at the distal ends of the primary lamellae. They vary from 10-40 on each side of the primary lamella, being more numerous in active species.

Each secondary lamella consists of a central vascular core composed of pillar cells covered by a basement membrane and an outer epithelium. In some species, this lamellar epitheliem is smooth, but in others it is rough showing microridges and microvilli. The grooves and ridges seen on the surface epithelium serve in increase the respiratory surface. The pillar cells are characteristic structures of the teleost gill, and separatethe epithelial layer of the opposite side of a lamella. Each cell consists of a central body with extensions at each end. These extensions are called the pillar cell flanges, which overlap those from the neighbouring cell and form the boundary of blood channels in the lamella. Columns of basement membrane material run transversely across the secondary lamella connecting the basement membranes of the opposite sides, and provide structural support to the secondary lamellae. Studies conducted by Munshi and Singh have provided evidence that in Channa pillar cells of each row form a complete partition between the neighbouring channels. This arrangement helps to develop a streamline flow, and may promote the counter current flow of blood and water, at the microcirculatory level. Thus pillar cells appear to perform the dual function of protection against distension or collapse of the vascular spaces, and regulation of the pattern of blood flow through the secondary lamellae.

6.2.4. Gill area

The relative number and size of the gill lamellae determines the respiratory area of the gill in the fish. The total gill area for a fish species is calculated as a product of the total length of the primary lamella, frequency of the secondary lamellae and the average bilateral lamellar area. The total respiratory area varies with the habits of the fishes generally, fast swimming fishes have more gill area and a larger number of gill lamellae per mm of gill filament, than the sedentary species. Gill area in air breathing fishes is reported to be half of the area is directly proportional to the efficiency of the gill sieve. It increases with the increase in the body weight during the growth of the fish.

The efficiency of the gill as a respiratory organ is also depends on the diffusion distance i.e., the barrier through which exchange of gases takes place between blood and water. This barrier is formed by the lamellar epitheliuin, basement membrane and the flang of the pillar cells, and is smaller in water breathers than in air breathing fishes. The total gill area and the diffusion distance of the lamellae, thus determine the diffusing capacity of the fish. The water breathing fishes have a higher diffusing capacity due to larger gill area and small diffusion distance, than the air breathing fishes which have smaller gill area and a larger diffusion distance.

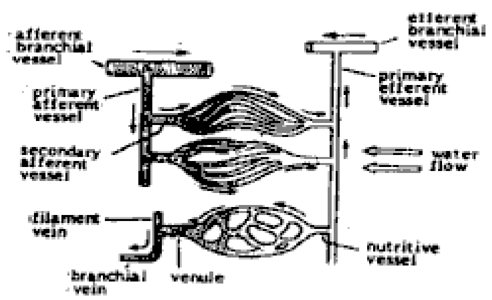


Fig. 6.7. Circulation of blood through gill lamella

6.2.5. Gill epithelium and branchial glands

The epithelium covering the lamellae is generally double layered but electronmicrographs of gills of *Anabas and Clarias* have shown a multilayered epithelium varying from 5-18 mm in thickness. Amoebocytes and lymphocytes are commonly found in the epithelium of these fishes. Some of the cells are glandular and are specialized to perform various functions. Most common of these branchial glands are the mucous glands and chloride cells.

The mucous glands are oval or pear shaped and are of the typical goblet type. These provide a thin film of mucus to prevent dehydration of the respiratory epithelium are reported to secrete acid and neutral glycoproteins. The chloride cells that are commonly found in the interlamellar epithelium of the filament are considered to regulate movement of chloride ions through the gill epithelium.

6.2.6. Vascular supply of a teleost gill

Generally only one afferent and one efferent branchial vessel is present in each gill arch in teleosts (fig. 6.7) but in some species such as *L.rohita, C.batrachus, Anabas*, there are two efferent branchial vessels in each arch. Recent studies have shown that there are two vascular pathways in the gill:

(i) Respiratory pathway and (ii) Non-respiratory or Nutritive pathway.

The respiratory pathway is associated with respiration. Each afferent branchial vessel brings oxygen deficient blood into the gill. It runs through the entire length of the gill arch and gives off a number of primary afferent branches (afferent filamental arteries) to the primary gill lamellae. Each primary afferent vessel divides laterally into a number of secondary vessels, one for each secondary gill lamella. These run across the gill rays dividing again into 2-4 tertiary branches. In the secondary Iamellae these capillaries break up and form lamellar channels interconnected with each other, thus forming the vascular central core of the secondary lamella Exchange of gases takes place while the blood is circulating through these channels. The oxygenated blood is collected by the efferent lamellar arterioles which carry the blood to the primary efferent vessel running along the margin of the primary gill lamella. The blood is finally carried to the main efferent branchial vessel of the gill arch.

The non-respiratory pathway consists of a complex arrangement of sinuses and veins that carry the blood direct to the heart, by-passing the systemic circulation. Its function is believed to provide nutrition and oxygen to the filament tissue, and may also be associated with the circulation of hormones. This pathway cosists of the efferent filament artery, nutritive blood channel, central venous sinus, venules and the branchial veins.

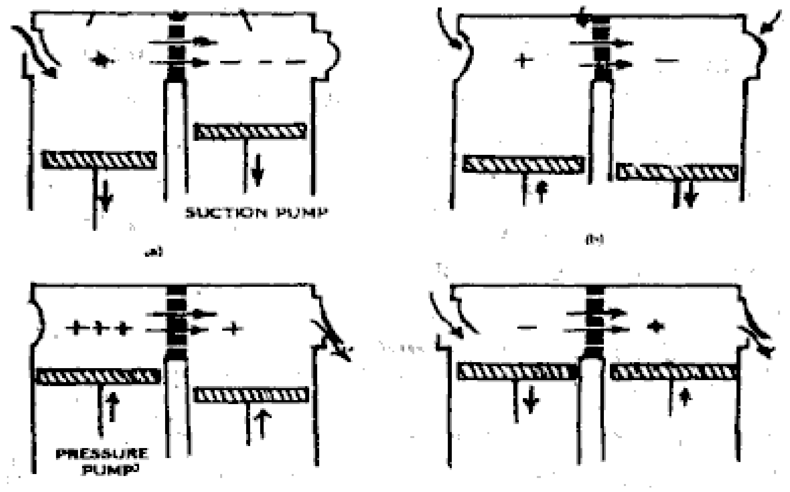


Fig. 6.8. Diagrammatic representation of the double pumping mechanism to maintain a continuous flow of water through the gills.

Thus, the structure of the gill in teleosts is such that water is brought in close contact with the secondary lamellae through which exchange of gases takes place. Functionally the gills are very efficient and utilize about 50-80% of oxygen present in water. The teleostean gill is supposed to be more efficient than an elasmobranch gill due to great reduction of interbranchial septum. Moreover, the arrangement of the afferent and the efferent branchial vessels is such that the blood and the respiratory water flow in opposite directions. This is called 'counter current' system, in which water containing oxygen flows from oral to aboral side of the gills, and the blood in the Iamellae flows from aboral to oral side, thus providing maximum exchange of respiratory gases.

6.3. Respiratory process

Blood is oxygenated in teleosts by rhythmical inhalation and exhalation of water through the bucco-pharyngeal cavity (fig.6.8). This is effected by suction of water into the cavity and its subsequent expulsion through the gill slits, during which the water bathes the highly vascular gill Iamellae. The bucco-pharyngeal cavity therefore applies both suction and pressure to propel water through the gills.

For respiration, the mouth is opened and the buccal cavity is enlarged by lateral expansion of its walls. For this various muscles contract as well as the branchiostegal rays are spread and lowered. An increase of the buccal cavity creates negative water pressure in it so that water is sucked in.

When the oral cavity is filled with water, the mouth is closed and the operculum is abducted anteriorly to increase the opercular cavity, but the opercular opening is kept closed due to pressure of the external water. A low pressure is thus created in the opercular cavity and water flows over the gills into it. Next the buccal and the opercular cavities are reduced so as to exercise pressure on the water inside it. The oral valves prevent the water from going out of the mouth. The opercula after reaching the maximum abduction are quickly brought towards the body. The water is expelled through the external branchial aperture, and is prevented from going back due to excess pressure in the buccal cavity as compared to the opercular cavity.

The respiratory process as described above may become modified according to differences in habits of the fish. Thus fast swimming species may leave their mouth and opercular aperture widely open so that the gills are bathed by a continuous current of water produced by swimming. In general, the gill cavities of fast swimmers are smaller than those of sedentary species. The mechanism is also modified in the trunk fish (Ostracion), globe fish *(Tetrodon)* and in the hill stream species. The rate of breathing also varies considerably in different fishes.

6.4. Other organs of respiraton

In addition to the gills, the skin of many fishes helps in respiration. In Periopthalmus tail is used for breathing. Some species possess larval gills which are filamentous outgrowth from the gills. In some species as Salmo and Misgurnus the gill lamellae are long, filiform structures and extend out of the gill slits in larval stages. *Polypterus* larva also has a pair of external gills which disappear n the adult. In some fishes, air bladder is modified as a lung for respiration. In *Amia* and *Lepidosteus*, the air bladder is highly vascular and sacculated internally and serves for respiration. In the *Dipnoi*, air bladder is completely modified as a lung. In other teleosts, air bladder may serve as a reservoir of oxygen. Besides these structures, some species possess accessory respiratory organs to help in breathing.

6.5. Accessory respiratory organs

In some tropical fresh water fishes, special structures called the accessory air breathing organs are present in addition to the gills. Such structures are generally developed in response to the exceptional environmental conditions which include life in foul water or lift out of water for short periods. The air breathing organs enable the fish-to tolerate oxygen depletion in the water or to live out of water for short periods. These additional respiratory structures are rarely developed in marine fishes and have been reported in *Chiloscylium indicum, C.griseum* and a sole fish of the genus *Achirus*. Air breathing organs are generally found in fishes living in shallow stagnant, fresh water of tropical regions where deoxygenation of water occurs. These organs may alsodevelop in fishes inhabiting torrenting streams of the hills, that are liable to dry upduring summer.

More than 140 species of fishes are reported to be adapted to air breathing among the teleosts and include species ranging from those that spend greater part of their life on land, to those which resort to air breathing in times of emergency only. The following air breathing fishes are found in India. .

	Family		Name of the fish
1.	Notopteridae	:	*Notopterus chitala, N.notopterus*
2.	Cobitidae	:	*Lepidocephalichthys guntea*
3.	Claridae	:	*Clarias batrachus*
4.	Heteropneustidae	:	*Heteropneustes fossilis*
5.	Channidae	:	*Channa punctatus, C.striatus, C. marulius, C:gachua.*
6.	Synbranchidae	:	*Symbranchus bengalensis*
7.	Amphipneidae	:	*Amphipnous cuchia*
8.	Anabantidea	:	*Anabas testudinius, Osphronernus nobilis. Colisa (Trichogaster) fasciatus*
9.	Gobidae	:	*Periopthalmus vulgaris, Boleopthalmus boddarti, Pseudopocryptis Ianceolatus.*
10.	Mastacembelidae	:	*Mastacembelus arniatus, mpancalus, Macrognathus aculeatum.*
11.	Amblycepidae	:	*Amblyceps*

Several types of accessory respiratory organs have been evolved in different species of fishes. In *Mastacembelus* however the unmodified gills secrete a large amount of mucus to keep them moist and facilitate gas diffusion for sometime when the fish is out' of water.

6.5.1. Skin as a respiratory organ

In the eel, *Anguilla anguilla, Amphipnous cuchia and in Periopthalmus* and *Boleopthalmus*, the skin is highly vascular and serves for exchange of gases as in the frog when the fish is out of water. These fishes habitually leave the water and migrate from one place to another through damp vegetation. During this period, the moist skin serves as an important organ for respiration.

Since *Amphipnous* and *Mastacembelus* live in oxygen deficient stagnant waters, the skin is of little use for respiration but it plays an important role in extracting oxygen from air, when the fishes are exposed in drying up muddy ponds or when fish is moving out of water. The glandular secretions of the skin protect it from desiccation in air.

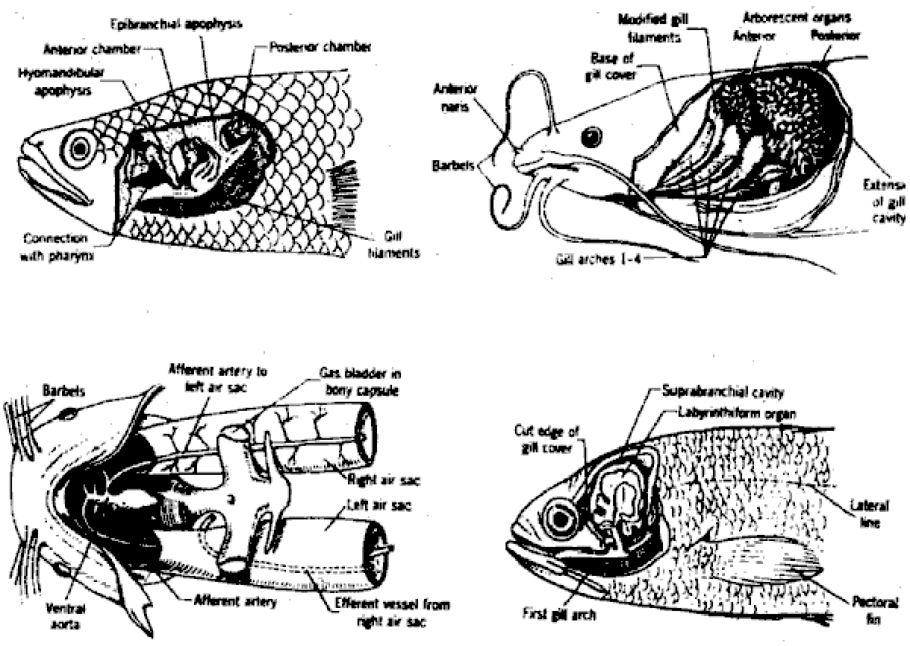


Fig. 6.9. Air breathing organs of(a) Snakehead, (b) Labyrinthic catfish, (c) Airsac catfish. (d) Climbing perch.

6.5.2. Buccopharyngeal epithelium

In some fishes the 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 and pharynx to make it an efficient respitatory organ. This is seen in Periopthalmus, *Boleopthalrnus, Amphipnous* and *Electrophorus*.

6.5.3. Phayngeal diverticulum

In *Channa marulius* and *C. striatus,* (fig. 6.9) supra branchial cavities developed in the roof of the pharynx. These cavities freely open into the buccopharynx antero-ventrally, and into the opercular cavity posteroventrally, and are lined with a highly vascular respiratory epithelium, that is raised into folds and tongues and has respiratory islets. The supra branchial cavities possess some alveoli also. Gill lamellae are present on all the gill arches but are reduced in size and those on the fourth arch are considerably reduced in size, and those on the fourth arch are considerably reduced. Cartilaginous processes arise from the parasphenoid, hyomandibular and the epibranchial of the first gill arch and project into the lumen of the supra branchial cavity. The epibranchial of the first gill arch appears to have greatly flattened. These processes are covered over by a thin vascular respiratory membrane which becomes highly folded and studed with a large number of papillae or modules forming a labyrinthine or dnedritic organ on the first gill arch. The respiratory surface may also extend anteriorly to the roof of the buccal cavity and the surface of the tongue. Thus not only the supra branchial chamber but almost the entire buccopharyngeal cavity serves for aerial respiration and is filled with air during the process. In *Periopthalmus* also a small shallow pharyngeal diverticulum lined with respiratory epithelium is present on each side of the roof of the pharynx.

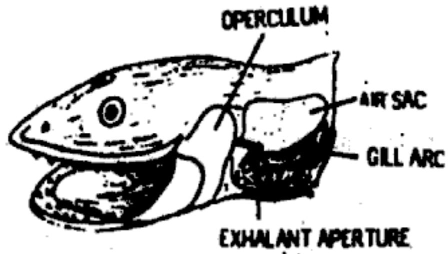


Fig. 6.10 Head of Amphipnous cuchia

In the cuchia eel (*Amphipnouscuchia*) the gills are reduced and gill lamellae are present only on the second gill arch, while the third arch bears a fleshy vascular membrane (fig. 6.10). The air breathing organs are in the form of a pair of sacs situated on the lateral sides of the head. These are diverticulae of the pharynx and are lined with vascular epitheliurn thrown into folds or ridges. Each sac is provided with an inhalant and exhalant aperture. The respiratory epithelium of the air sac consists of vascular areas in the form of islets' bearing numerous 'rosettes' or papillae. The islets are covered by a thin epitheliurn with numerous capillaries ending in it.

When the muscles of the bucco-pharynx contract, mouth is kept closed and the air is expelled from the air sac into the opercular chamber through the exhalant aperture and then passes out via the external branchial opening. When the mouth is opened and the bucco-pharyngeal muscles relax, air rushes in to fill the vacuum in the air sacs.

6.5.4. Opercular chamber modified for aerial respiration

In some species, the ihhaled- air is passed through the gill slits into the opercular chamber where it is stored for some time. The opercular chamber becomes bulged out in the form of two little balloons in the hinder region of- the head and after sometime its walls collapse and the air is passed out through the small external branchial opening. The membrane lining the opercular chamber becomes thin and highly vascular to allow exchange of gases. This is seen in *Periopthalmus* and *Boleopthalmus*.

The following structural modification are seen in *Periopthalmus:*

(i) The opercular bones have become thin and elastic.
(ii) The opercular chamber is enlarged and extends below the basibranchials and above the gill arches. Air pockets develop in the walls of the respiratory epithelium.
(iii) The branchiostegal apparatus of both sides develop a special type of safety valve movable by strips of muscles.
(iv) The epithelium lining the opercular chamber and the branchiostegal membranes becomes richly vascular.
(v) Intricate mechanism has been evolved for opening and closing the inhalant and exhalant apertures.

6.5.5. Development of diverticula from the opercular chamber

In more specialized air breathing fishes sac-like diverticulae develop from the dorsal surface of the opercular or branchial chamber. These air chamber or “opercular lungs” lie above the gills and may contain specialized structures called labyrinthine organs or rosettes to increase the respiratory surface. Such air breathing organs are present in *Hetetopneustes, Clarius*, *Anabas, Trichogaster, Macropodus, Betta*, etc. important modifications in some of these species are described below.

6.5.5.1. Heteropneustes fossilis

In this species the accessory respiratory organs are (.fig. 6.9):

(i) the 'fans' or the expanded gill plates,
(ii) the air sac and
(iii) the respiratory membrane.

Four pairs of gills are present in this species as in other teleosts, but the gill lamellae are reduced in size. Four pairs of 'fans' develop on these gill arches. The gill filaments of the inner side of the first gill arch become joined laterally to form first 'fan'. The second fan is well developed and is umbrella like, the third fan is formed by the fusion of the outer gill filaments of the third arch. The gill filaments of the fourth arch fuse to form the fourth 'fan'. Besides these fans, a pair of simple sac-like structures extend posteriorly from the supra branchial chamber upto the middle of the caudal region. They are thin walled, long tubular structures with highly vascular walls, and lie embedded between the myotomes of the body. The air sac receives blood from the fourth afferent branchial vessel of its own side through a thick 'branch called the afferent respiratory sac vessel. It gives off a number of lateral blood vessels which supply blood to the respiratory islets of the sac. The blood is collected from the islets by the efferent islet vessels which open into the efferent respiratory sac vessel, which in turn carries blood to the fourth efferent branchial vesel of its own side.

The respiratory membrane lining the air sac is thrown into folds and ridges, andis composed of both vascular and non-vascular areas, the former comprising of a large number of "respiratoiy islets". The islets show a characteristic biserial arrangement of lamellae which are the sites of gaseous exchange. Th non-vascular areas show irregularly arranged "lanes" between the islets, and possess mucous glands.

The air first enters the supra branchial chamber through the inhalant aperture guarded by the second and third fans, and then into the posterior tubular part. The air sacs and the fans are formed by the fusion and modification of the primary lamellae and shortening of the secondary lamellae. Thus, the air sacs are the modified derivatives of the basic gill structure.

6.5.5.2. Anabas testudineus

The air breathing organs consist 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 (fig. 6.9). The respiratory epithelium lining the air chamber is highly vascular and may even be folded. Besides this, a characteristic. labyrinthine organ is lodged in the air chamber. The labyrinthine organ develops from the epibranchial segment of the first gill arch and consists of three concentrically arranged bony plates. The first plate if used, with the epithelium lining the air chamber, so as to divide it incompletely into two parts. The second and third plates are much folded and the whole labyrinthine apparatus becomes highly complex and is covered over by vascular epithelium Thus, it serves to increase the area for the absorption of oxygen.

6.5.5.3. Trichogaster fasciatus

The accessory organs in this species consist of a supra branchial chamber, a labyrinthine organ and the respiratory membrane (fig. 6.11). The supra branchial chamber is situated above the gills on either side and as in *Anabas*, pharynx by communicated with the pharynx by means of an inhalant aperture and with the exterior through the opercular chamber by means of an exhalant aperture. The labyrinthine organ develops from the epibranehial of the first gill arch and is simpler in structure than that of *Anabas*. It is in the form of a spiral organ possessing two leaf-like expansion and is composed of loose connective tissue covered by a vascular epithelium. The respiratory membrane lining the air chamber and covering the labyrinthine organs, consists of vascular and non-vascular areas, of which the former possesses a large number of 'islets' containing parallel, blood capillaries. The islets are believed to be derived from the secondary lamellae of a typical gill filament.

6.5.5.4. Clarias batrachus

The accessory air breathing organs of this fish consist of (i) the supra branchial chamber, (ii) the two beautiful 'rosettles' or air-trees. (iii) the 'fans' and (iv) the respiratory membrane (fig. 6.9).

The supra branchial chamber lies above the gills and is divided into two cup-like compartments and is lined by a highly vascular respiratory membrane. Two beautiful 'rosettes' or the dendritic organs are present on each side and are supported by the epibranchials of the second and the fourth branchial arches. The first of these is smaller in size and lies in the anterior compartment. Each is a highly branched tree-like structure supported by cartilaginous internal skeleton. The terminal knobs or bulbs of each dendritic organ consist of a core of cartilage covered by vascular epithelium showing eight folds in it. Some of the primary gill lamellae of each gill arch are fused so as to form a 'fan' or gill plate. Hence, there are four 'fans' on either side and each consists of vascular and non-vascular areas. The respiratory membrane lining the supra-branchial chamber is also composed of vascular and non-vascular areas, of which the former show a larger number of 'islets'.

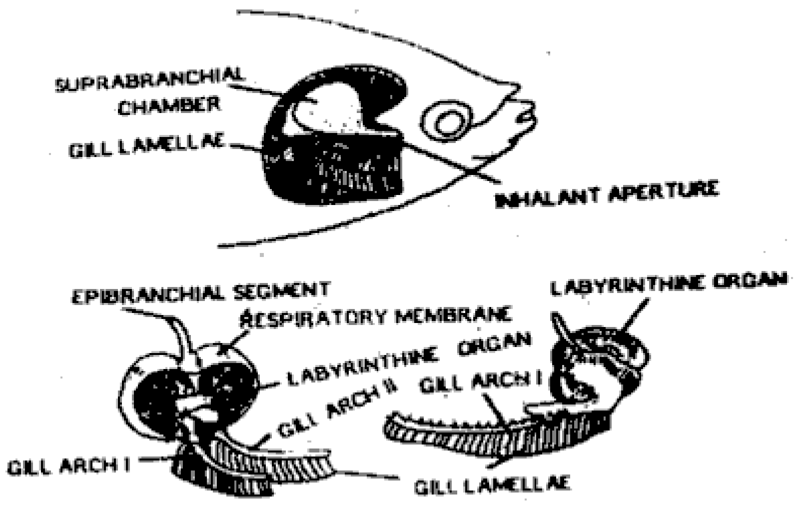


Fig. 6.11. Accessory respiratory organs of Trichogaster fasciatus.

Well defmed exhalant and inhalent apertures are present for the supra branchial chamber. The fish rises to the surface of water and gulps in air, which from the pharynx enters into the suprabranchial chamber through the inhalant aperture, which is the narrow gill slit between the second and third gill arches. When the air enters the opercular cvity, it is directed into the supra branchial chamber by the action of the two fans on the fourth gill arch works as the exhalant aperture and provides exit to the air from the supra branchial chamber into the opercular cavity and then to the exterior. The exhalation of the air is effected by the contraction of supra-branchial chamber and the movement of the fans. This creates a partial vacuum in the supra branchial chamber. The mouth is opened and the buccopharyngeal cavity is enlarged to inhale air.

6.5.6. Respiratory membrane

The respiratory epithelium covering the air breathing organs of various teleosts shows a complicated structure. It consists of vascular areas called the respiratory islets" and non-vascular areas called the "lanes". Exchange of gasses takes place inthe islets which are highly vascular and show lamellar structure in *Heteropneustes* and *Clarias*, but are in the form of papillae in *Channa* and *Amphipnous* (cuchia eel). Pillar cells that are characteristic of the teleostean gill, are present in the respiratory epithelium also (as in *Clarias* and *H.fossilis*).

6.5.7. A part of the alimentary canal modified for aerial respiration

In few fishes, either the stomach or the intestine is specially modified to serve for aerial breathing. In these species, the inhaled air is swallowed and forced back into the alimentary canal and is stored for sometime in a special part of it. After respiratory exchange, the following modifications take place.

(a) the wall of the stomach or the intestine becomes thinned out considerably and is practically transparent due to great reduction of the muscle layers.

(b) Inner surface is lined by a single layer of epithelial cells. Mucus secreting cells or glands are absent and the epithelium is richly vascular.
(c) Circular muscle fibres are greatly reduced and the longitudinal muscle fibres form a very thin layer.

The intestinal respiration is found in loaches *(Misgurnusfossilis)* and in some American fishes of the Siluridae and Loricaridae. In Cobitidae, the middle and hinder parts of the intestine serve for both digestive and respiratory functions. In some species, the digestive and respiratory phases of the intestine alternate at short intervals. In others the digestive tract is non-respiratory during winter and helps for breathing during summer.

6.5.8. Air bladder modified as respiratory organ

The air bladder of some fishes is modified for aerial respiration. Thus. in *Polypterus,* ***Amia,*** *Lepidosteus, Gymnarchus* and in the Dipnoi, the air bladder is most highly evolved acting as a lung in many of these fishes, the circulatory system is also modified so as to reseamble the urodele condition.

The swim bladder of *Notopterus* has a wide pneumatic duct and acts as an accessory respiratory organ. The network of blood capillaries covered by a single layer of epithelium facilitates diffusion of gases between the blood and the air contained in the swim bladder.

6.6. Origin and significance of the air breathing organs

During development, the fifth gill arch does not develop gill lamellae, and its embryonic gill material forms rudiments of the gill arch, and aggregates to form a structure called the 'gill mass'. The air breathing organs develop from this gill mass (Singh, 1993). In some species, the gill arches other than the fifth arch, also take part in the formation of air breathing organs. The gill lamellae which normally develop on the gill arches for aquatic respiration. According to Singh (1993), the air sacs have evolved from the same basic material which has given rise to the gill in teleostean fishes. The air breathing organs of *Heeropneustes* and *C/arias,* are modifications of the gills (Munshi, *1985).* In these species, the swim bladder is either absent of greatly reduced. During the Tertiary and Quarternary period of the Cenozoic era, the oxygen level of the atmosphere and of water was reduced. Due to depletion of oxygen in rivers and swamps. the gills were unable to cope with the requirements of the body. Hence, several teleostean species developed accessor organs to absorb oxygen from air.

Most of the fishes possessing air breathing organs are capable of living in highly deoxygenated water of the swamps and muddy ponds infested with weeds. They have been observed to gulp in air from the surface and to pass it to the accessory respiratory organs. If prevented from reaching the surface, these fishes die due to asphyxiation. This shows that the accessory respiratory organs re capable of maintaining life of the fish in oxygen deficient water. It has been shown that the absorption of oxygen in the air breathing organs is much greater than the excreation of carbon di-oxide. Hence, most of the $C0_2$ is excreted in the gills, and the chief function of the accessory organs is the absorption of oxygen required for the sustenance of life.

SUMMARY

The main respiratory organs of fishes are gills- hence called as branchial respiration. The gill are located either side of the pharynx in the branchial chamber. The gill are open to exterior in elasmobranches, hence known as open type of branchial system. In bony fishes the gill are covered by operculum, hence known as closed type of branchial system. Each gill consists of arch, lamellae and rackers. Gasseous exchange takes place in gill lamellae. Water enter into the body through the mouth except in few elasmobranches. The water enter into branchial chamber through buccal cavity and pharynx and go out though external branchial openings after bathing the gill lamellae.

According respiratory organs found in few fishes and useful to live out side the water for sometime. Some of the accersory respiratory in fishes are skin (*Amphiphous, Periopthalmus, Baleopthalmus*), respiratory trees (*Clarias*), Labyrinthine organ (*Channa, Anabas*), air sac (*Iteteropheustes*) and part of alimentary canal (*Misgurnus*).

Questions:

1. Describe the structure of gill.
2. Discuss the mechanism of respiration in fishes.
3. Give an account on accessory respiratory organs in fishes.
4. Write a note on significance of accessory respiratory organs in fishes.
5. Describe the branchial system in cartilaginous fishes.
6. A murrel survives out side the water — explain.

7

CIRCULATORY SYSTEM OF FISH

7.1. Blood

The blood of fishes is similar to that of any other vertebrates. It consist of plasma and cellular components. The cellular components are red blood cells (RBC), white blood cells (WBC) and thrombocytes. The plasma is liquid portion and consists of water. It acts as the solvent for a variety of solutes including proteins, dissolved gases, electrolytes, nutrients, waste material and regulatory substances. Lymph is the part of plasma that perfuses out of the capillaries to bathe the tissue. It also contains cellular components particularly more lymphocytes.

7.1.1. Plasma

The plasma composition is as follows
Water
Proteins (fibrinogen, globulin, albumin)
Other solutes
Small electrolytes (Na^+, K^+, Ca^{++}, Mg^{++}, Cl^-, HCO_3, PO'SO_4)
Non protein nitrogen (NPN) substance (urea, uric acid, creatine, creatinine, ammonium salts).
Nutrients (glucose, lipid, amino acid)
Blood gases (oxygen, carbon dioxide, nitrogen)
Regulatory substances (hormones, enzymes).

If the blood is collected in a vial containing an anticoagulant, the blood will not coagulate and if centrifuged, the blood cells will be separated and settle down, the liquid portion is known as 'plasma'. If the blood is collected in the vial without any anticoagulant, then the blood will coagulate and if this is centrifuged then the liquid portion is known as 'serum'. Actually the serum has lost the clotting factor prothrombin and fibrinogen but the plasma contains clotting factor proteins also.

Fish plasma contains albumin, the protein which control osmotic pressure. It also contains lipoprotein whose main function is to transport lipid. Ceruloplasmin, fibrinogen and iodurophorine are some important proteins of fish blood. Ceruloplasmin is a copper binding protein. The total plasma protein in fish ranges from 2 to 8 gdl^{-1}'. The thyroid binding proteins such as T 3 and T4 is present in the blood circulation in free form. Thyroxine binds to vitellogenin in several Cyprinid species. Enzyme such as CPK, alkaline phosphatase (Alk Pase), SGOT, SGPT, LDH and their isoenzymes are reported in fish plasma.

There are three varieties of cells or corpuscles present in blood:

(a) Red blood corpuscles or Erythrocytes

(b) White blood corpuscles or Leucocytes.

1. Agranulocytes
   (a) Lymphocytes (b) Monocytes
2. Granulocytes
   (a) Neutrophils (b) Eosinophils (c) Basophils
   (b) Thrombocytes.

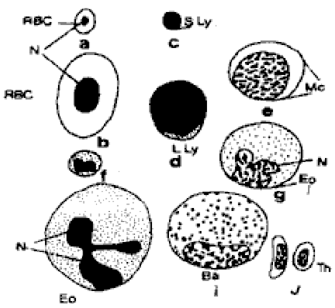


Fig. 7.1. Diagramatic sketch of the blood cells of fishes.
(a) Erythrocyte (RBC) of elasmobranch (larger). (b) Erythr (RBC) teleost (smaller). (c) Lymphocyte (small) (SLY). (d) Lymphocyte (large) (LLy).

(e) Monocyte (Me). (f) Neutrophil (g) Eosinophil (Eo). (h) Eosinophil (Eo). (i)-Basophil (Ba). (j) Thromobocyte (th). N, nucleus; RBC, red blood cells.

11.1.2. Erythrocytes

The number of erythrocyte in blood varies according to the species as well as the age of the individual, season and environmental conditions. However, under similar conditions, a fairly constant number of reticulocytes are present in species. The nucleus is centrally placed and round or oblong in shape.(Fig. 7.1 .a,b)

The RBC size is larger in elasmobranchs in comparison to teleosts. The brackish water species of *Fundulus* have smaller blood cell than fresh water species. The erythocytes are slightly smaller in active species than in nonactive. In deep sea teleosts, the size of the RBC is larger than normal teleosts. The mature erythrocytes of fishes vary greatly in their shape and outline and in peripheral blood they are mostly mature. The shape is generally circular in *Clarias batrachus, Notopterus notopterus, Co/isa fasciatus, Tor tor* but ellipsoid, oval or oblong in *Labeo rohita* and *Labeo calbasu.*

7.1.3. White blood cells or leucocytes

Although the fish white blood corpuscles have been well investigated, there is no unanimity regarding their classification. The fish leucocytes in peripheral blood are generally (i) Agranulocytes (ii) Granulocytes. The nomenclature is based on affinity of acid and basic dyes and depends upon human hematology. Plasma cells, basket and nuclear shades are also present.

7.1.3.1. Agranulocyles

They have no granules in the cytoplasm. The most important distinguishing character is unlobed nuclei. Thus they are distinguished from granulocytes, which possess specific segmented nucleus. Agranulocytes have two varieties (a) Lymphocytes, (b) Monocytes.

7.1.3.1.1. Lymphocytes

They are most numerous types of leucocytes. The nucleus is round or oval in shape. They constitute 70 to 90% of the total leucocytes. They are rich in chromatin, although its structure is obscure, and is deep reddish violet in colour in preparation with Giemsa. Large and small lymp hocytes are found in peripheral blood smears of teleosts, fresh and marine fishes similar to that of mammals. The cytoplasm is devoid of granules but cytoplasmic granules occasionally present. In large lymphocytes there is large amount of cytoplasm but in small only little quantity of cytoplasm is evident and nucleus constitute most of the cellular volume.(Fig. l.c&d)

The main function offish lymphocytes is to produce immune mechanism by the production of antibody.

7.1.3.1.2. Monocytes

It consists of much less proportion of WBC population often absent in few fishes. It is suggested that they originate in the kidney and become apparent in the blood when foreign substances are present into the tissue or blood stream. The cytoplasm usually stain smoky bluish or pinkish purple. The nucleus of monocyte is fairly large and varied in shape (Fig. 7.1 ,e). The function of monocyte is phagoeytic.

7.13.1.3. Macrophage

They re large size, the cytoplasm was occasionally finely or coarsely granulated. They belong to mononuclear phagocyte septum. They are abundant in renal lymphomyeloid tissue and spleen. Macrophages are present in various other tissues of fishes such as pronephros and olfactory mucosa etc. Macrophages system of the spleen, bone marrow and liver play a role in phagocytosis of RBC which undergo degradation. Iron separated from hemoglobin molecule are removed by the liver.

7.1.3.2. Granulocytes

These cells possess specific granules in large numbers and they retain their nucleus. They are of three types (a) Neutrophils, (b) Eosnophils, (c) Basophils

7.1.3.2.1. Neutrophils

The neutrophils in fishes are most numerous of the white blood cells and constitute *5-9%* of total leucocyte in Solvelinus fontinalis. They are *25%* of total leucocytes in brown trout. They are named for their characteristic cytoplasmic staining. They can be easily identified by the multilobed shape of their nucleus and therefore they are segmented or multilobed but in some fishes neutrophils are bilobed(Fig. U. 1). Their cytoplasmic granules are pink, red or violet in peripheral blood smear. The nucleus often looks like the human kidney. In Giemsa stained smear the nucleus is reddish violet in colour and usually exhibits a reticular structure with heavy violet, colour. Neutrophils show peroxidase and sudan black positive reaction. The neutrophil is an active phagocyte. It reaches to inflammation site and inflammation refers to local tissue'response to injury.

7.1.3.2.2. Eosinophils

These cells are generally round and cytoplasm contains granules which has affinity to acidic dye and they take deep pinkish orange or orange red with purple orange background. The nucleus is lobed, takes deep orange purple or reddish purple stain. (Fig. 11.1, g and h).

11.1.3.2.3. Basoplsils

The basophils are round or oval in outline. The cytoplasmic granules take deep bluish black stain. They are absent in anguilled and plaice. (Fig. 7.l.i).

7.1.4. Thrombocytes

Thrombocytes or spindle cells: These are round, oval or spindle shaped cells hence called thrombocytes but in mammal they are disc like and are calledplatelet. (Fig. 7.1)

They occupy as much as half of the total leucocytes in fish. It constitutes 82.2% of WBC in herring but only 0.7% in other teleosts. The cytoplasm is granular and deeply basophilic in centre and pale and homogenous on the periphery. The cytoplasm takes pinkish or purplish colour. The thrombocyies help in clotting of blood.

7.1.5. Formation of blood cells (hemopoiesis)

The formation of cells and fluid of the blood is known as hemopoiesis.

Both RBCs and WBCs are originated from lymphoid hemoblast or hemocytoblast usually mature after they enter the blood stream. In fishes apart from spleen and lymph nodes many more organs take part in the manufacture of the, blood cells. In elasmobranch fishes, the erythrocyte and granulopoietic tissues are produced in the organ of Leydigs, the epigonal organs and occasionly. in the kidney. The Leydig organ is whitish tissue and analogus to bone marrow - like tissue found in oesophagus but the main site is spleen. If the spleen is removed then the organ of Leydig takes over rythrocyte production. In teleost, both erythrocyte and granulocytes are produced in kidney (pronephros) and spleen. The teleost spleen is distinguished into a red outer cortex and white inner pulp, the medulla. The erythrocytes and thrombocytes are made from cortical zone and lymphocytes and some granulocytes originate from medullary region. In higher bony fishes (actinopterygii) red blood cells are also destroyed in the spleen. It is not known whether other organs also function into blood decomposition or how blood destruction comes about in the jawless fishes (Agnatha) or in the basking. shark and rays. In Chondrichthyes and lung fishes (dipnoi), the 'spiral valve of the intestine produces several white blood cells types.

7.1.6. Function of blood cells

The blood of fishes like other vertebrates consists of cellular components suspended in plasma. It is a connective tissue and is complex non-Newtonian fluid. The blood is circulated through out the body by cardiovascular system. It is circulated chiefly due to the contraction of heart muscles. The blood performes several function. A few important functions are mentioned as follows

1. **Respiration**: An essential function is the transport of oxygen from dissolved water from the gills (respiratory modifications) to the tissue and carbondioxide from the tissue to the gills.
2. **Nutritive**: It carries nutrient material, glucose amino acids and fatty acids, vitamin, electrolytes and trace elements from alimentary canal to the tissue.

3. **Excretory**: It carries waste materials, the products of metabolism

such as urea, uric acid, creatine etc. away from cell. Trimethylamine oxide (TMAO) is present in all fishes. It is in high concentration in marine elasmobranches. Creatine is an amino acid which is the end 'product of metabolism of glycine, arginine, methionine whereas creatine is formed spontaneous cyclisation of creatine. Its level in plasma is 10-80 gm and is excreted by kidney.

4. **Hemostasis** of water and electrolyte concentration: The exchange of electrolyte and other molecules and their turn over is the function of blood. Blood glucose levels are often cited is being a sensitive physiological indicator of stress in fish and there is no unanimity about the blood glucose levels amongst fishes.

5. **Hormones** and humoral agents contain regulatory agent such as hormones and also contains cellular or humoral agent (antibodies). The concentration of various substances in the blood is regulated through-feed back loops that sense changes in concentration and triggers the synthesis of hormones and enzymes which initiate the synthesis of substances needed in various organs.

Fishes possess a closed circulatory system consisting of heart, arteries and veins

7.2. Heart

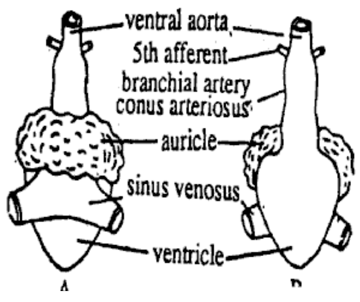
The heart is situated immediately behind the gills but in teleosts, it is relatively anteriorly placed than in the elasmobranchs. The heart in the elasmobranchs is most primitive in structure among the fishes and lies in a spacious pericardial chamber. It consists of sinus vinosus, atrium, ventricle and a well developed contractile conus arteriosus. The sinu-auricular and the atrio-ventricular openings are guarded by paired valves. In the conus, as many as six tiers of valves may be present. The presence of a muscular, contractile conus is considered as a primitive feature and it persists in some lower teleostomi as *Acipenser, Polypterus* and *Lepidosteus.* In *Amia* the conus as well as bulbus arteriosus are present, the latter being a noncontractile region having fibrous walls. Some lower teleosts -belonging to the order clupeiformes also show an intermediate condition and a distinct conus with transverse rows of valves is present in *Albula, Tarpon* and *Megalops.* In higher teleosts the conus is absent or very much reduced and bulbus arteriosus is present. There is a considerable variation in the size of the heart in relation to body weight in fishes.

7.2.1. Structure of the heart of a teleost

The heart lies within the pericardial sac interior to the septum transversum and consists of sinus venosus, auricle, ventricle and the bulbus arteriosus. The sinus is a fairly spacious chamber with smooth walls and receives blood through the paired ductus Cuvieri, paired hepatic veins, a posterior cardinal and an inferior jugular vein. The openings of these blood vessels are not guarded by valves. The sinus opens into the auricle through a sinuauricular aperture guarded by a pair of membranous semi-lunar valves, each having a longer limb that projects anteriorly into the auricle.

The auricle covers the ventricle in dorsal view and is fairly large in size with an irregular outline. It is orange in colour, spongy in texture and has a narrow lumen extending upto the ventricle. The spongy wall of the auricle shows numerous spaces or cavities delimited on all the sides by muscular strands running in various directions. The valves of nearly equal size. Each of these valves has shorter limb attached to the wall of the auricle and a longer one adhering to the ventricular wall, while the convexities of the valves project into the auricle.

The ventricle is a highly muscular chamber with thick walls and a narrow lumen in between. The ventricle leads into the bulbus arteriosus throught the ventriculo-bulbus opening guarded by a pair of semi-lunar valves. Each valve has a shorter limb attached to the wall of the ventricle and a longer one connected to the wall of the bulbus in such a way as to



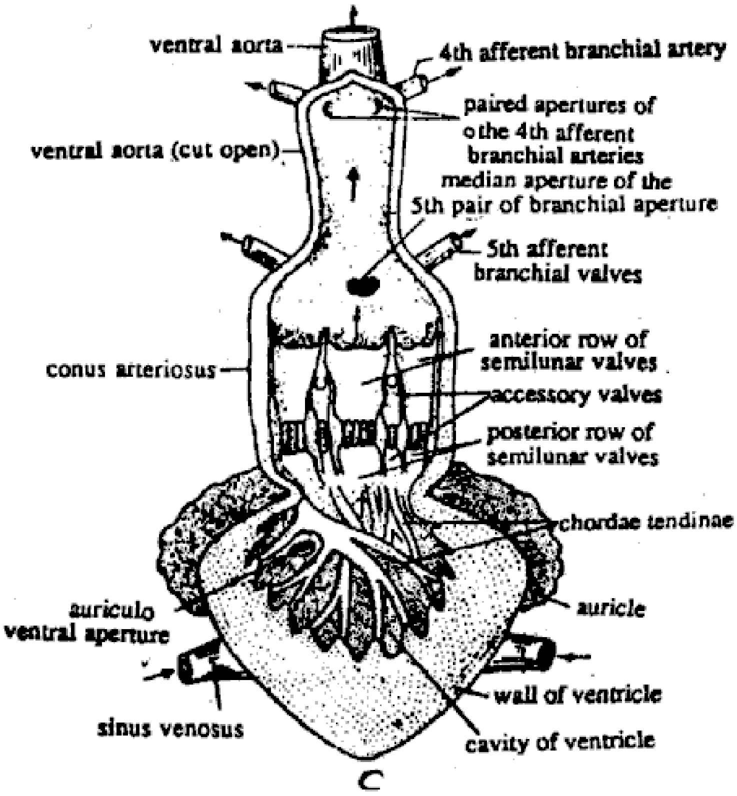


Fig. 7.2 heart of shark. A. dorsal view, B. ventral view, C. internal structure.

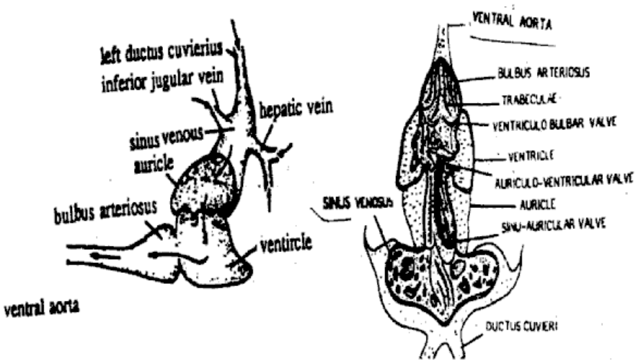


Fig. 7.3 Heart of labeo A. and its internal structure.

cross the limb of the other valve. The valves hang into the lumen of the ventricle. There is no conus, and the base of the ventral aorta is thickened to form the bulbus. The bulbus has thick walls and a narrow lumen, its cavity has a number of thin ribbon-like trabeculae running parallel to each other. The bulbus extends anteriorly into the ventral aorta.

The heart of cyprinids like *Labeo rohita, Cirrhina rnrigala, Cat/a catla* and *Schizothorax* has the same general structure is found in *Tor tor. In L.rohita, C.mrigala* and *C.catla,* the sinus venosus is large and has a pair of lateral appendages. It is spongy and fibrous in the first two species. One limb of the dorsal sinu-auricular valve in *Catla catla* extends into the auricular cavity upto the auriculo-ventricular aperture and becomes attached to the wall of the auricle.

In *Clarias batrachus, Mystus aor* and *Wa//ago attu,* the sinus venosus is a thin walled chamber with a pair of membranous sino-auricular valves placed obliquely to the long axis of the heart. One end of the dorsal valve extends forwards into the auricular cavity and becomes attached to it. The auricle is spongy looking like a honeycomb. The auriculo-ventricular opening is guarded by four valves, two of which are well developed and prominent while the other two are very small and insignificant. The ventricle is highly muscular and the two ventriculo-bulbar valves are semi-lunar in shape.

A small sinus venosus is present in *Channa striatus* and the sinuauricular valves are absent in it. The sinu-auricular aperture is guarded by five to seven nodular valves in *Notopterus notopterus* and eight to ten in *N.chitala.* Four auriculo-ventricular valves are present of which two -are small is size. A muscular conus arteriosus is present between the ventricle and the bulbus in *N.chitala.* The ventriculo-bulbar valves are also peculiar in being ribbon-like and form a pair of vertical partitions dividing the cavity of the bulbus into three chambers in *Notopterus.*

7.2.2. Working of the heart

The venous blood flowing continuously towards the heart reaches the sinus and passes into the auricle by pushing apart the semilunar valves. During this, the pockets of the valves also become full of blood and the pressure due to the contraction of the auricle causes the valves to swell and adhere with each other, thus preventing the backward flow of the blood. The blood now flows from the auricle into the ventricle by pushing apart the four auriculo-ventricular valves. As soon as the ventricular cavity is full, the valves also receive 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 bulbar 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.

7.2.3. Cardio-vascular control

Fishes control their cardio-vascular systems by two methods: (i) aneural, and (ii) neural mechanisms.

Aneural cardio-vascular control is exercised by changes in blood volume, by direct responses of heart muscles to changes in temperature, and by secretions of various glands. Temperature acts as aneural regulator of circulation by direct action on the pace makers in the myocardium. In some species, rise in temperature causes increase in heart beat resulting in higher cardiac output. This increase in blood flow provides higher delivery of oxygen throughout the body, which is operating of a higher metabolic rate in the warm water. Aneural control is also effected by the secretion of certain hormones. Thus, epinephrine stimulates heart rate, and experiments have shown that the level of circulating epinephrine and nor-epinerphrine rises with exercise in rainbow trout.

Neural control is effected though the tenth cranial nerve. The heart of all fishes are innervated by a branch of the vagus. Stimulation of vagus slows the heart rate in elasmobranchs and teleosts. Various stimuli as the light flashes, sudden improvements of object, touch or mechanical vibrations usually cause a decrease in heart rate. In fishes a built-incapacity for circulatory adjustments in response to environmental or other changes.

7.3. Arterial system in a teleost

The ventral aorta runs forwards and gives off four pairs of afferent branchial vessels of which the third and the fourth have a common origin from the ventral which the third and the fourth have a common origin from the ventral aorta. These blood vessels enter into the respective holobranchs of the corresponding side and give off paired capillaries to the gill lamellae. After oxygenation in the gills the blood is collected by means of four pairs of efferent branchial arteries. Only one efferent is present in each gill arch and the first two of these emerge dorsally from the gills and join to form the first epibranchial vessel. The epibranchial of the two sides run posteriorly and meet to from the dorsal aorta. The third and fourth efferent branchial vessels also emerge from their respective holobranchs and join to form a short second epibranchial which opens into the dorsal aorta.

A short common carotid arises from the first efferent branchial vessel and divides almost immediately into an external carotid and an internal carotid artery. Near its base, the carotids receive an efferent pseudobranchial artery from the pseudobranch. A cerebral artery arises from the common carotid to supply the brain. The external cartid artery gives off a number of branch and supplies blood to the opercular and auditory regions and to the muscles of the jaw. The internal carotid artery supplies blood the snout and the optic region. A small branch of the internal carotid runs towards and middle line and joins its fellow of the opposite side to form the circulus cephalicus.

The dorsal aorta runs posteriorly below the vertebral column. The subclavian artery arises from the dorsal aorta, a little behind the second epibranchial and supplies blood to the pectoral fins. The coeliaco-mesenteric artery arises from the dorsal aorta a little behind the subclavian and soon divides into coeliac and mesenteric arteries. The coeliac artery supplies blood to the anterior part of the intestine while the mesenteric gives off branches to the liver, spleen, air bladder, gonads and to the rest of the alimentary canal.

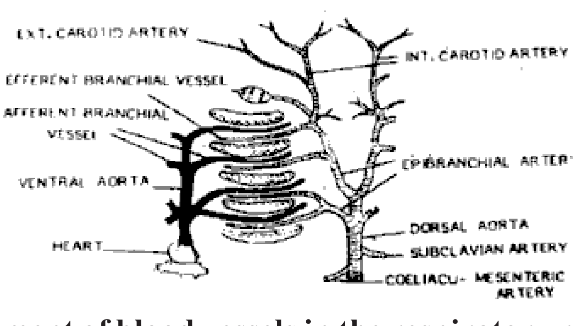


Fig. 7.4. Arrangement of blood vessels in the respiratory region of a teleost.

The dorsal aorta runs through the substance of the kidneys and gives off several pairs of renal arteries to it, one of which continues into the pelvic fins also. The dorsal aorta then continues posteriorly as the caudal artery within the haemal canal and gives off several pairs of segmental arteries to the muscles during its course.

The above description represents typical arrangement of the arteries in teleosts but some variations have been found in different arteries in teleosts but some variations have been found in different species of fresh water fishes. Thus, all the four pairs of afferent branchial vessels arise independently in *Catla catla* but in general the third and the fourth afferents of each side have a common origin as in *Tor tor, Mystus aor, Rita rita, Clarias batrachus, Heteropneustes fossils, Wallago attu* and *Notopterus chitala.* In a few species the second pair of afferent arteries may also have a common origin from the ventral aorta *(Rita rita* and *H. fossilis).*

A psudobranch is present in some species *(Cat/a cat/a, Tor tor*) and is supplied with blood by the afferent pseudobranchial artery arising from the first efferent branchial vessel. The blood is collected from it by the efferent pseudobranchial artery that joins the internal carotid artery. In *W.attu* and M.aor, in which a pseudobranch isabsent, the internal carotid artery is wollen at the base to form a labyrinth.

The alimentary canal and its associated glands receive their blood supply from the branches of the coelicomesenteric artery. The gonads receive blood either from the coaliaco-mesenteric or the posterior mesenteric artery.

7.4. Venous system in a teleost

The blood from the head is collected by external and internal jugulars which unite to form an anterior vein on each side. The internal jugular vein receives blood from the premaxillary, nasal and optic regions while the external jugular collects 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 runs through the substance of the right kidney. Renal veins from both the kidneys open into the posterior cardinal which, runs forwards and opens into the sinus venosus. The blood from the tail is collected by the caudal vein which after receiving several segmental veins, discharges into the kidney.

The hepatic portal veins 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 arise and carry the blood to the sinus venosus.

The venosus sytems of *Tor tor* represents the typical arrangement of veins as seen in teleosts is general and differences are observed in some respects only. The inferior jugular veins are generally unpaired but in some respects only. The inferior jugular veins are generally unpaired but in some species two veins may be present (*Wallago attu, Clarias batrachus).* The posterior cardinals are unpaired in *Tor tor, Catla catla, Wallagu attu* but paired in *Clarias batrachus* although the right posterior cardinal is better developed in this species.

SUMMARY

Closed type of circulatory system is found in fishes. Blood is reddish in colour due to the presence of haemoglobin. Haemoglobin is found in erythrocytes. Thrombocytes are useful in blood clotting. Heart in fishes is two chambered with an auricle and ventricle. It also consists conus arteriosus in cartilaginous fishes and bulbus arteriosus in teleosts. It known as venous heart due to the circulation of only impure blood. Arterial and venous systems are developed in fishes. Hepato portal system is developed in fishes.

Questions:

1 Give an account on blood of fishes.
2. Describe the structure and working mechanism of heart of fishes.
3. Discuss the arterial system of fishes.
4. Write a note on various system of fishes.
5. Describe the arrangement of blood vessels in fishes.

8

NERVOUS SYSTEM OF FISH

Changes occur in the environment. Organisms detect such changes through receptor organs and convey the message to specialized tissues for necessary adjustments. In higher animals the activities are coordinated by the nervous system. Nervous system regulates and controls the activities of different organs present in the body such as muscle contraction, glandular secretion, heartbeat etc: It connects various system of the body and coordinates all their activities and ensures the integrity of the organism. The stimuli are received by the nervous system through sense organs. Thus, the nervous system is responsible for receiving and responding various activities. Various organs of the body and activities of the organism are controlled and coordinated by the nervous system.

Nervous system is derived from ecotoderm. The study of nervous system is known as neurology. The study of functioning of it is called neurophysiology and its diseases is known as neuropathology.

The nervous system is divisible into three parts:

1. Central nervous system
2. Peripheral nervous system
3. Autonomous nervous system.

8.1. Central nervous system

The brain is formed by the enlargement of the cephalic end of the spinal cord. In size the fish brain shows considerable variations in different species and is relatively small in relation to body size of the adult fish. It does not fill the entire cranial cavity and the empty space between the brain and the cranium is filled with gelatinous material. The brain of a teleost is typically divisible into three regions fore train, mid brain and hind brain.

8.1.1. Brain

8.1.1.1. Fore Brain (Prosencephalon)

The fore brain consists of telencephalon and the diencephalon. The telencephalon is the anterior most part of the brain and is mainly concerned with the reception and conduction of smell. The telencephalon consists of a pair of solid olfactory lobes and two large cerebral hemispheres. Short oar; long olfactory nerves arise from the olfactory lobes and end infront in a pair of olfactory bulbs at the base of olfactory rosette. Both these structures are present in species like *Puntius ticto* and are simple swellings of the olfactory tract. But in many species as *Tor tor. Schizothorax, Mystus seenghal,* only the olfactory bulbs are present at the fore ends of the olfactory nerves and the olfactory lobes are not present at their base. In others like *Channa striatus and Mastacembelus armatus* the olfactory lobes are present while the olfactory bulbs are not developed

The cerebral hemispheres form the most important part of the telencephalon, these are in the form of solid masses, joined with each other in the mid-line and are covered over by a thin membranous pallium, which is non-nervous. The narrow space between the thin roof and the solid hemisphere may be considered to represent the first and second brain ventricles. A large bundle of fibres the anterior commissure, connect it with the diencephalon. Hence, these structures are probably concerned with other activities of the fish also besides being centres of smell reception. It is believed, that the telencephalon plays an important role in the reproductive behaviour of fishes. Possibly it controls aggression. sexual ‘activity and parental behaviour, maintaining the proper balance to ensure successful reproduction of the species.

The diencephalon is hardly visible from the dorsal side being represented by a median diamond shaped area between the cerebral hemispheres and the optic lobes (fig.8.l). It is divisible into a dorsal epithalamus, a thalmus and a ventral hypothalamus. In the epithalamic region are present two ganglionic masses called the habenulae, that are almost equal in size. From the roof of the diencephalon arises the pineal body as an evagination. Pineal body is not so well developed in bony fishes and has a doubtful function. It is suspected to be an endocrine gland. The diencephalon attains its maximum development on the ventral side in the form of hypothalamus and infundibulum. The cavity of the diencephalon is the third ventricle of the brain.

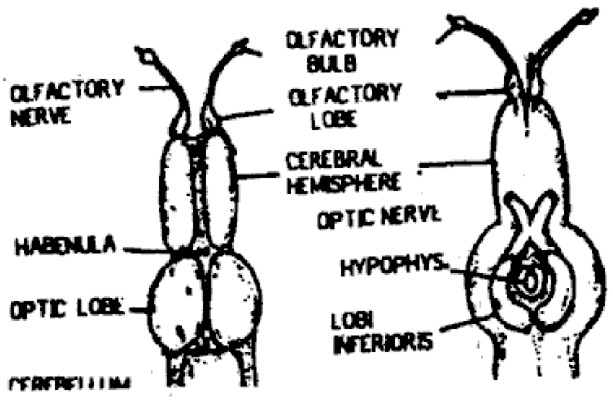


Fig.8.1. Brain of *Puntius ticto.*

The infundibulum is applied to the hypophysis in the mid-ventral line. The latter is an important endocrine gland and is attached to the brain by means of a stalk. The infundibulum is enlarged laterally to form a pair of bean-shaped 'inferior lobes', that lie ventral and opposite to the optic lobes. The inferior lobes are close to each other posteriorly but remain separate in their anterior regions, thus leaving a small area between their fore ends which projects as median infundibulum. A pair of stout optic nerves enter the brain in the antero-dorsal part of the inferior lobes. They cross each other just infront of the diencephalon but do not fuse to forman optic chiasma in many species. The diencephalon has a large number of important nuclei and several fibre tracts, connecting it with different parts of the brain. It is an important correlation centre for afferent and efferent impulses. The hypothalamus influences the endocrine system of the fish through the pituitary gland. Neuro-secretory cells are also present in the hypothalamic nuclei and their secretions are conveyed to the hypophysis.

8.1.1.2. Mid brain (Mesencephalon)

The mesencephalon consists of the dorsally placed optic tectum and the ventral tegmentum (fig. 8.1). The tectum is seen in the form of two well developed optic lobes and is composed of at least five zones differing from each other in the shape and size of their cells. The fibres of the optic nerves end in the tectum and the image formed on the retina is projected on it. In all the higher bony fishes, the optic tectum projects into the optocoel in the form of a pair of torus longitudinalis, which connect it with the posterior commissure. The optocoel is nearly obliterated due to the presence of the valvula cerebel in it consisting of a granular layer and a molecular layer. The optic tectum in fishes is associated with the reception and elaboration of the visual sensations (sight) and correlates them with the muscular responses of the animal. It has also been associated with learning and is believed to perform functions similar to those of the cereberal cortex in mammals. However, the optic tectum differs in its degree of development in various species and is reduced in the blind fishes and cave fishes. The torus longitudinalis is also believed to be connected with vision but. may better be described as a correlation centre for photostatic and gravistatic centres of the brain.

8.1.1.3. Hind brain (Metencephalon)

The hind-brain consists of the cerebellum which develops as a large dorsal out-growth from the hind brain. It is only partly visible externally (as corpus cerebelli) and its anterior part enters into the cavity of the optic lobes in the form of valvula cerebelli. The corpus cerebelli is composed of an outer molecular layer and an inner granular layer. These layers are reversed in position in the valvula cerebelli. The cavity of the cerebellum is absent and its main function appears to be the maintenance of the body posture during swimming by coordinating muscular activities. In Mormyrids, the cerebellum is very well developed and is probably associated with the reception of impulses from the electric organs of the fish.

The myelencephalon or the medulla oblongata is the last part of the brain. It is very well developed in all the teleosts and has a cavity called the fourth ventricle. It is broad infront and has one median facial lobe and. two lateral vagal lobes, that are variously developed in different species, depending upon the relative importance of various senses in them. The vagal lobes are the gustatory centres of the medulla and are better developed in species that depend upon taste for feeding as in the carps (*Puntius ticto, Tor tor*). Facial lobes are prominent in species that search their food and explore the surrounding area with the help of long barbels as the siluroids (*Mystus seenghala*). Species having a better sense of hearing possess a well formed central accoustic lobe in the medulla oblongata. Fifth to tenth cranial nerves arise from this part of the brain which is therefore, associated with both sensory and motor impulses from different parts of the body.

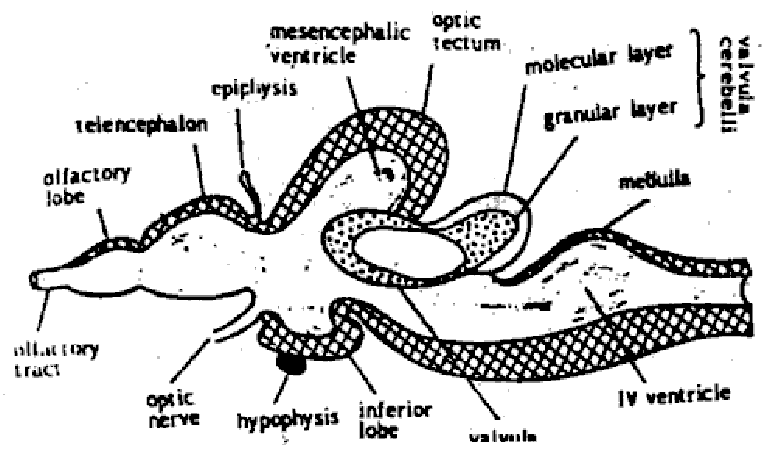


Fig. 8.2. L.S. of brain

8.1.2. Spinal cord

The spinal cord is uniform in structure throughout its length and extends for the whole length of the body. In a cross section the spinal cord shows a central canal surrounded by gray matter consisting of nerve cells and an external area of white substance consisting of nerve fibres. The gray matter has the appearance of the letter X with paired dorsal and ventral horns (fig. 8.3). The dorsal horns receive the somatic and visceral sensory fibres whereas the ventral horns contain motor nuclei.

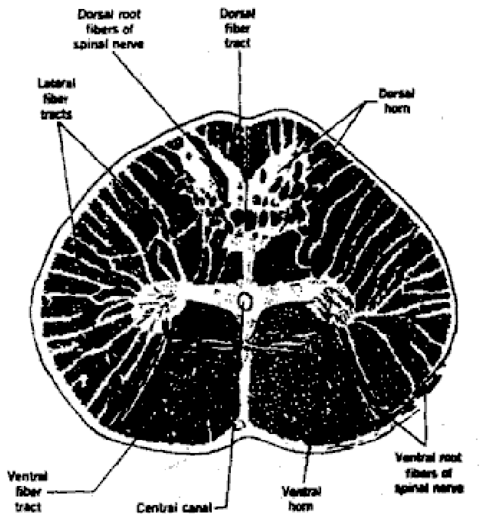


Fig. 8.3. cross section of spinal cord.

8.2. Peripheral nervous system

It consists of two kinds of nerves. spinal and cranial. The former take their origin from the spinal cord and are metamerically arranged i.e., their number corresponds with that of the vertebrae. Cranial nerves arise from the brain and ten pairs of them are typically present in a teleost.

8.2.1. Cranial nerves

I. there are ten pairs of cranial nerves in fishes (fig. 8.4). The Olfactory nerve takes its origin from the olfactory lobes or the front end of the cerebral hemispheres and runs forwards to end in the olfactory rosette. It is a special sensory nerve conveying smell impulses to the brain.

II. the Optic Nerve arises from the optic tectum of the mid-brain and emerges from its ventral side. The two optic nerves cross each other infront of the diencephalon, and each nerve then enters the orbit through the optic foramen and supplies the retina of the eye. It is a special sensory nerve carrying visual impulses.

III. the Occulomotor nerve arises from the ventral side of the mid-brain and enters the orbit through the optic foramen to supply to the superior, inferior, anterior rectus and the inferior oblique muscles of the eye ball. It is a somatic motor nerve and innervates four of the six striated muscles of the eye ball.

IV. the Trochlear nerve arises from the dorso-lateral side of the brain between the optic lobes and the cerebellum, and enters the orbit through a foramen in the orbitosphenoid. It supplies the superior oblique muscle of the eye ball.

V. the Trigeminal nerve arises from 'the lateral side of the medulla oblongata and supplies the snout and upper and lowerjaws. It a mixed nerve and is divided into three important branches-the opthalmic, maxillary and mandibular. In the common fresh water fish, *Wallago attu*, the trigeminal and the facial nerves, join immediately after their origin to form the trigeminofacial complex.

VI. the Abducens nerve arises from the ventral side of the medulla oblongata, a little behind the trigeminal nerve. It also enters the orbit and supplies the posterior rectus muscle that move the eye ball.

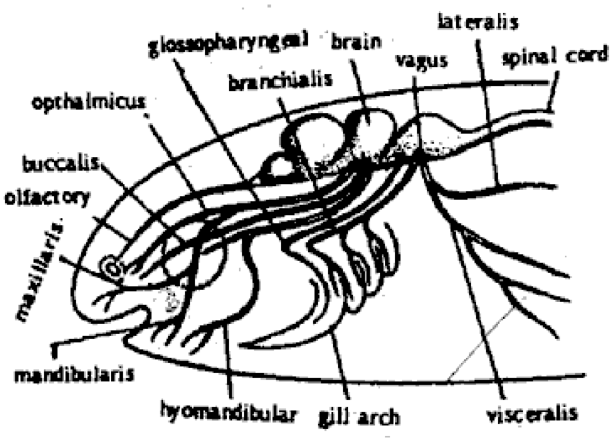


Fig. 8.4. Cranial Nerves Labeo

VII. Facial nerve has independent origin from the side of the medulla oblongata behind the trigerninal, but soon joins the latter to form the trigemino-facial complex which divides into three trunks, the supraorbital, infra-orbital and the hyomandibular.

Supra-orbital trunk arises from the trigemino-facial complex as a dorsal branch and divides ito (a) Opthlmicus superficialis trigeminalis to supply the skin of the snout, innervates the supra orbital canal of the lateral line system.

Infra-orbital trunk arises from the trigemino-facial complex and runs ventral to the supra orbital. It divides into three branches maxillaris, buccàllis and the mandibularis. The maxillaris is a branch of the fifth cranial nerve and is intimately associated with the buccalis branch of the seventh cranial nerve for some length. The maxillaris then separates and supplies the maxillary barbel, upper lip and the premaxillary teeth. The buccalis, after separating from the maxillary, runs forward and supplies the skin of the snout. One of its branch enters the maxillary barbel to supply sense organs on it.

Mandibular branch of the trigeminal nerve runs along the posterior border of the eye and on reaching the angle of the mouth divided in to two, rnandibularis externus and the mandibularis internus. Both these supply the skin of the lower jaw, mandibular barbel etc.

A palatinus branch is also given off from the infraorbital trunk and supplies the roof of the buccal cavity. The hyomandibular trunk of the seventh nerve comes out of a foramen in the hyomandibula. It gives of a slender branch to the operculum and then divides into two: a ramus mandibularis. facialis and (b) ramus hyoidus to supply the lowerjaw, lower lip and the mandibular teeth.

From the trigemino-facial complex arises a lateralis accessorius branch and emerges out through a forarmen in the supra occipital bone. It runs backward close to the neural spines of the vertebrae and receives the dorsal rami of the spinal nerves. .

VIII. Auditory nerve arises from the side of the medulla oblongata behind the facial, and divides into two branches: a vestibular branch to supply the utriculus and the ampullae of the inner car, and (b) a saccular branch, to supply the sacculus and the lagena.

IX. Glossopharyngeal nerve arises from the ventrolateral aspect of the medulla oblongata behind the auditory and enters the first gill slit. It is mixed nerve and supplies a part of the lateral fine system, taste buds in the pharynx and the muscles of the first gill slit.

X. Vagus nerve arises behind the glossopharyngeal and has an extensive distribution. It divides into a lateralis branch and a branchio-visceral trunk. The lateralis is a stout nerve that runs upto the end of the tail along the lateral line canal and innervates it by several branches. The branchio-visceral trunk divides into four branchialis nerves and a visceralis branchi. Each branchial branch gives off a slender branch to the pharynx and then divides into a pretrematic and a post-trematic branch to supply the muscles of the gills. The visceralis branch supplies various organs of the viscera.

SUMMARY

Central nervous system of fishes consists of brain and spinal cord. The forebrain consists of olfactory lobes, cerebral hemispheres and diencephalon. Olfactory lobes are well developed in fishes. The diencephalons consists of pituitory gland which is attached to hypothalamus with the help of infundibulum. The midbrain consists two optic lobes, hence called as corpora bigemina. The hindbrain consists of cerebellum and medulla oblongata. The spinal cord is uniform extends from medulla oblongeta and extend upto the tail of the fish. Ten pairs of cranial nerves are found in fishes.

Questions:

1. Explain the structure and functions of fish brain.
2. Write a note on spinal cord.
3. Describe the cranial nerves in fishes.
4. Discuss the functions of various parts brain.

9

EXCRETION AND OSMOREGULATION IN FISH

Various body parts which are concerned with the removal of metabolic wastes are included in the excretory system. Elimination of nitrogenous waste products from the body is a process called excretion. The excretory products are formed during the amino acid catabolism. The amino group (NH,) is separated from the amino acid through the process of deamination. These excretory products are-harmful to the body, if they are accumulated.

Aquatic animals, which have no problem of water excrete ammonia predominantly. They are called ammnotelic forms. eg: crustaceans. polychaetes, teleosts, tadpoles of amphibia etc.

Some animals live partly in water and partly on land. In such forms the toxic ammonia is changed into less toxic ammonia is changed into less toxic urea in liver. Urea can be retained in the body for much longer period than ammonia. The animals which excrete urea as the chief excretory product are known as ureotelic forms. eg: elasmobranchs. amphibians and mammals.

Terrestrial animals which have scarcity of water cannot afford to loose water from their body. In such forms nitrogenous waste is converted into still less toxic substance called uric acid. It is excreted in crystalline form. The animals which excrete uric acid as the chief excretory product are known as uricotelic forms. eg: Insects, gastropods, Lizards, snakes and birds. The excretory and reproductive organs are closely associated with each other in fish and these systems are together called urino-genital system. The excretory and genital systems work independently.

9.1. Excretion in fishes

The functions of excretion and osmoregulation are closely related and are performed by gills and kidneys in fishes. Although the gills are chiefly the respiratory organs, they are also important as excretory and osmoregulatory organs. Kidneys play the most important part in the excretion of nitrogenous wastes and in maintaining the water-salt balance (homeostasis). A kidney consists of a large number of tubules or nephrons which develop from infront backwards. The tubules of the anterior region develop and become functional in early life and constitute the pronephros. Those of the more posterior region develop and become functional in later life and form the mesonephros. The ancestral craniate probably had a complete set of segmental tubules in the trunk region forming an archinephros and opening into an archinephric duct. The archinephros became differentiated into pro meso, and meta-nephros. A functional pronephros is found in fishes and is later replaced by mesonephric tubules. These open into the pronephric duct which therefore becomes the mesonephric duct. The tubules of the more anterior region of mesonephros have a tendency to become reduced and even degenerate becoming converted into a lymphoid organ. However the more posterior tubules take up the posterior tubules behind the pronephros, in fish and amphibia are also known as opisthonephros.

9.1.1. Structure of the kidney

The kidneys are paired, elongated structures placed above the alimentary canal and are close to the vertebral column. The teleostean kidney is generally divided into two portions, the head kidney and the trunk kidney, but in many species these regions can not be distinguished by external examination. Generally there are no conspicuous differences in shape between the two sexes. The marine teleostean kidney can be divided into five types (Fig.9.l).

1. The two kidneys are completely fused and there is no distinction between the trunk and head kidney as in clupeoideae.
2. The middle and posterior portions of the kidneys are fused. There is a clear distinction between the trunk and head kidney, as in the marine catfishes (piotosidae) and eels (Anguillidae).
3. Only the posterior portions of kidney are fused The anterior portion is represented by two slender branches, head and trunk kidney are clearly distinguishable. Example : most marine fishes belonging to the Belonidae, Scopelida, Mugilidae, Scombridae, Carangidae, Cottidae and Pleuronectide.

4. Only the exterme posterior portion of the kidney is fused. There is no distinction of head and trunk kidney, as in Syngnathidae (Sea horse *and* pipe fishes.
5. The two kidneys are completely separated as in Lophiidae.

The fresh water teleostean fishes possess kidneys of the first three types. Completely fused kidneys of type 1 are found in Salmonidae (salmon and trout). The cyprinidae (carps) have kidneys of type 2, i.e., their middle and posterior portions are fused. Their anterior free lobes form the head kidney, while the fused portions constitute the trunk kidney. In many species, the trunk kidney is broad in the middle and gradually narrows in the hinder part (e.g. *Cirrhina, Labeo* and *Barbus).* Fishes belonging to Cyprinodontidae, Gasterosteidae and Cottidae posses kidneys of type 3, in which only the posterior poriton is fused. In some species e.g., *Mystus, Amiurus, Dactylopterus* and *Anus,* the head kidney is completely separate from the remaining part.

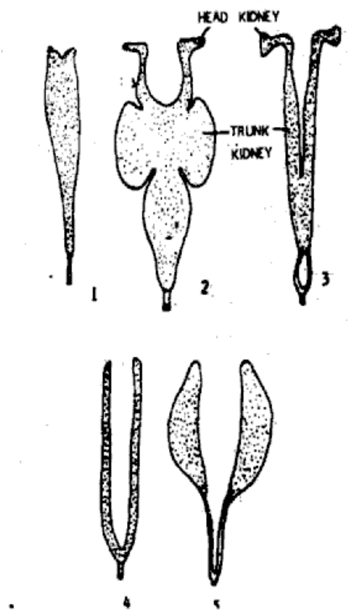


Fig. 9.1. Teleost kidneys

Two mesonephric ducts are usual present and each runs along the outer border of the corresponding kidney. They are clearly visible in the middle and the posterior regions of the kidney. The two ducts always fuse to form the common duct. The fusion may occur at the posterior end of the kidney (e.g.. *Mystus)* or at some point between the kidney and the urinary papilla. They remain separate till they open into the urinary bladder as *Labeo* and *Cirrhina.* The urinary bladder may be a simple enlargement of the common mesonephric duct, or it may be a simple enlargement of the common mesonephric duct, or it may be a distinct sac-like structure on one side of the common mesonephric duct *(Barbus* and *Mystus).* The urinary bladder usually opens to the exterior by a common urinogenital aperture in the male fish and by a separate urinary pore in the female fish. The urinogenital aperture of the male may be situated at the tip of a papilla. Generally the urinary and the genital apertures are situated on the external surface, but in some species a small integumentary cloaca is formed and the ducts open into it. A pair of abdominal pores may also be present on either side of the genital pore of some species. The abdominal pores are special openings from coelom to the exterior and appear to be of no significance and are of doubtful function.

9.1.2. Histology of kidney

Histologically, the trunk kidney is made up of a large number of nephrons, each consisting of a renal corpuscle or the Malpighian body and the tubule. The intertubular space is full of lymphoidal tissue which is unevenly distributed (Fig.9.2a). The head kidney (Fig.9.2b) is generally made up of lymphoid, hematopoietic, interrenal and chromaffin (supra renal) tissue and is devoid of renal corpuscles and the tubules. In some species however a few nephrons and collecting ducts may be present in the lymphoid tissue of the head kidney, but the glolmeruli and the renal corpuscles are usually absent. The head kidney is therefore, not excretory in function. It is derived from the pronephric hematopoetic tissue but in some teleosts, the mesonephros grows forwards extending into the head kidney. The real elements found in the head kidney of some teleosts are very likely mesonephric.

A typical nephron of a fresh water teleost consists of the following parts:

a) a renal corpuscle containing a well vascularised glomerulus.

b) a ciliated neck region of variable length, connecting the renal corpuscle with the tubule.

c) an initial proximal segment with prominent brush border and numerous prominent lysosomes.

d) a second proximal segment with numerous mitochondria but less well developed brush border.

e) a narrow ciliated intermediate segment which may be absent in some species.

f) a distal segment with relatively clear cells and elongated mitochondria.

g) a collecting duct system.

The renal corpuscles are numerous, generally spherical in shape and each contains a highly vascular glomerulus in the fresh water fishes. In the marine fishes, however, there is a great variation in number, shape and size of the renal corpuscles. Large and well vascularised renal corpuscles are rarely found. The kidneys of many marine fishes generally have less well developed glomeruli which are poorly vascularised and are probably non-functional (e.g.; *Theraponjarbua, Arius, Myoxocephalus).* Only a few medium sized glomeruli may be present along with the smaller ones. In some species, the glomerulus has a central avascular core surrounded by capillary loops which effectively reduces its functional area (e.g. *Chirocenturs, Tricanthus. Myoxocepha!us).* in the goose fish. *Lophius,* the glomerulus becomes non-functional in the adult, by losing its connection with the tubule. A number of marine fishes *(Porichthys notatuy, Hippocampus* and *Syngnathus)* have completely aglomerular kidney. A typical nephron (Fig. 9.3) of a marine glomerular teleost consists of:

i) renal corpuscle containing the glomerulus.
ii) a neck segment which may be very short.
iii) two or three proximal segments.
iv) a variably present intermediate segment.
v) collecting tubule.

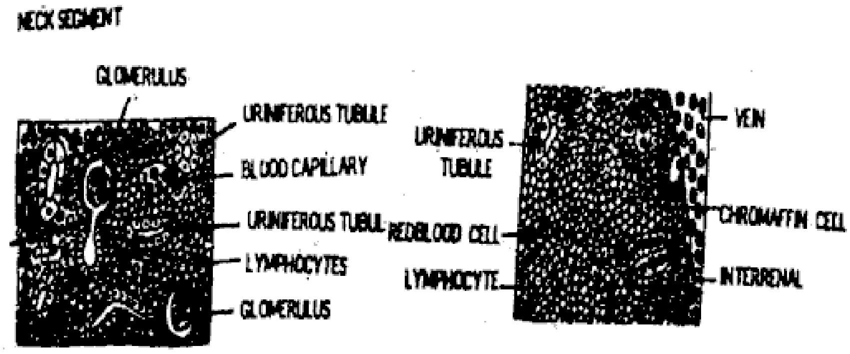


Fig. 9.2. T.S. of trunk (a) and head (b) kidneys.

A distal segment is probably absent.

The glomerulus and the Bowman's capsule together act as ultra filters where the blood is filtered under high pressure. The excretory fluid flows through the renal tubule and is driven by the net filtration pressure, and the movement of the long cilia of the neck segment and cilia of the cells cf other segments. Na^{++} and Cl^{-} are almost completely reabsorbed from the ultrafiltrate. Glucose is also largely removed from the filtrate. The kidney of fresh water fishes may also serve as an important excretory organ for minor nitrogenous compounds such as creatine and uric acid, but gills are the principal organs through which NH_3 and urea (major nitrogenous waste products) are removed from the body. In marine fishes, the kidney takes up function of removing magnesium and sulphate which enter the intestine of the specific fish along with sea water. Other ions like Na^{++}, Cl^{-}, K^{+} and Ca^{++} are also removed. Urine flow is much greater in fresh water teleosts than in the marine. The process of filtration and reabsorption are under the control of various harmones.

Osmoregulation in teleost fishes, whether they live in freshwater or sea, its physiological activity is very closely related to their survival, yet inspite of the important of osmoregulation surprisingly little is known about how fish deals with physiological problems inherent in living in hypoosmotic and hyperosmotic environments. The ability of some fish (e.g. *salmon*) to regulate in both environments during migration is of great interest.

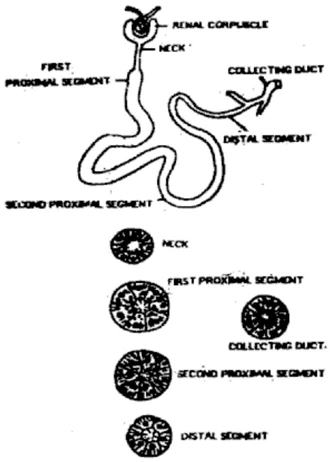


Fig. 9.3 Nephron and its cross sections of a teleost.

In fishes the kidneys plays an important role in osmoregulation, but major portion of the osmoregulatory functions are carried out by other organs such as the gills, the integument and even the intestine.

Osmoregulation may be defined as the ability to maintain a suitable internal environment in the face of osmotic stress As a consequence there is always difference between the optimal intracellular and extracellular concentrations of ions. In the fish body, number of mechanisms take place to solve osmotic problems and regulate the difference. Of which most common are i) between intracellular and extracellular compartment ii) between extracellular compartment and the extenal environment. Both are collectively called 'osmorëgulatory mechanisms', a term coined by Rudolf Hober.

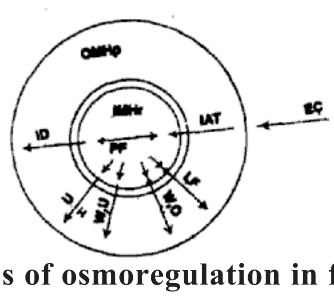


Fig. 9.4. Principal process of osmoregulation in fresh water fishes. EC. ecological condition; I, ion; IAT, ion active transfer; ID, ion diffusion

IMHr, inner medium hypertonic; 0, osmosis; 0MPH, outer medium hypotonic; PF, physiological factor; U, urine; W, water.

The osmotic exchanges that take place between the fish and its environment may be of two types i) obligatory exchange — It occurs usually in response to physical factors over which animal has little or no physiological control and ii) regulatory exchange — these are the exchanges which are physiologically well controlled and help in the maintenance of internal homeostasjs.

9.2. 1. Factors affecting obligatory exchanges

9.2.1.1. Gradient between the extracellular compartment and the environment

The greater the ionic difference between the body fluid and external medium, the greater the tendency for net diffusion to low concentrations. Thus, a bony fish in a sea water is affected by the problem of losing water into the hypertonic sea water.

9.2.1.2. Surface/volume ratio

Generally the animal with small body size desicates (or) hydrates more rapidly than a larger animal of the same shape.

9.2.1.3. Permeability of the gills

Fish gills are necessarily permeable to water and solutes as they are the main site of exchange of oxygen and carbondioxide between the blood and the water. Active transport of salts also takes place in the gills. Euryhaline fishes (who have tolerance of wide range of osmolarity) are well adapted to salt water by reduced permeability to water.

9.2.1.4. Feeding

Fishes take water and solute along with the feeding. A gill takes high quantity of salt than water at the time of feeding on seashore invertebrates, these fishes therefore must have some special device to excrete excess of salt However a fresh water fish ingest large amount of water than salt and thus needs special means of salt conservation.

9.2.2. Osmoregulators and osmoconjirmers

Osmoregulators are those animals who can maintain the internal osmolarity different from the medium in which they live. The fishes are generally true osmoregulators maintaining the concentrations of body fluid. In these fishes which migrate between fresh and salt waters, the changing osmotic stress due to environmental changes is overcome with the help of endocrine mechanism.

Osmoconfirmers are those animals who are unable to control osmotic state of their body fluids but confirms to the osmolarity of the ambient medium. Majority of fishes either live in freshwater or in saltwater. Due to various physiological processes, metabolic wastes are removed from the body' in vertebrates by gut, skin, and kidneys. But in fishes and aquatic animals their gills and oral membranes are permeable both to water and salts in marine environment salt is more in water against the salt inside the body fluid hence water moves out due to the process of osmosis'. The 'osmosis' may be defined as "if two solutions of different concentrations are separated by a semipermeable membrane, the solvent from the less concentrated part will move through the membrane into more concentrated solution. Hence to compensate the loss of water marine fishes drink water. The salt will enter the body due to concentration gradient and so salt will be more inside the body. On the other hand, in freshwater fishes, the salt will go out to the environment as the salt concentration will be more inside the body fluid. The water will move inside the body due to osmosis through partially permeable membrane. This means solvent will pass into more concentrated solution, but solute will also pass in the opposite direction. There will be. however, a difference in the rate dependent upon the relative permeability for two types of molecules usually solvent pass rapidly.

9.2.3. Osmoregulation in freshwater fishes

The body fluid of freshwater fishes in generally hyperosmotic to their aqueous medium. Thus they are posed with two types of osmoregulatory problems.

1. Because of hyperosmotic body fluid they are subjected to swelling by movement of water into their body owing to osmotic gradient.
2. Since the surrounding medium has low salt concentration, they are faced with disappearence of their body salts by continual loss to the environment. Thus freshwater fishes must prevent net gain of water and net loss of salts. Net intake of water is prevented by kidney as it produces a dilute, more copious (i.e. plantiful hence dilute) urine (Fig.9.5)

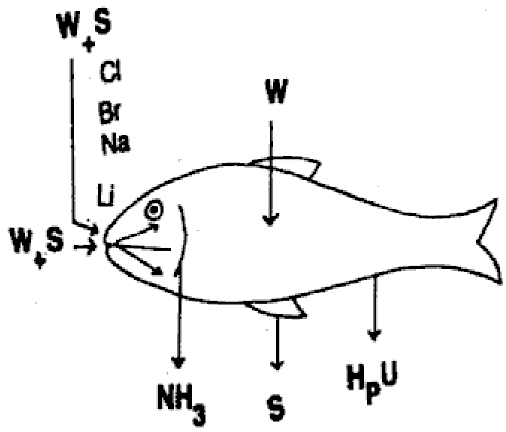


Fig.9.5. Osmoregulatory inflow and outflow of salts and water in a fresh water fish. HpU, hypotonic urine, S, salt , W, water, W+S, water and salt

The useful salts are largely retained by reabsorption into the blood in the tubules of kidney and a dilute urine is excreted. Although some salts are also removed along with urine which creates torrential loss of some biologically important salts such as KCI, Nacl, $CaCI_2$ and $MgCI_2$, which are replaced in various parts. Freshwater fishes have remarkable capacity to excrete Na + and Cl- through their gills from surrounding water having less than 1 mm/L NaC1, even though the plasma concentration of the salt exceeds 100mMIL Naci. Thus NaC1 actively transported in the gills against a concentration gradient in excess of 100 times. In these fishes the salt loss and water uptake are reduced by the integument considerable with low permeability or impermeability to both water and salt also by not drinking the water (Fig.9.6)

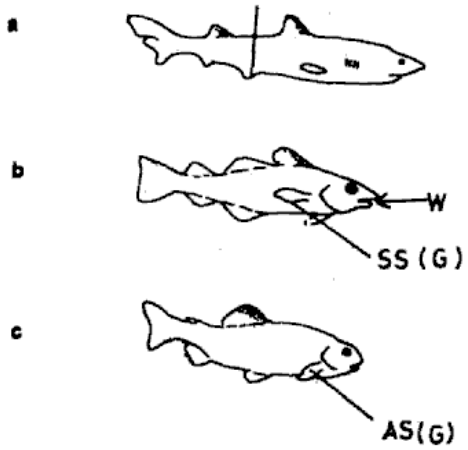


Fig.9.6. Exchange of water and salt in some fishes.(a)Marine elasmobranch does not drink water and has isotonic urine.(b)Marine teleost drinks water and has isotonic urine.(c)Fresh water teleost drinks no water and has strongly hypotonic urine. ASG, absorbs salt with gill;Hr NaCI(RG), hypotonic NaCI from rectal gland; SS (G), secretes salts from gill; W, water.

9.2.4. Osmoregulation in marine water fishes

In marine fishes, the concentration of body fluid and marine water is almost similar. Therefore, they do not require much energy for maintenance of osmolarity of their body fluid. The classic-example is hagfish, Myxine whose plasma is isosmotic to the environment. Hagfish maintains the concentraion of Ca^{++}, Mg^{++} and SO_4 significantly lower and Na^+ and Cl^- higher in comparision to seawater. Other marine water fishes such as sharks. rays, skates and primitive coelacanth Latimaria have plasma which is isomotic to seawater. They differ from the hagfish in having capacity to maintain very lower electrolyte (i.e inorganic ions) concentrations. They also have difference with organic osmolyte (i.e. inorganic ions) concentrations. They also have difference with organic osmolytes like urea and trirnehtylamine oxide. Kindeys of coelacanth and elasmobranchs excrete excess of inorganic salts such as NaCl. Also rectal gland located at the end of alimentary canal takes part in the excretion of NaCl. Modern bony fishes (marine teleosts) have the body fluid hypotonic to seawater, so they have tendency to lose water to the surroundings particularly from gill via epithelium. The lost volume of water is replaced by drinking salt water (Fig. 9.6). About 70-80% sea water containing

NaCl and KCl enters the blood stream by absorption across the intestinal epithelium. However, most of the divalent cations like Ca^{++}, MG^{++} and SO_4 which are left in the gut are finally excreted out. Excess salts absorbed along with sea water is ultimately removed from the blood with the help of gills by the active transport of Na^+, Cl sometimes K+ and eliminated into the seawater. However, divalent ions are secreted into the kidney (Fig. 9.7).

Thus urine is isosmotic to the blood but rich in those salts, particullarly Mg^{++}, Ca^{++} and SO_4 which are not secreted by the gills. Combined osmotic action of gills and kidney in marine teleosts resulted in the net retention of water that is hypotonic both to the ingested water and urine, By using similar mechanism some teleost species such as the salmon of pacific northwest maintain more or less constant plasma osmolarity inspite of being migratory between marine and freshwater environment.

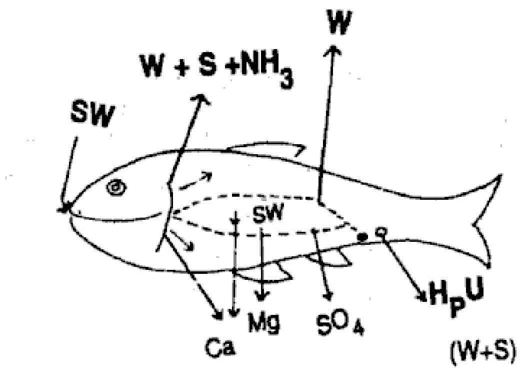


Fig 9.7. Osmotic regulation in marine boney fishes. HpU, hypotonic urine: SW, sea water, W+S+NH_3, water, salt and ammonia, W. water.

9.2.5. Control of osmoregulation

The concentration and dilution of urine is controlled by hormones, which affects the rate of renal filteration by changing the blood pressure and thus control the quantity of urine. Hormones also influence the rate of diffusion and absorption across the gill epitheliurn. Thyroid gland and suprarenal bodies secrete adrenocortical hormones which control osmoregulation in fishes.

SUMMARY

The excretory organs of fishes are mesonephtic kidneys. Kidneys are located in the abdominal cavity close to. the vertebral column. Kidney is made up of large number of nephrons. Each nephron consists of a renal corpuscle with a glomerulus, neck proximal segment, distal segment and collecting duct. Fishes are ammonotelic animals which excrete ammonia. Osmorgulatory mechanism is well developed in fishes. In freshwater fishes, osmatic pressure of body fluid is higher than that of surrounding water and water diffused into the body through gills, oral membranes. Freshwater fishes produce a large amount of hypotonic urine. In marine fishes, the salt concentration is high in surrounding water when compared to body fluids. They excrete concentrated urine. Elasmobranchs retain urea and TMO in blood.

Questions

1. Describe the excretory system of fishes.
2. Discuss the osmoregulation in freshwater fishes.
3. Give an account on osmoregulation in marine fishes.
4. Explain the structure of nephron.

10

REPRODUCTIVE SYSTEM OF FISH

Reproduction is the process by which animals increase their population to continue their races in the nature. There are four types of reproduction monosexuals — bisexual, Hermophrodites and parthenogenetic. Reproductive system mainly consists of reproductive organs known as gonads, (testes and ovary), the gamets (sperms, ova). Fishes reproduce by several methods and are generally bisexual. Some species are hermophrodite and even parthenogenetic reproduction occurs in a few cases. Some fishes are highly specialised for breeding and show interesting development of parental care comparable with higher animals. The sperms and the eggs develop in separate gonads except in some species of Sparidae and Serranidae, which are true hermophrodites and the eggs and sperms develop in the same gonad and self fertilisation takes place. However, hermophrodite gonads sometimes occur in other species also. Parthenogenetic development takes place in *Poeciliaformosa,* in which the sperms simply induce the egg to develop, but take no part in fertilization.

10.1. Sexual dimorphism

The characteristics of sexual difference or sexual dimorphism that enables identification of the sexes are classed as primary and secondary. Primary sexual characters are concerned with reproductive organs, the testes in males and overies in females. The primary sexual characters often require dissection for their discrement, which makes the secondary sexual characters often more useful, although sometimes not so possitive.

Some species show well marked sexual dimorphism, which may be of two kinds:

(i) Some species possess structural peculiarities directly related with fertilization of ova. These are in the form of copulatory organ in the male for introducing the milt into the body of the female, as the claspers in sharks.

(ii) Some species possess structural peculiarities that are not connected with sexual union or fertilization, but are related with courtship, or fight among rival males.

In most fishes excepting the elasmobranchs and a few teleosts, fertilization is external in water. In Chondrichthyes the eggs are fertilized within the the body of the female, and the males are provided with claspers or myxopterygia for transferring the sperms into the body of the female (fig. 10.2). Each clasper has an internal cartilaginous skeleton and a groove or canal runs along its whole length, leading from a glandular sac at its base. During copulation the two grooves or canals close to each other, and both the claspers are thrust into the cloacal aperture of the female. The Holocephali possess an additional clasper in mate. Distinct marks or scratches have often been observed on the skin of the female. Chimaera, at the base of the dorsal fin. These are believed to be caused by the frontal claspers of the male, who appears to make use of them to retain its hold on the female, while curling its body round her Among teleosts an intromittent copulatory organ is present only in those species in which the fertilization is internal. The simplest condition is seen in *Mystus seenghala* in which a conical genital papilla is present and fertilization is external. In Cyprinodonts (e.g., *Gambusia*) the vas deference is produced into a tube upto the end of the anterior rays othe anal in (Fin 10.2). In the Poecifidae also, the males are provided with complicated intromittent organ developed -from modified anal fin rays, ending in curved hooks,spines and barbs. The male four- eyed fish, Anableps, is also provided with a special tube for copulation. In some marine Ophididae, a penis-like intromittent organ is present in the male. In the male white sucker, *Catostomus cominersoni,* the enlarged anal fin serves to transfer the watery milt. In clasping cyprinodont, *Xenodexia*, the pectoral fin is modified for use in mating by holding the gonopodium in position for insertion into the oviduct or female.

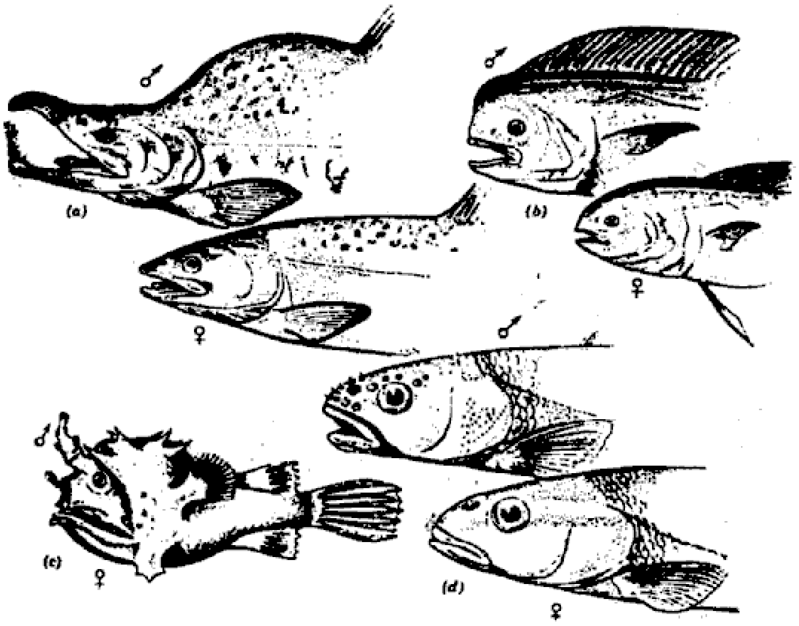


Fig. 10.1 Sexual dimorphism in fishes. a. Pink salmon, b. Dolphin, c. Angler fish, D. creak chub.

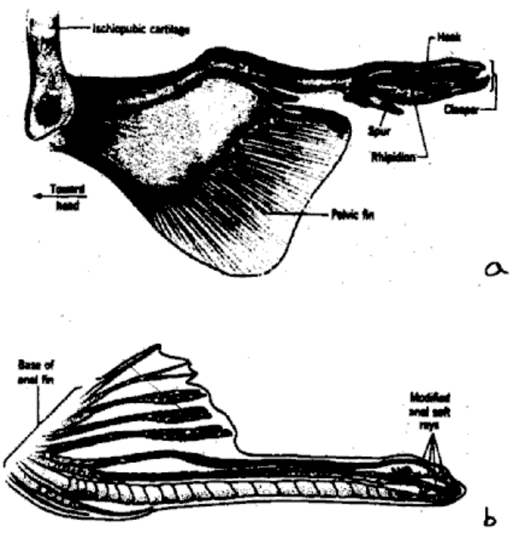


Fig. 10.2 Male intermittent organs. a. Shark, B. Gambusia

In several species of fishes, sexual differences are not related with copulation between male and female, and are generally well marked during spawning season. In most of the teleosts, females are larger in size with enlarged rounded belly during the breeding season. A common secondary sexual character is the brighter colour of the body and fins in the male, as in the Cyprinodontidae, Cichlidae, Labyrinthidae and Labridae. In a number of cyprinids, the male becomes much brighter in colour during the breeding season. The male Bow-fin (*Amia*) has a characteristic black spot at the base of the caudal fin. Some species show differences in the shape of their fins, and the rays may be prolonged to form long feelers in the male. In some catfishes of the family Loricaridae, the sexes differ in shape of their snout, mouth, lips, and in the development of bristles on their head. In some flat fishes, first few fin rays of the dorsal fin, as well as some rays of the pelvics are prolonged to form lengthy filaments in the male. In the flat fish *Bothus*, males have spines on snout; eyes are much wider than in the females, and the rays of the pectoral fin on the coloured side are generally elongated. In the male sword fish, *Xiphophorus*, the lower lobe of the caudal fin is drawn out to form a long blade-like structure. In another species, Mollenesia, the dorsal fin of the male is enlarged to form a sail-like structure, bearing brilliantly coloured ocelli.

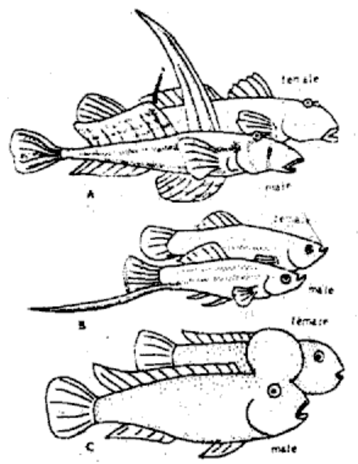


Fig. 10.3. Sexual dimorphism in a. Drogonet, b. Sword fish, c. Lion-head chichilid.

The ma1e in many cyprinids develop horny tubercles on the head and body, specially during breeding season. In male Salmon, the snout and the lower jaw protrude out, and the lower jaw is turned upward looking like a hook (fi.l0.l). Some male cichlids,sparids and labrids develop a large fleshy hump on the fore head. In some gobies and blenies the males possess enlarged canines. Domed forehead and interior position of the dorsal fin are found in the male klphin ***(Caryphaena).*** Parastic male is attached to female in the deep sea igler fish (photocormus). Nuptial tubercles are found on the snout and forehead of male in creek chub ***(Semotilus).***

10.2. Reproductive organs

The gonads develop from the coelomic epithelium. The ovaries may be naked as in the Elasmobranchs, Dipnoi, Chondrostei and Amia. This is called 'gymnovarian' condition and is primitive. Here, the ova are discharged into the coelomic cavity and pass out through the anteriorly placed oviducal funnel of the Mullerian duct. In Lepidosteus and teleosts. the ovaries become enclosed in coelomic sacs and the lumen of the ovary is continued into the oviduct. This is called the 'cystovarian' condition, and is secondary. In a few teleosts belonging to the Salmonidae, Galaxidae. Hyodontidae, Notopteridae and Osteoglossidae the oviducts degenerate partly or completely and the ova are shed into the coelomic cavity and then pass out through pores or funnels. In the eels (Anguillidae) both male and female gonoducts degenerate losing all connection with the gonads.

10.2.1. Male reproductive organs

The male fish consist of a pair of testes which are elongated and flattened structures, situated on either side, ventral to the kidneys in the posterior region of the abdominal cavity. The testes remain attached to the body wall and the air bladder by means of mesorchia. They may or may not be equal in size The two sperm ducts join posteriorly to open into the urinogenital papilla. The testes may show indentations along their margin which become prominent during the breeding season.

In a few species, the anterior three-fourth part of each testis is functional and the pdosterior one-fourth is sterile as in *Mystus seengha/a* and Tor tor. The posterior region of the testis in these species is structurally and fiinctionally different from the anterior region. Various stages of germ cells are present in the anterior and middle part of the testis whose function is to produce sperms but the posterior region consists of sterile empty lamellae and probably serves for the storage of sperms during the breeding season. In some species, the entire testis is functional and serves to produce sperms. Paired glandular structures called the seminal vesicles are present as outgrowths of the hinder ends of the vasa deferentia in some teleosts as *Clarias batrachus, C. lazera, Hereropneustesfossilis.* However, in some other species *(Rita rita, Mystus vitattus)* the posterior part of the testis is glandular. The seminal vesicles are secretory in nature and show periodical changes in correlation with the testicular cycle. The function of the fluid secreted by the seminal vesicles is not known and it has been suggested that the fluid may serve to keep the sperms in an active but viable condition or it may help in nourishing the sperms.

10.2.1.1. Histology of the tests

The structure of the testis is variable in teleosts, and two types have been recognised: (i) lobular type, and (ii) tubular type. Most teleosts have typical lobular type of testis, consisting of a large number of seminiferous lobules which are closely bound together by a thin layer of connective tissue. The lobules are of various sizes and are highly convoluted structures, separated from each other by a thin connective tissue stroma. The walls of the lobules are not fined by a permanent germinal epithelium. The lobules open into a spermatic duct which is generally formed by a secretory epithelium. The lobules of the testis may be surrounded by lobule boundary cells which resemble connective tissue cells. The spaces between the lobules are filled with connective tissue, blood capillaries and interstitial cells.

Within the lobules, (fig. 10.4 a and b) the primary spermatogonia undergo mitotic divisions to produce cysts containing spermatogonial cells. As maturation proceeds, cysts enlarge and finally rupture to liberate sperm into the lumen of the lobule, which continues into the sperm duct. The second tubular type of testis is found only in Atheriniformes (e.g., *Poecilia reticulata).* In this type the tubules are arranged regularly between the external tunica propria and the central cavity. There is no structure comparable to lobular lumen in this type. The spermatogonia are restricted to the distal end of the tubule, immediately below the tunica albuginea.

During the growth period, the resting germ cells become active and divide, and are transformed into sperm mother cells or nests of spermatogonia. The spermatogonia are large, spherical cells containing a large round, centrally placed nucleus, having a distinct nucleolus. The cytoplasm of these cells does not take much stain. These cells multiply and give rise to primary spermatocytes which are smaller in size than the spermatogonia and possess darkly staining nucleus. These undergo various stages of division during which the chromatin matter is visible as a fine reticulum and is later thickened on one side of the nucleus. The secondary spermatocytes are smaller in size and their chromatin material is seen in the form of a thick clump. They last for a short period only and divide to give rise to spermatids which are still smaller in size and possess an elliptical nucleus that is deeply stained with hematoxylin. The spermatids give rise to sperms which are further reduced in size. The process of metamorphosis of spermatids into sperms is called 'spermiogenesis'. At the end of spermiogenesis, the seminiferous tubules are packed with sperm masses.

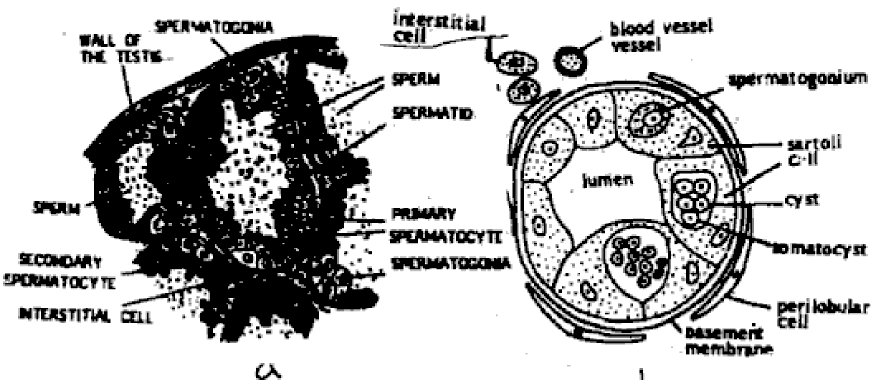


Fig. 10.4.a.T.S. mature testis. b. T.S. of lubule.

10.2.1.2. Interstitial and the lobule boundary cells

The interstitial cells are present in several species of teleosts, and Craig-Bennet (1931) has correlated changes in these cells with the secondary sexual characters of *Gasterosteus aculeatus* suggesting them to be the source of male hormones. Typical interstitial cells or Leydig cells have been identified in several teleosts. These cells are present singly or in small groups between the lobules. Electron microscopic studies have shown that these cells resemble steroid producing cells. The interstitial cells of teleosts are homologous with the Leydig cells of mammals, and produce male hormones.

The lobule boundary cells are not present in the interstices but fie within the walls of lobules, and-stain positively for lipids and cholesterol. The lobule boundary cells are repørted to be present in those teleosts in which interstitial cells are not present, although many teleost ar said to possess both the cell types. The lobule boundary cells are beIived to be homologous with the Sertoli cells. The Sertoli cells of mammals are supporting cells. Inteleosts, the lobule boundary cells or Sertoli cells may perform supporting or nutritive function. Studies on the ultra structure of the lobule boundary cells of some teleosts, suggest their involvement in phagocytosis of residual bodies and degenerating sperm cells, and in the transport of metabolites.

10.2.2. Female reproductive organs

The ovaries are paired elongated sac-like structures lying in the abdominal cavity, ventral to the kidneys. They are attached to the body wall by means of the mesovarium. The anterior ends of the two ovaries are free but their caudal ends may become united into one. The hinder end of each ovary is continued posteriorly into a short oviduct. The two oviducts fuse and open to the exterior by a separate genital aperture or by a common urinogenital opening. Generally, both the ovaries are equal in size, but occasionally they are unequal also. They are thin, flaccid and traslucent when immature, but on maturity, they become enlarged and lobulated, while the ripe ova are seen bulging out. The wall of the ovary is fairly thick during the non-breeding season but becomes thin and highly vascular during the spawning period. It consists of three layers (i) an outer-most thin peritoneum, (ii) a thicker tunica albuginea made up of connective tissue, muscle fibres and blood capillaries, (iii) the innermost layer is the germinal epithelium which projects into the ovocoel in the form of lamellae. These ovigerous lamellae are the seat for the development of oocytes. which are visible in various stages of development. The germ cells or oogonia are found in clusters in the lamellae and probably originate from the germinal epithelium. An oogonium has a large nucleus, and a thin layer of ooplasm which is chromophobic. Each oogonium passes through a number of maturation stages to become a ripe ovum. Several of these stages may be present at the same time in the ovary. As the oogonium increases in size, there is increase in the quantity of ooplasm which is stained with basic dyes.

10.2.2.1. Oocyte stages

The developing egg is known as an occyte of which several stages can be recognised in the ovary. (fig. 14.6). These are:

10.2.2.1.1 *Oocyte I.*

This is larger than the oogonium, spherical in shape and with a central nucleus, having 2 or 3 nucleoli. The cytoplasm is basophilic.

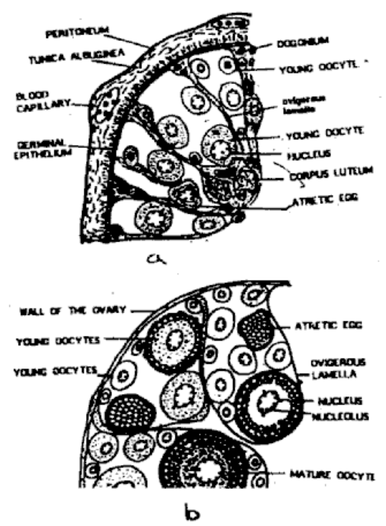


Fig. 10.5. T. S. of ovary, a. immature stage, b. mature stage.

10.2.2.1.2. Oocyte II.

There is further increase in the size of the oocytes, number of nucleoli and basophilia of the cytoplasm. Several small nucleoli of various sizes are seen along the periphery of the nuclear membrane. Many oocytes at this stage, possess a yolk nucleus, lying close to the nuclear membrane in the cytoplasm. Later, the yolk nucleus moves away towards the periphery of the oocyte.

10.2.2.1.3. Oocyte III.

This is still larger in size, and is distinguished by the appearance of a thin layer of folicular cells around the cytoplasm, a few nucleoli pass out of the nuclear membrane, and are seen in the cytoplasm of the oocyte.

10.2.2.1.4. Oocyte IV

There is further increase in the size of the oocyte and a large number of small, clear vacuoles called the yolk vesicles, appear in the periphery of the ooplasm. The vesicles appear empty in the early stage and are not stainable. Many oocytes show an undulated nuclear membrane, and the nucleoli enter into the pockets of the nuclear membrane, and pass out into the ooplasm.

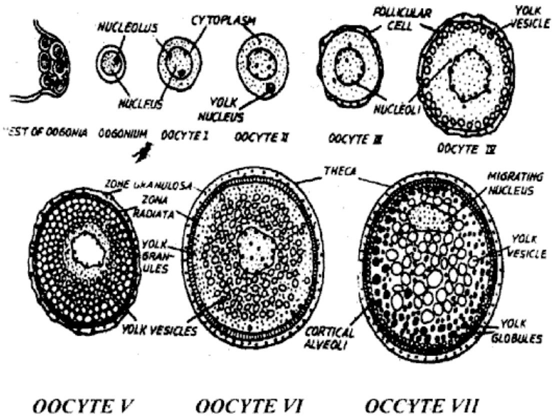


Fig. 10.6. Stages in the maturation of an oocyte.

10.2.2.1.5 Oocyte V.

As the oocyte grows further, the yolk vesicles increase in number and fill the entire ooplasm. A vitelline membrane of zona radiata is also clearly visible, between the ooplasm and the follicular layer or the zona granulosa. Nucleolar extrusion continues at this stage.

10.2.2.1.6. Oocyte VI.

This is characterised by the appearance of yolk in the form of minute granules in the extravesicular ooplasm. They appear first in the peripheral region and accumulate there in large numbers. The yolk granules then proceed centripetally, till the whole-ooplasm becomes impregnated with them. The yolk granules fuse to form larger globules, and the oocyte is of considerable size. A thin layer of fibroblasts, known as theca is also distinguishable outside the follicular layer.

10.2.2.1.7. Oocyte VII.

There is heavy deposition of yolk globules which are fairly large in size. The yolk vesicles also fuse and become large. The nucleus migrates gradually towards the periphery. Some yolk vesicles are pushed towards the periphery of the egg and form cortical alveoli.

10.2.2.1.8. Ripe egg.

A ripe egg is largest in size, yellowish in colour and translucent. It is full of large amount of yolk globules and yolk vesicles may lie scattered in it. The nucleus is generally not visible in the ripe egg. An ovary contains several ripe eggs at a time during the spawning period. A mature egg is surrounded by an external layer of theca, followed by the follicular epithelium (zona granulosa), and the innermost, zona radiata. The zona granulosa is a syncytial layer having deeply staining nuclei. The theca is sometimes differentiable into theca externa and theca interna. The function of the follicular epithelium in fish oocyte, is controversial. The granulosa cells are believed to be responsible for the deposition of yolk in the developing ovum, and for its removal in ova which degenerate and become atretic. In addition to these, the granulosa cells may also be responsible for the secretion of ovarian hormones.

10.3. Maturation and spawning

Both male and female gonads undergo marked cyclic morphological and histological changes before reaching full maturity and becoming ripe. This is called maturation of the gonads. Most of the fishes exhibit seasonal cycle in the production of gametes. The expulsion of gametes from the body into the surrounding water is called ‘spawning resulting in fertilization. Fish spawns during a specified period which depends upon several factors. The period during which the gonads attain full maturity and spawning takes place in the population is called the breeding season of the species. After spawning, a new crop of germ cell is formed, which gradually mature to become ready for the next season.

10.3.1. Maturity stages in the male fish

Seasonal morpho-histological changes are seen in the testes of teleosts and the cycle can be divided into different phases as mentioned below:

10.3.1.1. Resting phase of early immature condition

The testes are thin, slender, translucent and pale in colour. Histologically, seminiferous tubules are small in size and full of spermatogonia.

14.3.1.2. Late immature phase

The morphological appearance is similar to the previous phase, except that there is a slight increase in the weight and volume of the testes. Histologically, slow mitotic activity is seen, and the spermatogonia start dividing.

10.3.1.3. Maturing phase

There is an increase in the weight and volume of the testes, which look more vascular and opaque. Histologically, intense spermatogenesis is seen during the later part of this phase. Spermtogonia decrease in number, and numerous primary and secondary spermatocytes are visible.

10.3.1.4. Mature phase

During this period, the testes show a marked increase in weight and volume. They are turgid and pink in colour. Milt oozes out on pressing the abdomen. Histologically, the seminiferous tubules are larger in size and full of sperm. Spermatogonia are few, and all stages of spermatogenesis can be seen in various lobules.

10.3.1.5. Spent phase

The testes become flaccid due to excessive discharge of sperm. The weight and volume is considerably reduced and the testes again become thin, slender and translucent. Histologically, empty and collapsing seminiferous tubules are seen, some of which contain residual or unexpelled sperm. After a brief period of rest, the testes start the cycle again. The spermatogonia are the only germ cells during resting phase, but are present throughout the year, although their number is reduced during the spawning period. These are known as 'resting germ cells' and are believed to give rise to the next generation of sex cells.

10.3.2. Maturity stages in the female fish

On the basis of shape, size, colour of the ovary and other histomorphological features, at least six maturity stages can be recognised. (Fig. 10.7)

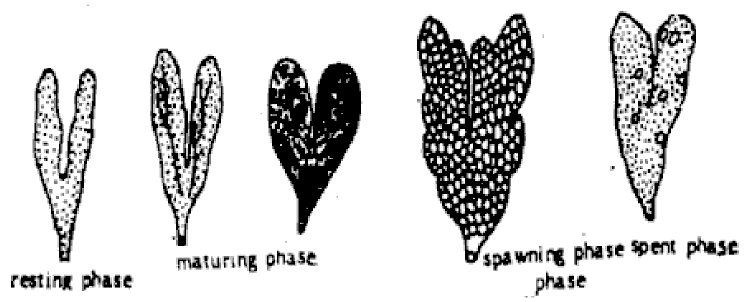


Fig. 10.7. Seasonal changes in the ovary.

14.3.2.1. Resting phase (Immature)

The ovaries are small, thin, thread like, translucent, pale or dirty white in colour with inconspicuous vascularisation. The ovaries occupy only a small part of the body cavity and ova are not visible to the naked eye. Histologically, the ovary shows ovigerous lamellae, having nests of oogonia. and immature oocytes in the stage I and II are visible under a microscope.

10.3.2.2. Early maturing phase

Ovaries become slightly larger, thicker, opaque and are light yellowish in colour. There is an increase in the weight of the-ovary and they occupy nearly 1/2 of the body cavity. Histologically, oocytes in stage Ill and IV are present in large number.

10.3.2.3. Advanced maturing phase

There is a further increase in the weight and volume of the ovaries, which have a deep yellow colour and occupy 2/3 to 3/4 of the body cavity. Vascular supply increases and the blood capillaries become conspicuous. Immature oocytes are reduced in number while stage IV and stage V oocytes are present in large number. A few stage VI oocytes may also be seen.

10.3.2.4. Mature or prespawning phase

The ovaries are further enlarged occupying almost the entire body cavity. They are turgid, deep yellow in colour and a large number of spherical ova are visible to the naked eye through the thin ovarian wall. The blood supply increases considerably. Both translucent and opaque ova are present, and the ovaries attain their maximum weight. The fish becomes gravid due to ripe ova tucked inside, and the abdomen becomes round. The ova are not discharged till the envionmental conditions become favourable. Histologically, a large number of ova in stage VII, and ripe eggs are seen in the ovary.

10.3.2.5. Spawning phase

Ovaries are very much enlarged, occupying the entire body cavity. They are turgid and yellow in colour with a large number of traslucent eggs. Ovarian wall is very thin, almost transparent. Eggs are present in the oviduct also, and the fish spawns a number of times during this period. The ovary is now said to be in running phase. At the beginning of this phase, ova are extruded by applying a gentle pressure on the abdomen.

10.3.2.6. Spent phase

The ovaries are flaccid, shrinked and sac-like, reduced in volume and have a dull colour. The vascular supply is reduced. Some unspawned large ova and a large number of small ova are present. Histologically, the ovary shows thick and discharged follicles, long with stage I and II oocytes.

10.4. Gamate release

The egg gradually enlarges and projects into the lumen of the ovary. At ovulation the follicle ruptures and the egg escapes from the aperture like an amoeba. The muscle fibres present in the ovarian wall may be responsib1e for it. In teleosts having cystovarian ovary, the ova are discharged ino the oviduct, while in those fishes which have a gymnoariailovary, the eggs are discharged into the body cavity. The muscles of the oviduct and those of the body wall contract causing movement of the ova through the oviduct.

Fertilization is external in water in majority of the teleosts and internal fertilization also takes place in some species. Spermatozoa and the eggs are discharged into water in close proximity. The sperms become very active in water, and survive only for a few minutes, during which fertilization takes place which may be controlled by several chemicals released by both sperms and eggs.

In some species of teleosts, fertilization is internal and the urogenital papilla or anal fin is enlarged and modified for the transfer of sperms. In cyprinodont fishes like *Gambusia,* the anal fin rays of male-are modified to form an elongated copulatory organ which is tubular or grooved and is called the gonopodium. In *Scorpaenidae* and *Embiotocidae*, which include viviparous teleosts, thereis no gonopodium and the sperms are transferred by genital papillae of the male coming into contact with the cloaca of the female. In *Cottidae*, the genital papilla is enlarged to form the penis in the male. Wiesel (1949) has described erection tissue in the genital papillae of both males and females. In Apogon imberhis, the female has an elongated genital papilla which is introduced into the male for receiving the sperms (Garnaud, 1950). Female Rhodeus has a much elongated genital papilla, to transfer the eggs into the shell of bivalve Anodonta, where they are fertilized by the sperms shed in water and develop inside the shell.

In the viviparous teleosts, fertilization generally takes place while egg is within the follicle. The egg may continue its development within the follicle (follicular gestation) or development takes place within the ovarian cavity (ovarian gestation).

10.5. Eggs

The number of eggs produced by a single female differs considerably and depends upon several factors like her age, size, condition and species. The egg is generally surrounded by a shell but when it leaves the ovary, it is enclosed in a vitelline membrane. Generally, the egg is spherical or oval in shape and has some amount of yolk in it. Eggs of bony fishes are of two main types.pelagic eggs are buoyant and provided with a thin, nonadhesive membrane, while demersal eggs are heavy and sink to the bottom, and are covered by a hard adhesive membrane. Sticky, demersal eggs become attached to the debris of the bottom and are prevented from being swept away along the current of water at the time of deposition. Marine fishes, produce either pelagic or demersal eggs, but the eggs of fresh water fishes are generally demersal. Pelagic eggs are of small size and single large oil globule may be present on the surface of its yolk. The eggs of some species (scomberisocidea, belonidae and exocoetide) have sticky threads for attachment with some object or with each other.

10.6. Development

The cleavage is incomplete and meroblastic, development is direct.

10.6.1. Cleavage and the formation of blastula

The development of an egg begins soon after it is fertilized by a sperm. The egg of bony fishes have a relatively large amount of yolk, which is segregated from the active, cytoplasm. Cleavage is confined to the superficial layer of the cytoplasm and is incomplete (meroblastic). In the earlier stages cleavage planes are all vertical so that all the blastomeres lie in one plane only. The blastomeres are separated from each other by furrows but lie over the yolk. In the later stages, cleavages occur in the horizontal plane also, so that the blastomeres become arranged in more than one row (fig. 10.8). The marginal cells are in contact with the yolk. The disc of cells thus formed on. the animal pole of the egg, is called the blastoderm. The central cells of the blastoderm divide to form a number of 'free' blastomeres which become arranged on the top of the yolk so as to form a layer of cells called the periblast. The space between the blastoderm and periblast is the blastocoel and the embryo is in the blastula stage. The blastoderm gives rise to the embryo while the cells of the periblast probably serve to digest the yolk, and supply it to the developing embryo

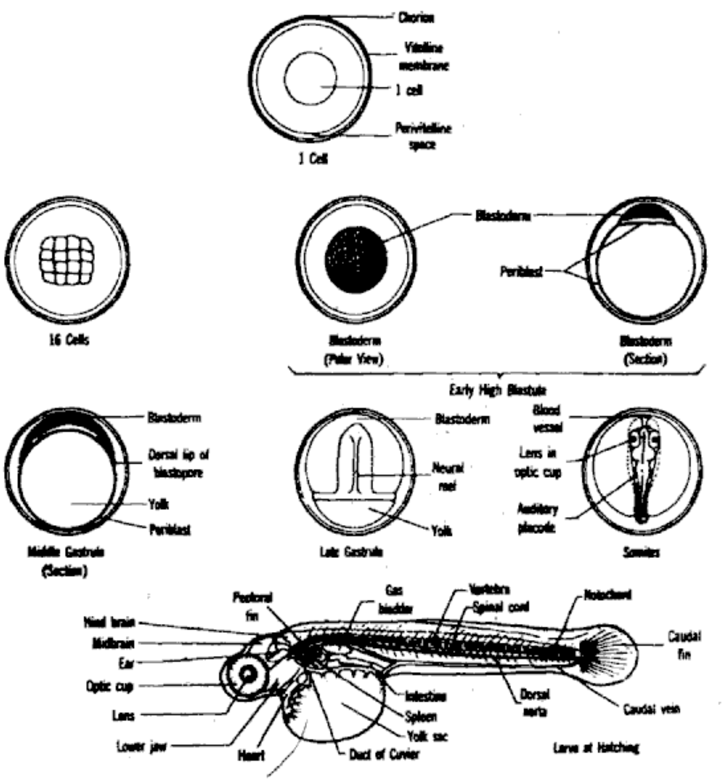


Fig. 10.8. Developmental stages of a bony fish.

10.6.2. Fate map of blastula

It is possible to identify various regions of the blastula wall that are destined to give rise to specific organs in the embryo. Thus a fatemap of the teleostean blastula can be constructed showing the presumptive ectoderm, mesoderm, notochord, neural plate etc. In the fish blastula, the areas which are destined to give rise to the organs of the dorsal region of the animal, are concentrated towards one side of the blastodisc. This is the posterior end of the future embryo. At this end, along the margin of the blastoderm, lies the presumptive endoderm which is destined to form the gut. In front of this lies the presumptive notochord, and still further forwards, towards the centre of the blastoderm, lies the area of the nervous system. The presumptive mesoderm lies along the sides of the areas for endoderm, notochord and neural plate. The mesodermal area extends mainly along the margin of the blastoderm and in *Fundulus,* is not continuous at the anterior end due to the presence of presumptive epidermis. But in Salmo the presumptive mesodermal area is present all round the margin of the blastoderm.

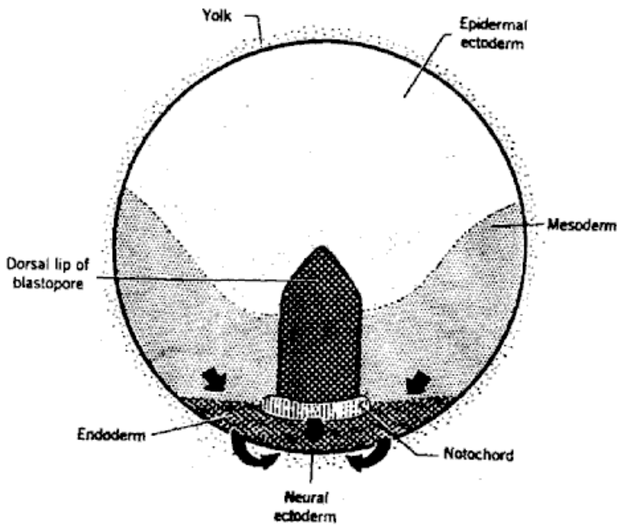


Fig. 10.9. Fate map of the blastoberm showing the presumptive areas.

10.6.3. Gastrulation

Gastrulation in bony fishes is accomplished by two processes. invagination and epiboly. At the beginning of gastrulation, the presumptive endodermal and mesodermal cells at the posterior end of the blastoderm turn inward and migrate forwards under the blastoderm, so as to form the hypoblast. However there is no inpushing of the epithelial layer and no true archenteron is formed. The presumptive endodermal cells lying along the posterior margin of the blastoderm , migrate inward along the surface of the yolk. As these cells move inwards, they are concentrated towards the midline of the blastoderm. The presumptive mesoderm cells also invaginate in a similar way and roll over the edge of the blastoderm. Although no true archenteron is formed the edge of the blastoderm may be compared with the dorsal lip of the blastopore of amphibians. The mesodermal cells, after invagination, also converge towards the midline, where the axial organs of the embryo are formed.

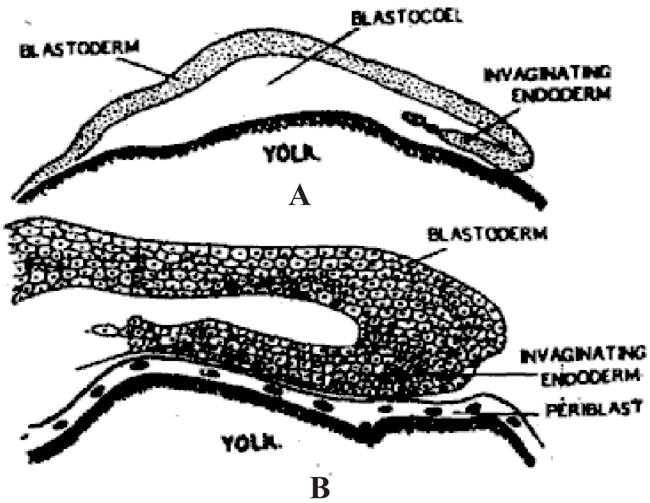


Fig.10.10. Early stages of gastrulation (A) Under low magnification (B) Posterior end under high magnification.

Next, the prechordal plate as well as the cells of the notochord are also passed inwards by rolling over along the posterior edge of the blastoderm, which corresponds with the dorsal lip• of the blastopore. Notochord, prechordal plate and mesoderm are continuous with each other and form the chordamesoderm. Initially, this involuted cell mass is called the hypoblast.

The presumptive neural plate is now stretched towards the posterior edge of the blastoderm and it comes to occupy the areas vacated by the cells that have migrated to the inside. The presumptive neural cells also become concentrated towards the midline and form a strip of tissue lying above the notochord and extending forward from the posterior edge of the blastoderm.

A peculiar feature in the development of fishes is that the formation of the primary organ rudiments begins in the anterior part of the embryo, long before the invagination is completed in the posterior part. The anterior part of the neural plate, corresponding to the forebrain appears first, and is followed by the mid brain region. The notochord becomes separated from the mesoderm, which becomes thickened due to concentration towards the midline, and is segmented into somites lying on either side of the notochord. The rest of the mesoderm remains unsegmented and is called the lateral plate mesoderm. The endoderm also becomes separated from the mesoderm and forms an endodermal plate in the middle line. This later forms the alimentary canal.

The process of neurulation in bony fishes is not like that of the amphibians. The neural plate does not roll into a tube but narrows gradually and sinks deeper into the underlying tissue. It then separates from the epidermis, which grows over it and becomes continuous to form the dorsal surface of the embryo. A cavity is not formed by rolling over of the neural plate, but it appears later in the brain and the spinal cord by separation of cells in their middle region.

During the period of the involution of cells, the cells of the blastoderm have continued to grow over the yolk. This process is known as epiboly. During this, the presumptive ectoderm cells grow over and cover the yolk mass from outside, forming a layer of cells called epiblast. At the same time the periblast also grows and forms an inner covering of the yolk. The periblast and epiblast enclose the yolk in a yolk sac. Gastrulation is completed when the yolk sac is thus formed. Externally the body of the embryo and the yolk sac can be easily distinguished.

10.6.4. Hatching and post-embryonic development

After the completion of gastrulation, various organs of the body are formed resulting in a small embryo with more or less cylindrical and bilaterally symmetrical body. The body is raised up from the surface of the yolk. so that the embryo proper becomes distinct from the yolk sac. In this condition, the head of the embryo projects anteriorly from the yolk sac, the trunk lies over the yolk and the tail projects behind. The broad connection between the body and the yolk sac becomes constricted so as to form a stalk. Blood vessels develop in the wall of the yolk sac. Yolk is digested by the periblast and supplied to the body through blood vessels. The yolk sac is gradually reduced in size while the embryo grows. Finally, hatching takes place and the embryo becomes a free swimming larva.

During this period of development, various organs of the body are formed from the ectoderm, mesoderm and endoderm. The ectoderm gives rise to the epidermis and its derivatives like the enamel of the teeth, olfactory epithelium, lens of the eye and the inner ear. The neural plate is also ectodermal and gives rise to the brain, spinal cord, retina etc.

The mesoderm divides into three parts-dorsal epimere, middle mesomere and ventral hypomere. The dorsal epimere becomes divided into somites at a very early stage. Each somite is subdivided into three parts - sclerotome, myotome and dermatome. The selerotome collects round the notochord to form the vertebral column. The myotome gives rise to the muscles of the trunk. appendicular skeleton, appendages and their muscles. The dermatome gives rise to the connective tissue and muscles of the dermis of the skin and its derivatives i.e., scales.

The middle part of the mesoderm (mesomere) gives rise to the kidneys, gonads and their ducts. The hypomere splits into somatic and splanchnic layers of the mesoderm and enclose the coelomic cavity. The splanchnic layer forms the mesenchyme which forms the.involuntary muscles and connective tissue of the gut. Heart and blood vessels also develop from the splanchnic mesoderm. Skeleton and musculature of the head, outer layers of the eye and the dentine of the teeth develop from the mesenchyme of the head region.

10.6.5. Development of young ones

Young stages of fish, from the time of hatching till they become fully mature adult are known as hatching, and fry and fingerling. The period of larval development varies considerably in different fishes. A newly hatched fish with a yolk sac is known as a sac- fry or hatching and after the yolk sac disappears, it is known as the advanced fry or spawn.

In some species the advanced fry resembles closely the adults except in size. This is called direct development and is seen in and many fishes. On the other hand an indirect development takes place in eels, where the larval form is leptocephalus or elever. In many fishes the fry undergoes metamorphosis during which the larval characters are lost and the adult features appear. A fry which loses the larval characters, is like a miniature adult and is called fingerling. This enters an active feeding stage which results in the growth of the body and maturation of gonads to give rise to the adult. The females ar usually larger in size than the males but the latter attain sexual maturity earlier.

The development of youngone of a cyprinid fish described in the following stages. Fig (10.11)

10.6.5.1. STAGE I

This is called prolarva with fairly large sized yolk sac. The yolk sac is broad anteriorly, tapering towards the posterior end, and has a row of pigments on its upper part. It has a broad head, pigmented eyes, and a median continuous fold. The dorsal fin is demarcated but rays are not present in it. The caudal fin is truncate and 7-8 rudimentary rays are present in it. Anal fin is not demarcated and the pelvic fin is not yet formed. The pectoral fin is represented by a membranous flap without any rays.

10.6.5.2. STAGE II

Yolk sac is slightly reduced, and chromatophores are present on the head. Dorsal fin is further demarcated and 7-8 rudimentary rays can be seen in it. Caudal fin consists of *15-16* rays. The anal fin is slightly demarcated but rays are not seen in it. The pectoral fin does not contain rays and is still in the form of a membranous flap. The air bladder is now visible.

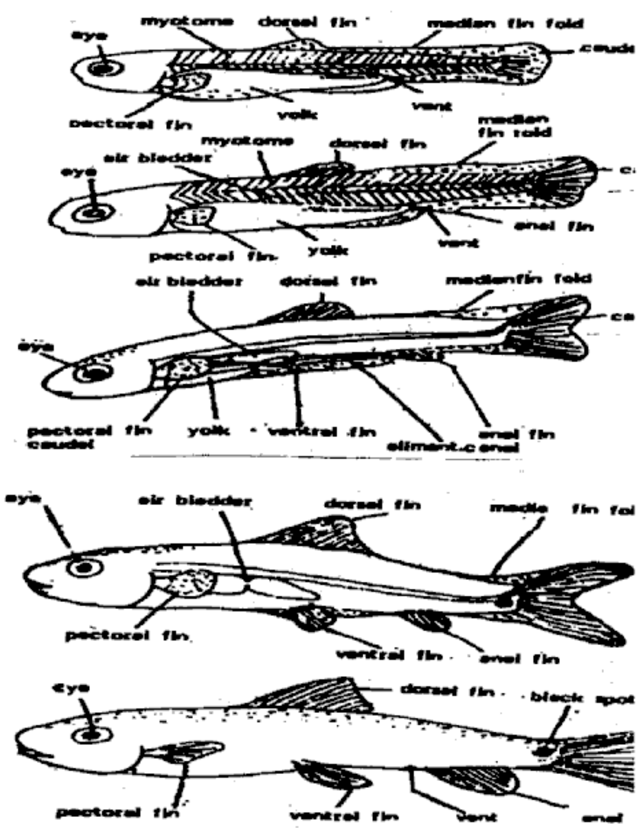


Fig. 10.11. Developmental stages of a bony fish.

10.6.5.3. STAGE III

The yolk sac is considerably reduced. The gape of the mouth extends backwards. The dorsal fin is almost complete with rays but is still connected with the caudal fin which is now deeply forked and contains 19 rays. The anal fin now has three rudimentary rays. A rudimentary pelvic fin can he seen as a minute bud. Pectoral fin is still without rays. Alimentary canal is now visible and chromatophores are present on the head.

10.6.5.4. STAGE IV

Yolk is completely absorbed and the it resembles the adult fish. The dorsal fin is fully developed and is not connected with the caudal fin. The anal fin contains 7 rays and is still connected with caudal. Pelvic in is further developed. Pectoral fin is still without rays and a black spot is present on the caudal peduncle.

10.6.5.5. STAGE V

It larva is almost like the adult fish and all the fins are fully developed. Anal fin contains 9 rays and is separate from the caudal fin. Pectoral fins are well developed and contain 9-10 rays. Black spot on the caudalpeduncle and the chromatophores on the back of the larva are more prominent.

SUMMARY

Fishes are generally bisexual and sexual dimorphism is exhibited by few fishes. few fishes possess of copulatory organs (eg sharks) and others possess structural pecularities, but not connected with sexual union (eg cichlids). A pair of testes and ovaries are reproductive organs in male and females respectively. Many seminiferous tubules are found in testis. Oocytes are developed inside the ovigerous lamellae of ovary. Seven oocyte stages are found in fishes. Ripe eggs are in largest in size and with large amount of yolk globules. Five maturity stages are found in males and females. Most of fishes are oviparous and external fertilization is found. Cleavage is incomplete and meroblastic development is direct except in Auguilla.

Questions:

1. Describe the reproductive organs in fishes.
2. Give an account on embryonic development in fishes.
3. Write about the sexual dimorphism in fishes.
4. Write a note on mating and courtship in fishes.

11

ENDOCRINE SYSTEM OF FISH

Endocrine system usually control long-term activities of target organs and also physiologyical processes such as digestion, metabolism, growth, development, reproduction etc. endocrine system includes certain glands known as endocrine glands, which ae distributed in various regions of the bodyof fish.

Animals contain two types of glands, namely exocrine glands and endocrine glands. Exocrine glands have ducts to carry their secretion. The endocrine glands have no ducts to carry their secretions. Hence, the endocrine glands are also called ductless glands. The study of endorcrine glands is called endorcrinology.

The term endocrine is derived from Greek, which means endo=inside, crinos=secretion. The endocrine gland produce their secretions called hormones, which are liberated into the blood stream. The term hormone was first coined by Bayliss and Starling in 1902. It is derived from Greek which means "to excite". Study of hormones is called hormonology.

A hormone may be defined as a specific product (organic substance) of an endocrine gland secreted into the blood, which carries it to some part of the body where it produces a definite physiological effect. The effect may be excitatory or inhibitory in its action. Hormones act specifically on certain organs. Such organs are referred to as target organs. Thus, the hormones act as chemical messengers.

The hormones do not participate in biochemical reactions and hence they are also called autonomes or autocoids. Hormones maintain internal environmental factors of the body like temperature regulation, water and ion balance, blood glucose level etc: such maintenance is known as homeostasis.

Hormones have no cumulative effect. After perfoming their function, they get destroyed or inactivated or excreted. They are soluble in water. They also act as catalysts. Various systems present in the body of animals are coordinated by nervous and endocrine systems. Hence, these two systems together called integrated system. Hormones are also important regulating substances which control almost every aspect of the metabolism in living cells.

Classically the endocrine glands have been defined as being ductless glands, since they release their secretory product directly into the blood or lymph. The components of endocrine system can be classified on the basis of their organization, which is as follows:

a) Discrete endocrine glands : These include pituitary (hypophysis), thyroid and pineal (Fig. 11.1).

b) Organs containing both endocrine and exocrine function. In fishes, it is kidney gonads (Fig.11.1) and intestine. Kidney contains heterotophic thyroid follicles, interrenal, and corpuscles of Stannius.

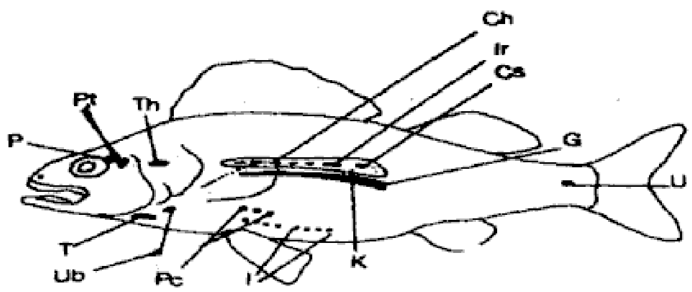


Fig. 11.1. Schematic diagram to show position of various endocrine glands in fishes. Ch, chromäffin tissue;Cs, corpuscles of Stannius; G, gonad; I, intestinal tissue; Ir, inter renal tissue; K, kidney, P. pineal: Pc, pancreatic islets; Pt, pituitary; T, thyroid; Th, thymus; U, urohypophysis: Ub, ultimobranchial.

c) Scattered cells with endocrine function : They are known as diffused neuroendocrines. They are present in digestive tract (Fig.11.l) They are generally called as paracrines (eg. Somatostatin). There are gastrointestinal peptides whose definite classification as hormone or paracrine agent has not yet been established, these are designated as putative hormones.

11.1. Hormones

Hormones are classified into four types:

1) Protein or Peptide hormones: These hormones are made up of proteins or peptides.
Ex: Hormones of pituitary, parathyroid, pancreas, hypothalamus and relax in of ovary.
2) Steroid hormones: These hormones are made up of steroids.
Ex: Hormones produced by adrenal cortex, ovaries and testes.
3) Amino acid derivatives or biogenic amines: These hormones are derived from amino acids.
Ex: Melatonin and adrenalin of adrenal medulla.
4) lodinated amino acid: Iodine combines with amino acid and forms different iodinated hormones.
Ex: Thyroxine.

Endocrine glands of increasing complexities are found in elasmobranchs and osteichthyes. Elasmobranchs (sharks) possess well developed endocrine glands but these show some interesting differences from those of higher chordates. However, osteichthyes have endocrine glands rather more similar to higher chordates. The difference between fish and mammal endocrine glands is probably due to the development and modification of various body systems in these two classes, and also due to exogencies of an aquatic mode of life. Mammalian endocrine glands are well advance and well studied but fish endocrinnology is limited to the work on its influence on chromatophores, action of sex cells, function of pituitary and thyroid and control on migration.

Unlikenervous system, the endocrine system is basically related to comparatively slow metabolism of carbohydrate and water by adrenal cortical tissue, nitrogen metabolism by adrenal cortical tissue and thyroid glands and the maturation of sex cells and reproductive behaviour by (lie pituitary gland and gonadal hormones.

11.2. The pituitary or hypophysis

11.2.1. Origin

The pituitary gland occupies the sme central part in the endocrine signalling system of fish that it has in mammals. This master endocrine gland originates embryologically from the two sources. One as ventral downgrowth of a neural element from the diencephalon called the infundibulum to join with another, an ectodermal upgrowth (extending as Rathkes pouch) from primitive buccal cavity. These two outgrowths are thus ectodermal in origin and enclose mesoderm in between them, which later on supply blood to the pituitary gland, originating from the interrenal carotid artery.

11.2.2. Location

The pituitary gland is located below the diencephalon (hypothalamus). behind the optic chiasma and anterior to saccus vasculosus. and is attached to the diencephalon by a stalk or infundibulum (Fig.11.l). The size of infundibulum varies according to the species usually in cyclostomes it is smaller but increases in bony fishes, with prominence in groove or depression Of parasphenoid bone receiving the gland. The pituitary is an oval body and is compressed dorsoventrally. The pituitary gland is completely enveloped by a delicate connective tissue capsule.

11.2.3. Anatomy of the gland

Microscopically, the pituitary gland is composed of two parts:

(i) Adenohypophysis, which is a glandular part originated from the oral ectoderm.

(ii) Neurohypophysis. which is nervous part orginated from th infundibular region of the brain. Both parts are present in close association.

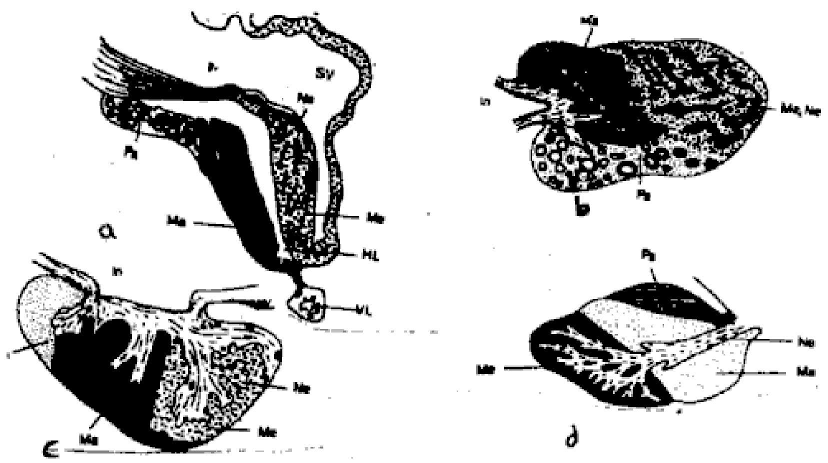


Fig.11.2. Diagrams of pituitary of various fishes. (a) Dog fish shark (Squalus). (b) Trout (Salmo). (c) Perch (Perca). (d) Carp. HL, lumen of hypophysis; In, infundibulum; Ma, mesoadenohypophysis; Me, metaadenohypophysis; Ne, neurohypophysis: Pa, proadenohypophysis: SV, saccus vasculosus; VL, ventral lobe.

Adenohypophysis has three parts (Fig 11.2).

1. Rostral pars distalis (Proadenohypophysis): Lying dorsal to the mesoadenohypophysis in the form of thin strip.

2. Proximal pars distalis (mesoadenohypophysis): Lying almost in between the rostal pars distalis and pars intermedia.

3. Pars intermedia or metaadenohypophysis viz: Lying at the distal tapering end of the pituitary gland.

Pituitary are broadly characterised as platybasic and leptobasic. In platybasic form, the neurohypophysis consists of flat floor of the caudal infundibulum which sends processes into disc shaped adenohypophysis eg. murrels, eels. In leptobasic, the neurohypophysis has a fairly welldeveloped infundibulum stalk and the adenohypophysis is globular or egg shaped. e.g. carps.

11.2.4. Pituitary hormones

There are seven hormones secreted by pituitary (Table 11.1 *.)*. The different hormones secreting cell are spread over in part of the adenohypophysis (Fig. 11.3). All hormones secreted by the pituitary are necessarily proteins or polypeptides. There is a slight difference in the pituitary hormones of the different group of fishes.

11.2.4.1. Tropic or stimulating hormones

The pituitary hormones of fishes are of two types. One which regulates the function of other endocrine glands. Such hormones are called tropics or tropic hormones. These are

1. Thyrotropin activates thyroid
2. Adrenocorticotropic hormones activate adrenal cortex,
3. The gonadotropins (FSH and LH).
4. Growth hormones-somatotropin.

Second which directly regulates the specific enzymatic reactions in the various body cells or tissues. These hormones are melanin hormones (MH) and melanophore stimulating hormone (MSH) etc. Thyrotropin hormone is secreted from proadenohyopophysis and stimulate activity of thyroid hormones. The TRH is secreted under the influence of thyroid releasing hormones from diencephalon in fishes. It is proved that TRH influences the TSR cell activity and thyroid activity in fish.

11.2.4.2. Gonadotropin

Gonadotropin (GTH) cell are richly found in the proximal pars distalis (PPD), where they may form a solid ventral rim of cells. In fishes there is only one functional gonadotropin is found, which is often regarded as piscian pituitary gonadotropin (PPG). This single gonadotropin has similar properties of two hormones, LH and FSH of mammals. Mammalian luteinizing hormone (LH) promotes release of gametes from nearly mature gonads in fishes and stimulates appearance of secondary sexual characters. This indicates that there must be a similar hormone in fishes also. Salmon pituitary secretes gonadotropins which resembles LI-I. Furthermore, the gonadotropins from human chorion and urine of gravid mares, have LH like properties which hasten the release of eggs in female fishes.

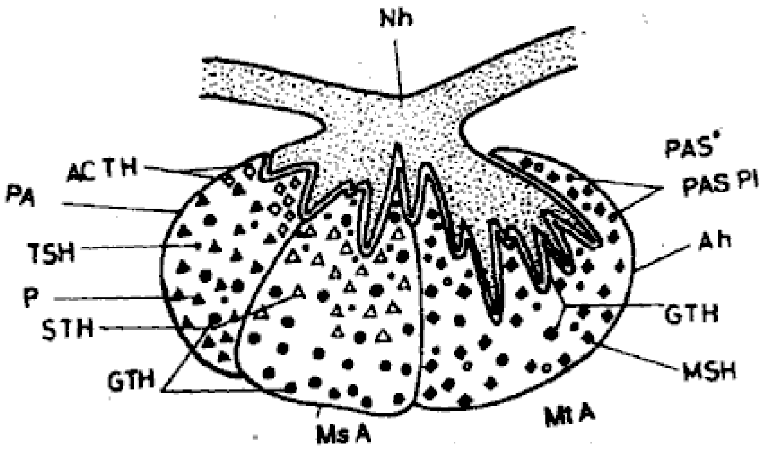


Fig. 11.3. Section of the pituitary to show various hormone secreting cells in the adenohypophysis (Ah). ACTH. adeno corticotropic cell; GTH, gonado tropic cell; MSH melanotropic cell; Nh, neurohypophysis; PAS, periodic acid Schiff— positive cell in pars intermedja; PPD, proximal pars distalis: P. prolactin producing cell; RPD, rortral pars distalis Ce; STH, somatotropic II, TSH;, thyrotropic cell.

11.2.4.3. Adrenocorticotropic hormone (ACTH)

It is secreted by ACTH cells located between the rostral pars distalis and the neurohypophysis. Secretion of ACTH from pituitary is stimulated by the hypothalamus through corticotropin releasing factor (CRF).

11.2.4.4. Prolactin

It is a similar hormone that influences lactation in mammals and is released from proadenohypophysis.

11.2.4.5. Growth hormone (GH)

Mesoadenohypophysis secretes a growth hormone which accelerates increase in the body length of fishes.

11.2.4.6. Melanocyte stimulating hormone (MSH) or intermedin

MSH is secreted from the meta — adenohypophysis and acts antagonistically to melanin hormone. MSH expands the pigment in the chromatophores. thus take part in adjustment of background.

11.2.4.7. Oxytocin and vasopressin hormones

In fishes the neurohypophysis secretes two hormones i.e. oxytocin and vasopressin, which are stored in hypothalmic neurosecretory cells. Vasopressin and antidiuretic (ADH) hormones are responsible for the constriction of blood vessels in mammals and thus stimulates retention of water by their action in kidney. Oxytocin stimulates mammalian uterine muscles and increase the discharge of milk from lactating mammae. In fishes this is control osmoregulation by maintaining water and salt balance.

11.3. Thyroid gland

11.3.1. Location

In many teleosts the thyroid gland is situated in the pharyngeal region in between the dorsal basibranchial cartilages and ventral sternohyoid muscle. The thyroid surrounds anterior and middle parts of first, second and sometimes third afferent brancial arteries of ventral aorta. In *Heteropneustes fossilis* it occupies almost the entire length of the ventral aorta and afferent arteries. In *Clarias batrachus* the thyroid gland is concentrated around the ventral aorta, middle ends of two pairs of afferent arteries and the paired inferior jugular veins. In majority of teleosts the thyroid is unencapsulated and thin follicles are dispersed or arranged in clusters around the base of afferent branchial arteries. It is thin walled, saclike, compact dark brownish and enclosed in a thin walled capsule of connective tissue.

11.3.2. Histology of the thyroid gland

In teleosts the thyroid gland consists of a large number of follicles, lymph sinuses, venules and connective tissues. The follicles are round, oval and irregular in shape. Each follicle contains a central cavity surrounded by a wall composed of single layer of epithelial cells. The structure ofepithelium vary according to its secretory activity. Less active follicles generally have thin epithelium. Epithelial cells are of two types.

(i) Chief cells which are columnar or cuboidal in shape, having oval nuclei and clear cytoplasm.

(iii) Colloid cells or Benstay's cells - They possess droplets of secretory material. The follicles are supported in position by connective tissue fibres, which surrounds them. The central lumen of follicle is filled with colloid containing chromophilic and chromophobic vacuoles. Thyroid hormone is synthesized in the thyroid gland, for which inorganic iodine is extracted from the blood. Thyroid hormones appear to be involved in carbohydrate metabolism in fish, as liver glycogen is low when this gland is active. Thyroid hormones also play an important role in reproduction, osmoregulation and migration of fish.

11.4. Adrenal cortical tissue or interrenal tissue

11.4.1. Location

Among the rays they lie in more or less close association with posterior kidney tissue, including some species possessing interrenal tissue concentrated near the left and in other near the right central border of that organ. In sharks (Squaliformes) they are present between the kidneys. In teleosts the interrenal cells are multilayered and situated along the postcardinal veins as they enter the head kidney (Fig. 11.4). In some fishes like *Puntius ticto* interrenal cells are arranged in the form of thick glandular mass while in others like *Channa punctatus* they are present in form of lobules. Each interrenal cell is eosinophilic and columnar with a round nucleus.

Adrenal cortical tissue or interrenal tissue secretes two hormones. These are (i) mineral corticoids concerned with fish osmoregulation, (ii) glucocorticoids, which regulates the carbohydrate metabolism, particularly blood sugar level.

11.5. Chromaffin tissue or suprarenal bodies or medullar tissue

In sharks and rays chromaffin tissue are found associated with the sympathetic chain of nerve ganglia while in bony fishes the chromaffin cells have wide variation in their distribution. On the other hand, they are elasmobranch like, distributed as in flounders (Pleuronectus), on the other hand they have true adrenal arrangement as in sculpins (Cottus) where chromaffin and adrenal cortical tissue are joined into one organs, similar to the mammalian adrenal gland.

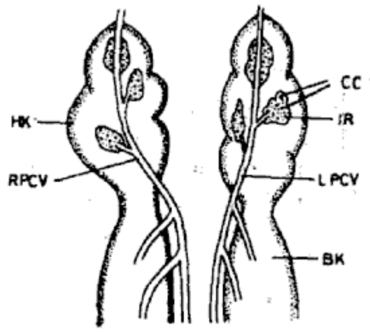


Fig. 11.4. Diagram to show location of interrenal glands in fishes. BC, body kidney; CC, chromaffin cells; HK, head kidney; IR, interrenal tissue; LPVC, left post cardinal view; RPCV, right post cardinal view.

Chromaffin tissue of fishes richly contain adrenaline and noradrenaline. Injection of adrenaline and noradrenaline causes changes in blood pressure, bradycardia, branchial vasodilation, diuresis in glomerular teleosts and hyperventilation.

11.6. Ultimobranchial gland

Ultimobranchial gland is small and paired and is situated in the tansverse septum between the abdominal cavity and sinus venosus just ventral to the oesophagus or near the thyroid gland (Fig. 11.1) Embryonically the gland develops from pharyngeal epithelium near the fifth gill arch. It consists of parenchyma, which is solid and composed of cell cords and clumps of polygonal cells covered by capillary network. The gland secretes the hormone calcitonin which regulates calcium metabolism. The ultimobranchial gland is under the control of pituitary gland.

11.7. Sex glands as endocrine organs

The sex hormones are synthesized and secreted by specialized cells of the ovaries and testis. The release of sex hormones are under the control of mesoadenohypophysis of pituitary. In fishes these sex hormones are necessary for maturation of gametes and in addition of secondary sex characteristics such as breeding tubercies, colouration and the maturation of gonopodia. In elasmobranchs (Raja) and in salmon the blood plasma contains male hormone testosterone with a correlation between plasma level and the reproductive cycle. *Oryzias letipes* (medaka) and sockey salmon comprise another gonadal steroid i.e 11- ketotestosteron, which is 10 fold more physiologically androgenic than testosteron. Ovary secretes estrogens of which estradiol -17- has been identified in many species in addition of presence of estrone and estriol. In some fishes progesteron is also found but without hormonal function. There is little information about the influence of gonadial hormones on the reproductive behaviour of fish.

11.8. Corpuscles of Stannius

The corpuscles of Stannius (CS) were first described by Stannius in 1939 as discrete gland like bodies inthe kidney of sturgeon. The corpuscles of Stanniiis are found attached or lodged in the kidneys of fishes particularly holostean and teleosts (fig. 11.4). Corpuscles of Stannius are asymmetrically distributed and often resembles with cysts of parasites but lie different from the latter by higher vascular supply and dull white or pink colour. Histologically, they are similar to the adrenal cortical cells, Their number varies from two to six according to species. The C.S. may be flat oval as in gold fish, trout, salmon. It is made up of columnar cells which are covered by a fibrous capsule. They are filled with secretory granules. The parenchyma comprises vasculoganglionic units consisting of a bunch of gangl ion cells, blood vessels and nerve fibres.

The corpuscles of Stannius reduces serum calcium level which have environment containing high calcium, such as seawater. Recently, it has been shown that corpuscles of Stannius work in association with pituitary gland, which exert hypercalceriic effect, in order to balance relatively constant level of serum calcium.

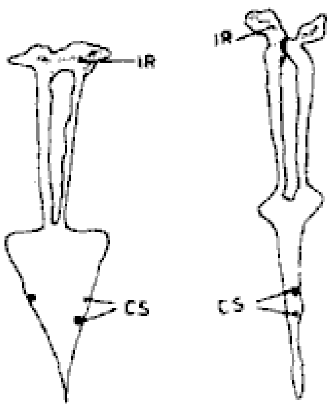


Fig. 11.5. Diagram of kidney of fishes showing corpuscles of Stannius. (a) *Cirrhina niri gala.* (b) *Labeo rohita.* CS. corpuscles of Stannius: IF. interrenal corpuseles.

11.9. Intestinal mucosa

The intestinal mucosa produces secretin and pancreozymin. which are controlled by nervous system and regulate pancreatic secretion. Secretion affects flow of enzyme carrying liquids from the pancreas. whereas pancreozymin accelerate flow of zymogens. These hormones aie usually synthesized in anterior part of the small intestine. In carnivorous fish these hormones are brought into the stomach, containing acidified homogenate of fish flesh or by injection of secretin into gastric vein which stimulates the secretion of pancreas.

11.10. Islets of langerhans

In some fishes like *Labeo, Cirrhina*, and *Channa* small islets are

Table-1: Details of the pituitary gland and its hormones

Divisions	Cell types	Staining Property	ecretion	Action
Pars-Distalis	Somatotrops- (1)Acidophil cells (A type) (ii) Acidophil cells (B type) (in few species)	Orange-G(+) PAS (-) AF (-) A blue (-) Azacarnine (+)	Somatotropins Growth horm-One (GH)	Growth of body. Increase in Basal metabolic rate
Proximal Pars distalis	Thyrotrops (i) Basophils	AF (+)	Thyrotropins e.g. Thyroid stimulating hormone (T S H)	Controls and regulates the growth and secretion from thyroid
	Ganadotrops Secreting cell Initially lie in Proximal pars Distails but also migrate to distal pars distalis during breeding	PAS (+) AF (+) Aniline blue (+) Alcian blue (+)	Ganadotropins e.g. Follicular stimulating harmone (FSH) Leutinizing horomone (LH)	Control secretion of gonadal hormone. oogenesis & spermato-genesis
Rostral pars distalis	Lactotrops Prolactin cells	Azocarmine & Erythro-sine (+)	Prolactin	Probably concerned with osmoregulation and melano-genesis
	Corticotrops ACTH cells lying between neurohypo- physis and pars distalis	Alizarine blue (+)	Corticotropin Adrenocortico-trophic hormone (ACTH)	Controls secretion of corticotropins from adrenal gland or interrenal cells.
Pars intermedia			MSH & MCH Melanophore dispercing and melanophore contracting hormone	Probably control the concentration and dispersion of pigments within melanophores
Neuro-hypophysis			Vasopressin & Oxytocin	Osmoregulation and salt water balance Mating and egg laying

present which are separate from pancreas and are found near gall bladder, spleen. pyloric caeca. Such islets are often referred to as principle islets. But in some species like *Clarias batrachus* and *Heteropneustes fossilis* the number of large and small islets are found to be embedded in the pancreatic tissues, similar to the higher vertebrates. In fish the islets are big and prominent and consists of there kinds of cells (Fig. *11.6)*. (i) The beta cells which secretes insulin and take aldehyde fuschin stain. (ii) Another type of cells are alpha cells, which do not take aldehyde fuschin stain and have two types. A_1 and A_2 cells, which produce glucagon. The function of the third type cells is not known. Insulin is secreted by beta cells and regulate the blood sugar level in fishes.

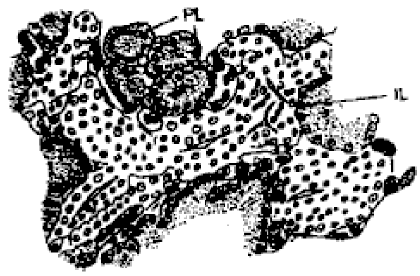


Fig. 11.6. Diagram of pancreas showing endocrine components IL, islets of langerhans, PL, pancreatic lobule

11.11. Pineal organ

It is situated near the pituitary (Fig. 11.1). Inspite of being a photoreceptor organ the pineal organ shows endocrine nature of doubtful function. Removal of pineal from Lebistes species causes reduced growth rate, anomalies in the skeleton, pituitary, thyroid and corpuscles of Stannius. It has been reported that thyroid and pituitary glands influence the secretion of pineal.

11.12. Urophysis

Urophysis is a small oval body, present in the terminal part of spinal cord (Fig. 11.1). It is an organ deposits, which releases materials produced in the neurosecretory cells situated in the spinal cord. These cells together with the urophysis are called the caudal neurosecretoty system. This neurosecretory system is found only in elasmobranchs and teleosts but it corrosponds to the hypothelamo neurosecretory system present in vertebrates.

SUMMARY

The ductless glands are called as endocrine glands. Their secretions are known as hormones. The endocrine glands in fishes are pituitary glands, interrenal tissue, chromaffin tissue, corpuscles of stannous, ultimobranchial glands. islets of Langerhans, thyroid gland, gastro intestinal glands, pineal glands and urophysis.

Questions

1. Discuss the endocrine system in fishes.
2. Describe the pituitary gland and list out the hormones produced by it.
3. Explain the thyroid gland in fishes.

12

SENSE AND SPECIALISED ORGANS IN FISHES

Fishes have various sense organs like lateral line system, olfactory organs, eyes, ampullae of Lorezenii and membranus labyrinth and specialised organs like electric organs, Webarrian ossicles, etc.

12.1. Lateral Line System

This is an unique system found in fieshes. This system is an integral part of the acoustico lateralis system which include the ear. Lateral line system involves sensory lines distributed on the head and body. It consists of lateral line canal and neuromast organs.

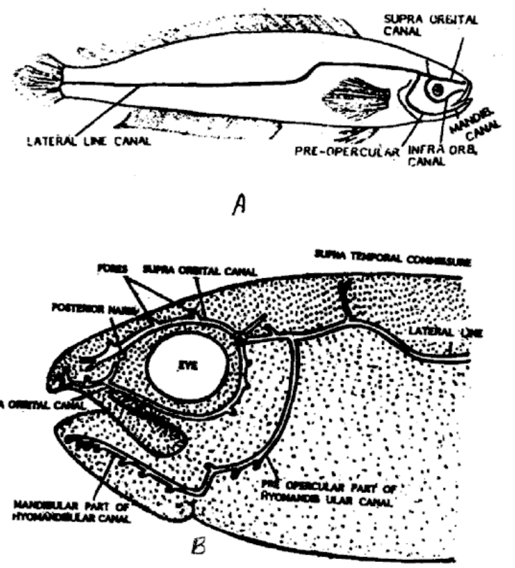


Fig.12.1. Lateral line canal on the body (A) and head (B)

The lateral line canal exists as a continuous groove, that follows a definite pattern on the head and extends along each side of body to the base of the caudal fin (Fig. 12.1). The groove contains the sensory receptors (neuromasts), which are arranged in rows and follow closely the routes of the nerves (Fig. 12.2).

In Holocephali and in numerous ancient amphibians, the grooves remain open even in the head region. In lung fishes (e.g. *Protopterus)the* canal is partially roofed over by bordering denticles, and the closed tube of head region opens by minute pores on the surface of the skin. The canals of many fishes, including both the cartilagenous and bony fishes, lie deep in the skin and their path can only be traced by the distribution of pores, which piers through the scale to open on the surface. A vertical shaft between the canal and its external pore. apparently exists in many fishes.

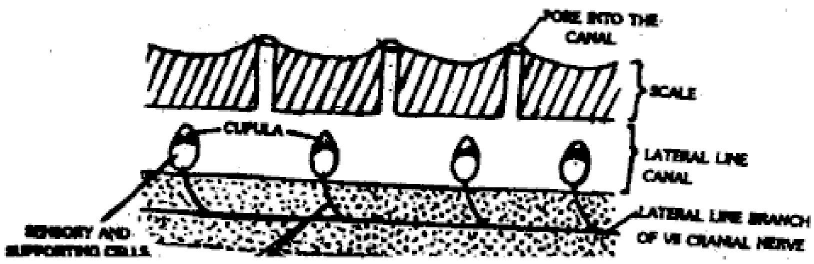


Fig.16.2. A part of lateral line canal magnified to show the neuromast organs in groove.

The groove of canal remains filled with a watery fluid in all the fishes and the apertures of their pore contain a mucoid substance. During embryonic life the lateral line canal differentiates as grooves along the longitudinal axis, on dorsal, ventral and the lateral side. Of these the dorsal and ventral canals disappear later, while only the lateral canals persist in adults. These canals terminate into several branches in the head region or lose connection with the trunk canals in adults. Of the various canals in the head region a supra and an infra orbital differentiate respectively above and below the orbits. A hyomandibular canal in lower jaw and supra temporal stretching across the rear end of the head is normally found. Many more canals in head region also appear in different fishes and named according to their position on the head.

Variations in pattern of arrangement of canal in different group of fishes is discussed on the following pages.

12.1.2. Neuromast organ

The neuromast organs are the receptor components of the lateral line system. They may occur on the surface of the skin or subsequently may sink into the grooves of lateral line canal. Typically they arise from a linear series of embryonic ectodermal placodes of head, trunk and the tail.

Each neuromast organ comprises two types of cells (Fig. 12.3). The sensory receptor or hair cells and the supporting or sustentacular cells.

The receptor cells are pear shaped. and aggregate to form clusters in the centre while the supporting cells are long and slender and arrange around the receptors to form the periphery of neuromast organ. Each sensory cell bears a hair like sensory process at its apical end. The hair comprising many (about 20-25) small stereocilia and a large kinocilium at one edge projects into a geleatinous cupula which is secreted by the neuromast cells and protrudes into the water. The rest of the hair cells are directionally polarized towards the kinociliurn. Any displacement of cupola. caused by movement in water is transferred to hair, to deplorize it and to induce a receptor potential. Basal ends of receptor hair cells continue into the axonic fibres of VII. IX or Xth cranial nerves. Neuromost organs of certain fishes modify into the scattered pit organs. ampullae of Lorenzini and the vesicles of Savi.

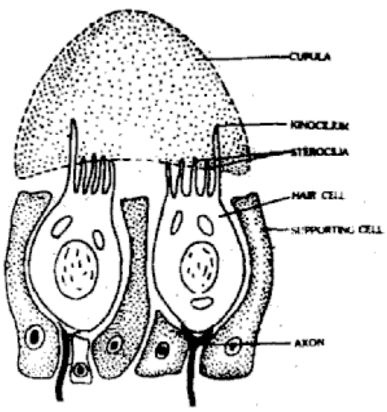


Fig. **12.3.** Neuromast organ.

In sharks there are two lateral canals which run along the entire length of the body. They overlie the septum separating the epaxial and hypaxial myotomal derivative. In the head region (Fig. 12.4a) the canals of both the sides connect by a transverse supra temporal canals anterior to which they both branch. Various cephalic canals include a supra orbital, a infra orbital and a mandibular canal. The supra orbital extends forward above the eye and connects with the infra orbital behind the nasal capsule. The infra orbital canal after giving off a hyomandibular canal to hyoldean arch extends forwards below the eye to end near the tip of the snout. Mandibular branch extends to the tip of the lower jaw and then joins its fellow of the other side.
In bony fishes. there are several variations in the pattern of arrangement of lateral line canals and their neuromast organs. The canals lie within the dermal bones in the form of closed tubes and open to the surface by pores borne on minute tubules. The neuromast organs lie enclosed within the grooves of canal.

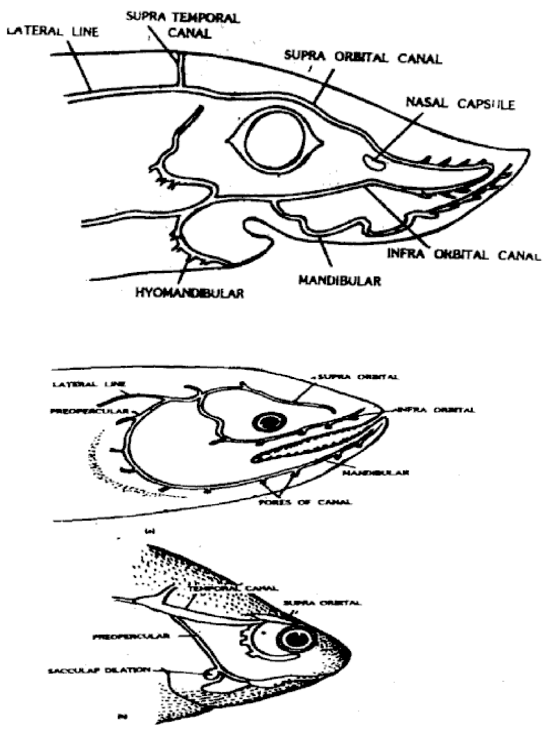


Fig. 12.4 Lateral line canals in a. cartilaginous fish, b. Wallago, c. Notopterus.

The supra orbital canal of the head region connects with the temporal canal of the lateral line canal and the infra orbital runs its usual course. The hyoid arch canal connects with the temporal canal and the mandubular canal is represented only by pit lines on the cheek. In Polypterus (Chondrostei) the supra orbital joins the infra orbital at the tip of the snout.

Greater variations are found among the teleosts. Typically. however. all the cephalic canals viz, the supra orbital, infra orbital and hyomandibular connect with the lateral line canal of the trunk. A supra temporal or occipital canal connects transversly the lateral line canals of the two sides at the rear of the head. The supra orbital may or may not connect with temporal canal and at no stage join the infra orbital at the tip of the snout. They. however, join behind the eye in l-Ieteropneustes fossilis and *Wallago* attu (Fig. 12.4b & c*)* but remain separated in cyprinids.

The hyoid arch canal joins the temporal canal, but often it ends on a line. Mandibular canal, is poorly developed in cyprinids but clearly marked in silurids. The lateral line trunk canal of *Notopterus chitala* do not join the cephalic canals. The latter are represented by closed tubes having dilated walls forming sacculations (Fig. 12.4 b).

The lateral line canals are absent from abyssal species such ass the gulper eels and ceratioid anglers in which the sense organs lie on the papillae of skin. The canals are huge in Macrouidae and organs are widespread over the face in Cobits. In many families a lot many accessory lines also occur.

12.1.3. Nerve supply

As mentioned earlier the lateral line system is innervated by VII, IX & Xth cranial nerves. The seventh nerve supplies branches to the neuromasts in the head region. the ninth to a limited area near the supra temporal canal and the tenth to the lateral line organs in the region of the trunk.

12.1.4. Functions

Although many functions have been assigned to the lateral line system of fish, its basic function is the one of monitoring the flow of water. The lateral line neuromasts are sensitive to low frequency vibrations and pressure wave, built up by the movement of aquatic organisms or solid objects under water. The fishes have been reported to respond upto the frequencies of 200 Hz and are thus able to detect their prey and predators in water. The slightest displacement of water causes a difference of external pressure between the two successive pores of lateral line canal, deflecting thus the cupola of the neuromast and so the hair of sensory cells. The mechanical bend of hair process of sensory cell, eventually generates nerve impulse from the receptor cells. It is because of this reason that the fish never stikes the wall of aquarium and detects the distant objects in water to a considerable extent. They are thus able to detect presence of unseen prey and or enemies in water.

To enhance the sensitivity of neuromast organs Aphanopus makes no use of dorsal fin, while looking for its prey, for any deflection in water may result into a near field effect to warn to prey. Most trichurids (e.g. Trichurus) have a lateral line along their ventral side so that the disturbance caused by movement of their own ‘dorsal fin may not effect their ability to locate or warn the prey. These fishes with the help of undulating movement of dorsal fins move slowly while heading of vibrations produced by the prey.

Another important function ascribed to the system is the schooling ability of the fish, in which each fish of a school reacts to the movement of its closest neighbour.

12.2. Electric organs

The electric organs are highly specialized structures, that enable their possessors to produce, store or discharge the electric current. About 250 species of both, the cartilagenous and bony fishes fresh and marine waters are known to possess the electric organs (Table 12.1). Most of these restrict to the tropical fresh waters of Africa and South America. Marine forms are very limited and include the torpedo ray, the ray genus Narcine and some skates among the elasmobranchs and only the star grazers amongst teleosts.

Table. 12.1 Characteristics of electric organs of electric fishes

Teleosts	Mormvrids (Osteo glassomorpha)	Fresh water. Weakly electric. emits pulses of variable frequency
	Gymnarchus (Osteoglossmorpha)	Fresh water. Weakly electrical, pulses constant. frequency may even cease.
	Electric eel (Cypriniformes)	Fresh water, have both strong & weak organs. pulses of variable frequency
	Gymnotus (Cypriniforrnes)	Fresh water, weak electric organs. may discharge continuously the constant frequencies.
	Electiric can fishes (Silurifonnes)	Fresh water. strong electic organs. intermittently active.
	Stargrazers (Acanthopterygil)	Marine. strong electric organs. intermittently active.
	Rays (Rajidae)	Marine. weak electric organs. intermittently active.
Elasmobranchii	Scates (Torpediformes)	Marine. strong and weak electric organs. intermittently active.

12.2.1. Source of origin

The electric organs of all the fishes, are formed by. modification of muscle fibres. Exception to this are the sternarchids. in which the organ takes its origin from the nervous tissue.

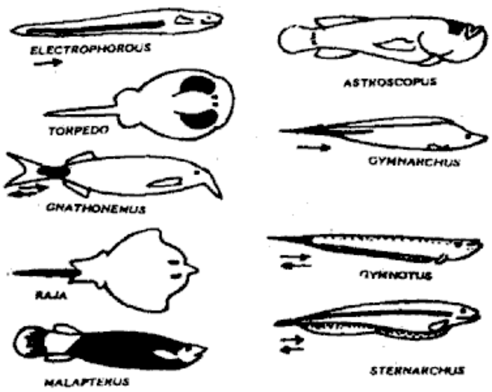


Fig. **12.5.** Electric organs in fishes (dark area indicates, position of electric organ and arrows indicate direction of current *flow).*

In skates *(Raja),* electric eels *(Electrophorous electricus).* and in mormyrids (e.g. the *Gvninarchus* and *Mormyrus)* the organ is derived by modification of tail muscles; in rays *(Torpedo)* from branchial muscles, in cat fishes *(Malapterus)* from body muscle and in stargrazer *(Astroscopus)* from the eye muscles. The electric organs of cat fish Malapterus are thought to have been formed from dermis, rather than from the muscular tissue.

12.2.2. Location

Location of electric organs varies in different fishes (Fig. 12.5). In Torpedo they lie on either side of head, between the gills and anterior part of pectoral fin, and are innervated by nerves connected to the brain. In electric eels such as the Electrophorous and Gymnotus and in Sternarchus, the organ extends laterally along on each side from trunk to the end of the tail. In Raja, Gnathonemus,. and in Gymnarchus they confine only to the region of tail and receive nerves supply from the spinal cord. More unusually in African cat fishes (Malapterus). they are situated between the skin and the muscles along the whole length of the body and in Astroscopus they are placed behind the eyes, one ach side. in the form of patches.

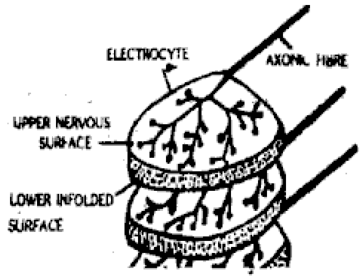


Fig. 12.6 Stalked electrocytes in Torpedo

12.2.3. Structure

Typically each electric organ comprises a large number of columns, held together by connective tissue. These columns may arrange vertically from ventral to dorsal surface as in *Torpedo* or may extend longitudinal from the tail to the head as in Electrophorous.

Each column contains (Fig. 12.6) a variable number of disc like cells called the electrocytes. All the electrocytes of a column are stacked together in a manner that the nervous sides of all the plates (electrocytes) face the same direction. A vascular gelatinous material of mesodermal origin fills the gaps between the adjacent plates. Each plate of a column can be distinguished into an outer, middle and an inner parts. The outer part is nervous and innervated by the terminal ends of nerve fibres. The middle part bears striations and the inner part is highly infolded to form a large number of papillae like structures, most probably for thepurpose of increasing surface area for discharge. The electric organs of Torpedo mormorata consists of about 450 columns, each containing about 400 plates.

It is supplied by the branches of Vth, VII, IX and X cranial nerves. South Americal electric eel (Electrophorous electricus) has about 70 columns; each containing about 600 plates. The later are innervated by over 200 nerves arising from the spinal cord.

Electric organ of *African Malapterus* electricus differs from others in being a dermal derivative. It lies between the skin and the muscles, in the form of a continuous layer and comprises a large number of columns separated by connective tissue. The electrocytes of the column are supplied by the spinal nerves and their nervous parts point towards the caudal end of the fish.

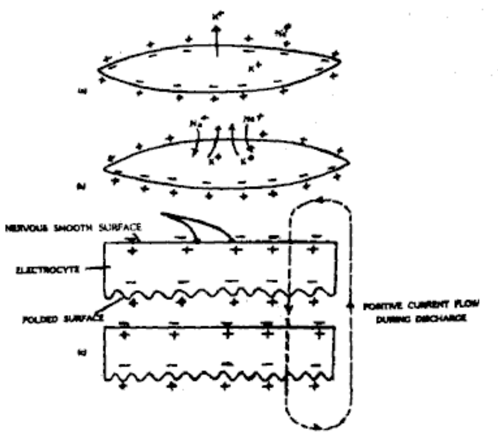


Fig. 12.7. Mechanism of electricity production and discharge
(a) resting potential; (b) when the electrocyte is stimulated.
(c) Na influx across the nervous surface and K leakage across the rough surface leading to positive current flow in the direction indicated.

12.2.4. Mechanism of function

The exact mechanism of function of electric organs in producing and storing the electric current is not accurately understood. The current is believed to be generated mostly by the modified muscle end plate on the nervous side of electrocytes. Small potentials arise by membrane deplorization in a manner similar to one which occur in normal nerve and the muscle cell. At rest the two surfaces (nervous and alveolar) of electroplates (cells) remain positively charged outside and relatively negatively charged inside (Fig. 12.7a). It is because, at rest the permeability of membrane to K^+ exceeds the Na membrane permeability, resulting into faster diffusion of K^+ exceeds the Na^{++} membrane permeability, resulting into faster diffusion of K^+ outwards than the diffusion of Na inwards and a resting potential of 100 mV is achieved.

As soon as the stimuli comes to the nervous face of the cell, the face becomes deplorized owing to the movement of positively charged Na+ inside the membrane (Fig.12.7). It is because, when appropriately stimulated, the permeability of membrane to Na^+ increases with the result that local influx ofNa^+ is generated. This large influx inverts the membrane potential and excites adjacent membranes to depolarize. Consequently the disturbance propagates over the cell surface and the innervated cells surface deploraizes. The resulting Na^+ flux across the smooth surface into the cell and K^+ leakage across the rough surface and out of cell yield a net positive current which flows from nervous to non nervous (rough) face (Fig. 12.7). The brief discharge called spike potential, arising from each electroplate are added up to give rise to much large external potential that even exceeds 600mv in many fishes.

The polarization of electric organs and the direction of current flow is however, not the same in all the electric fishes. Thus in *Torpedo* the current flows from dorsal (+ve) to ventral (-ve) side, In *Electrophorous* and *Gymnarchus*. it flows from tail to the head end and in *Sternarchids* the current has been reported to be produced by the nerve fibres themselves.

Depending upon the intensity of discharge, the electric fishes may be divided inte two groups viz, those producing discharge of large and other of small potentials. The fishes like *Torpedo, Electrophorous Malapterus*. *Astroscopus* and *Gymnarchus* produce very large potentials of high frequencies in the form of a regular series of small groups of pulses which travel like a wave. These fishes emit a continuous, nearly sinusoidal voltage with a very brief interval in between and between the two organs. In Torpedo this interval between the two organs has been measured to be of 0. 1 ms. The response of the wave fishes is therefore very similar to a reflex response. Fishes producing discharges of small potential include many mormyrids and the gymnotids. In these fishes, very small potential of low frequencies is generated in the form of irregular small pulses that have intervals ranging from one sec to a second or more in between.

Electrophorous however, emits both, the strong and the weak currents. Strong current produced from the large electric organs. measures from 500 to 600 V and the weak current produced from smaller organs measures to about 10V.

Total peak voltage as measured in some electric fishes is enumerated below:

Torpedo-50V in water and slightly more in air
Narcina sp tens of millivolts (weakly electric)

Electrophorous	-	500 V to 600 V
Malapterus	-	150V
Astroscopus	-	5 V
Gymnotus	-	fraction of volt
Stenarchids	-	high frequency 1 700 Hz.

The control and command system of electric organ lies within the brain. The neurons in torus semicircularies are reported to integrate lower order phase and the probability coded impulses. The lobus lateralis (posterior) and cerebellum suggested to be adapted better for detection of object than the microsecond temporal analysis.

12.2.5. Adaptive significance

When a fish discharges its electric organ an electric field is established in this surrounding. The field extend outwards from the fish to a considerable distance in the water. Ifthe field is distorted due to the presence of any conducive or highly resistant object in water, the electrical potential distributed, causing them to detect the presence of the object. However, the conductivity of sea water is very high and so the current generated by the fish get short circuited and therefore limited in range. It is because of this reason that the electric marine forms are limited and the function of clectrolocation in these fishes is questionable. It is in the fresh water, having much lower conductive that the organs are really in use.

The weak electric fishes like *Electrophorous.* mormyrids and some gymnotids, when stimulated produce pulses of increased frequencies and under some circumstances may cease altogether, presumably to comouflage themselves against the enemy which could detect them elctrically.

In strongly electric fish species, such as the torpedos, electric eels. electrical cat fishes, and the stargrazers, the discharge is of sufficient intensity to be of use in defensive or predatory behaviour.

12.3. Olfactory organs

Olfactory organs are paired occupying a conspicuous lateral position in the head and consists the olfactory rosettes, bulbs, lobes and nerves. Olfactory organs (Fig.12.8) are the receptors of the sense of smell. In fishes, they are confined to the olfactory epithelial lining of the olfactory sacs.

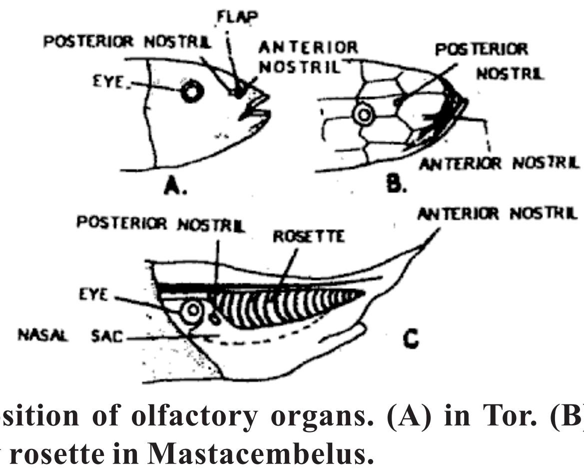


Fig. 12.8. Position of olfactory organs. (A) in Tor. (B) in Channa. (C) olfactory rosette in Mastacembelus.

The first rudiments of olfactory organs appear, close in front of the stomodaeum, in the form of pair of ectodermal placodes. Each placode invaginates to form the olfactory sac. Its epithelium folded forming the lamellae and cells differentiates into the neurosecretory olfactory and the supporting cells. Axons of olfactory cells grow and extend further to connect with the olfactory bulbs of telencephalon.

The position of each olfactory chamber is marked externally by a pair of dorso-ventrally oriented oval slits. They are situated half-way in between the eyes and mouth. They are separated significantly by an internasal distance. The nostrils lie very close to one another. Both are almost circular and wide open, the posterior being larger than the anterior. The incurrent opening is guarded by a hood like nasal flap on its posterior edge. This projecting hood like structure is continuous on the internal side like a short tube. The whole unit of internal nostril on inlet looks like a funnel which channelizes the water to the anterior region of the cavity of olfactory chamber bathing the olfactory rosette from its very tip. Hence by this combination of an external hood and an internal tubular curtain, water would be deflected during the forward progression of the fish, through the anterior nostril down amongest the lamellae of the rosette. The posterior opening also known as excurrent opening also known as excurrent opening or outlet, is large and helps in expelling the used water through it.

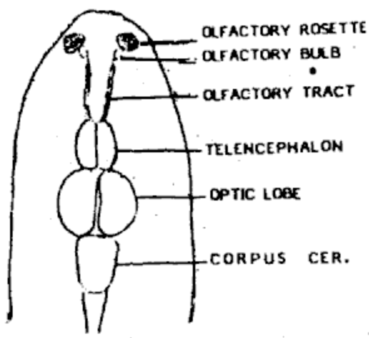


Fig. 12.9. The relationship between olfactory organ and brain in carp.

The olfactory chamber is oval in shape. it is supported by a bony skeleton comprising of nasal, frontal, lachrymal, ethmoid. palatine and supplemented by maxillary. The supra-ethmoid and the lateral ethmoid are modified for the accommodation of the olfactory organs. The postero-ventral boundary of the olfactory chamber is marked by lateral ethmoid. through which the olfactory tract passes from the rosette to the brain. The lateral wall of the chamber is formed by lachrymal. and is attached to the anterior margin of the lateral ethmoid. The floor of the olfactory chamber is supported by palatine. The anterior region of the chamber is supplemented by maxillary. Mesethmoid separates the olfactory chambers of the either side.

The olfactory chamber is transversely oval in shape and completely occupied by an olfactory rosette which is cup shaped. The dorsal surface of the rosette is concave, while the convex ventral surface is attached to a thin membrane, which inturn attaches to the olfactory chamber. This thin membrane is provided with a number of black pigments restricted to areas which lie directly under the two openings i.e.. incurrent and excurrent. Overall, the pigmentation occurs on the outer angle of the rosette. An olfactory nerve arises from the well developed olfactory lobe of the brain and is attached to a pear shaped olfactory bulb lying at the postero-ventral border of the olfactory rosette. The olfactory fibres arise from olfactory lobes, along with its olfactory stalk, lie parallel to the longitudinal axis of the body and re-oriented in such a way that concave free surface of the rosette is directed antero-laterally.

Each rosette has an elongated median axis, the raphae, to which are attacehed the olfactory lamellae. The lamellae, attached at the middle region of raphae are larger in size when compared to those of sides. This arrangement suggests a possible addition of new larnellae towards the anterior nostril. Each olfactory lamella is a crescentic structure, bearing a linguiform process at its concave end. The linguiform processes of all the lamellae combine to form a central cavity and a peripheral channel for water circulartion. The lamellae are simple and without any lamellar ridges or secondary branch. They are flattened leaf like structure, attached to the raphae by broader proximal and free distally.

12.3.1. Histology of the olfactory organ

The olfactory rosette has a continuous fold of olfactory epithelium covering the lamellae and the inter-lamellar raphae. which are a mass of connective tissue core. A well developed basement membrane is also present.

The olfactory epithelium comprises of the various cell types which include supporting cells, receptor cells, basal cells and goblet cells supporting cells also known as sustentatularells, are colunmar in shape and bear cilia. They have oval to spherical nuclei with granulated cytoplasm. The receptor cells have found and dark staining nuclei with dendrites ending at free epithelial surface. The inter lamellar epithelium has abundance of these cells. The basal cells lie close to the basement membrane. They are cuboidal in shape with fine cytoplasmic processes and prominent nuclei. On the free surface of olfactory epithelium are distributed, profusely a number of mucous secreting goblet cells. They are oval to pear-shaped with basal nuclear and granular cytoplasm. The central core of lamellae comprises of loose connective tissue, blood vessels, nerve fibrils, scaltered basal cells and few small spaces. The raphae also shows the same cell structure except for the collagenous and elastic fibres and areolar tissue. It is encircled by basement membrane and provided with large blood vessels. The nasal flap, extending over the rosette in the olfactory chamber. is made up of flattened epithelial cells, supported over a layer of elastic connective tissue.

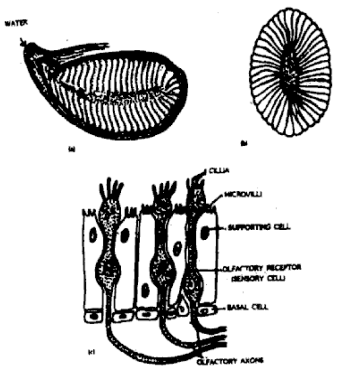


Fig. 12.10. Structure of olfactory organ (a) olfactory rasette of Tor; (b) rosette of Mastacembalus, (c) composites of olfactory epitheliurn.

The olfactory organs of elasmobranchs are a pair of blind olfactory sacs, each opening to the exterior by an aperture, the external flare. The external nare is divided by a fold of skin into an anterior and a posterior aperature, in order to direct water in, through one and out through other aperture. Many elasmobranchs possess an oronasal groove, connecting each nostril to the corresponding corner of the mouth. The olfactory epithelium confines to the drosal part of the groove and consists of the usual folds containing the olfactory and the supporting cells.

Olfactory organs of bony fishes are a pair of olfactory sacs, lying dorsally in front of the eyes. Each sac is a blind pit, that lie well protected within an ossified capsule and opens only to exterior through the external nostril. The nostril may be single (e.g. *Gasierosteus),* or may bepartitioned (as in most other bony fishes) into an anterior and a posterior nare for allowing one way flow of water through the olfactory pit.

The olfactory epithelium of olfactory sac folds to assume different shapes. Folding may betransverse, longitudinal, radial, or in a manner leading to the rosette shape of teleosts (Fig. 12.10 a,b). The rosette is oval in *Tor* and *Labeo*. elongated in *Clarias*, circular in *Channa* and in a few carps, and feather shaped in *Anguilla.*

Many fishes have accessory sacs lying in close association with the olfactory sacs. These are believed to help in maintaining the current of water through the olfactory sacs.

Fishes being aquatic animals, depend largely on their olfactory sense to defect their food. Oflactory organs are also employed in their social behavior such as in recognizing themale by a female fish (e.g.*Lebistes*) and in identifying different genera of fishes by minnows. Slamon responds by olfactory sense to different odours like that of boar, dog or the human hands.

Water enters the olfactory chamber through the incurrent anterior nare and leaves through the excurrent posterior nare. The entry into the chamber is gained by the action ofcillia lining the sac, aided by the forward motion of the fish or by the active pumping caused by the accessory sacs. Function of olfaction is performed mainly by sensory receptor cells which send their axons to the olfactory bulbs for analysis and interpretation of the impulse.

SUMMARY

Fish consists of many sense and specialized organs like eyes, olfactory ogans, membranous labyrinth, lateral line system, electric organs and sound producing organs. Lateral line system consists of lateral line canals and large number of neuromast cells. Canals are arranged on lateral side of fish from head to tail. This system is sueful in detecting water currents.

Electric organs are found in *Tarpedo. Narcine, Raia, electrophorus, Gymnarchis*, etc. The electric orttgans are modification of muscles and nerves. The electricity is useful for protection, predation and attrafin opposite sex.

Olfactory organs are found in the snout region of the fish. It constists of ofactory rosset, lamellatre, and connect to brain with olfactory nerve. It is useful for olfaction.

Questions

1. Describe the lateral line system in fishes
2. Discuss theelectric organs in fishes.
3. Give an account on olfactory organs of fishes.

13

ECOSYSTEM

Ecology embraces an interrelationships of organisms with the environment, the organisms and environments in a single location constitute *ecosystem* (Tansley, 1935). Ecological system or ecosystem comprises specific unit of all the organisms occupying a given area thereby producing distinct tropic structure, biotic diversity and material cycles. The term ecosystem was first of all coined by A.G. Tansley (1935) and defined it as an "integrated system resulted from interaction of living and non-living factors of the environment". As the term *ecosystem* indicates *'eco'* meaning environmental and "system" implying an interacting inter-dependent complex. Thus ecosystem may be defined as any unit which includes all the organisms (i.e., communities) in a given area, which interacts with the physical environment resulting in the flow of energy and biotic diversity as well as material cycle. Other ecologists such as Mobius (1877) and Forbes.(1877) used *biocoenosis* and *micrososm,* terms for ecological system. Still others, namely, Russian ecologists (Sukachev, 1944 etc.) called ecosystem as geobiocoenosis.

According to Odum (1963), organisms and physical features of the habitat form an ecological complex or ecosystem. Thus ecosystem is the basic functional unit of ecology embracing biotic communities and abiotic environment both influencing each other. Every ecosystem encompasses interacting organisms that transform and transmit energy and chemicals. These energy and chemical flow processes support ecosystem organisation and are responsible for the functional identities of ecosystem. The ultimate source of energy for all the ecosystem is sun.

In nature, different types of ecosystem exist constituting giant ecosystem so called biosphere. There are mainly two categories:

1. Natural ecosystem: These operate under natural conditions independently without any major interference by man. On the basis of various kinds of habitats, natural ecosystem may be further subdivided into terrestrial type (e.g. grassland, desert, forest, etc.) and aquatic including freshwater (ponds, rivers, etc.) and marine (sea, estuary, etc.) ecosystems.

2.Artificial ecosystem: These are man-made ecosystem being maintained by artificial means. In them, natural balance is disturbed by addition of energy and planned manipulations. Cultivation of crops (maize, rice, wheat crops) represents man-made ecosystem.

Ecosystems are also classified into terrestrial and aquatic ecosystems. In aquatic ecosystems, the characters and extent of community succession in a given area depends on climate and soil condition. The climax community is achieved only if environmental factors permit a fish sequence of serial stages. All ecosystems resemble each other in the sense that all have same components, i.e. autotrophic and heterotrophic, interacting upon each other thus bringing about circulation of materials. In one ecosystem, the climate and soil conditions are relatively uniform and they favour the growth of a certain kind of climax community.

Aquatic ecosystems are usually, divided into (i) fresh water, (ii) marine water, and (iii) estuarine water.

There are two categories of fresh water ecosystems (a) lentic or standing or stagnant water including ponds, lakes and reservoirs (b) lotic or running Water are those which occur in fast running streams, springs, rivers and brooks. Fresh water ecosystems have low percentage of dissolved salts. They have fluctuating physical and chemical factors affecting the flora and fauna.

13.2 POND ECOSYSTEM

A pond as a whole serves a good example of a freshwater ecosystem. A pond indeed exhibits a self-sufficient, self-regulating system. Not only in the pond a place where plants and animals (living organisms) live, but plants and animals make the pond what it is physico-chemical environment. This would become clear if you examine a bottle full of pond water or a scoop full of bottom mud, which shall show the living organisms (plants as well as animals) and a mixture of inorganic and organic compounds. Some larger forms of life are also present in pond. Thus, whole system becomes much complex indeed. However, we may study the pond as an ecosystem by making its convenient division in some basic components, as shown in Figure 13.1 These components are as follows.

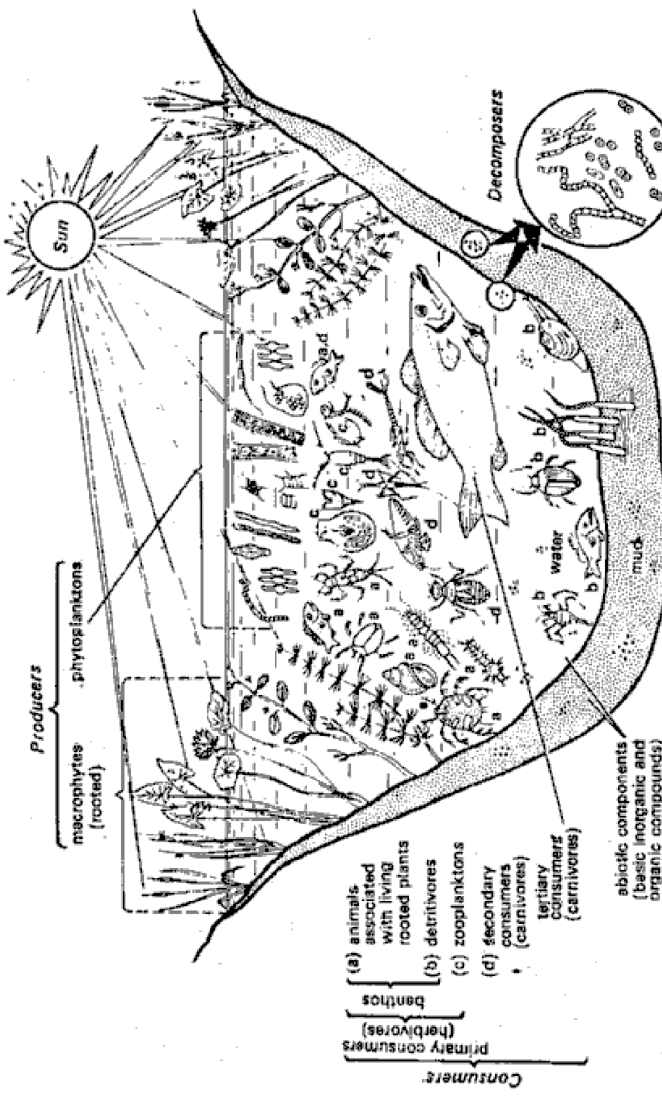


Fig. 13.1 Diagram of the pond ecosystem, showing its basic structural units- the abiotic (inorganic and, organic compounds) and biotic (producers, consumers and decomposers) components.

13.2.1. ABIOTIC COMPONENTS

The chief substances are heat, light, pH value of water, and the basic inorganic and organic compounds, such as water itself, carbon dioxide gas, oxygen gas, calcium, nitrogen, phosphates, amino acids, humic acid etc. some proportions of nutrients are in solution state but most of them are present as stored in particulate matter as well as in living organisms. The light intensity is measured by a Lux-photometer. Turbidity index of water at different depths is obtained by a Sechhi disc. Rates of evapo-transpiration are calculated. The pH of water and mud is determined by an electric pH meter. Dissolved oxygen content, carbon dioxide content, solute contents including colloidal suspensions, phosphate and nitrogen contents of water, and plant and animal matter are estimated by appropriate methods (Misra, 1968). Amounts of various organic compounds (carbohydrates, proteins, lipid etc.) are also estimated for biomass determination.

13.2.2. BIOTIC COMPONENTS

The various organisms that constitute the biotic component are as follows:

13.2.2.1. Producers

These are autotrophic, green plants-and some photosynthetic bacteria. The producers fix radiant energy and with the help of minerals derived from the water and mud, they manufacture complex organic substances as carbohydrates, proteins, lipids etc. producers are of the following types

13.2.2.1.1. Macrophytes

These are mainly rooted larger plants which include partly or completely submerged, floating and emergent hydrophytes. The common plants are the species of *Trapa, Typha, Eleocharis, Sagittaria, Nymphaea, Potamogenton, Chara, Hydrilla, Vaillisneria, Utricularia, Marsilea, Nelumbo* etc. Besides them some free-floting forms as *Azolla, Salvinia, Wolffia, Eichhornia, Spiroclella,.* etc. also occur in the pond.

13.2.2.1.2. Phytoplanktons

These are minute, floating or sustpended lower plants. Majority of them are such filamentous algae as *Zygnema, Ulothrix, Spirogyra, Cladophora* and O*edogonium.* Besides them there are also present some *Chiorococcales, Closterium, Cosmarium, Eudorina, Pandorina, Pediastrum, Scendesmus, Volvox, Diatom, Anabaena, some chroococcajes, Gloeotrichia, Microcytstic, Oscillotoria, Chiamydonionas, Spriulina* etc. and also some flagellates.

Macrophytes may be sampled by quadrat method in a unit volume of water. Biomass is estimated as weight of standing crop per unit area or volume. Generally, biomass of vegetation decreases from the margin of the pond towards its center. Energy contents of macrophytes may be estimated by igniting the samples in an Oxygen-Bomb-Calorimeter. The energy content is generally expressed in terms of Cal/g dry wt or Cal/g ash-free dry wt. The rates of radiant energy fixation during photosynthesis are also determined by appropriate methods. Generally, the energy content of vegetation decreases from margin towards the center of pond.

Phytoplanktons are sampled by nets tied to a collection glass bottle. Their biomass is estimated in terms of number per unit volume of water, after sedimentation. It is expressed as average biomass/cubic meter of water.

13.2.2.2. Consumers

They are heterotrophs which depend for their nutrition on the organic food manufactured by producers, the green plants. Most of the consumers are herbivores, a few as insects and some large fish are carnivores feeding on herbivores. Some fish also feed on other carnivores as well. The consumers in a pond are distinguished as follows:

13.2.2.2.1. Primary consumers (herbivores)

Also known as primary macroconsumers, these are herbivores feeding directly on living plants (producers) or plant remains. These may be large as well as minute in size. The herbivores are further differentiated as:

(i) **Benthos**: These are (i) the animals associated with living plants (producers), labeled as ‘a’ in diagram, and (ii) thos bottom forms which feed upon the plant remains lying at the bottom of pond. These are known as detritivores, labeled as ‘b’ in the diagram. Benthic populations include fish, insect larvae, beetles, mites, mollusks, crustaceans etc. weight of benthic fauna is estimated in different zones of the pond, and the biomass expressed as g/m^2 of water.

Besides the above said herbivores, some mammals as cows, buffaloes etc. also visit the pond casually and feed on marginal rooted macrophytes. Some birds also regularly visit the pond feeding on some hydrophytes:

(ii) **Zooplanktons**. These are chiefly the rotifers *as Brachinous, Asplanchna, Lecane* etc., although some protozoans as *Euglena, Coleps, Dileptus* etc., and crustaceans like *Cyclops, Steno cypris* etc. are also present. They feed chiefly on phytoplanktons. In diagrams these are labeled as ‘c’.

13.2.2.2.2. Secondary consumer (carnivores)

They are the carnivores which feed on the primary consumers (herbivores). These are chiefly insects and fish. Most insects as water beetles feed on zooplanktons. These are labeled as ‘d’ in the diagram.

13.2.2.2.3.Tertiary consumers (carnivores)

There are some large fish as game fish that feed on the smaller fish, and thus become the tertiary (top) consumers as shown in diagram.

In a pond, fish *may* occupy more than one trophic levels. The smaller fish belong to herbivores levels, feeding on phytoplanktons as well as living plant (Fig.13. 1) parts (labeled as *‘a’),* and also on plant remains lying at the bottom (labeled as ‘b’). some fish may feed on some zooplanktons, thus occupying the secondary consumers level — the carnivores level (labeled as ‘d’). still it is common to observe the large fish feeding on smaller fish, and thus occupying the tertiary consumers level.

13.2.2.3Decomposers

They are also known as micro consumers, since they absorb only a fraction of the decomposed organic matter. They bring about the decomposition of complex dead organic matter of both — producers (plants) as well as the macroconsumers (animals) to simple forms, Thus they play an important role in the return of mineral elements again to the medium of the pond. These include a variety of heterotrophic microbes that are osmotrophs. These are sampled by the use of several isolation methods. They are chiefly bacteria, actinomycetes and fungi. Fungi are isoland by Warcup 's method on Martin's medium, bacteria on Thornton's medium, and actinomy cetes on Jenson's medium. *Rhizopus, Penicillium, Thielavia, Alternaria, Trichoderma, Circinella, Fusarium,,Curvu1aria, Paecilomyces, Saprolegnia* etc. are most common decomposers in water and mud of the pond.

13.3. LAKE ECOSYSTEM

A lake is a stretch of water surrounded on all sides by land. They seem, on the scale of years or of human life-span, permanent features of landscapes, but are geologically transitory, usually borne of catastrophes, to mature and to die quietly and imperceptibly (Fig.13.2). Forel (1892) defines a lake as a body of standing water occupying a basin and lacking continuity with the sea. By this definition, he eliminated those so-called lakes which are semi-isolated, small arms of the sea. Muttkowski (1918) defines lakes are large bodies of freshwater, usually deep enough to have a pronounded thermal stratification for part of the year. Typically, shores are barren and wave-swept.

Welch (1952) regards all large bodies of standing water as lakes, eliminting in his definition, ponds which, according to him, are very small, shallow bodies of quiet, standing water in which extensive occupancy by higher aquatic plants is a common feature.

13.3.1.ABIOTIC FACTORS

13.3.1.1. Thermal Properties of Lakes

Temperature is one of the most important factors affecting standng waters. In fact no other single factor has so many profound as well as so many direct and indirect influences. A lake affords a rather neat environmental unit in which temperature relations have been studied intensively.

One of the thermal effects in standing water bodies is the process of stratification, created by density differences resulting from differential heating of the water body. In the absence of strong winds and with increasing solar radiations, there is a gradual rise in the temperature of the surface waters

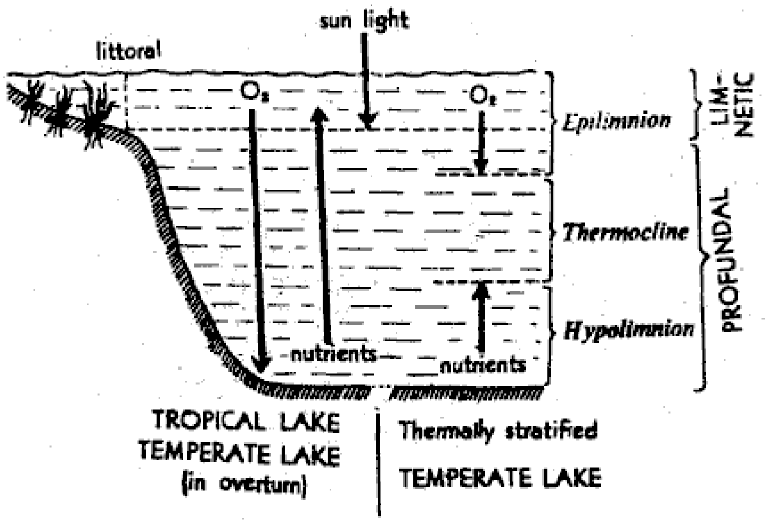


Fig.13.2. Ecology of lake

which, therefore, become less dense than the water in the deeper layers. As the surface layer warms up, an incrasing density difference develops between it and the deeper layers, and a direct *stratification* is established in which the warn upper layer of water, the epilimnion, is separated from the col4 lower water, the hypolimnion by a narrow transition zone (zone of gradient), the thermoeline. Birge's arbitrary rule for the location of the thermocline limits it to the region in which the drop in temperature is at least 1^0C per meter of depth.

Due to the anomalous expansion of water, lakes can stratify in different ways according to the temperature regime imposed through the local physiography. In some lakes stratification is permanent, in some seasonal, intermittent in others, and completely absent in still others. The usual geographic and physiographic classification of lakes of the world is based on these relationships was originally suggested by Forel (1991) and later modified by Whiple (1927) and Welch (1935).

In general, lakes over 90 meters in depth belong to the first order; those between 8 and 90 meters, to the second order; and those lesser than 8 meters, to the third order. Ponds are considered to be lakes of the third order consisting of only the epilimnion, the thermocline and hypolimnion being absent. Based on the temperature cycle and stratification, Hutchinson (1957) has classifed standing waters into six types. However, lakes may be intermediate in type and may vary from year to year.

Classification of lakes on the basis of geography and pattern of circulation.

I. Polar lakes:Surface temperature never above 4^0C

II. Temperature lakes: Surface temperature vary above and below 4^0C

Temperature of bottom water similar to that of surface water; circulation in all seasons.

Classification of lakes on the basis of temperature cycles and stratification

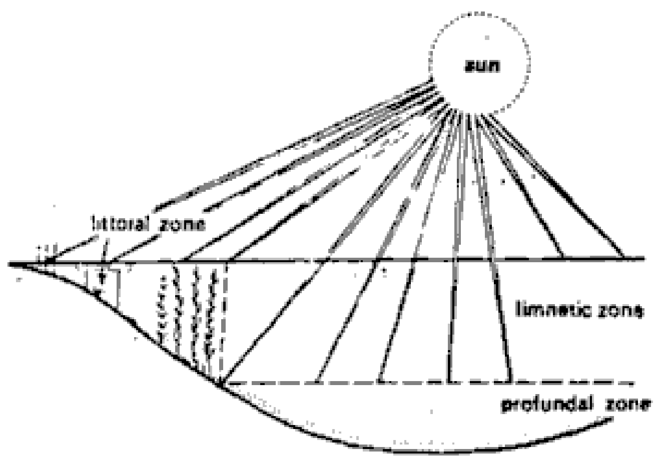
Type		**Characteristic**
1. Amictic	:	Sealed off by ice permanently, and always remain below 4^0C. They never undergo circulation.
2. *Cold monomictic*	:	Water temperature never rises above 4^0C at any depth. Freely circulating in summer at or below 4^0C.
3. Dimictic	:	Lakes circulating completely in spring when

water temperatures rise above 4°C; they stratifyduring summer, and mix again in autumn, when the lake cools.

4. *Warm monomictic* : Water never below 4^0C at any level; freely circulating in winter at or above 4^0C; directly stratified in summer.

5. Oligomictic : These lakes are confined to very warm areas. Water tempertures are always considerably above 4^0C, and permanent stratification is normal, although this may break down intermittently due to wind. Found in the humid tropics.

6. Polymictic : Mixing is continuous but occurs only at low temperatures (just over 4^0C). No thermal stratification.



With increasing radiation in summer, the lake gains heat and stratification sets in. Stratification is evidenced by a gradual rise it the temperature of surface waters, compared with those at greater depths. Stratification divides the lake horizontally into two parts separated by a thermocline. The epilimnion consists of more or less uniformly warm, circulating and fairly turbulent waters, while the hypolimnion is made up of a deep cold and relatively undisturbed region.

13.3.1.2 Water Current

Wind is an important factor in relation to the water current it generates. The effect of wind action depends to a large extent on the area of the exposed water surface, the presence or absence of protecting upland, and the configuration of the lake relative to the prevailing wind direction.

When the temperature of the lake is uniform, and a wind blows at the surface, there is a vertical circulation of the water due to currents created by this wind. A return current provides water to replace that driven along by the wind, and this may extend even at the bottom, although much weaker. This complete circultion is responsible for the even temperatures found in lakes between periods of stratification.

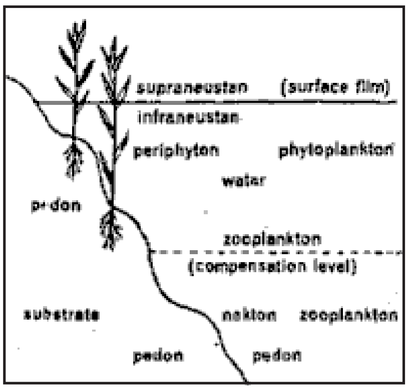


Fig. 13.4. Stratification of fresh water fauna in a lake

As stratification (Fig.13.4.) develops and a thermocline is formed, the temperature and density gradients become marked, the water movement within lake is affected. Wind-induced currents do not penetrate below the thermocline. Waves may become sizeable in large lakes, but the formation of a wave does not involve any gret mass of water, and the effect rarely penetrates below 20 meters. The rate of movement of surface water is usually lesser than five per cent of the velocity of the wind.

13.3.1.3. Turbidity

Turbidity results from the presence of suspended matter, often referredto as seston. The suspended material may be composed of both inroganic and organic material (tripton) as well as living oranisms (mainly phytoplankton and zooplankton). In natrual waters autochthonous materials such as phytoplankton are sometimes sufficiently abundant to produce a noticeable reduction in light, but also induces additional reflection.

Allochthonous material derived from the surrounding land may also increase the turbidity. These flow into the system along with rain water and consists mainly of silt, fallen leaves and decaying material. Eventually these settle down to the pond bottom.

Turbidity is an important limiting factor in the productivity of lakes and ponds, since it restricts the amount of light passing into the water body. Inadequate light for phytoplankton means less food for zooplankton and ultimately for the entire food chain.

13.3.1.4. Light

The amount of radiation entering lake waters depends upon the degree of reflection and refraction, the angle of incidence, water motion, and the amount of dissolved and suspended solids. Light entering lake waters is reduced in intensity and quality both by absorption and scattering, and the rate of reduction is measured as the extinction rate. Red light is absorbed most rapidly, at the rate of 64.5 per cent per meter, green at 1.1 per cent and blue at 0.52 per cent.

In general, the phytocommunity is distributed in standing waters according to their energy requirement, and most of them are present in the euphotic zone where sufficient light is available for photosynthesis. The depths to which rooted macrophytes and attached algae can grow on suitable are capable of growing where light intensity may be as little as one per centof that of the surface. Normally light restricts the growth of rooted macrohytes to waters lesser than 10 m in depth.

13.3.2 CHEMICAL CHARACTERISTI CS

13.3.2.1.Oxygen

As in other aquatic systems, the quantity of dissolved oxygen present in lake waters is of prime importance. The amount of oxygen that can be held in water even at saturation, is small compared to air, and is directly proportional to the partial pressure in the gas phase and decreases in a non-linear manner with increasing temperature. The amount of oxygen present in water is only one-fortieth to one-twentieth of that present in an equal volume of air when the two are in equilibrium, although their partial pressures are the same.

The amount of oxygen in a lake depends on the extent of contact between water and air, on the circulation of water and on the amounts produced and consumed by the lake community. The amount of oxygen released by plants varies with their abundance and time of day. At night when photosynthesis ceases, the plants consume oxygen and release carbon dioxide through respiration.

The upper layer of a lake, where photosynthesis predominates, is called the trophogenic zone. Below this zone there may still be considerable photosynthesis, but oxygen consumption is greater than oxygen release. This zone is termed as the tropholytic zone. These two zones are separated by a thin layer, where oxygen-gains from photosynthesis during the daylight hours are balanced by the respiratory and decomposition losses during the night. This is the compensation depth, at which generally one per cent of the radiant energy at the surface, is available.

13.3.2.2Carbon Dioxide

The amount of carbon dioxide present in the medium is crucially important for aquatic organisms, just as it is for terresrial forms. However, the amount of free carbon dioxide present in natural standing waters is generally low and the concentation is generally maintained by diffusion from the atmosphere, respiration of animals andplants, bacterial decomposition of organic matter, seepage of inflowing ground water, and from bound carbon dioxide. The respiration of aquatic plants and animals, and the decomposition of organic matter in the water add to the carbon dioxide supply of the water medium. In contrast, the photosynthesis by plants tends to draw upon the CO_2 reserve.

13.3.2.3 Total Alkalinity

Natural waters in the tropics show a wide range of fluctuation in alkalinity values depending upon the locatin, season, plankton population and natrue of bottom deposits. Water in heavy-rainfall areas, and infested with submerged weeds usually have low total alkalinity values. However, stagnant waters in tropical plains, in low-rainfall areas are likely to have a high total alkalinity during the summer season.

In its diurnal fluctuation, bicarbonate ions are generally high in the early hours of the morning. As the rate ofphotosynthesis increases and free carbon dioxide is rapidly utilized, the bicarbonate ions provide free carbon dioxide forphotosynthesis. The utilization of bicarbonate ions leads to a decrease in its concentration, while the concentration of carbonate ion increases.

At night when carbon dioxide is added by the community respiration, it combines with water to form carbonic acid, which then dissociates to form bicarbonate and hydrogen ions. The hydrogen ions thus released shift the pH towards the natural side. The carbonate ions then buffer the pH and are exhausted in the process. This diurnal chemical rhythm continues.

13.3.2.4.pH

The pH of most unpolluted standing waters is between 6.0 and 9.0.

There is a diurnal as well as seasonal fluctuation of pH in ponds and lakes. The daily rhythm is in correlation with two metabolic activities, photosynthesis and respiration. Since the pH is dependent on the amount of CO_2 and bound carbon in the system, any change in the carbon dioxide concentration results in a consequent change in pH. The pH is generally maximum around midday, decreasing with decrease in photosynthesis.

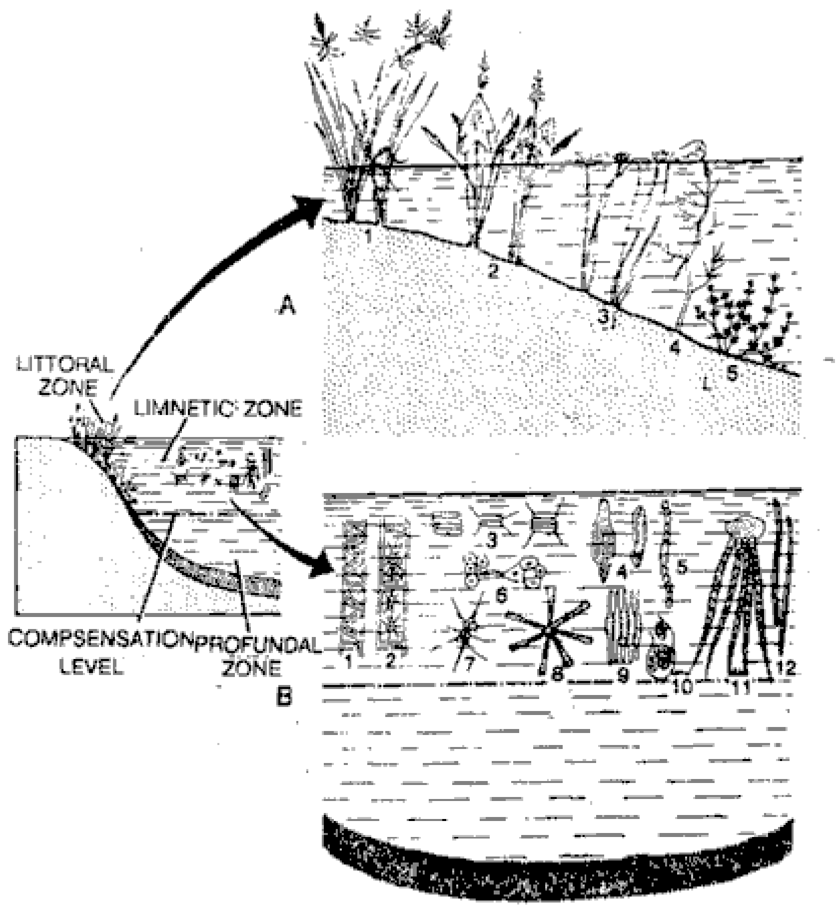


Fig. 13.5 Some producers of lentic communities including emergent, floating and submerged rooted plants of littoral zone A: (1-5).
B 1. *Spirogyra;* 2. *Zygnema;* 3. *Scendesmus;* 4. *Navicula;* (5) *Anabaena;* (6) *Goelastrum;* (7) *Richteriella;* (8) *Asterionella;* (9) *Fragilaria;* (10) *Microcystis;* (11) Gloeotrichia and 12. *Nitzschia.*

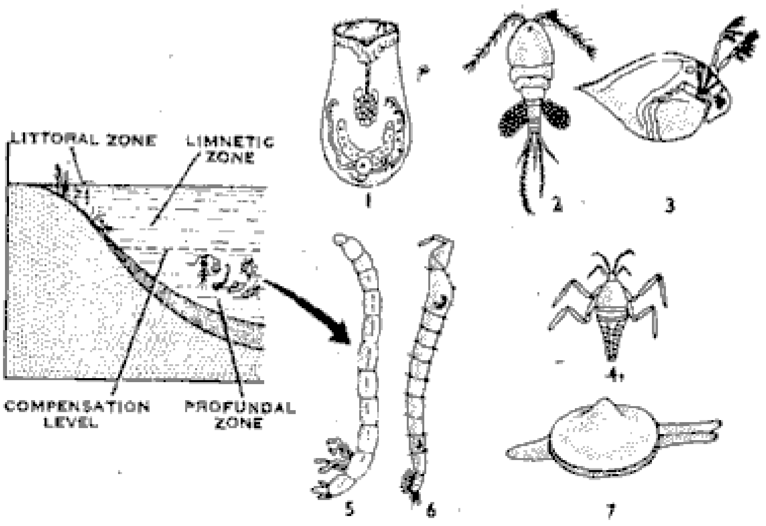


Fig.13.6. Zooplankton-1.Rotifer; 2. Copepod; 3. ***Daphnia; 4.*** **Water.**

In deep waters, especially during the stagnation and stratification periods when the carbon dioxide concentration increases considerably, the pH decreaes and these layers become acidic favouring the growth of microorganisms and the resultant enhancement of the process of decomposition. In its seasonal variation the pH decreases with the onset of monsoons when rain water brings in a fresh load of carbon dioxide.

13.3.2.5. Disolved Solids

All natural waters contain dissolved solids, the quality and quantity of which depends on the geological nature of the drainage basin and the influence of human activities. However, other processes such as erosion of shoreline, wind-blown materials, inflow of surface waters, decay of organic materials -all provide a lake. with quantities of solid materials either already in solution or subsequently becoming so.

Precipitation in the form of rain may contain as much as 30 to 40 mg/L of solids, and the runoff dissolves more as it drains over the upland into streams and lakes. Water draining off siliceous or sandy soils may contain 50 to 80 mg/L of dissolved minerals; off more fetile calcareous soils, 300 to 600 mg/L. Lake waters commonly vary from about 15 to 300 mg/L of dissolved minerals, and sometimes much more, as for example, in inland salt lakes.

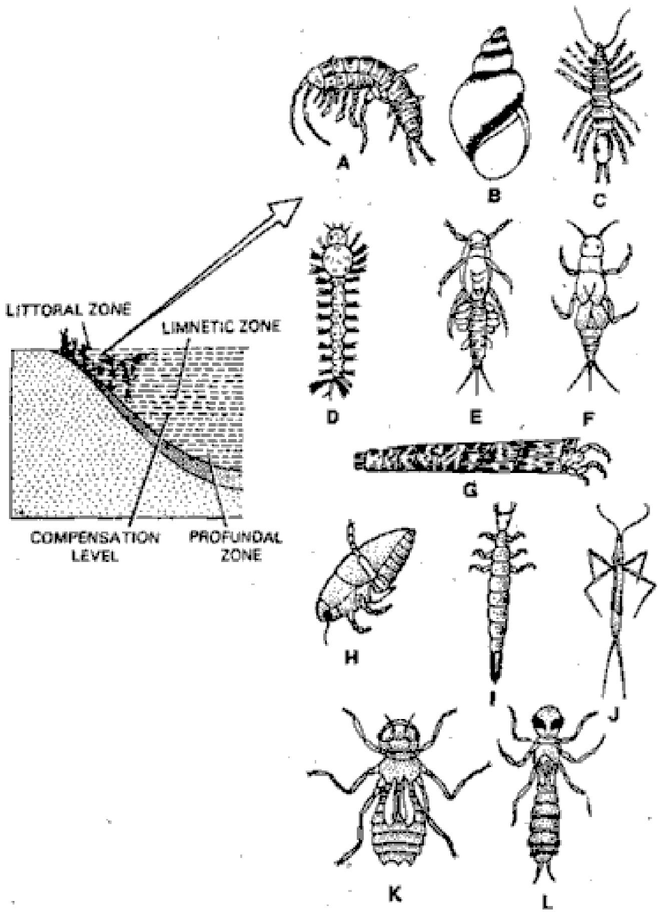


Fig. 13.7 Some animals of the littoral zone of ponds and lakes-1. Amphipod; 2. Pond snail; 3. Isopod; 4. Mosquito larva; 5. and 6. Mayfly nymphs; 7. Caddisfly larva; 8. Adult *Dysticus* and; 9. Its larva; 10. Water scorpion, *Ranatra*; 11. and 12. Dragonfly nymphs

The total dissolved content of a lake is important in determining its general level of productivity. Seasonal fluctuations occur in the amounts of dissolved substances in water, being maximum after the overturns. By summer, their quantities are heavily reduced by the spring and early summer outburst of planktonic algae. A seasonal cycle is generally found in tune with the environmental conditions and activity of the biota.

13.3.3. BIOTIC FACTORS

It is described in detail in Limnology of this chapter.

13.4. RESERVOIR ECOSYSTEM

River water is usually running or flowing water. Construction of dam turns the section of the river immediately behind it into a lake, called reservoir or dam-lake, in which the lotic water of the upper reaches becomes lentic as water approaches the dam. (Fig. 13.8). Reservior ecology is thus changed from the usual riverine ecology to lacustrine ecology with passage of time. Thus necessitates an entirely different type of fishery, called reservoir-fishery, in place of riverine fishery, to suit the ecology of the reservoirs. A reservoir, however, has its own special features in which it differs from natural lakes. But, unlike in natural lakes, the time for which ‘cater is retained is relatively very short, and, since the water outflow may take place from deep water also, the hypolimnion is removed in temperate reservoirs. In reservoirs, in contrast to condition in lakes, water level is subject to great fluctuation.

The riverine ecology of the water of the upper reaches becomes increasingly changed into lacustrine ecology in the reservoir. The benthic riverine fauna disappears and it is replaced by typical lacustrine benthic fauna. With the change from lotic to benthic condition of the water current, riverine plankton are replaced by lacustrine plankton. The turbidity level is also reduced as reservoirs act as settling besins. Fish fauna is greatly affected. The running water fish species become fewer or are completely eliminated. Slow water fish species prodomine. Floating plants (Pistia, Salvinia, etc.) may come up, particularly in tropics where they create deoxygenation conditions for cause other serious ecological problems.

The dam in some way interferes with the ecology of the upper reaches of the river. Migratory fishes are completely wiped out from the upper reaches. This often leads to disturbances in the ecosystem especially with advantage to the prey (in the absence of its predator - the migratory fish).

The reservoir itself may affect the ecology of the lower reaches of the river. Periodical discharge of sediments from the reservoirs may cause mud and silting in the lower reaches with serious consequences on the fauna. However, plankton is increased in the lower reached due to drift from the reservoir, and turbidity is reduced. Reservoir act as fertility trap reducing the amount of dissolved plant nutrients which would otherwise be freely arriving at the lower reaches. However the tail - water released from the outlet often supports extensive fisheries in the stream below. If the discharge is from the hypolimnion, an excellent sport fishing for angling occurs for cold water species (trou etc.). If the discharge is from upper outlets warm water fish species will largely support fishery.

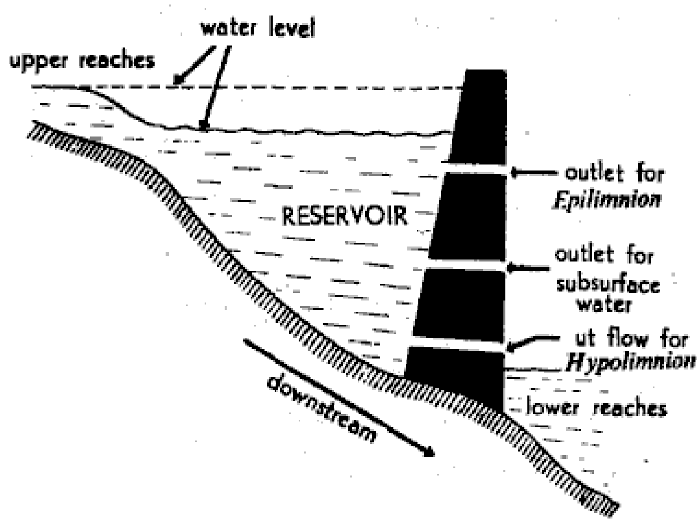


Fig. 13.8. Ecology of reservoirs

13.5. ESTUARINE ECOSYSTEM

An estuary is usually defined as a semi-enclosed coastal body of water having free connection with open sea. Thus, it comprises of both sea water and fresh water and occurs, usually nor the river mouths, coastal bays and tidal marshes. Primarily it is a passage or inlet where tidal water comes in contact with a river current. In other words, it may be designated as a confined arm of the sea situated at the lower and / or mouth of a river. Generally, estuaries may be thought as transition zones (or ecotones) between fresh water habitat and marine habitat. They consist of brackish water which may be either oligohaline, mesohaline or polyhaline on the basis of degree of salinity. They undergo seasonal organismal changes and thus belong to "fluctuating water-level ecosystem".

13.5.1. KINDS OF ESTUARIES

On the basis of geomorphology; the estuaries are broadly classified into four categories. They are:

13.5.1.1. Drowned river valleys

These are very common along the coastlines and are characterized by low and wide coastal planes, e.g., Chesapeake Bay of the United States.

13.5.1.2. Fjord type estuaries

They are deep, U-shaped coastal formations usually formed by glaciers, e.g., Norwegian fjords.

13.5.1.3. Bar built estuaries

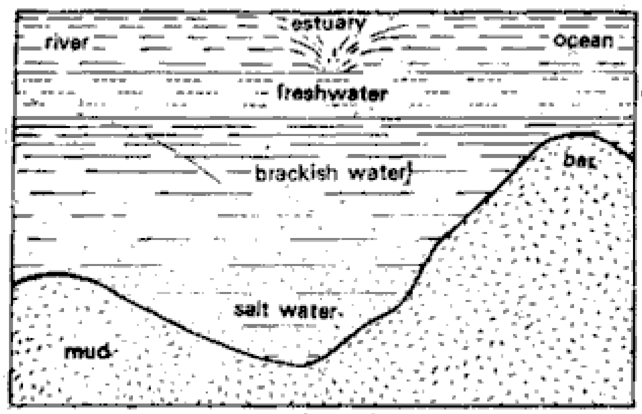
These are shallow basins along the seashores being partly exposed at low tide and surrounded by a discontinuous chain of barrier islands. The inlets between these barriers connect various estuaries with the sea, e.g., 'sea islands', salt marsh estuaries from Georgia.

13.5.1.4. Tectonic estuaries

These are formed as a result of local subsidence (sinking) of land or by some geological faulting along the coasts, e.g., San Francisco Bay.

13.5.1.5. Other kinds

Besides the above four categories, there are *river delta estuaries* present at the mouths of large rivers., e.g., Nile river.



On the hydrographic basis, they are further classified into three categories.

13.5.2.1. High stratified estuaries

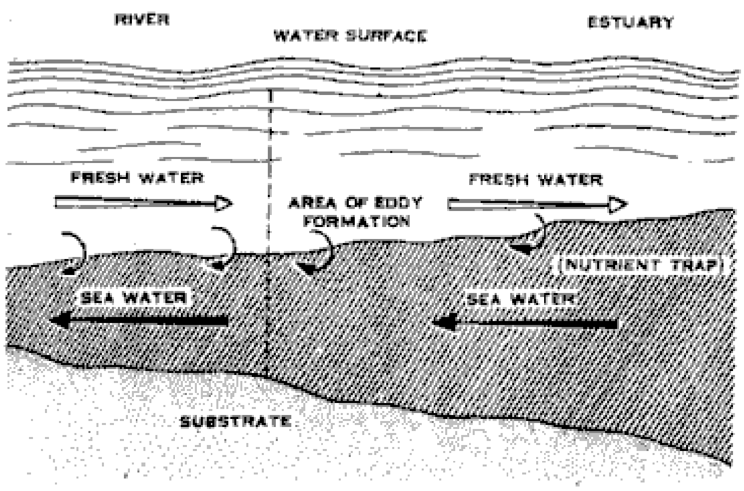
These are also called as salt-wedge estuaries, characterized by higher stratification of water. In it, flow of river water is dominant over sea water's tidal action with the result that fresh water overflows heavy salt water forming a sort of 'wedge' extending forward. Thus, two layered or stratified estuary is produced, e.g.: mouth of Mississippi River.

13.5.2.3. Moderately stratified estuaries

It is also termed as 'partially mixed' estuary, where fresh water and tidal inflow balance each other, e.g., Chesapeake Bay.

13.5.2.4. Vertically hemogeneous estuaries

These comprrise of "completely mixed" system in which tidal action is dominant and water mixes from top to bottom. Salinity is relatively higher, e.g., Bar-built estuaries.



. . Horizontal turbulance and formation of eddies. The horizontal turbulance forms nutrient traps in the interface zone between the ˡavyers of fresh and salt water.

13.5.3. Turbulence in Estuaries

Generally, the amount of fresh water entering into the estuary at its upper end will vary with the seasonal changes. The flood tide volume of water entering a particular estuary may bring about an increased amount of longitudinal movement of water. Thus in salt-water estuary, a boundary is formed by the mass of fresh water current coming into contact with the underlying mass of salt water and at this boundary, there is great shearing force which causes horizontal turbulence resulting in *eddy formation.* These eddies contain most of the nutrients of the estuaries and some ecologists call them *nutrient traps.*

13.5.4. ABIOTIC FACTORS

13.5.4.1. Temperature

The temperature in the estuaries varies considerably diurnally and seasonally. The temperature of estuarine waters increases by solar radiation, tidal currents, and defect of high tide on the mud flats, etc.

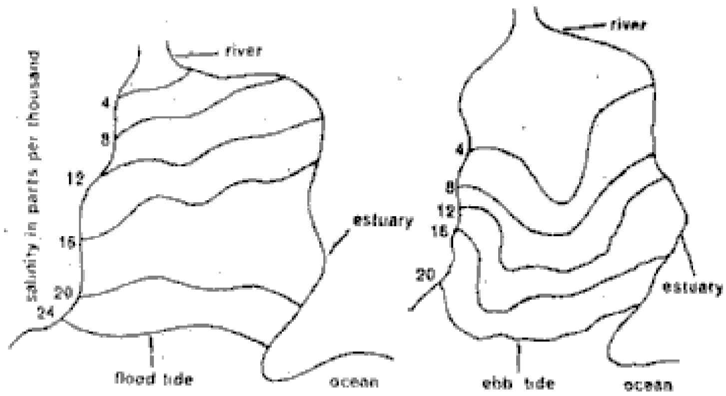


Fig. 1: A) Isohaline lines across an estuary at flood tide.
B) Isohaline lines at ebb tide.

13.5.4.2.Salinity in Estuaries

In shallow temperate water estuaries, salinity conditions are varied vertically, i.e., fresh water flowing from the river will be less dense than the sea water Salinity conditions may be dependent on the flood tide and on the ebb-tide. In estuary at flood-tide, the isohaline lines (indicating equal salinity values) are more or less parallel as the tidal current moves into it. But at ebb tide, these isohaline lines (or salinity values) show marked deviations or curvatures in its path. The causative factor for the curvature in the salinity line across the estuary is due to the fact that tidal current moves more rapidly along the centre of the channel and therefore alters the salinity quickly in these areas. Salinity values are relatively low at the surfaces but these increase with the depth for any given point along the estuary. The salinity fluctuates between 5 - 35%.

13.5.5. CHARA CTERIS TICS OF ESTUARINE BIOTA

The organisms of estuarine waters must have the capacity to tolerate changing salinity conditions continuosly which are mainly of tidal and seasonal nature. Thus euryhaline species are most common inhabitants on a permanent or semipermanent basis. Besides, silt content and turbidity of the water are limiting factor with regard to the distribution of biota. Increased silt contents adversely affect both flora and fauna of the estuary.

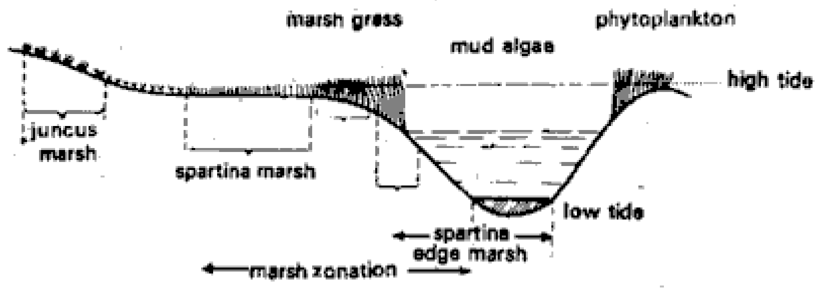


Fig.13. 12. Zones in marsh estuary.

Estuarine species may be grouped into three categories.

(i) Marine species found along the outer limits of the estuary occasionally enter the estuary, e.g., Polychaetes *(Phyllodoce, Lanice)*, Bivalve (Abra). (ii) Permanent estuarine animals found primarily in the estuaries but may also be found in certain marine areas if ecological conditions permit, e.g., Polyehaete, (Nephthys), Gastropods *(Nerita, Littorina)* and Carcinous (Crab). (iii) Strictly estuarine animals found only in estuarine environment and not in marine e.g., Nereis, Gastropods *(Neritina Hydrobia)* and crustacea *(cyathura)*.

13.5.5.1. Biota and Productivity

The estuarine communities are usually composed of endemic species (i.e., those confined to estuarine zone) and movable! species which come in from the sea, and also fresh water environment. Most of the estuarine biota is of marine origin. In addition to this, estuaries serve as very good nursery grounds for many fishes, plankton and organisms. Many shrimps pass their larval history in the estuaries, whereas adults inhabit the sea. fishes like eels, mullets and salmons, etc., remain for a considerable period during the migrations.

Thus, estuaries are suitable media for the reproduction and artificial breeding of various aquatic vertebrates especially fishes few holoplanktons and a number of diversed meroplanktons. Consumers include mainly fishes. In estuarine sediments organic contents are highly developed, thus accelerating production. The estuaries are not productive than sea or land presumably because an estuary is a *nutrient trap* collecting organic aggregates and detritus from sea by way of waves and also minerals by way of rivers. Secondly, estuaries get benefitted from various producer types, e.g., macrophytes such as seaweeds, seagrasses and marsh grasses, benthic microphytes and phytoplanktons. The small benthic algae (mud algae) account for as much as the third of total primary production. *Tidal actions* increase production and it is generally held that higher the tidal amplitude, the greater the production potential, provided currents do not cause damage. Finally, *inflow of river,* containing fertilizers washed in from land into estuaries, contributes to the estuarine productivity. Minerals are also actually come from sea via cycles into estuaries.

13.6. MARINE ECOSYSTEM

The marine habitat constitutes a dynamic environment with continuous cycles, waves, tides and currents. The oceans and seas cover approximately 71 per cent of the earth's surface, an area of about 361 million square kilometres, The great stretches of salt water are termed as the oceans, while the smaller areas are referred to as seas.

There are five great oceans. These are the Pacific, Atlantic, Indian, Arctic and Antarctic oceans. The largest ocean of the world is the Pacific ocean. In spite of their vast size, all the oceans are connected with each other. In addition to the oceans, there are seas. Some of these, such as the Arabian sea and the Sargasso sea, are parts of oceans. Other seas are surrounded by continents, such as the Mediterranean sea, Red sea and the Black sea. Some shallow seas, such as the North sea and Baltic sea, are the flooded edges of continents. The largest of the worlds seas is the South China sea.

The oceans being connected with each other, form a single-phase environment, but the diversity is enormous with respect to temperature, salinity, physical nature, dissolved gases, dissolved organic and inorganic matter. The diversity, along with the circulatory pattern of the oceanic water masses and the nutrient concentration determines the distribution of organisms. The major difference between the fresh water and the sea is that the latter is highly saline, and organisms found here are not only adapted, but also use this characteristic to their own benefit. Some, such as the Dead sea are so salty that no plants or animals can live in it.

13.6.1. STRUCTURE OF THE OCEAN FLOOR

13.6.1.1. Beach

Where the, land meets the oceans and seas it is called the seashore or beach. A beach is said to extend from the farthest point where sand has been carried by wave action to the depth beyond which wave action does not have sufficient force to move the sand particles.

13.6.1.2.Sea Floor

Close to the beneath the sea is mostly shallow, the bottom shelving from the shore to a depth of about 200 metres. This coastal ledge of shallow sea- bottom is the continental shelf and its seaward margin is termed as the continental edge. Beyond the continental edge, the floor descends downwards steeply, and is known as the continental slope. The slope plunges into the floor of the ocean basin, often reaching a depth of 300 to 6000 metres or even deeper in some places. The slope is often fissured by irregular gullies and steep-sided submarine canyons.

13.6.2. ZONATION OF THE SEA

The marine environment can be classifed into two major divisions, the pelagic and the benthic (Fig.13. 13).

13.6.2.1. Pelagic division

The pelagic division comprises the whole body of water forming the seas and oceans. The pelagic part can be divided into the following

13.6.2.1.1.Neritic province

Consists of the shallow water over the continental shelf. This region has a more dynamic environment due to constant water movement and greater variations in the physical and chemical parameters.

13.6.2.1.2. Oceanic province

The deep water beyond the continental edge constitute the oceanic province. This region is relatively stable with less fluctuations, water movement is very slow and conditions change with depth. The oceanic province is subdivided into three zones which are:

Epipelagic zone extends vertically downwards from the surface to a depth of 200 metres. In this zone, sharp gradients of illumination and temperature occur between the surface and deeper levels. Temperature gradients and thermocline is common, and marked diurnal and seasonal changes in light intensity and temperature occur. The effect of water movement (in the form of waves) is prominent, especially in the upper layers, and determines the conditions in the layers beneath.

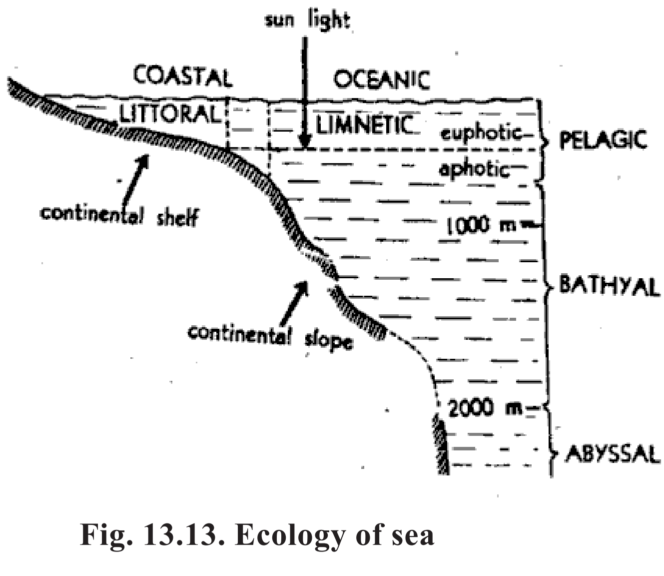


Fig. 13.13. Ecology of sea

Mesopelagic zone extends from 200 metres to about 1000 metres. Wave action does not reach here, and very little light is available. The temperature gradient is more even and gradual, and there is very little seasonal variation. An oxygen-minimum layer is found here, along with maximum concentrations of nitrates and phosphates.

Bathypelagic zoneextends from about 100 metres to the sea floor which is typically 3000 to 4000 metres in depth. Here darkness is virtually complete, except for bioluminescence. Temperatures are low and constant, and water pressure are enormous.

The vertical border separating the neritic from the oceanic province is set at the edge of the continental shelf, hence all waters of depths shallower than 200 metres fall within the neritic province. This boundary is arbitrarily set at 200 metres since this would correspond with the set depth for the edge of the continental shelf and at the same time, place the littoral system and the neritic province and areas definitely within the lighted portion.

13.6.2.2.1. Benthic division

The benthic division includes all the bottom terrain from the wave-washed shoreline at flood tide to the ocean abyss. The benthic division is further classified into the littoral and the deep-sea zones which are:

13.6.2.2.1. Littoral Zone

The littoral zone extends from the high-tide level to a depth of 20 metres, that is, it includes the benthic region up to the continental edge. It has two subdivisions.

13.6.2.2.2. Eulittoral Zone

It extends from the wave-splashed high tide level to a depth of about 40 to 60 metres. The lower border is set roughly at the lowest limit at which the more abundant attached plants can grow. In the upper part of the eulittoral zone is a well-defined tidal or intertidal zone that is bounded by the high and low-tide levels.

13.6.2.2.3. Sublittoral Zone

It extends from the lower pit of the eulittoral zone down to a depth of 200 metres, or the edge of the continental shelf.

13.6.2.2.4.Deep Sea Zone

The deep-sea zone includes the benthic region from the edge of the continental shelf to the ocean abyss which is usually at great depths. It has two zones, an upper archibenthic zone and a lower abyssalbenthic zone.

13.6.2.2.4.1. Archibenthic Zone

It extends from the sublittoral to a depth between 800 and 1100 metres.

13.6.2.2.4.2. Abyssalbenthic Zone

It comprises all the deep-sea benthic system below the archibenthic zone. It is a region of relatively uniform environmental conditions with uniformly low temperatures (50 to -1°C), with total darkness, and without seasonal changes.

13.6.3. PHYSICAL CHARACTERISTICS OF SEA

These are four general types of water movements in the oceans. They are, waves, subsurface currents, surface currents and tides.

13.6.3.1.. Waves

The most common type of water movement in the seas and oceans are the waves. Waves are caused by the wind. Wind action does not move the water from place to place like currents or tides, but transmits energy into the water, setting it in orbital motion. Where waters are deep and wind velocities are low or moderate, water movements are smoothly progressive; with each water molecule essentially describing a circle as the wave impulse passes. The water rises on the front of the wave, forward as the crest passes, drops down the rear slope, and moves backwards in the succeeding trough. With high wind velocities, the crest of the wave is tipped forward and breaks, forming a white cap. The size of the waves depends of the velocity of the wind, length of time for which it blows and the distance over which it acts.

Near the shore, where the depth of the water decreases, an approaching wave is slowed down by friction from below. When the depth is equal to the wave-height, the crest rises, steepens and finally crashes forward in the form of a breaker. This is known as the surf.

Surface waves do not mix the water to any great depth. Their motion falls off sharply with depth and at a depth equal to the wavelength of the waves, the water is virtually still.

13.6.3.2. Ocean currents

The ocean waters are constantly moving in a great circulatory system that involves both horizontal and vertical transfers. These movements are intiated by the transfer of kinetic energy from the winds to the surface waters and by variations in the densities of waters resulting from differences in their temperatures and salinities. The resulting flows, involving huge volumes of water, help to transport heat from the tropical and subtropical zone of excess receipt of solar radiation to the poleward zones where the energy received from the sun is much lower. The movement is aided by the Coriolis force and produces clockwise currents in to the northern hemisphere and anticlockwise in the southern hemisphere.

Except for the polar seas, all the great oceans exhibit broadly similar patterns of surface currents and drifts in coordination with the prevailing wind pattern.

Apart from wind-driven surface currents there are deep currents or circulations. The waters of the seas can be thought of as being composed of a rather thin, warm surface layer overlying a much thicker, colder lower layer. The warm water is slightly less dense, so it remains on top until it becomes denee enough, largely through cooling, to sink. A considerable amount of very cold water is produced by radiation of heat in the polar areas sinks and moves towards the equator at depths. Radiation and freezing near the poles supplies most of the bottom water of the oceans.

13.6.3.3. Tides

Nearly all shores of the open seas experience the distinct periodic rise and fall of sea-level known as the tides. The level of the sea or ocean rises twice in a day, water covers the shore and we say that the tide is in the level of water falls, Twice in a day the seashore is uncovered and we say that the tide is out.

Two important forces involved in a system, are responsible in tide generation: (i) the gravitational pull of the moon upon the earth, and (ii) the centrifugal reaction which necessarily accompanies the smaller revolution of th earth. The gravitational attraction decreases rapidly with increasing distance from the moon, and hence it is significantly greater on the side of the earth nearest the moon than on the side opposite. That centrifugal reaction, on the other hand, is the same everywhere on the earth, for as the centre of the earth revolves in a circle around the centre of gravity of the pair, all points on the earth follow circular paths of the same size and move at the same speed.

As the earth rotates on its axis, each point in the ocean, receives two outward pulls per day, one reaching maximum when the point is on the side towards the moon and the other when the point is on the side away from the moon. Because the moon rises about 50 minutes later each day, the successive periods of high water at a given point come at intervals of about 12 hr 25 minutes.

At times of new moon and of full moon, the earth, moon, and sun are nearly in line, so that the lunar tides and the solar tides occur in the same places, and the height of the solar tides is added to the lunar tides. These causes the high tides of these periods to be unusually high and the intervening low water to be unusually low. These are the periods of spring tide, which occur every two weeks.

When the moon is at its first and third quarters, the earth-sun line is nearly at right angles to the earth-moon line. The solar tides then fall between, and detract from the lunar tides, causing the difference between low and high tides to be less pronounced than usual. These are the periods of neap tide, which also recur every two weeks.

13.6.3.4. Temperature

Temperature changes with depth differ in different latitudes. In high latitudes, heat passes from the sea to the atmosphere. Surface waters usually have a temperature of-1.9^{0}C; there is an inversion around 500 metres, and below 1000 metres the temperature is almost uniform to the bottom.

At low latitudes,, a distinct thermocline is formed between 100 - 500 metres. The thermocline divides the waters into an upper warm thermosphere and a lower cold psychrosphere. The temperature decreases from about 25°C in the surface layers to about 0 °C in the bottom layers.

In middle latitudes seasonal thermocline occurs during the summer months at a depth of 15 - 40 metres. In winter the thermocline disappears, being replaced by a slight permanent thermocline, below which the temperature decreases steadily to around 0^{0}C.

Water temperature has a major impact on the activity and distribution of organisms. The marine biogeographical regions are closely related to the course of the isotherms. Thus warm-water populations are mainly found in the surface layers of the tropical belt where the surface temperature is above about 18 - 20^{0}C. The corals for instance, are bounded by the 20^{0}Cisotherm on each side of the equator.

13.6.3.5. Pressure and wind flow

Pressure differences ace primarily important in wind generation which leads to the formation of surface currents, wind waves and swells. Major winds which have an influence on oceans are the winds in the equatorial region, the westerlies of the midlatitutde, and the polar winds in the high latitudes. Apart from these, pressure changes create cyclones and anticyclones. A cyclone has a low pressure centre, while an anticyclone has a high pressure centre. Monsoonic winds are periodic and create local effects, such as the clockwise and anticlockwise gyre in the Bay of Bengal

13.6.3.6.Light

Compared to the great depth of the oceans, light does not reach very far into the sea. Illumination of the surface layer varies with place, time and conditions depending upon the light intensity, transparency of the water and angle of incidence. The strength of the incident light varies diurnally, seasonally and with latitude, and is considerably influenced by cloud cover. Much of the incident light falling on the sea surface is reflected. Depending upon conditions some 3 - 50% of the incident light is usually reflected.

Extinction coefficients vary from 1.0 to 0.1 between turbid inshore and clear offshore areas. In the seas around India the extinction coefficients vary from about 0.17 to 0.07. The depth of the photosynthetic or euphotic zone varies from 40 - 50 metres in temper & nature areas to about 100 metres in the tropics. Below the euphotic zone, down to about 200 metres, is the dimly illuminated dysphotic zone. Below 200 metres is the aphotic zone consisting of lightles waters which continue down to the sea bed.

Most of the plants are restricted to the euphotic zone by their dependence upon light as the energy source. Animals too are most numerous at or near the surface layers because they derive their food, directly or indirectly from plants.

Below this zone, organisms depend largely on the rain of organic debris coming from the upper layers, and consists of carnivores and detritus feeders moving in complete darkness.

13.6.3.7.Density

Pure water has its maximum/density at 4^0C, but for sea water the temperature of maximum density decreases with increasing salinity, and at salinities greater than 24.7% (parts per thousand) it is below the freezing point.

The distribution of density in sea waters is characterized by two features. In a vertical direction the stratification is generally stable, and in a horizontal direction differences in density exist only in the presence of currents. In every ocean region, water of a certain density which converges from the sea surface tends to sink to and spread at depths where a similar density is found.

13.6.3.8. Hydrostatic pressure

Hydrostatic pressure increases with depth at approximately 1 atmosphere per 10 metres of depth. In the deepest ocean trenches, pressures may exceed 1000 atmosheres Although water is only slightly compressible, such enormous pressures are sufficient to produce a slight adiabatic compression of the deep waters, resulting in a detectable increase in temperature.

13.6.3.9. Evaporation and precipitation

The oceans have a major role in the hydrological cycle through the processes of evaporation and precipitation. For the oceans, the average annual evaporation is between 116 and 124 centimetres and the average annual percipitation is between 107 and 114 centimetres. This system is controlled by a large number of factors, for instance, temperature, precipitation, evaporation, vapour pressure and relative humidity. All these can be combined to form a hydrothermal indes (Hin).

13.6.4. CHEMICAL CHARACTERISTICS OF SEA

Sea water is an extremely complex solution, its composition being determined by an equilibrium between dissolution and deposition, evaporation, precipitation and addition of fresh water as river run-off. Although it is not known as to what extent the composition of sea water has changed over the geologic period, but large-scale changes are definitely ruled out (Table 13.3).

Table 13.3. Major constituents of sea water aat a salinity of 35 gams per kilo

Constituents	**Concentration g/kg**
Sodium	10.77
Magnesium	1.30

Calcium	0.409
Potassium	0.388
Strontium	0.010
Chloride	19.37
Sulphate	2.71
Bromide	0.065
Total inorganic carbon	0.023 - 0.027

13.6.4.1. Salinity

The amount of inorganic material dissolved in sea water expressed as its weight in grams per kilogram (parts per thousand) of sea water is termed as salinity. The salinity of sea water varies from place to place. The average salinity of the oceans as a whole is generally considered to be 35 g/kg of which the chloride ion constitutes about 19 gms per kilo and the sodium ion a little over 10 gms per kilo. The salinity is lower where large rivers enter the sea, but in areas where the influx from the land is negligible, and where surface evaporation is great.

Surface salinity is closely related to the process of evaporation, by which the salts re concentrated and this varies with latitude.

13.6.4.2. Dissolved Oxygen

The oxygen content of the sea water is seldom limiting for the occurrence of animals and plants, except in the deper waters.

The oxygen content of the sea water generally varies between 0 and 8.5 mill, mainly within the range of 1 - 6. Higher values occur at the surface, due to diffusion and photosynthesis, especially in coastal areas where the phytoplankton and benthic algae are nemerous. The process of diffusion is enhanced in wave-splashed shores. Oxygen is more soluble in cold water than in warm, the oxygen content of the surface water is usually greater at higher latitudes than nearer the equator, and the sinking of cold surface water in olar seas carries oxygen-rich water to the bottom of the deep ocean basins.

13.6.4.3. Free and bound carbon

40 chemicals elements (including four principal cations Ca^{++} Mg^{++}, K^{+} and Na^{+}), gases excluded are dissolved in sea water. The abundance of these ions enables.a considerable amount of carbon dioxide to be contained in solution in the form bound carbon (CO_2^{3-} and HCO_3^-). Infact, the ocean serves as a major reservoir of carbon dioxide, containing about 50 times more CO_2 (47 ml/L) than the atmosphere and serves as a modulator of the atmosphereic carbon dioxide.

13.6.4.4.PH

The pH of sea water in free contact with the atmosphere normally varies within the range of 7.5 and 8.4. The higher values are found at or near the surface layers where CO_2 is withdrawn rapidly for photosynthes . In general, there is a decrease of pH with depth to about the region of minimum dissolved oxygen, and then increases in deeper waters where respiration and decomposition become the dominant metabolic processes.

13.6.4.5.Nitrogen

Nitrogen in the combined form is present in sea water as nitrate, nitrite. ammonium ions and traces of nitrogen-containing organic compounds. Nitrogen-fixing bacteria such as Nitro cystic oceans are known to occur in the sea, but the amount fixed is negligible. Substantial quantities of nitrates nitrites and ammonia enter the sea as river run-off.

13.6.4.6. Phosphates

Phosphates are typically present in the sea water as orthophosphates. Like nitrates, large amount of phosphates are brought to the sea through river run-off. Phosphates show much the same distribution in depth as nitrates (Fig.13.20), and in broad outline, their seasonal and geographical variation approaches that of nitrate. Phosphates are present in much smaller concentration than the nitrates and appear to be an important limiting factor in the development of phytoplankton. Surface values of phosphate are in the range of 0 - 20mg per litre while at depths of 500 - 1500 metres it 1s40 -80 rug per litre. The ratio of nitrates of phosphates present in the sea roughly approaches a constant value of 7 1 by weight.

13.6.4.7. Iron and other elements

The amount of iron present in sea water in solution is about 2 mg per litre, but there are appreciable amounts of iron in particulate form as collodial micelles, mainly as ferric hydroxide. There is a continuous loss of iron from sea water and accumulation at the bottom due to sedimentation.

Manganese is a plant nutrient which, like iron, is probably present mainly in the particulate form as oxide miceles. The amount varies from 0.3 to 10mg per litre. These two elements along with coper, nickel and cobalt give rise to polymetallic nodules at the sea bottom.

13.63.4.8. Silicate

Silicon is present in sea water chiefly as silicate ions. The concentration of silicates is usually low in surface waters but increases with depth to about I- 5 mg/L.

13.6.4.9. Dissolved organic matter

Varying quantities of organic matter are present in solution in sea water. Although the concentration is small, it has been estimated that there is on average about 15 kg of organic matter beneath each square metre of the ocean surface. The sources 'are diverse and include materials origination (from the break-down of tissues, excretory materials and organis secretions.

13.7.1. BIOTIC COMPONENTS OF SEA

The marine community is diverse and diversification is a measure of the success of a species. In these terms, many marine groups are highly successful. The community is segregated into the range of environmental niches provided by the sea.

Regardless of their phylogenetic position, marine organisms can be placed in two large categories dependent on whether they live on the water mass pelagic) or on the bottom sediments (benthic). A third category is made of those organisms which live in the air-water interface (pietistic). However, these categories are not rigidly defineable. Some species are benthic as adults but pelagic as larvae, and a number of pelagic organisms may spend much time resting on or feeling at the sediment-water interface.

The biotic components of marine ecosystem are of the following orders:

13.7.1.1.Producers

These are autotrophs and also designated as primary producers, since they are responsible for trapping the radiant energy of sun with the help dinoflagellates and some microscopic algae. Besides them, a number of macroscopic seaweeds, as brown and red algae (members of Phaeophyceae and Rhodophyceae), also contribute significantly to primary production. These organisms show a distinct zonation at different depths of water in the-sea.

13.7.1.2 Consumers

These all are heterotrophic macroconsumers, being dependent for their nutrition on the primary producers. They are:

(a) Primary consumers. The herbivores, that feed directly on producers are chiefly crustaceans, mollusks, fish etc.

(b) Secondary consumers. Still in the food chain, there are other carnivorous fishes like Cod, Haddock, Halibut etc. that feed on other carnivores of the secondary consumers level. Thus these are the top carnivores in the food chain.

13.7.1.3. Decomposers

The microbes active in the decay of dead organic matter of producers and macroconsumers are chiefly bacteria and some fungi.

13.7.1.4. Pelagic biota

The pelagic region has a larger group of organisms and includes all the species inhabiting the entire water column. These can be divided in to two broad categories, the plankton and the nekton.

13.7.1.4.1. Plankton

The plankton of the sea includes a great variety of forms and exceeds that of fresh water, but differences in composition usually occur. The phytoplankton (Fig.13.14) population of the sea is dominated by the diatoms and the dinoflagellates also present and are occassionally important. The diatoms tend to dominate in higher latitudes, while dinoflagellates are predominant in the subtropical and tropical waters. As a group, the dinoflagelates are the most versatile of organisms, since they not only function as autotrophs, but some species are facultative saprotrophs or phagotrophs. Some, such as Gymnodiniumbrevis, Goiniauluxpolyedra and Exuviella baltica give rise to red tides causing death of enormous number of fishes.

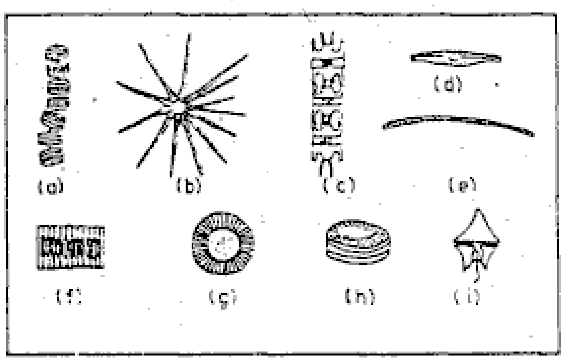


Fig 13. 14 Representative members of the phytoplankton

(a) Thalassiosira (b) Asterionella
(c) Bidduiphia (d) Navicula
(e) Thalassiothrix (t) Fragilaria
(g) Planktoniella (h) Coscinodiscus
(i) Peridinium.

The animal plankton (Fig .13.15) are defined according to duration of the life cycle in the pelagic state. The planktonic eggs and larvae of the nekton and benthos constitute temporary plankton or meropilankton. These are especially abundant in the neritic waters and are composed mainly of the developmental stages of invertebrates, but also include the young of fishes.

Fig. 13.15 Marine zooplankton

a) Siphonophore b) Beroe.
c) Pleuro brachi d) Tompteris
g) Eupliansut h) Amphipod
i) Lucifer j) Chaetognath

13.7.1.4.2. Nekton

The assemblage of organisms comprising this group are provided with efficient locomotory organs enabling them to swim against currents and waves, The large cephalopod molluscs (squid), crustaceans (prawn) and a great variety of vertebrates (fish, turtles, snakes, mammals Fig.13.16) comprise this group.

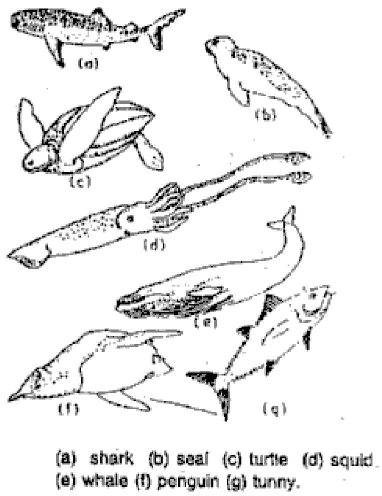


Fig.13. 16. Representative members of the nekton.

The locomotion efforts of necktonic organism are not only capable of being sustained for a considerable length of time, but the movement is also effectively directed towards pursuit of prey, escape from enemies, and instinctive migratory journey. Active swimming requires the development of muscular systems and often of relatively large size. They are the terminal consumers of the sea, mostly carnivorous, while a few are herbivores and even fewer take detritus.

13.7.1.5. Benthic biota

The benthos consists of diverse group of organisms with specific adaptations and is zonated both horizontally and vetically. These zonations are based on their energy requriements and the physical and chemical factors to which they have adjusted. In the well-lit waters of the euphotic zone are to be found the phytobenthos; they extend down to the compensation zone and are graded at different levels based on environmental factors and community dynamics. The phytobenthos includes three categoreis of photosynthetic organisms; protists essentially similar to those of the phytoplankton but here associated with soft sediments, symbiotic within littoral animals such as corals, and occurring in various other microhabitats; larger, multicellular algae in a variety of forms but especially as the large, leathery sea-weeds of rocky outcrops (forming kelp beds) and the finer, more filamentous species growing on the surfaces of coarser sea-weeds and rocks; and the community of marine tracheophytes consisting of sea-grasses, salt-marsh herbs, and mangrove-swamp shrubs and trees.

Beyond the euphotic zone the benthos lacks photosynthetic organisms organism and is replaced by chemosynthetic bacteria (nitrifying, sulphur, hydrogen methane, carbonnionoxide, and iron bacteria) which occur in the benthic sediments, and fix their carbon dioxide by oxidizing ammonia, hydrogen sulphide, methane, and others. These regenerate nutrient materials for the phytosynthetic forms.

Benthic animals are very abundant in the littoral zone and decrease in number with depth in the only scattered individuals are found unit deep ocean trenches. These consist of sessile forms such as sponges, barnacles (Fig.13.27), mussels, oysters, crinoids, hydroids, bryozoans, and some worms; creeping forms such as crabs, lobsters, certain copepods, amphipods, crustaceans, snails, echinoderms, bivalves, and some fishes; and burrowing forms including mostly clams, worm,s some crustaceans and echinoderms.

In the shore zone, organisms are characteristically zonated. This zone represents transition between the marine and terrestrial environments. The organisms living here have to withstand varying degrees of stress resulting from tides, waves, sea-spray, pounding of surf and the alternate inundation and exposure to air. based on the type of substratum, the zone is classified into rocky and sandy shores. Each has its own peculiar feature and the organisms living in these environments have specific adaptations for the same.

13.8. LOTIC ECOSYSTEM

As already stated that lotic, waters are those which occur in fast running streams, springs, rivers and brooks. The biotic community in stream and rivers is quite different from that in lakes and ponds. The differences in the community are largely due to the differences in the physical and chemical conditions of their environments. The important differences between standing and flowing water ecosystems are the currents of water, close association with surrounding land areas, and constant high oxygen contents. The ecological communities are determined by the rapidity of the flowing water. The communities found differ between areas where a stream moves rapidly and where a stream is slow moving. In fact flowing water, the plants are usually submerged and are mainly made up of algae and masses. The dense growth of these plants covers the rocks in the pounding waters of rapids and waterfalls. The sandy bottom is occupied by burrowing aquatic animals such as worm clams and insect larvae. It might be assumed that plankton would be absent from streams since such organisms are largely at the mercy of the current. Plankton in small streams, if present, originate in lakes, ponds, or backwaters connected with streams and is soon destroyed as it passes through rapids of streams.

13.9. ENERGY FLOW IN ECOSYSTEM

The energy used for all plant life processes is derived from solar radiations. A fraction i.e. about 1/50 millionth of the total solar radiation reaches the earth's atmosphere. Solar radiation travels through the space in the form of waves, wavelength ranging from 0.03A to several km. While most radiations are lost in space, those ranging from 300m (and above 1 cm (radiowaves) enter the earth's outer atmosphere (which is about 18 miles or 28 km altitude). The energy reaching the earth's surface consists largely of visible light 390-160m and infra-red component. On a clear day radiant energy reaching the earth's surface is about 10% UV, 45% visible and 45% infra-red. Plants absorb strongly the blue and red light (400-50m (and 600-700 m (respectively).

In ecological energetics, we study (i) quantity of solar energy reaching an ecosystem, (ii) quantity of energy used by green plants for photosynthesis and (iii) the quantity and path of energy flow from producers to consumers.

About 34% of the sunlight reaching the earth's atmosphere is reflected back into its atmosphere, 10% is held by ozone layer, water vapour and other atmosphere gases. The rest, 56% reaches the earth's surface.

Only a fraction of this energy reaching the earth's surface (ito 5%) is used by green plants for photosynthesis and the rest is absorbed as heat by ground vegetation or water. In fact, only about 0.02% of the sunlight reaching the atmosphere is used in photosynthesis. Nevertheless, it is this small fraction on which all the organisms of the ecosystem depend.

The behaviour of energy in ecosystem can be termed energy flow due to unidirectional flow of energy. From energetics point of view it is essential to understand for an ecosystem (I) the efficiency of the producers in absorption and conversion of solar energy, (ii) the use of this converted chemical form of energy by the consumers, (iii) the total input of energy in form of food and its efficiency of assimilation, (iv) the loss through respiration, heat, excretion etc. and (v) the gross net production.

13.9.1. SINGLE- CHANNEL ENERGY MODELS

The principle of food chains and the working of the two laws of thermodynamics can be better made clear by means of energy flow diagrams shown in Figure 13.17.

Out of the total incoming solar radiation (11 8,872g cal/sm2/yr), 118,761 gcal/cm2/yr remain unutilised, and thus gross production (net production plus respiration) by autotrophs is 111 gcalcm2yr with an dificiency of energy capture of 0.10 per cent (Fig. 13.17). It may also be noted that 21 per cent of this energy, or 23 gcal/cm2/yr is consumed in metabolic reactions of autotrophs for their energy, or 23 gcal/cm2/yr is consumed in metabolic reactions of autotrophs for their growth, development, maintenance and reproduction. It may be seen further that 15 gcal/cm2/yr are consumed by herbivores that graze or feed on autotrophs — this amounts to 17 per cent of net autotrophy production. Decomposition (3 gcal/cm2/yr) accounts for about 3.4 per cent of net production. The remainder of the plant material, 70 gcal/cm2/yr or 79.5 per cent of net production, is not utilised at all but becomes part of herbivory than is consumed. It may also be noted that various pathways of loss are equivalent to and account for total energy capture of the autotrophs i.e. gross production. Also, collectively the three upper ‘fates’ (decomposition, herbivory and not utilised) are equivalent to net production. Of the total energy incorporated at the herbivores level, i.e. 15 gcal/em2/yr, 30 per cent or 4.5 gcal/cm2/yr is used in metabolic reactions. Thus, there is considerably more energy lost via respiration by herbivores (30 per cent) than by autotrophs (21 per cent). Again there is considerable energy available for the carnivores, namely 10.5 gcal/cm2/yr or 70 per cent, which is not entirely utilised; in fact only 3.0 gcal/cm2/yr or 28.6 per cent of net production passes to the carnivores. This is more efficient utilization of resources that occur at autotrophy (herbivore transfer level. At the carnivore level about 60 per cent of the carnivores energy intake is consumed in metabolic activity and the remainder becomes part of the not utilised sediments; only an insignificant amount is subject to decomposition yearly. This high respiratory loss compares with 30 per cent by heribivores and 21 per cent by autotrophs in this ecosystem.

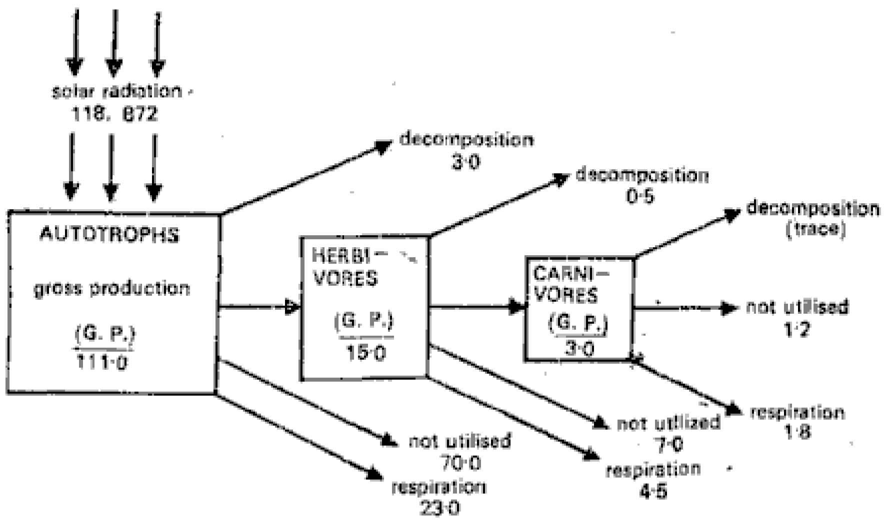


Fig. 13.17. Energy flow in a water body (g cal / cm^2 yr)

From the energy flow diagram shown in Fig. 13.17, two things become clear. Firstly, there is one-way Street along which energy moves (unidirectional flow of energy). The energy that is captured by the autotrophs does not revert back to solar input; that which passes to the herbivores does not pass back to the autotrophs. As it moves progressively through the various trophic levels it is no longer available to the previous level. Thus due to one-way flow of energy, the system would collapse if the primary source, the sun, were cut off. Secondly, there occurs a progressive decrease in energy level at each trophic levels it is no longer available to the previous level. Thus due to one-way flow of energy, the system would collapse if the primary source, the sun, were cut off. Secondly, there occurs a progressive decrease in energy level at each trophic level. This is accounted largely by the energy dissipated as heat in metabolic activities and measured here as respiration coupled with unutilized energy.

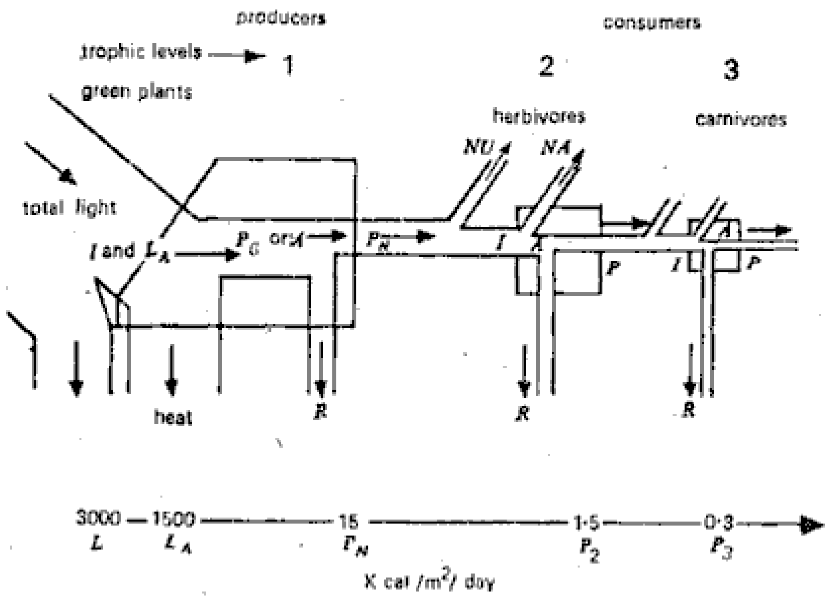


Fig. 13.18. A simplified energy flow diagram depicting three trophic levels (boxes numbered 1,2,3,) in a linear food chain. I — total energy input; LA — light absorbed by plant cover. PG gross primary production; A — total assimilation; PN — net primary production; P — secondary (consumer) production; NU — energy not used (stored or exported); NA — energy not assimilated by consumers (egested); R — respiration. Bottom line in the diagram shows the order of the magnitude of energy losses expected at major transfer points, starting with a solar input of 3,000 kcal per square meter per day.

In fig. 13.18 the 'boxes' represent the trophic levels and the 'pipes' depict the energy flow in and out of each level. Energy inflows balance outflows as required by the first law of thermodynamics, and energy transfer is accompanied by dispersion of energy into unavailable heat (i.e. respiration) as required by the second law. Fig. 13.18 presents a very simplified energy flow model of three trophic levels, from which it becomes evident that the energy flow is greatly reduced at each successive trophic level from producers to herbivores and then to carnivores. Thus at each transfer ofenergy from level to another, major part of energy is lost as heat or other form. There is a successive reduction in energy assimilation) or secondary production and respiration components. Thus, of the 3,000 Kcal of total light falling upon the green plants, approximately 50 per cent (1500 Keal) is absorbed, of which only 1 per cent (15 Keal) is converted at first trophic level. Thus net primary production is merely 15 Kcal. Secondary productivity (P2 and P3 in the diagram) tends to be about 10 per cent at successive consumer trophic levels i.e. herbivores and the carnivores, although efficiency may be sometimes higher, as 20 per cent, at the carnivore level as shown (or P3 = 0.3 Kcal) in the diagram.

It becomes evident from Fig. 13.17 and 13.18 that there is a successive reduction in energy flow at successive trophic levels. Thus shorter the food chain, greater would be the available food energy as with an increase in the length of food chain, there is a corresponding more loss of energy.

It is natural to argue that with a reduction in energy flow (shown as 'pipes' in the diagram) at each successive trophic level, there is also a corresponding decrease in standing crop or biomass (shown as 'boxes' in the and energy (Fig.13.18). Indeed energy as taken, here represents rate functions, say production rates. The relationships between biomass and energy content may differ according to the situations. For example, one gram of an alga (lesser biomass) may be equal to many grams (more biomass) of a forest tree leaves, due to the fact that rate of production (metabolism rates i.e. rates at which radiant energy is fixed to form carbohydrates) of the alga is higher than that of tree leaves. Thus standing crop or biomass (structure) and productivity (rate functions) should note be confused with each other, and the two are not necessarily correlated. Organism with higher biomass does not necessarily mean it would be more productive too.

13.9.2. Y-SHAPED ENERGY FLOWMODELS

Fig. 13.17 and 13.18 describe simple, single-channel energy flow diagrams. Similar energy flow models for different kinds of ecosystems have been described by several authors. For instance Teal (1957) prepared an energy flow diagram of Root Spring in U.S.A. Similarly Odum (1957) prepared energy flow model for silver springs, Florida, U.S.A. In Silver Spring, there is 410,000 Kcal/m2/yr effective solar radiation falling or green plants thr photosynthesis. Of this 389,190 Kcal/m2/yr was lost as heat; only 20,810 Kcal/m2/yr could be used in gross primary production. Again, out of this 11,977 Kcal/m2/y was lost by way of respiration, and only 8,833 Kcal/m2/y remained for net production. Thus energy followed again as in Figs. 10 and 11 three main paths — transfer to next trophic level (producer to consumer); heat loss as respiration; and through death to decomposers. In these two diagrams, there were basic differences. In model given by Teal (1957) for Root Spring, most of the heterotroph's food in food chain was produced by green autrophic plants. Odum (1962) noted this basic feature that to begin with some systems heterotrophs consume living plants while in others they feed on dead plant parts, (detritus). Thus in this case in Root Springs, the chain began with dead plant parts, whereas in silver springs with live plant parts. Odum pointed out thus in nature that there are present two basic food chains in any system. We have already considered these two kinds of food chains (i) the grazing food chain beginning with green plant base going to herbivores and then to carnivores, and (ii) the detritus food chain beginning with dead organic matter acted by microbes, then passing to detritivores and their consumers (predators). Fig. 13.19 presents one of the first published energy flow models as pioneered by Odum in 1956. There is shown a common boundary, and, in edition to light and heat flows, the import, export and storage of organic matter are also included. Decomposers are placed-in a separate box as a means of partially separating the grazing and detritus food chains. Decomposers are in fact a mixed group in terms of energy levels.

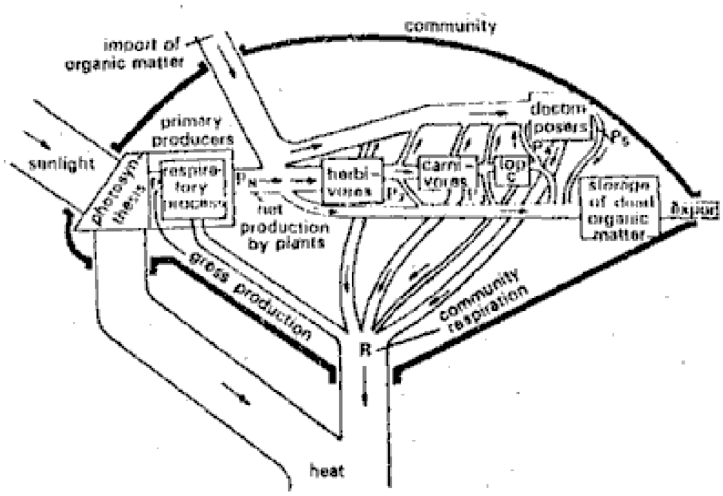


Fig. 13.19 The relationship between flow of energy through the grazing food chain and detritus pathway.

Fig. 13.20 shows two Y-shaped or 2-channel energy flow models. In each –shaped model one arm represents the herbivore food chanin and the other, the decomposer (detritus) food chain. The two arms differ fundamentally in the way in which they can influence primary producers. In each model the grazing and detritus food chains are sharply separate. This figure contrasts the bio-mass-energy flow relationships in the sea and the forest. In the marine bay the energy flow via the grazing food chain is shown to be larger than via the detritus pathway (forest), whereas the reverse is shown for the forest in which 90% or more of the net primary production is normally utilised in detritus food chain. Thus in marine ecosystem the grazing food chain is the major pathway of energy flow whereas in the forest ecosystem the detritus food chain is more important. In grazing chain herbivores feed on living plants and, therefore, directly affect the plant populations. What they do not eat is available, after death, to the decomposers. Decomposers are not able to directly affect the plant populations. But such a difference is not necessarily inherent in aquatic and terrestrial systems. In a heavily grazed pasture or grassland 50% or more of the net production may pass down the grazing path, whereas there are many aquatic ecosystems especially shallow water ones, that like mature forests, operate largely as detritus systems. Since not the community depends on the rate or removal of living plant material as well as on the amount of energy in the food that is assimilated. Marine zooplankton commonly graze more phytoplankton than they can assimilate, the excess being egested to the detritus food chain. Thus, energy flow along different paths is dependent on the rate of removal of living plant material by herbivores as well as on the rate of assimilation in their bodies. The Y-shaped model further indicates that the two food chains are in that, under natural conditions, not completely isolated from one another. For instance, dead bodies of small animals that were once part of the grazing food chain become incorporated in the detritus food chain as do the feces of grazing food animals. Functionally, the distinction between the two is of lime lag between the direct consumption of living plants and ultimate utilization of dead organic matter. The importance of the two food chains may differ in different ecosystems, in some grazing is more important, in others detritus is major pathway;

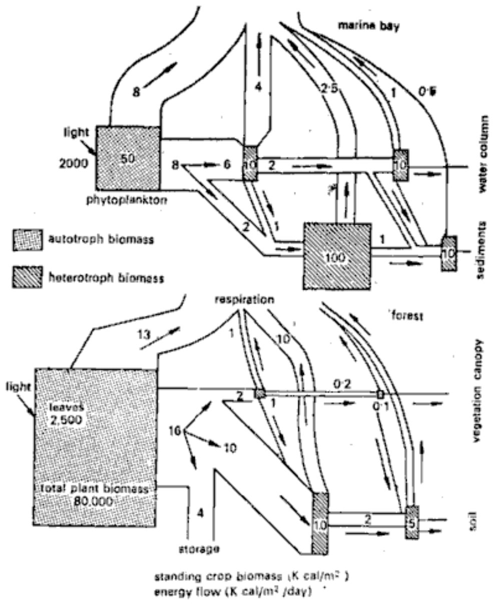


Fig. 13.20. A Y-shaped or 2-channel energy flow diagram that separates a grazing food chain (water column of vegetation canopy) from a detritus food chain (sediments and in soil). Estimates for standing crops (shaped boxes) and energy flows compare a hypothetical coastal marine ecosystem (upper diagram) with a hypothetical forest (lower diagram).

The important point in Y-shaped model is that two food chains are not isolated from each other. This Y-shaped model is more realistic and practical working model the single-channel model because, (1) it confirms to the basic stratified structure of ecosystems, (ii) it separates the grazing and detritus food chains (direct consumption of living plants and utilization of dead organic matter respectively) in both time and space, and (iii) that the microconsumers (absorptive bacteria, fungi) and the macroconsumers (phagotroghic animals) differ greatly in size-metabolism relations.

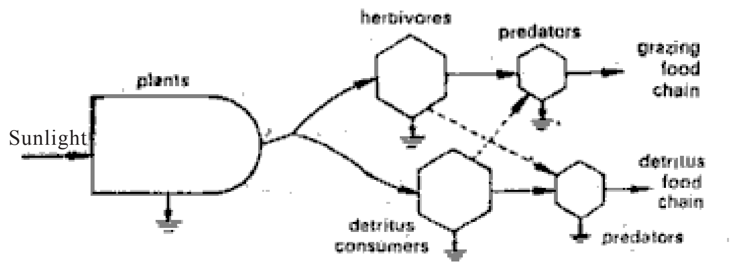


Fig. 13.21. The Y-shaped energy flow model showing linkage between the grazing and detritus food chains.

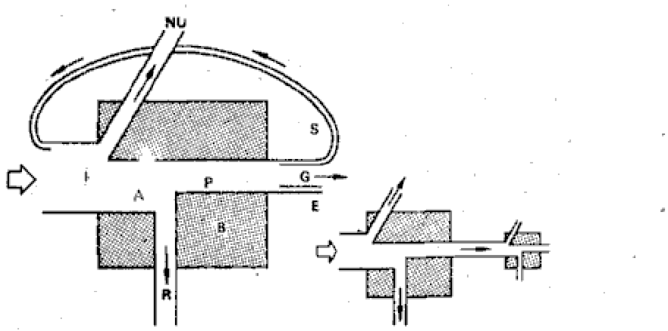


Fig. 13.22 Components for a 'universal' model of energy flow. I = input or ingested energy; NU = not used; A = assimilated energy; P = production; R = respiration; B = biomass; G = growth; S = stored energy; E = excreted energy.

Odum (1983) gave a generalised model of Y-shaped or 2-channel energy flow model (Fig. 13.21) applicable to both terrestrial and aquatic ecosystems. Fig. 13.22 presents what might be called a universal model, one that is applicable to any living emponent, whether a plant, animal, micro-organism, or individual, population or a trophic group (Odum., 1968). Such a model may depict food chain as already shown in single and Y-shaped energy flow systems, or the bioenergetics of an entire ecosystem. In this figure, the shaded box labeled "B" represents the living structure or biomass of the component. The total energyinput or intake is indicated "I", which is light for strict autotrophs and organic food for strict heterotrophs. This universal model of energy flow can be used in two ways: (i) it can represents a species population in which case the appropriate energy inputs and links with other species would be shown as a conventional species-oriented food-web diagram or (ii) the model can represent a discrete energy level in which case the biomass and energy channels represent all or parts of many populations supported by the same energy source. foxes, for example, herbivores (rabbit, field mice, etc.). A single box diagram could be used to represent the whole population of foxes if our objective is to stress intrapopulation energetics. On the other hand, two or more boxes (as shown on the right of Figure 13.22) would be employed if we wish to separate the metabolism of a population into two or more trophic levels in accordance with the propotion of plant and animal consumed.

It must however, be remembered that these Models depict the basic pattern of energy flow in ecosystem. In practice, under natural conditions, the organisms are interrelated in a way that several food chains become interlocked and this results into a complex food web. We have already referred to food webs in grassland and in pond ecosystems. The complexity of food web depends on the length of the food chains. Thus in nature there operate multi-channet energy flows, out in these the channels belong to either of the two basic food chains i.e. will be other a grazing or a detritus food chain. Interlocking pattern of such several chains in food web of an ecosystem would lead to a multi- channel flow of energy. Thus in practice, under field conditions, we might face difficulties in measuring the energetic of ecosystem.

13.10. FOOD CHAINS AND FOOD WEB

The transfer of food energy from the producers, through a series of organisms (herbivores to carnivores to decomposers) with repeated eating and being eaten, is known as a food chain. Producers utilize the-radiant energy of sun which is transformed to chemical form, ATP during photosynthesis. Thus green plants occupy, in any food chain, the first trophic (nutritional) level - the producers level, and are called the primary producers. The energy, as stored in food matter manufactured by green plants, is then utilized by the plant eaters- the herbivores, which constitute the second trophie level - the primary consumers level, and are called the primary consumers (herbivores). Herbivores in turn are eaten by the carnivores, which constitute the third trophic level-the secondary consumers level, and are called the secondary consumers (carnivores). These in turn may be eaten still by other carnivores at tertiary consumer level i.e. by the tertiary consumers (carnivores). Some organisms are omnivores eating the producers as well as the carnivores at their lower level in the food chain. In any food chain, energy flows from primary producers to primary consumers (herbivores), from primary consumers to secondary consumers (carnivores), and from secondary consumers to tertiary consumers (carnivores/omniovers) and so on. This simple chain of eating and being eaten away is known as food chain.

In nature, we generally distinguish two general types of food chains:

13.10.1. GRAZING FOOD CHAIN

This type of food chain starts from the living green plants, goes to grazing herbivores (that feed on living plant materials with their predators), and on to carnivores (animal eaters). Ecosystems with such type of food chain are directly dependent on an in flux of solar radiation. This type of chain thus depends on autotrophic energy capture and the movement of this captured energy to herbivores. Most of the ecosystems in nature follow this type of food chain. From energy standpoint, these chains are very important. The phytoplanktons - zooplankons - fish sequence or the grasses-rabit-fox sequence are the examples of grazing food chain.

13.10.2. DETRITUS FOOD CHAIN

This type of food chain goes from dead organic matter into microorganisms and then to organisms feeding on detritus (detritivores) and their predators. Such ecosystems are thus less dependent on direct solar energy. These depend chiefs' on the influx of organic matter produced in another system (Fig. 13.23a).

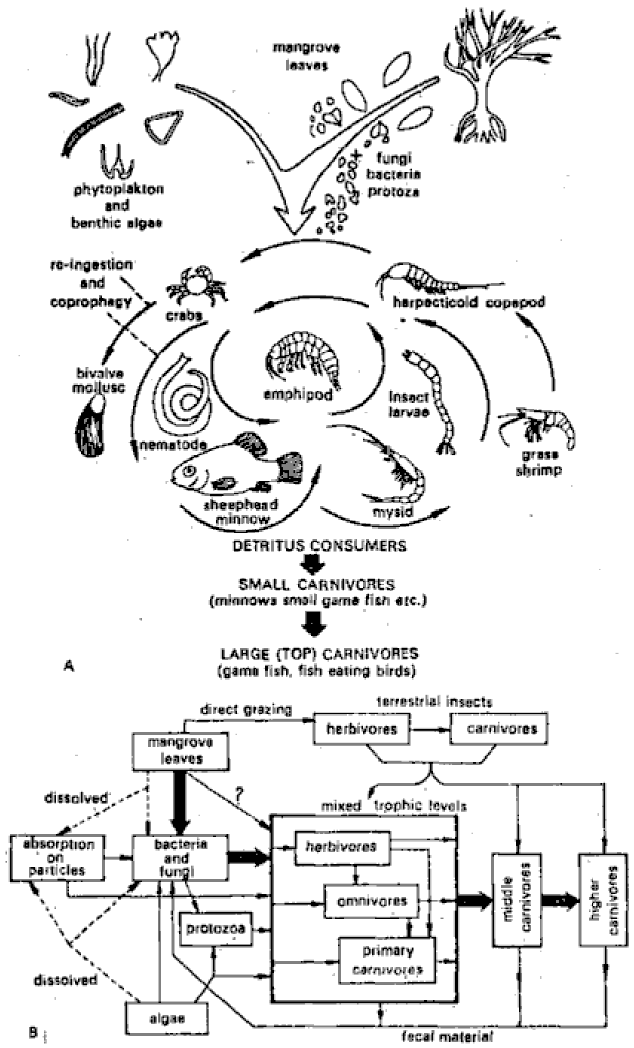


Fig.3.7.A Detritus food chain based on mangroves leaves falling into shallow estuary waters. Leaf fragments acted on by the saprotrophs and colonized by algae are eaten and re-eaten (coprophagy) by a key group of small detritivores which in turn, provide the main food for game fish, herons, stroke and ibis. B-a "pictorial model" of the food chain "compartmental model".

In detritus chain, the detritus consumers, in contrast to grazing herbivores, are a mixed group in terms of trophic levels (Fig.13.23b). These include herbivores, omnivores, and primary carnivores. As a group, the detritus feeders obtain some of their energy directly from plant material, most of it secondarily from microorganisisms, and some tertiarily throguh carnivores (for example by eating protozoa or other small invertebrates that have fed on bacteria that have digested plant material).

But under natural situations, a system must always be self sufficient. In fact this type of food chain (detritus type) is simply a sub-component of another ecosystem. And, the aboversaid two types of food chain in nature are indeed limited together belonging to the same ecosystem.

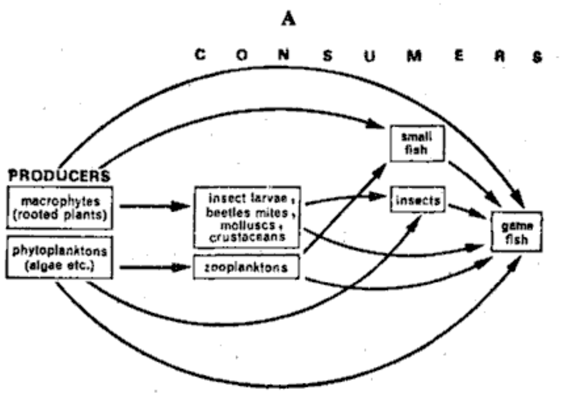
13.10.2 FOOD WEB

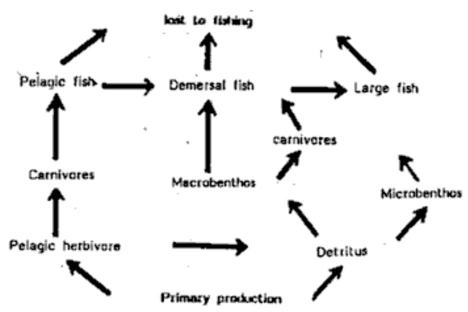
However, food chains in natural conditions never operate as isolated sequences, but are interconnected with each other forming some sort of interlocking pattern, which is referred to as a food web. Under natural conditions, the linear arrangement of food chains, hardly occurs and these remain indeed interconnected with each other through different types of organisms at different trophic levels.

A similar food web in a pond, with different interlinked food chains is shown in Fig. 13.24. The food web are very important in maintaining the stability of an ecosystem in nature. For example, decrease in the population of rabbit would naturally cause an increase in the population of alternative herbivore, the mouse. This may decrease the population of the consumer (carnivore) that prefers to eat rabbit. Thus alternative (substitutes) serve for maintenance of stability of the ecosystem, Moreover, a balanced ecosystem is essential for the survival of all living organisms of the system. For instance, had primary consumers (herbivores) not been in nature, the producers would have perished due to overcrowding and competition. Similarly, the survival of primary consumers is linked with the secondary consumers (carnivores) and so on. Thus, each species of any ecosystem is indeed kept under some sort of a natural check so that the system may remain balanced.

The complexity of any food web depends upon the diversity of organisms in the system. It would accordingly depend upon two main points:

(i) Length of the food chain. Diversity in the organisms based upon their food habits would determine the length of food chain. More diverse the organisms in food habits, more longer would be food chain.
(ii) Alternatives at different points of consumers in the chain. More the alternatives, more would be the interlocking pattern. In deep oceans, seas etc. where we find a variety of organisms, the food webs are much complex.





B

Fig. 3.24 The food web in a pond (A) and see (B)

13.11. TROPHIC LEVELS AND ECOLOGICAL PYRAMIDS

The producer organisms are autotrophs, largely phytoplankton and other green plants, that manufacture their food through photosynthetic activity utilizing the abiotic elements of the water. Other organism in the aquatic ecosystem, largely animals, are consumers which utilize the producers as their food. These organisms are phagotrophic heterotrophs, micro or macro consumers. Another category of heterotrophs is of those organisms, chiefly bacteria and fungi, which are decomposers (saprophytes) of dead organic matter, partly utilizing these as their food, and partly releasing simple products utilizable I as food by both autotrophs and consumer heterotrophs. Fish belongs to the category of phagotrophic hetetroph of the macro consumer type. In this set up, complex patterns of food relatinship occurs in which there are repated stages of one organism eating the other and in turn serving as the food for the third one and so on. Fish populations may be classified, thus, into several trophic levels, depending upon their position in this food chain. There are some fish communities which occupy thesecond trophic level (the producers belong to the first trophic level). These are herbivores, eating green plants (the producers) and in which, the transfer of food energy from producers reaches fish in one step. Other fish communities belong to the third trophic level. These are carniovorous fish, eating herbivorous fish or other herbivorous animals like zooplankter (zooplankters belong to the third trophic level, since they eat insects and their larvae and other arthropods living on detritus (these themselves occupying the second trophic level alongside bacteria and fungi). Still other fish commuities occupy the fourth trophic level. These are predatory fish eating carnivorous fish or other carivorous animals. The trasfer of food energy from producers occurs thus in two or three steps in the third and the fourth trophic levels respectively. A relatively simple food chain operates in managed fish ponds but a complex one occurs in large lakes and other fresh water ecosystems. The picture is very complicated in trophic relations is still large and wild water bodies, especially in seas, where complicated food chains are referred to as food webs which infact represent several food chains interconnected into a whole. There are again fish communities which occupy multiple positions or mixed positions between different trophic levels. Such fishes consume a variety of food, both plants and animals. These are called omnivorous fishes and these cannot be naturally classified with any one particular trophie level.

13.11.1. ECOLOGICAL PYRAMIDS

Trophic structure i.e. the interaction of food chain and the size metabolism relationship between the linearly arranged various biotic components of an ecosystem is characteristic of each type of ecosystem. The trophic structure and function at successive trophic levels, i.e. producers herbivores carnivores, may be shown graphically by means of ecological pyramids where the first or producer level constitutes the base of the pyramid and the successive levels, the tiers making the apex. Ecological pyramids are of three general types - (i) pyramid of numbers, showing the number of individual organisms at each level, (ii) pyramid of biomass, showing the total dry weight and other suitable measure of the total amount of living matter, and (iii) pyramid of energy, showing the rate of energy flow and or productivity at successive trophic levels. The pyramid of numbers and biomass may be upright or inverted depending upon the nature of the food chain in the particular ecosystem, whereas pyramids of energy are always upright.

13.11.1.1. PYRAMIDS OF NUMBER

They show the relationship between producers, herbivores and carnivores at successive trophic levels in terms of their number. The pyramids of numbers in three different kinds of ecosystems are shown in Fig. 13.25 (A-C) In a grassland (Fig.13.25A) the producers, which are mainly grasses are always maximum in number. This number then shows a decrease towards apex, as the primary consumers (herbivores) like rabbits, mice etc. are lesser in number than the grasses; the secondary consumers, snakes and lizards are lesser in number than the rabbits and mice. Finally, the top (tertiary) consumers hawks or other birds, are least in number. Thus, the pyramid becomes upright. Similarly in a pond ecosytem (Fig. 13.25B) the pyramid is upright. Here the producers, which are mainly the phyto-planktons as algae, bacteria etc. are maximum in number; the herbivores, which are smaller fish; rotifers etc. are lesser in number than the each other, water beetles etc. are lesser in number than the herbivores. Finally, the top (tertiary) consumers, the bigger fish are least in number. In a forest ecosystem (Fig. 13.25C), however, the pyramid of numbers is some what different in shape. The produces, which are mainly large-sized trees, are lesser in number, and form the base of the pyramid. The herbivores, which are the fruit-eating birds, elephants, deers etc. are more in number than the producers. Then there is a gradual decrease in the number of successive carnivores, thus making the pyramid again upright. However, in a parasitic food chain (Fig.13.25D) the pyramids are always inverted. This is due to the fact that a single plant may support the growth of many herbivores and each herbivore in turn may provide nutrition to several parasites, which support many hyperparasites. Thus, from the producer towards consumers, there is a reverse position, i.e. the number of organisms gradually shows an increase, making the pyramid inverted in shape.

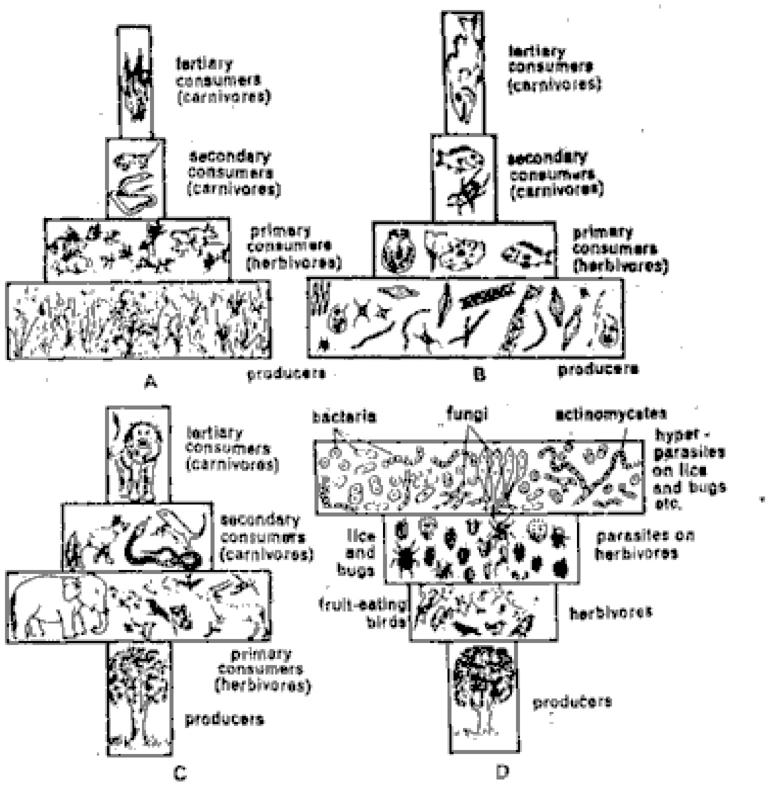


Fig. 13.25. Pyramids of numbers (individuals per unit area) in different kinds of ecosystem/food chains. A - grassland ecosystem. B - pond ecosystem, C - forest ecosystem. In A-C parasitic microorganisms and soil animals are not included. D - parasitic food chain.

Actually the pyramid of numbers do not give a true picture of the food chain as they are not very functional. They do not indicate the relative effects of the 'geometric', 'food chain' and 'size' factors of the organisms. They generally vary with different communities with different types of food chains in the same environment. It becomes sometimes very difficult to represent the whole community on the same numerical scale (as in forests).

13.11.1.2. PYRAMIDS OF BIOMASS

They are comparatively more fundamental, as they, instead of geometric factor, show the quantitative relationships of the standing crops. The pyramids of biomass in different types of ecosystem are shown in Figure 13.26 (A-C). In grassland and forest (Fig. 13.26 A.B), there is generally a gradual decrease in biomass of organisms at successive levels from the producers to the top carnivores. Thus pyramids are upright. However, in a pond (Fig. 13. 26C) as the producers are small organisms, their biomass is least, and this value gradually shows an increase towards the apex of the pyamid, thus making the pyramid inverted in shape.

13.11.1.3. PYRAMID OF ENERGY

Of the three types of ecological pyramids, the energy pyramid give the best picture of overall nature of the ecosystem. Here, number and weight of organisms at any level depends not on the amount of fixed energy present at any one time in the level just below but rather on the rate at which food is being produced. In contrast with the pyramids of numbers and biomass, which are pictures of the standing situations (organisms present at any movement), the pyramid of energy (Fig. 13. 27) is a picture of the rates of passage of food mass through the food chain. In shape it is always upright, as in most of the cases there is always a gradual decrease in the energy content at successive trophic levels from the producers to various consumers.

The species structure includes not only the number and kinds of species but also the diversity of species i.e. the relationship between species and number of individuals or biomass; and the dispersion (spatial arrangement) of individuals of each species present in the community.

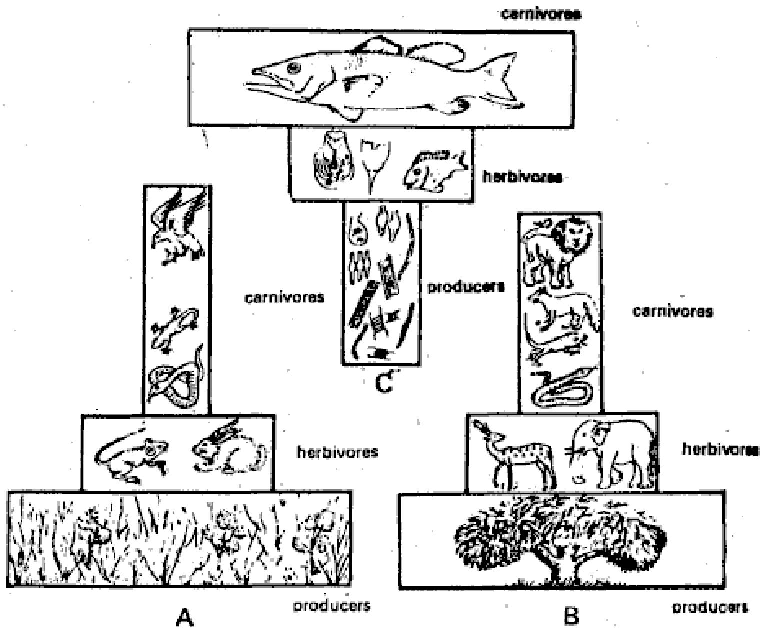


Fig. 13.26 (A- C) Pyramids of biomass (g. dry wt. per unit area) in different kinds of ecosystems. A - grassland, B - forest, C - pond.

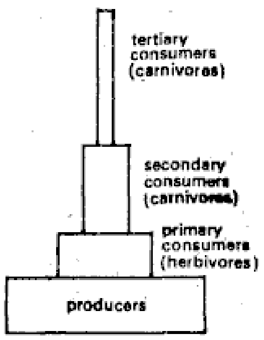


Fig. 13.27 Pyramid of energy (K cal per unit area within unit time, season or years) in any ecosystem.

13.12. PRODUCTIVITY OF ECOSYSTEM

The productivity of an ecosystem refers to the rate of production i.e. the amount of organic matter accumulated in any unit time. Productivity is of the following types:

13.12.1. Primary productivity

It is associated with the producers which are autotrophic, most of which are photosynthetic, and to a much lesser extent the chemosynthetic microorganisms. These are the green plants, higher macrophytes as well as lower forms, the phytoplanktons and some photosynthetic bacteria. Primary productivity is defined as "the rate at which radiant energy is stored by photosynthetic and chemosynthetic activity of producers." Primary productivity is further distinguished as:

a) *Gross primary productivity.* It is the total rate of photosynthesis including the organic matter used up in respiration during the measurement period. This is also sometimes referred to as total (gross) photosynthesis or total assimilation. It depends on the chlorophyll content as, Chl/g dry weight/ unit area, or photosynthetic number i.e. amount of CO2 fixed/g ChI/hour.

(b) *Net primary productivity*. It is the rate of storage of organic matter in plant tissues in excess of the respiratory utilization by plants during the measurement period. This is thus the rate of increase of biomass and is also known as apparent photosynthesis or net assimilation. Thus, net primary productivity refers to balance between gross photosynthesis and respiration and other plant losses as death etc.

13.12.2.Secondary productivity

It refers.to the consumers or heterotrophs. These are the rates of energy storage at consumers level. Since consumers only utilize food materials (already produced) in their respiration, simply converting the food matter to different tissues by an overall process, secondary productivity is not divided into 'gross' and 'net' amounts. Thus, some ecologists as Odum (1971), prefer to use the term assimilation rather than 'production' at this level the consumers level. Secondary productivity actually remains mobile (i.e. keeps on moving from one organism to another) and does not live in situ like the primary productivity.

13.12.3. Net productivity

It refers to the rate of storage of organic matter not used by the heterotrophs (consumers) i.e. equivalent to net primary production minus consumption by the heterotrophs during the unit period, as a season or year etc. it is thus the rate of increase of biomass of the primary producers which has been left over by the consumers. Net productivity is generally expressed as production of Cg/m2/day. Which may then be consolidated on month, season or year basis.

13.13. LIMNOLOGY

Limnology is a branch of science, which deals with the study of freshwater ecosystems of all kinds ranging from lakes, reservoirs, streams, ponds, marshes, bogs, etc - physically, chemically and biologically. It started withthe study of lakes (Forel's Lelemane - 1888 to 1909), which was defined as 'an ecosystem'. In general, lakes vary in latitude, altitude, size and depths, but each lake constituted as a 'closed system' (Ecosystem). The largest lake in the world is Lake Tanganyika in Africa (34,000 km^2) and Woolar lake (200 km^2) and Bhopal lake (150 km^2) are conisdcrd to be the smallest ones.

Limnological studies such as, physical, chemical and biological forms a part of limnology.

i) *Physical:* Physiography, morphometry, bathymetry, temperature, turbidity, conductivity, water volume, water current etc. are covered in this area of study.

ii) *Chemical*: Study of H^+ ion concentration dissolved oxygen, CO_2. alkalinity, No_3, PO_4, Silicate, Calcium hardness, chloride, ammonia in solution, H_2S and trace elements like B, Mn, Mg, Fe, Cu, etc.

iii) Biology: Study of plankton (phyto, zoo, nanno plankton); nekton (fish, Insects, crustacea, annelids, molasses and other free swimming animals); Benthos (phyto benthos, zoo benthos); pedon (botton fauna or zoo benthos) and microorganism inform of dead organic matters (DOM, bottom mat etc.,)

Apart from these studies (Qualitative), quantitative production studies are also forms a partin limnology. It also comprises, the correlations between an organism or a community with other organisms and physico - chemical environment (climate and rainfall). The food chains (in water) of fishes, plankton, pedon, other animals and macrophytes are all studied under limnology.

Limnology requires a multidisciplinary approach. Besides physical, chemical and biological studies, it also encampass some area of other disciplins, such as geology, geography, matereology, hydrology, statistics, biochemistry, bacteriology, geodesy and engineering.

13.13.1. PLANKTON

The plankton is nothing but a group heterogenous tiny piants and animals adopted to suspension in the sea and fresh waters. Their intrinsic movements are essentially depends upon the mercy of water currents. The plankton occurs in all natural waters as well as in artificial impoundments like ponds, tanks, reservoirs, irrigation channels etc.

The term 'Plankton' was first coined by victor Hensen in 1887. According to Hensen's (1887) terminology, "plankton" (singular-planktre) included all organic particles which float freely and involuntarily in the open water, independent of shores and bottom. The planktons are classified in different ways.

1) Depending upon the ability to carry out the photosynthetic activity, planktons are classified into

(i) Phytoplankton (plant plankters) and

(ii) Zooplankton (animal plankters)

2) Depending upon the basis of size they are of

(i) Megaloplankton - More than 8 cm.

(ii) Macroplankton - Size vary from 1 mm to -scm

(iii) Meroplankton - 0.5 to 1 mm

(iv) Microplankton - 0.06 to 0.05 mm

(v) Nanoplankton - 0.005 to 0.06 mm. and

(vi) Ultraceston - 0.005 to 0.005 mm.

Even recently, the term picoplankton has been introduced, for which the organisms are less than 0.0005 mm of size. -

3) Depending upon their habuat, they are classified as,

(i) Heleoplankton - Pond water plankton

(ii) Limnoplankton - Lake water plankton

(iii) Rheo/potamo plankton - Running water planlcton

(iv) Haliplanktob - Salt water plankton

(v) Hypahnyro plankton - Brackish water plankton and

(iv) Pseudoplankton - Planktons occurs on the upper layer of waters.

Planktons are having an immense value as a food and play an important role in the disposal of sewage and in natural purification of polluted waters. But some plankton form a harmful bloom that may cause a high mortality among the aquatic organisms and pose a serious hazard in the water supply for domestic and industrial use.

The fish culture practices attaining a greater importance in the field of aquaculture throughout the world as well as in India. For an efficient fish culture, the fish seed should be properly feed with sufficient natural food organisms. These small microscopic organisms are nothing but the 'Planktons'. As far as freshwater fish ponds concerned, the planktons comprises both the phytoplankton as well as Zooplankton.

13.13.1.PHYTOPLANKTON

On land, plants of some kind are visible practically every where. But if one stand on the bundh of a tank, no plant is visible, except on the bundh area, their attached a few algae, which appear in luxuriant growth, where ever there is a sufficient light for carry the photosynthetic activity. If we collect the water from a tank and examine the contents of the collected water, you will find a large number of unicellular bodies in all kinds of shapes. Some of them are passive while other are feebly active. All of them were contains coloured material in side their cells. These are nothing but the phytoplankton. The phytoplanktons are autotrophic organisms, and are the producers of all the organic food available in the ponds/tanks. They form the foundation of all the food webs in the pond ecosystems.

Boney (1975) divided the phytoplankton into Macroplankton (> 1mm), Microplankton (< 1mm), Nannoplankton (5-60 mm) and Ultraplankton (<5 mm).

The phytoplanktons mainly consists of the groups of Chlorophyceae, Bacillariophyceae, Eugleninaceae, and Myxophyceae and some extent a few Dinophyceae. Some of the common phytoplanktons found in lakes and ponds of India is listed in the Table 13.1.

Table 13.1: Common phytolanktons in lakes and ponds of India

Class	**Characteristics**	**Common forms**
Cyanophceae (blue green algae)	Absence of distinct and organized chloroplast, with a diffuse blue-green pigment. Some have chains	Microcystis aeruginosa Microcystis aeruginosa Spirulina sp. Oscillatoria sp. Nostoc Sp.

	of cells termed as trichomes. Some have heterocysts which are capable of nitrogen	Nostoc sp. Anabaena sp. Schizothrix sp.
Xanthophyceae	Similar to green alage but is distinguisted by the lack of strch reaction. Presence of several discordal chloroplasts per cell.	Vaucheria sp.
Euglenophyceae	Mostly unicellular flagellates. Presence of a naked chloroplast. Noramlly with two flagella arising from a pronounced depression or pit near the cell apex. Presence of a conspicusous red stigma.	Euglena sp.
Dinophyceae	Cells with two flagllae lying partially within two deep furrows. One furrow giriding the cell, the other At right angles towards one apex. Chloroplast discodial.	Gymnodinium sp. Ceratium sp.
Bacillariophuyceae (diatoms)	Cell walls consist of two halves which are identical in shape and fit neartly. Held in position by intercalary bands. Silicified walls known as frustules. May be ciruclar with radial symmetry or boat-shapped with bilateral symmetry. Presence of a slit-like raphe which secretes mucilage.	Melosira sp Meridionsp. Diatoma sp. Asterionella sp. Fragilaria sp. Synedra sp. Rhociosphenia sp Stauroneis sp. Navicula sp. Nitzschia sp.
Chlorophyceae	Large well-defined group of algae which are motile in their vegetative state. Cholroplast pale to deep grass-green. Unicellular, colonial of filamentous. Normally with 1-2 parietal	*Chlamydomonas sp.* *Pandorina sp.* *Edudorina sp.* *Volvox sp.* *Scenedesmus sp.* *Hydrodictyon sp.* *Ulothrix sp.*

	or axile chloroplast, occasionally with many chloroplast	*Oedogonium sp.* *Spirogyra sp.* *Zygnema sp.* *Pediastrum sp.* *Euostrum sp.*

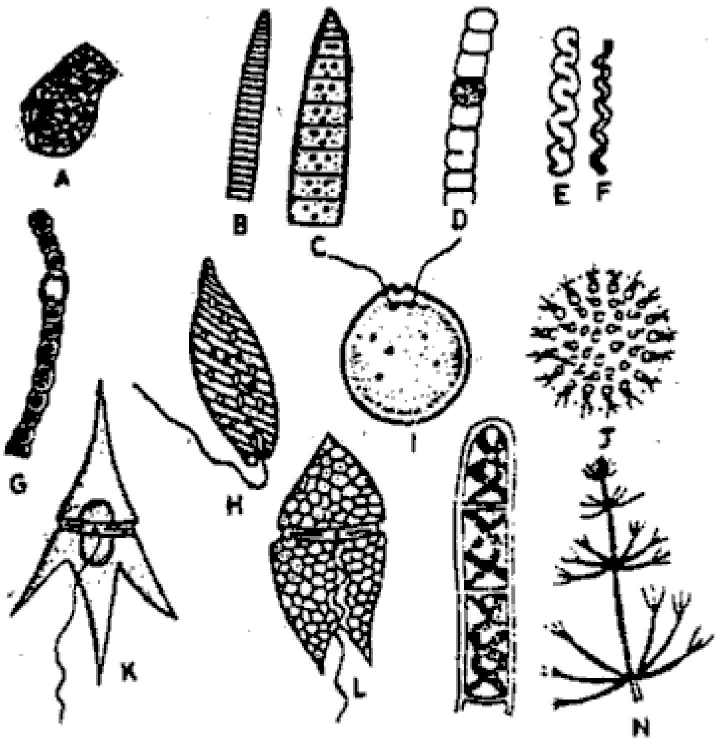


Fig. 13.28 **Phytoplankton**

(a) Microcystis, (b & c) Oscillatoria, (d) Anabaena, (e & f) Spirulina, (g) Nostoc, (h) Euglena, (i) Chlomydomonas, (j) Volvox, (k) Spirogyra, (i) Nitella.

13.13.1.2. ZOOPLANK TON

Animals, which are carried along by the moving waters are known as 'Plankton'. The planktonic animals are virtually at the mercy of the currents and generally drift about passively. Zooplankton consists mostly of invertebrates and larvae and immature stages of both invertebrates as well as vertebrates.

The planktonic community exhibits considerably variety as it is composed of every group from protozoa to chordata. However, coelenterats, and crustaceans predominates. Siphanophorans, ctenophorans and chaetognathans among invertebrates and Larvacea among chordates are exclusively planktonic forms. Planktonic animals must necessasily have the capacity to remain afloat,.

13.13.1.2.1.Classification

The Zooplankton may be classified according to their habitat and depth of distribution, size and duration of planktonic life, *I. Depending upon the basis of depth of distribution*, they are classified as

(i)	Pleuston	- Living at surface of the water
(ii)	Neustdn	- Living in the upper most few to tens of millimeters of the surface micro layer
(iii)	Epipelagic plankton	- Living between 0 and 30Gm.
	Upper epiplankton	- from 0 - l50m.
	Lower epiplankton	- from 150 - 300m.
(iv)	Mesopelagic plankton	- Living between 300 - 1000m.
(v)	Bathy pelagic plankton	-Living between 1000 - 3000m.
(vi)	Abyssopelagic plankton	- Living between 3000 - 4000m.
(vii)	Epibenthic plankton	- Living at the bottom, i.e, demersal plankton.

2. Depending upon the size, the zooplanktons areclassified as

(i)	Nanozooplankton	- <20mm
(ii)	Microzooplankton	- 20 - 200 mm
(iii)	Mesozoop(ankton	- 200 mm - 2 mm
(iv)	Macrozooplankton	- 2 - 20 mm
(v)	Megalozooplankton	- > 20 mm

Among the.unicellular organisms of the plankton, there are a few, which are neither plants nor animals. Flagellates are of this type and are classified as 'Protophyta'. These protophyta includes the members such as plants, animals (or) of both. The zooplanktonic forms shows a great variability ranging from protozoans to chordates. Several members of the class Sarcodina are planktonic among the protozoans. Ceolentarates are secohd only to the crustaceans in the number and variety of their planktonic members. In the planktonic stages, the adult annelidans are poorly represented, but larval stages are always represents in fairly large numbers. The Arthropods dominates as the planktons, particularly - of crustaceans. They are the aquatic counter parts of the terrestrial insects. Every order of crustaeea is represented in the plankton either by the adults (or) by their larvae. The molluscs are essentially benthic animals, but a few are acts as holoplanktonic forms. Even the chordates, specially of protoehordates are also represented as planktons.

The zooplankons, protozoans (Diffiugia, Arcella and many ciliates), rotifers (Keratella, Polyarthra, Pedalia etc), crustaceans (Cladocerans Daphnia, Meriodaphnia, Monia and copepods, Cyclops, Diaptomus and Crustacean larvae and other Zooplanktons were discussed briefly, and some of the more common zooplanktons found in lakes and India (Table 13.2. and Fig. 13.29).

Table 13.2: Common zooplanktons in lakes in India.

A. Protozoa	*Difflugia pyriformes, Trachelomonas sp. Euglypha acanthophora, Chilomonas sp. Placoysta sp., Amoeba proteus Didinium nasututn, Arcella discoides Paramecium caudatum, Arcella gibbosa*
B. Porifera	*Spongilla lacustris*
C. Coelenterata	*Hydra virdis, Pelmatohydra oligactis, Hydra vulgaris*
D, Rotifera	*Philodina sp., Hexarthra mirum. Filinia terminalis, Filinia longiseta Asplanchna sp.,*

	Branchionus calcyflorus, Brachionus forficula, Polyarthra sp. Keratella tropica, Keratella procurva Epiphanes sp.
E. Arthropoda	
Anostraca	*Strepiocephalus sp.*
Cladocera	*Daphnia carinata, Daphia lumholtzi Moina sp., Ceriodaphnia sp., simocephalus sp.*
Ostracoda	*Cypris sp., Stenocypris sp., Heterocypris sp. Centrocypris sp.*
Copepoda	*Mesacyclops sp., Diaptoinus sp., Neodiaptomus sp. Heliodiaptomus sp. Rhinediaptomus sp.*

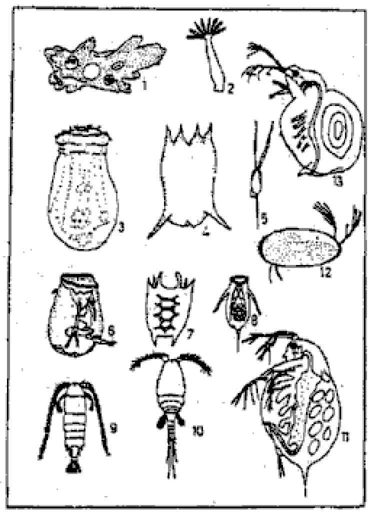


Fig. 13.29 Common Zooplãnkters found in freshwaters.
(1) Amoeba (2) Hydra (3) Asplanchna (4) Branchionus (5) filima (6) eiphanes (7) Keratella (8) triarthra (9) Diaptomus (10) Mesocyclops (11) Daphnia.

13.13.1.3.NEKTON

The nekton consists of actively swimming organisms, including a diverse group of insects and fishes (fig.13.30). Most of these insects can spend their time on the water surface and frequently dive inside the water for feeding. These are voracious feeders, feeding on plant oozes *(corixa),* Insects and crustaceans (*Nepa: Ranatra: Hydrophiues):* eggs, fry and fingerlings of fishes *(Lethocerus, Belostoma, Diphonychus).* While going under water, Notonecta usually enter the water with a store of air under wing covers, or beneath the abdomen. The hydrofhge hairs and body surface cause the surface film to form a more (or) less complete envelope about the body, there by enclosing an air space. The surface film acts as a diffusion membrane through which gases pass from the air space to the water and vice-versa.

Table-13.3: Common nektons in lakes of India.

A. Insects			
	Order	Hemiptera	
		Family Notonectidae	Nownecta sp.
		Family Nepidae	Nepa sp.
			Ranatra sp.
		Family Belostomidae	Lethocerus sp.
			Belostoma sp.
			Diplonuychus sp.
		Family Corixidae	Corixa sp.
	Order	Coleoptcra	
		Family Dytiscidae	Cybister sp.
			Laccophilus sp.
			Dytiscus sp.
		Family Hydrophilidae	Hydrophilus sp.
			Dineutes sp.
B. Fishes			
	Order	Cypriniformcs	
		Family Cyprinidae	Cat/a cat/a
			Labeo rohita
			Cirrhina mn gala
			Labeo calbasu
			Labea bata
			Labeofimbniatus

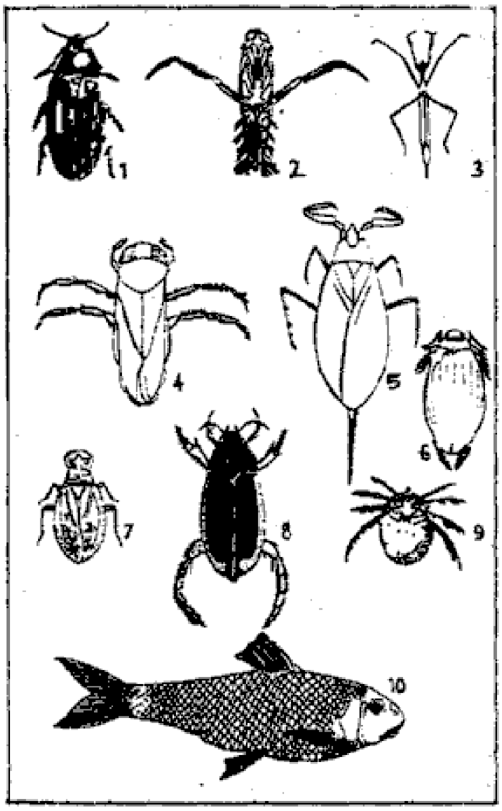


Fig. 13.30 Some nektonic animal of freshwater. *1. Hydrophilus 2. Notonecta 3. Ranatra 4. Corixa 5. Nepa 6. Dytiscus 7. Belostoma 8. Cybsiter 9. Hydrachna 10. Catla.*

13.13.1.4 BENTHOS

The Benthos included all bottom dwelling organisms. This group comprises both plants and animals, that are graded from the upper most water - bearing portions of the beach down to the greatest depths. Thus the benthos may be broadly divided into the littoral benthos; the sublittoral benthos and the poflindal benthos. The littoral and sublittoral benthos exclusively consists of the microscopic forms of insects and molluscs.

Hutchinson in 1967 has divided the benthie community based on the niche they occupy into 5 groups. They are.

(i) Rhizo benthos - rooted in the substratum by well - extended into the aqueousphase.

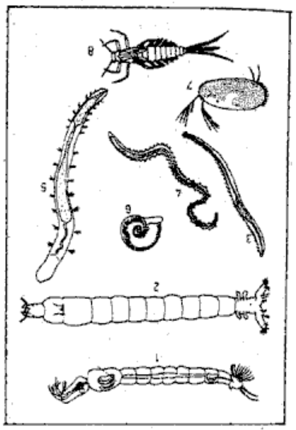
(ii) Haptobenthos - Attached to an iinmessedsolid surface

(iii) Herpobenthos - growing (or) moving through mud

(iv) Psammon - growing (or) moving through sand

(v) Endobenthos - boring into solid substrate

The littoral benthic region may or may not be occupied by the roots of maerophytes. They may be completely absent in unstable sand or bare rocks. Species such as Ulothrix ; Oedogonium; Spirogyra; Pandorina are common algae. The Animals inhabiting the littoral benthie region include protozoans, Coelentarates, Nematodes, Gastrotrichs, Insect larvae, Ogochaetes, Ostracods, Mites and Molluscs (fig.13.31).



1. *Chaoborus* larva 2. *Chironomus* larva 3. *Dero* 4. *Tubifex* 5. *Aelosoma* 6. *Planorbis* 7. *Heterocypris* 8. Mayfly nymph.

Fig. 13.31 The benthic fauna of standing freshwater.

The profoundal benthic zone is typically anaerobic, with a diversified group of microorganisms including cabo, sulphur and nitrogen bacteria. Some colourless algae may also occurs. Animals like bivalve molluscs and tubified oligochetes are common. Some dipteran insects such as chaoborus are also present along with few numbers of turbellarians, Ostracods and hydracarines.

13.13.1.5. PERIPHYTON

The under water stems and leaves of aquatic macrophytes are generally colonized by epiphytic organism (periphytons) such as algae, bacteria and protozoa. They acquire a covering of detritus which may in turn be followed by a covering of algae (or) fungi. This rich substrate forms the grazing ground of many animals such as snails (Lymnea, Gyraulus); Chironomid larvae, May fly nymphs (Baetis, Caenis) and many species of Caddisfly larvae. Among the carnivores, the active hunters and lurkers are also found attached to weed beds. Among the hunters, various fresh water beetles such as Dytiscus, Laccophilus. Even different species of annelids, such as Dero, Nalas, and Chaetogaster are also found (Fig.13.32)

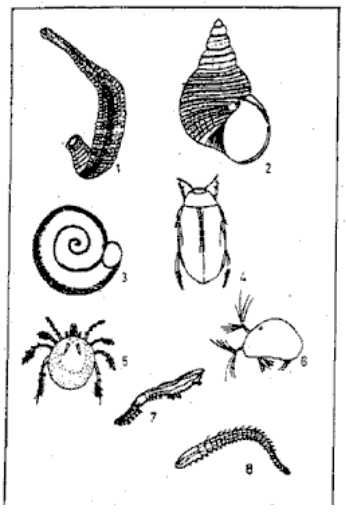


Fig. 13.32 Some opportunists of weed beds
1. Hirudinaria 2. Vivipara 3. Gyraulus
4. Dytiscus 5. Hydrarachna 6. Cypris
7. Chaetogaster 8. Nais

13.13.2. ROLE OF PLANKTON IN THE SURVIVAL AND GROWTH OF FISH

Experiments have shown that the main food of the young carp fry is zooplankton, and in the absence of enemies, their survival depends entirely on the production of thick swarms of zooplankton, and the time of stocking the ponds. However, development of thick algal blooms causes super saturation of dissolved oxygen in water, often resulting in gas trouble to the fry and large scale mortality.

Heavy manuring of ponds with cowdung almost invariably results in the production of swarms of zooplankton consisting of rotifers, cladocerans and copepods, in about 10 days. Volvox, Eudorina, Anabaena frequently occur in blooms of varying intensity, Algae also develop and Euglena may form surface scum. The growth and multiplication of algae s very rapid, and within a short multiplication of algae is very rapid, and within a short period of 2-3 weeks, blooms might develop and disappear completely. Among zooplankton, rotifers like Brachinous, Keratella and Polyarthra along with eopepods, nauplii make their appearance. Zooplankton multiply rapidly and appear in swarms in 4-6 days, and disappear in 7-8 days.

Laboratory experiments have shown that 90-100% fry survive if the fry are stocked during swarms of zooplankton and abundant food is available. Zooplankton are preferred by fry as they are easily digested. Phytoplankton is not utilized as food and is difficult to digest. The nutritional value of phytoplankton is also less than the zooplankton. However, production of zooplanton in a pond after heavy manuring is a matter of chance. It is not certain whether zooplankton will be produced or phytoplankton will appear. Application of heavy dose of cowdung in tanks, usually results in early production of zooplankton swarms, and the stocking of the fry has to be adjusted with time of its maximum production.

SUMMARY

The ecosystem is an integrated system resulted from interaction of living and non-living factors of the environment. The lentic ecosystems consists of pond, lake, reservoir and ocean. Pond is a small impondment which is the

typical example of an ecosystem. Lake and reservoir are the large water bodies which consists of both abiotic and biotic factors. Ocean is a largest ecosystem with different types or organisms in epipelagic, bathypelagic and abyssopeiagic regions. Estuari is a semi-enclosed postal body of water having free connection with open sea. It comprises of both sea water and fresh water and occurs usually the river mouth, coastal bays and tidal marshes. The lotic waters consists of rivers.

Ecosystem is an self supporting system where both abiotic and biotic factors acts and interact with each other to bring a structural and functional change. The abiotic factors components reftr to non-living elements or factors present in the ecosystem, whereas the biotic factors include the living elements. The behaviour of energy is termed as energy flow and it is unidirectional in an ecosystem. The energy in an ecosystem is represented in the form of energy pyramids. The transfer of the food energy from the produces, through a series of organisms with repeated eating and being eaten, is known as food chain. The food chains are inter connected with each other forming some soft of interlocking pattern known as food web.

Limnology is a branch of science, which deals with the study of freshwater ecosystems of all kinds ranging from lakes, teservoirs, streams, ponds, marshes, bogs, etc - physically, chemically and biologically. Limnological studies such as, physical, chemical and biological forms a part of limnology.

The plankton are nothing but a group heterogenous tiny plants and animals adopted to suspension in the sea and fresh waters. Their intrinsic movements are essentially depends upon the mercy of water currents. The planktons are classified on the basis of the ability to carry out the photosynthetic activity.They are (i) Phytoplankton (plant plankters) and (ii) Zooplankton (animal plankters). Planktons also includes nektons, periphyton and benthos. These planktons forms chief food component for growth and development of fish.

QUESTIONS

1) Describe the pond ecosystem.
2) Give an account on lake ecosystem.
3) What is reservoir and explain its abiotic and biotic factors?
4) Discuss the oceanic ecosystem.
5) Give an detailed account of estuarian ecosystem.
6) Describe the principles of ecosystem.
7) Give an account on abiotic factors of an ecosystem.
8) Write a short note on biotic factors of an ecosystem.
9) Discuss the energy flow in ecosystem.
10) What is food chain and give a detailed account on food web?
11) What are the trophic levels? Write about the significance of ecological pyramids.
12) What is Limnology? Discuss in brief about the plankton?
13) Define Plankton? Write a detail ac□ount on the role of plankton in fisheries?
14) Write short notes on nekton, benthos and periphyton?
15) What are common zooplanktons found in fresh water bodies and given an account on their classification?

14

SOIL

14. SOIL

Soil is one of the most important ecological factors. Plants depend for their nutrients, water supply, and anchorage upon the soil. Even for the free- floating aquatic plants which derive their nutrients dissolved in the water medium around them, soil (mud) is important as chief storage of all the nutrients, which are made available to the water medium. Soil system is indeed very complex and dynamic, undergoing continuous change, and the rates of such change being influenced by a number of other factors of the environment. Marsden-Jones and Tussill after growing plants is different types of soil concluded that soil may affect plants by affecting seed germination, size and érectess of the plant, vigour of the vegetative organs, woodiness of stem, depth of the root system, susceptibility to drought, frost and parasites, number of flowers per plant, and the time of flowering etc.

14.1. DEFINITION AND COMPOSITION OF SOIL

Any part of the earth's surface that supports vegetation also bears a covering of soil. Soil is thus usually defined as "any part of earth's crust in which plants root". Muddy bottom of ponds, porous rock surfaces, ravines or glacial-deposits, bottoms of lakes, peats etc., all are thus soils. But this is a limited definition of soil, as we know that soil is actually formed as a result of long-term process of complex interactions leading to the production of a mineral matrix in close association with - interstitial organic matter-living as well as dead. In soil formation, modification of parent mineral matter takes irly a longtime. Such a modifiction is actually the result of interactions between climate, topographic and t iological effects. Soil is thus not merely a group of mineral particles. It hs also a biological system of living organisms as well as some other componeñts. It is thus preferred to call it a soil complex, which has the following five categories of components:

1. ***Mineral matter***: A matrix of mineral particles derived by varying degrees of breakdown of the parent material-rock.

2. ***Soil organic matter or humus****:* An organic component derived from long and short-term addition of material from organisms growing above and below ground i.e., plants, animals, microorganisms.

3. ***Soil water/Soil solution***: Water contained in soil together with its dissolved solids, liquids and gases. Soil water is held by capillary and absorptive forces both between and at the surface of soil-particles. Soil water in reality is a dilute solution of many organic and inorganic compounds, which is the source of plant mineral nutrients.

4. ***Soil atmosphere****:* It occupies the more space between soil particles, which at any time, is not water-filled. Its composition differs from the above ground atmosphere in the sense that it is normally lower in oxygen and higher in carbon dioxide content.

5. ***Biological System***: To the above, there may also be added, the biological system, as each soil has a distinctive flora as well as fauna of bacteria, fungi, algae, protozoa, rotifers, nematodes oligochetes, molluscs and arthropods.

14.2. SOIL FORMATION

Soil is formed by the interaction of several mechanical forces such as oxidation, carbonation, hydration, solution, temperative effects and the effects of bacteria, fungi and other animals on rocks. The forces which are responsible for the decomposition of rocks under natural conditions are not get known fully. The earths crust composed of minerals is said to give way due to oxidation. Carbondioxide is credited with the power of weathering the rocks. Water by its solvent action plays a major part as a weathering agent. It is also responsible for effecting chemical changes. Fission among the rocks is effected when the temperature is lowered particularly below the freezing point of water. The temperature by its influence on chemical reaction helps the disintegration process of rocks. Bacteria and linchems pave way for the colonization of other organisms. Earthworms, millipedes, burrowing mammals bring about an admixture of soil and they serve to aerate the soil as well as to increase the water holding capacity of the soil. Thus soil is a complex system to living and non-living components. It is an example to illustrate the intimacy of the organism with the environment.

14.3. TYPES OF SOILS

There is no unamity among the pedologists as to the classification of soil. Lyon and Buckman proposed six major types of soils, namely. Alluvial soils, Black cotton or Rcgur soils, Red soils, Laterite soils, Mountain soils, Desert soils.

14.3.1. Alluvial soils

These soils are formed by river systems through deposition of fine grained sediments. There soils are of two types, the older alluvium, and the newer alluvium. The older alluvium is more clayey and darker colour whereas the newer alluvial is generally sandy in texture and -light coloured. In general, alluvial soils are rich in lime and potash but deficient in nitrogen and organic content. Phosphorus is also deficient in some areas.

Alluvial soils cover. 23.4 percent of the country's total land surface. In the north, there soils occur in the indogangetic plains covering from Punjab to Assam. In the penisular platean, they found in the coastal plains and river valleys of Narmada, Tapti, Mahanadi, Krishna, Godavari and Couvery. Due to deficiency of nitrogen and humus content, there soils require heavy fertilization particularly nitrogneous fertilizers. On the whole these soils are very fertile and suitable for the cultivation of almost all kinds of crops and also contributing the largest share to the agriculture wealth of the country.

14.3.2. Black cotton or Regular soils

Black soils have developed over Deccan lavas, gneisses and granites under semi-arid conditions. These soils are the tropical chenozems with vary.

in colour from deep black through light black to chestnut. Their black colour largely due to the fine iron content. The texture of black-soils is mostly clayey and are known for high moisture retentive capacity. During hot weather period, these soils develop deep cracks is the fields which helps in their aeration and absorption of nitrogen from the atmosphere. Chemically these soils are deficient in nitrogen, phosphoric acid and organic matter but rich in potash, lime, aluminium, calcium and magnesium carbonates. During dry period, they are hard baked and during rainy period, they are sticky and as a result difficult to work and tillage. Since the content of water, soluble salts is high, they are unsuitable for heavy irrigation. Black-soils are well-known for their fertility. They give good yields with less manuring. Cotton is the most suitable crop of block soils. Oil seeds, millets, fruits are widely grown. Block soils are ideal for dry farming due to thi moisture tentative capacity.

14.3.3. Red soils

Red soils derived from weathering of crystalline and metamorphic rocks specially in the low rainfall conditions. These soils are generally - characterized by lighter texture with porous and friable - structure; absence of like, konkar and free carbonates and presence of soluble salts in a small quantity. These are deficient is nitrogen- humus. Generally these soils are less fertile and are deficient in nitrogenous and organic matter and phosphoric acid. Red soil are airy and need protective irrigation for successful cultivation. All kinds of crops are grown on red soils.

14.3.4. Laterite soils

Laterite soils are formed under the conditions of high temperture and rainfall with alternative, wet and dry seasons. It leads to the lee'-hing away of the much of silica from the original rock. These soils are composed of a mixture of hydrated oxides of aluminum and iron. The soil consists of a honey-combed mass iron oxides in nodules form which turns black after expoure to rain. Literate are very poor in fertility and deficient in nitrogen, organic matter, potash, lime and magnesia contents. Due to very poor fertility status, there soils generally support postures and scrub forests. In agricultural sector, when these soils are manured and irrigated they support tea, coffee, rubber and coconut plantation

14.3.5. Mountain soils

The soils in the mountains posses a variety of soil texture, colour, profile and degree of development. They are the immature soils usually deficient is nitrogen, phosphorus and humus. Because of low chemical weathering and mass movement, the mountain soils are immature and skeletal which are of low fertility. Suitable for orchard crops, forest trees and plantation crops.

14.3.6. Desert soils

These soils, are formed under arid and semi-arid conditions. They include wind blow loss formations. They are very light consist of aelouian sand with high soluble salt content and very low humus content. They are also mostly firable and low in moisture content. Rich in phosphate content but poor in nitrogen. These sandy soil are very poor fertility but very high in salinity which restrict the growth of variety of crops. Suitable for high salt tolerant crops, such as barley, grape and cotton and also for medium salt tolerant crops like wheat, millets, maize, and pulses.

The soil may also be classified into four groups:

Coarse textured soils: It consists mainly of send and gravel and is capable of holding only a small amount of water.

Medium textured soil: It is composed of mixture of sand, silt and clay. Moderately fire textured soils: High proportion of stray are present in such soils

Fire textured soil: It contains more than 40 percent of clay which is more stickly and can hold more water and nutrients in it.

14.4. SOIL TEXTURE

Since soil influences the flora and fauna of the area, its texture Table 4.1 is of considerable ecological interest. Texture is determined by the size of constituent particles which have been named differently by the International Society of Soil Science.

Table. 14.1: The diameter of soil particles

S.No.	Name of Particles	Diameter of Particles
1.	Gravel	2.00 mm and more
2.	Coarse san	2.00 mm to 0.2 mm
3.	Fine sand	0.20 mm. to 0.02mm.
4.	Silt	0.02 mm. to 0.002 mm
5.	Clay	Bleow 0.002 mm.

Soils formed with various integrations of soil particles (Fig. 14.1) are of the following main types:

(i) Sandy soils mainly consist of sand particles. These are loose, dry and poor in nutrients. The water holding capacity of such soil is poort.

(ii) Clay Soils chiefly consist of clay particles. The day particles are of colloidal dimensions. They have high plasticity and possess high water holding capacity. Clay particles have very small interspaces between them so that neither water nor air can circulate freely. Such soils on getting water become water logged. Thus they are not suitable for plant growth.

(iii) Loam soils have sand, silt and clay particles in more or less equal proportions. Such soils are the most suitable for plant growth.

(iv) Sand barns soils are those spils in which sand particles predominate.

(v) Clay loam soils hhave a predominance of clay particles. Both sandy and clay loam soils are suitable for plant growth.

(vi) Silt loam soils have predominance of silt. On getting water, silt loam becomes water-logged with poor air circulation. Such soils are not suitable for plant growth.

Most soils are mixtures of the above mineral particles. Based on the proportion of various particles contained in them, soils can be grouped into the following five groups.

Table 14.2 : Percentage of Sand, Silt and Clay in Main Soil Types

Sl.No.	Soil Class	Percentage Sand	Silt	Clay
1.	Sandy soil	85-l00%	0-15%	0-15%
2.	Clay	0-59%	50-0%	31%ornae
3.	Loam	23-52%	28-50%	7-27%
4.	Sandy loam	50-80%	0-50%	0-20%
5.	Clay loam	20-80%	15-53%	20-30%
6.	Silt loam	0-50%	50-88%	0-27%
7.	Siltolay loam	0-20%	40-73%	27-40%

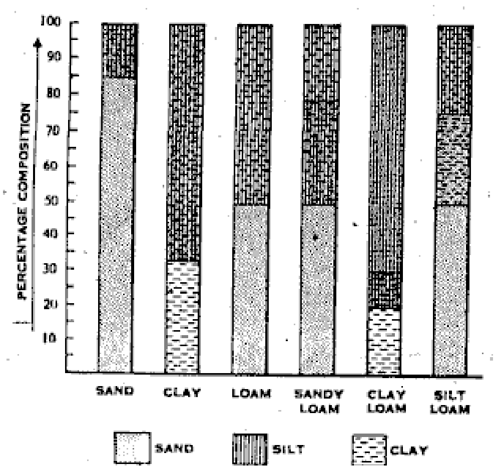


Fig.14.1 Diagrammatic representation of soil classification based on percentage of textural components of sand, silt and clay.

1. ***Coarse textured soils*** - These are loose soils consisting mainly of sand and gravel. These retain only a small amount of moisture and supply some nutrients to the plants.
2. ***Moderately coarse soils*** - These include sandy loam to very fine sandy loam.
3. ***Medium textured soils*** - These are mixture of sand, silt and clay. They hold enough water and nutrients.

4. ***Moderately fine textured soils*** - These are high in clay. These are moderately sticky and plastic when wet and form a crust on the surface if the organic matter in low.
5. ***Fine textuured soils*** - These contain 40% clay. These may be sticky and plastic when wet and hold considerable water and nutriens but have limited internal drainage.

14.5 SOIL STRUCTURE

The primary soil particles i.e. sand, silt and clay, usually occur in the form of aggregates. The arrangement of these individual particles into defined patterns is called soil structure. Natural aggregates are called peds whereas artifically formed soil mass is termed clod. Broken peds are called fragments. The soil structure is of the following four types.

1. Prism-like - These particlesa are prism-like but without rounded surface.
2. Prism-like or platy - These are plate-like particles. Sometimes plates are overlapped.
3. Block-like - In this case the peds are cube-like with flat or rounded thces. When the faces are flat and the edges sharp and angular, the structure is termed angular blocky. When the tces and the edges are mainly rounded it is called subangular blocky.
4. Sphere-like or sphaeroidal - These are rounded or sphaeroidal and smaller in size. The aggregates of this group are termed granular. These are less porous. When the granules are very porous, they are called as crumby.

Soil structure is influenced by texture, air, moisture, organic nutrients, micro-organisms, root growth and soil chemical nature. The best structure for favourable physical properties of soil are crumby and grannular.

14.6. PHYSICAL PROPERTIES OF SOIL

Soil possesses many characteristic physical properties which can be studied under the following headings

14.6.1.Soil Density

Though the average density of soil is 2.65 gm per ml., it varies greatly depending upon the degree of weathering.

The spaces present between soil particles in a given volume are called pore-spaces. The percentage of soil volume occupied by the pore spaces is called porosity of the soil. The porosity of soil depends upon the texture, compactness and organic contents of the soil. The increase in organic matter increases porosity of the soil.

The pore-spaces are of two types viz, micro-pore spaces and macro-pore spaces The macro-pare spaces (capillary pore spaces) can hold more water but restrict the free movement of water and air. The macro-pore spaces (noncapillary pore spaces) allow free movement of water and air in the soil as they have little water holding capacity.

14.6.2Soil Permeability

Soil permeability depends on the size of theores. It is higher for the loose soil, which has large number of macro-pore spaces and is low in compact soil with micro-pore spaces.

14.6.3. Soil Temperature

Soil temperature is effected by its colour texture, water contents, slope. altitude of land and by climate and vegetation. Evaporation of water from soil makes it cooler. Black soils absorb more heat as compared to white soils. Sandy soils absorb more heat but radiate it out quickly at night than the loamy

Germination of seeds, normal growth of roots and activity of soil organisms require specific temperature.

14.6.4.Soil Air

Soil air is essential for the respiration of soil micro-organisms and underground parts of the plants. Compared to atmospheric air, soil air is slightly poorer in oxygen. This is due to the metabolic activities of roots and soil organisms.

The oxygen present in the soil air is an important factor in soil fertility since it is necessary for the breaking down of insoluble minerals into soluble salts. It is essential for soil organisms whose activity increases the soil fertility. In the absence ofoxygen seed germination, root growth, water absorption by root hair etc. are slowed down and ultimately altogether cease. Under deficient supply of oxygen, due to anaerobic respiration, production of toxins takes place. Well aerated soils are free from such toxic substances.

14.6.5. Soil water

The amount of water present in the soil (Fig. 14.2) depends upon several factors. Soil water has been classified into
different categories which are follows:

1. ***Gravitational water (free water)*** - The water that moves downwards into the soil due to gravity pull is known as gravitational water. Such water is not available to plants.

2. ***Capillary water***: This water is available to plants and is responsible for providing moisture and nutrient to them. It fills the spaces between the non-colloidal soil particles or forms film around soil particles and is held by capillary forces around and in between the soil particles.

3. ***Hygroscopic water***: It is absorbed by soil colloids and is not available to plants.

4. ***Combined water***: It is a small amount of water, chemically bound to soil minerals.

5. ***Water vapour:*** Some soil water present as moisture df water vapour in the soil atmosphere.

The total water presèñt is ‘the soil is known as holard and chreased is the amount of water available to p(ants and the remaining of water available ‘plants and the remaining water is terned as Echard. The amount of water that asoil can with hold after gravitational water has been darained away of called field capacity. The percentage of water that is left in soil when the plants first wilts permanent wilting point or wilting coefficient.

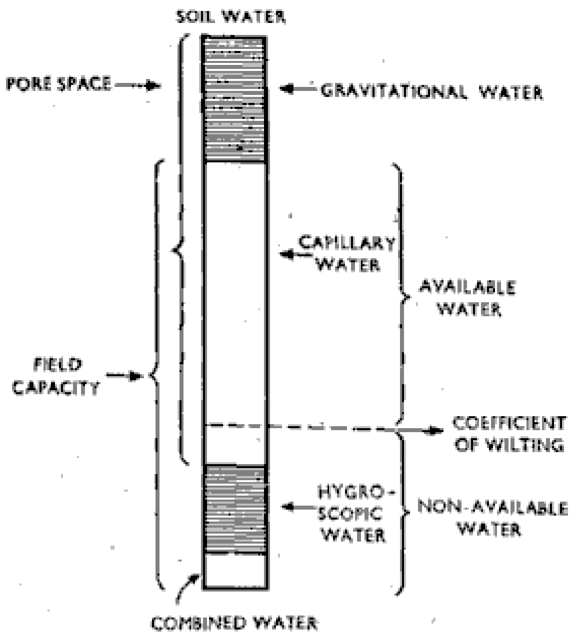


Fig.14.2 Different forms of soil water

14.7. CHEMICAL NATURE OF SOIL

The physico-chemical properties of pond water or less a reflection of the properties of the bottom soil. Productivity to -waters are produced by chemical and biochemical process from raw materials consisting of organic matter and mineral components of clay fraction of the soil. Not only the total and available quantity of raw material but also the requirement of the organisms of nutrients are essential for productive pond soil. In this respect the major chemical factors of importance are pH, total nitrogen, total phosphorus, Organic carbon, C/N ratio, availableN_2, available P, K and exchangeable-calcium.

14.7.1. Hydrogen ion concentration (pH)

The pH of soil depends on various factors. In pond muds, the decomposition of organic matter is slow due to lack of O_2. The H_2S, CH_4

and short chain fattyacids. These compounds make the condition acidic and leads to less productive. The release of essential nutrients at soil-water interface is greatly hampered due to low pH. pH range of 5.5 is highly acidic 5.5-6.5 moderately acidic, 6.5-7.5 nearly 7.5-8.5 moderately alkaline, 8.5 above (highly alkaline). However, moderately alkaline pH for soil has been considered favourable for fish ponds.

14.7.2. Phosphorus

The importance of available phosphorus in soil for increasing productivity is well recongnised. The total phosphorus in soil.is not so important owing to the fact the PO_4 ions in the form of calcium phosphate is insoluble in alkaline condition and (Ferric Iron phosphate) Fe2 (PO_4)3 are Al2 (PO_4)3 are insoluble in acidic conditions, rendering the phosphorus ion unavailable to the water The phosphorus in soil is both inorganic and organic forms. The inorganic phosphorus in the soil can be classified in to 4 groups (1) Calcium phosphate (2) Aluminium phosphate (3) Iron phosphate (4) reductant soluble phosphate. Calcium phosphate remains as apatite but dicalcium, monocalcium and octacalcium phosphate also exist in small amounts or as transitional form.

The organic form of phosphorus compound in the soil occur in 3 groups (1) Phytin and Phytin derivatives (2) Nucleic acids (3) Phospholipids. The organic form constitutes about 35-40% of the total phosphorus content of the soil.

However, the available soil phosphorus (P_2O_5) below 3mg/lOOgm (3oppm) as poor productivity, 3-6 mg/100gm (30-60 ppm) as average, above 6-12 mg./l00 gm (60-120 ppm) as high productivity and above l2mg/l00 gm (120 ppm) as excess are indicated.

14.7.3 Nitrogen

Nitrogen in soil is present mostly in organic forms as aminoacids, peptides and easily decomposable proteins where as the inorganic forms NH_4+ and NO_3 are utilized by green plants. The conversion of complex organic forms of nitrogen to simple inorganic forms are carried out the bottom mud by anaerobic microorganisms. Hence it is important to know the available nitrogen than the total nitrogen in soil. The range of available nitrogen 50-75 mg/100 gms of sol is relatively more favourable for pond productivity. Loss of nitrogen also occurs, in ponds through volatization of ammonia. The cause of volatisation of NH_3 are high pH and high temperature in pond environment.

Besides organic form of nitrogen transformation in to inorganic nitrogen and loss of nitrogen in pond environment, some microorganisms, blue green algae, aerobic and anaerobic heterotrophic bacteria present in the soil and water fix atmospheric nitrogen in to organic nitrogen. The process of mineralization helps in the release of fixed nitrogen in available forms.

14.7.4 Organic carbon and C/N ratio

Compared to the mineral constituents of the soil, organic compounds are more varied and complex. Microbiologists belive that the bacterial activity depends not only on the carbon content but also on the ratio of C/N in the parent substance. Bacterial activity is low when the ratio falls below 10:1 and good when 20:1 or higher. The importance of carbohydrates and C/N ratio in Nitrogen fixation has been indicated by Ncess (1949). Studies indicate that very high organic content is also not desirable for a pond soil. However, organic carbon less than 0.5% as average while 1.5 - 2.5% appeared to be optimal for good production.

14.7.5. Calcium

Calcium is generally present in the soil as carbonate. The deposition of $CaCo_3$ in freshwater are referred as marl. The amount of exchangeable phosphorus in pond mud is inversely related to the marl organic matter. It was however, noted that no marked influence of exchangeable calcium upon productivity could be noticed.

14.8. SOIL ORGANISM

Depending upon the size, the vast majority of organisms, found in soil are classified into four major groups, namely microflora, microfauna and macrofauna (Fig. 14.3). The meso and macroflora, no doubt, rooted in the soil, occur above the surface of soil and, therefore, are not included in the discussion.

14.8.1. Microflora

The microflora of soil comprises of bacteria, blue green algae, soil fungi and actinomycetes fungi.

14.8.2. Microfauna

It includes animals with body size within the range of 20m - 200m. These include protozoans, mites, nematodes, rotifers, tardigrades, etc.

(i) **Protozoans** - Most common protozoans inhabiting the soil are the flagellates, amoebae and ciliates occuring near the surface soils, while the forms like Euglypha, Difflugia and Thecamoeba have vertical distribution.

(ii) **Nematodes** - There are the most abundant and widespread soil organisms comprising 80 - 90% of all multicellular animals. These abound by as much as 20 million per square metre in grassland to 30 million per square metre in raw humus soils. The well known examples of plant parasitic nematodes are 'root know' or 'gall forming' nematodes like Meloidogyne and cyst nematodes like Heterodera. Monochus is a predatory nematode which occurs in almost all soils preying upon other nematodes and microorganisms.

14.8.3. Mesofauna

This group includes micro-arthorpods and insect larvae. These organisms poay a great role in makntaing the soil fertility. T his size varies frim 2000m to 1 cm.

i) Collembola- collembolans are springtails froming one of the predominant group of soil mesofauna, Common soil collembolans are Isotomids, Onchiurids, Entomobryids and Podurids, some of them are phytophagus and are serious crop pests, e.g. Sminthurus viridis (pest of of clover and some grasses), Bourlbrtiella hortensis (peas, beet and potatoes). Collembolans mostly feed on fungi, bacteria and nematodes.

The isopterans (termites) like Reticulotermes and Odontotermes are important soil - dwellers and play an important role in the break up of organic material and their mixing up wht mineral soils.

ii) Acarina (mites)- They also from a important group of soil organisms. Mites belonging to Cryptostigmata are herbivorous and feed on rotting plant tissues, fungi algae and lichens. These are most aboundant in forest litter and grass meadows. Since Acarina include predatory forms feeding on collembolans, pauropods, nematodes, etc. fungi and vorous and bark feeding forms, they are importannt sñil mesofàuna. They greatly influence on soil texture, organic matter content, vegetation, microclimate, water and other soil flora and fauna.

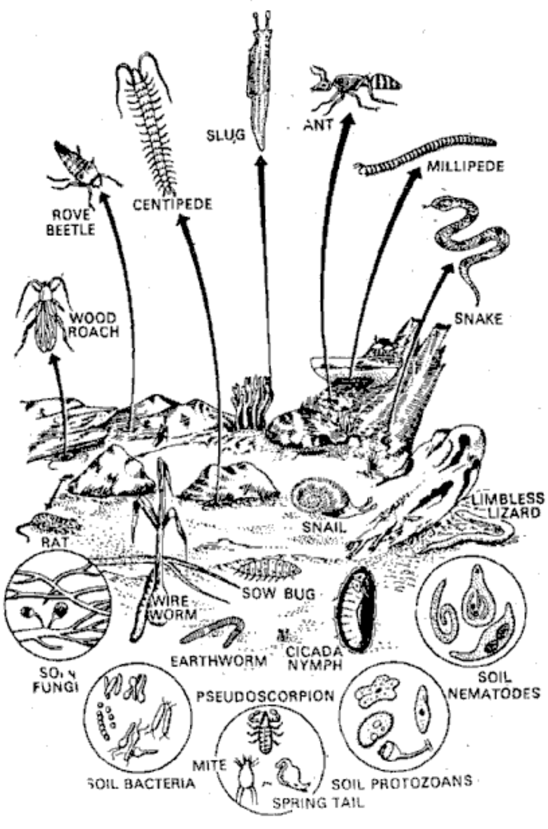


Fig. 14.3 Soil Organisms

14.8.4.Macrofauna

It includes those animals whose body size isgreater than lem. It includes earthworms, centipees, millipedes, pseudoscorpions, wood lice and insects belonging to different orders such as Psocoptera, Embioptera, Zoraptera, Hemiptera and grasshoppers.

The burrowing annelids include Lumbricus, Glycera and Arenicola. Certain ants and insects larvae are also quite common. Termites also form an important group. Among vertebrates adapted for burrowing life are Ichthyophis, Cacopus, Sytema, Breviceps (Amphiba), Sphenodon, Uromostix, limbless lizards and snakes (Reptiles), Talpa, Dasyurus, Notroryctes and among mammals, the insectivores and rodents.

SUMMARY

Soils defined as any part of earh's crust in which plants root. Muddy bottom of ponds, porous rock surfaces, ravines orgiacial-deposits, bottoms of lakes, peats etc., all are soils. The soil has five categories of components, mineral matter, soil organic matter or humus, soil water or soil solution, soil atmosphere and biological system of soil. Soil is formed by interaction of several mechanical forces such as oxidation, carbonation, hydration, solution, temperative effects and the effects of bacteria, fungi and other animals on rocks. The soils are six major types, alluvial soil, black cotton, red, laterite, mountain and desert soils. Soils also consists of both abiotic and biotic factors.

QUESTIONS

1) Write an essay on soil ?

2) Describe the various types of soils?

15

BIOGEOCHEMICAL CYCLES

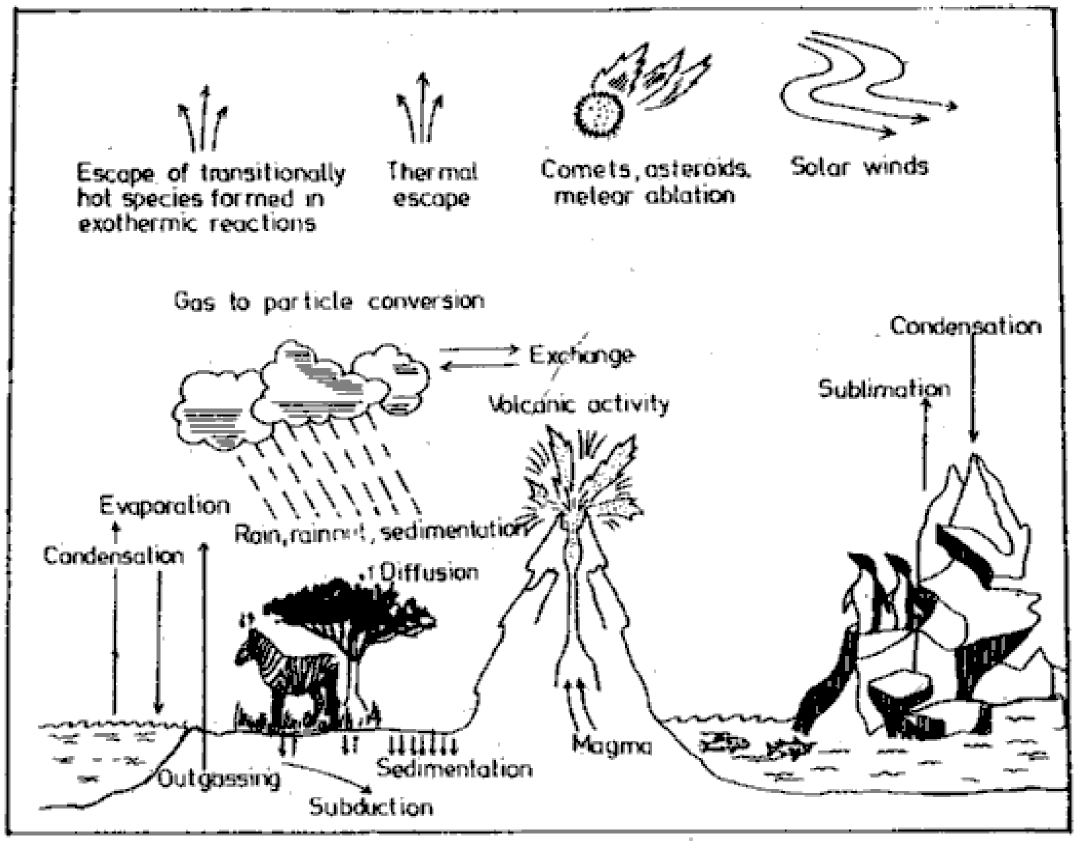
Living organisms in the biosphere requrie about 30-40 chemical elements or nutrients for their normal growth and development. They are distributed in various compartments of the earth. All these chemicals are tend to circulate in the biospherep in ‘characeristic circular pathst from non-living environment to living organisms and back to the environment. These circular paths are known as “inorganic cycles” or “bio-geo chemical cycles. The-cycling of these biogenic salts are quite essential fbr the working of any eco-system.

The term biogeochemical cycle is derived, because the cycling of elements involves biological organisms (bios), geoligical or environment reservoir (geo), and the chemical changes that occurs during the cycling processes. These elements circulate through air, land masses, the sea and living organisms along with an intricate pathways using the water cycle, geological cycleand ecological cycles of the opposing processes of photosynthesis and respiration.

All biogeochemical cycles involves organisms without life, biogeochemical cyles would cease, while without the biogeochemical cycles, life would not exists. So these cycles utilize the system organization of the biosphere for the cycling of mineral nutrients.

A bio-geochemical cycle may be defined as “the more or less circular paths, which brings about the circulation of chemical elements, including all essential elements of protoplasm, from environment to organisms and back to the environment. (Fig. 15.1)

Fig. 15.1. Representation of the cyclic processes of biogeochemistry that exchange constituents between air, land and sea.



According to the law of conservation of mass, matter is neither created nor destroyed. The earth neither receives any matter from other parts of universe nor it looses any amount of matter to outer space. The atoms of all essential elements are taken from the environment, used in the building of the cellular system of the organisms in a circular rate involving several other organisms and are returned back to the envirenment to be used again.

In the circulation of these essential elements, each cycle has consists of 2 compartments or pools. They are:

a) Reservoir pool: Large, slow moving, generally non-biological compartment, consists of the nutrients in a utilizable or non-utilizable form.

b) Exchange pool: Smaller, but more active, which under goes a rapid exchange of materials between organisms and to their immediate environment.

15.1. CHARACTERISTIC FEATURES OF THE BIOGEOCHEMICAL CYCLE

All biogeochemical cycles possessing certain characteristic features. They are

i) Presence of a geological, reservoir (Atmosphere, Hydrosphere or Lithosphere)

ii) Involvement of biota both in the cycling process and in the release of elements from the organic to inorganic world.

iii) Movement of the elements from the environment to the biota and back.

iv) Chemical changes occur in the process. and

v) The cycling linked with natural, physical processes (wind, water currents, erosion, sedimentation).

15.2. BASIC TYPES OF BIOGEOCHEMICAL CYCLES

Biogeochemical cycles broadly divided into two basic types.

a) **Gaseous Nutrient cycle**: In this the atmosphere acts as a major reservoir, where the nutrients accumulate. During the cyclic process, a little (or) no loss of the nutrients will be taking place. It consists of gaseous nutrients such as carbon, nitrogen and oxygen. There cycles can be considered as 'perfect' in the global sense, because of natural, negative feed back control.

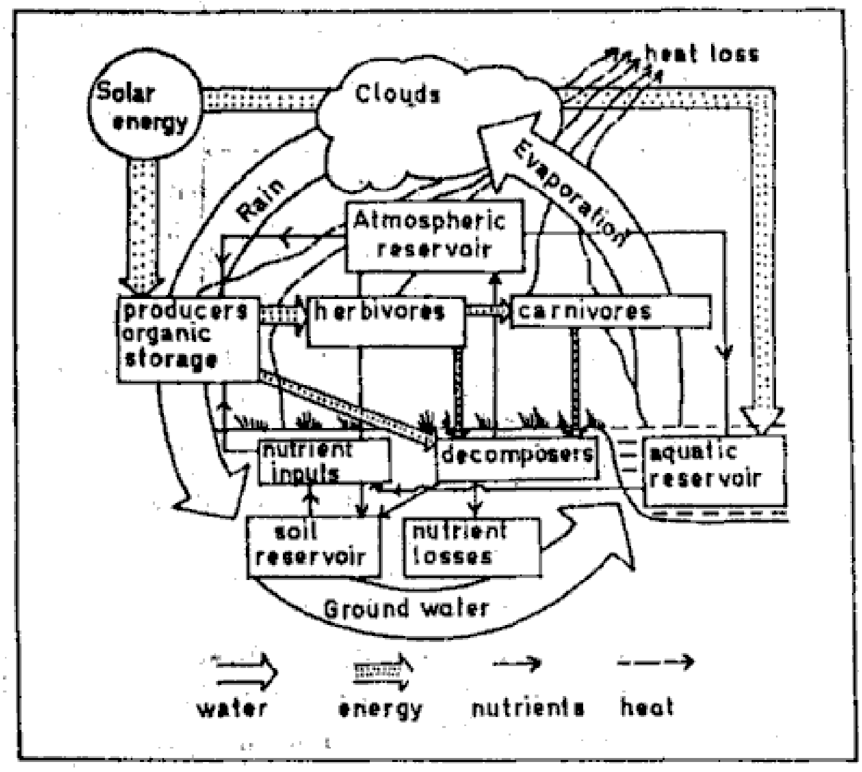


Fig. 15.2 The biogeochemical cycle of nutrient from the reservirs to the biota occurs via the water, while within the biotic system it moves through the food chain.

b) **Sedimentary nutrient cycle:** In this cycles, the sedimentary rock (or) Lithosphere is acting as major reservoir. The cycle is slower and tend to exert a more limiting impact. It comprises of the sulplur and the phosphorous cycles. The circulation will be taken place through the agents like erosion, sedimentation, volcanic activity and biological transport.

The above two cycles are more (or) less dependent upon the 'hydrological cycle' for efficient transport of matter through the biotic and abiotic compartments of the ecosystem. (Fig. 15.2)

As the water cycle plays a significant role in all biogeochemical cycles, the dissolved nutrients are carried from the earth's surface either into the soil (or) in to the oceans. Atmospheric nutrients are often brought to the earth surface by rain water. Nutrients held in rocks are gradually released by weathering, erosion through flowing water, and by freezing and defrosting of Ice. Nutrients are dissolved in water when they are absorbed into the roots of plants. Water is critical in accomplishing various chemical changes that nutrients experience as they pass through the bio and geo phases of the cycle.

15.3. WATER/HYDROLOGICAL CYCLE:

Water as a resource is present in extremely small quantities, when compared to that of the earth. Water covers 71% of the surface of the planet. The water is present, 97.5% in the form of ocean waters and the rest is as land ice, lakes, soil moisture, rivers, ground water and as the water content of the atmosphere. A large part of this water is locked up in the form of land Ice.

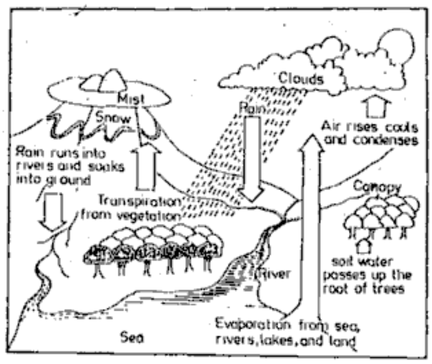


Fig. 15.3 Water cycle

The water in the atmosphere is limited, but it is very mobile and circulates continuously from air to land and sea and back to the atmosphere. This circulation is generally known as 'hydrological (or) water cycle'. (Fig. 15.3).

The water cycle is controlled by three main confounding factors like temperature, precipitation and evaporation. The energy that drives the cycle is obtained from the solar radiations, which intern brings evaporation of water. When the relative humidity in the atmosphere increases to saturation levels, precipitation takes place, there by the cycle tend to continues.

15.3.1, WATER CYCLE OR THE HYDROLOGICAL CASCADE SYSTEM

The water cycle can be defined by reserviors and transport pathways.

15.3.1.1. Reservoir or pool

a) Ocean Subsystem: About 97.5 per cent of the combined total liquid water, ice and vapour consists at present of ocean water. There is sonic exchange between ocean water There is some exchange between ocean water and sea ice, and some leakage into the oceans as ground water. Output occurs through evaporation and input through runoff and precipitation.

b) Ground Water system: Ground water is contained in rocks and forms the water table. It has about one-fifth of the water not contained in oceans. The amount increases with rainfall and decreases with drought.

c) Lake Subsystem: The lake subsystem contains about 0.1 per cent of the water not contained in oceans. These lakes may be with or without outlets. Closed lake standing at a given level illustrate an equilibrium situation. If they dry up, they are acting step-fhnctionally, that is, the system is in disequilibrium.

d) Soil Moisture: Soil moisture includes water passing down to the ground water table, and water taken into the substance of the soil. It amounts to about 0.44 per cent of the water not contained in oceans. It is liable to withdrawal by evaporation and by transpiration from plants. Mean residence time is about a month.

e) Rivers: Storage in rivers involves only about 0.005 per cent of the water not contained in the oceans. Residence time is in days at most. Leakage from ground water is necessary for sustaining perennial flow.

f) Atmosphere: The atmosphere contains as much water as much water as rivers. Mean residence time is about 10 days.

g) Biological Water: Biological water amounts to an extremely small total and the residence time varies from minutes to a lifrtime.

Thus water as a resoure of the earth-atmospheric system is limited. Most of it is locked in the form of water in the deep sea, ocean ice, and land ice, while the small amounts that are present in a utiliazable form have to be recycle so that the ecosystems can function properly.

15.3.1.2. Cyclic water

The water involved in the recycling process at any given time is called cyclic water. Precipitation on ocean surfaces amounts to 78 per cent of the cyclic water. The output of water from ocean and land surfaces is matched by inputs from land to ocean as mn-off Over the land surface, there is an exchange of water between the air and the ground. Evaporation delivers moisture to the air, but is compensated by precipitation back to the ground. About two-thirds of the precipitation over land originates by evaporation from the land surthce, the other one-third coming from the oceans.

15.3.2. LOCAL CYCLING

In local cycling evapotranspiration occurs from water and land surfaces, as well as from plants. The return from the atmosphere occurs through precipitation.

Rain under most conditions does not fall directly upon the ground but is affected by branches and foliage of plants. This is termed as interception. Precipation caught on vegetation can follow three possible routes. First, it can drip off the plant leaves to reach the ground beneath and so join the surface and soil water movement. This is known as throughflow. In the case of rain intercepted by trees, further interception can occur at lower levels, which is termed as secondary interception. Secondly, the rain may run along the leaves and branches and finally reach the ground by running down the major stems of the plants. This process is known as the stem flow.

15.4. CARBON CYCLE

Carbon is a basic component of all organic compounds, the building material of which all living things are constructed. Carbon is present in a variety of carbohydrates, fats, proteins and nucleic acids. The carbon cycle is essentially a perfect cycle in the sense that the carbon is returned to the environment about as fast as it is removed. It is an example of gaseous cycie as it involves a gaseous phase - the atmospheric carbon dioxide, The basic movement of carbon is from the atmospheric reservoir to producers, to consumers and from both these groups to decomposers, and then back to the reservoir i.e., the atmosphere. In atmosphere the concentration of carbon dioxide ' is about 0.03-0.04 percent. The main source of all carbon found in the living organisms is free atmospheric carbon dioxide and dissolved carbon dioxide in water. (Fig. 15.4).

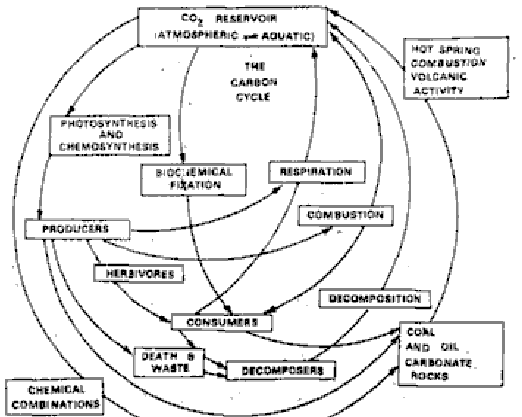


Fig. 15.4 Carbon cycle

The first step in the utilization of CO_2 by living organisms is photosynthesis by green plants. In photosynthesis, plants synthesize simple carbohydrate, which in turn are converted into polysaccharides and complex fats in plants. The polysaccharides and fats stored in plant tissues are eaten by animals, who digest and resynthesize these carbon compounds into others. Meat eating animals (carnivores) feed upon the herbivores and carbon compounds are again redigested and resythesized into other forms.

The respiratory activity of producers and consumers accounts for return of considerable amount of the biologically fixetcarbon as gaseous CO_2 to the atmosphere. The carbon locked up in the animal wastes and in the protoplasm of the plants and animals is released by the activities of the bacteria and fungi when the former die.

Part of the organic carbon becomes incorporated in the earth's crust as coal, gas, petroleum, limestone, etc. The carbon present in such deposits is removed from the circulation for long periods of time. Some of the carbon dioxide from such deposits is liberated by our agrcultural and industrial use of these products. Some of the CO_2 is released from limestone by weathering.

Thus we find the carbon cycle is relatively a complicated one. Actually there are a number of inlets and outlets by which carbon can enter or leave the cycle. Collectively these various pathways constitute self-regulating feed-back mechanisms resulting in a relatively homeostatic system.

15.5. NITROGEN CYCLE

Nitrogen is an essential element in the living substances like proteins and nucleic acids. Though the atmospheric air contains 79 percent nitrogen, yet most of the plants and animals cannot make use of this gaseous nitrogen. Animals must have their nitrogen in-the form of amino acids and plants in the form of soluble nitrogen salts like nitrates. From the nitrogen of soluble salts, plants manufacture their proteins and amino acids.

Essentially, the nitrogen cycle (Fig. 15.5) involves about five main steps. First, when any organism dies, or any leaf or tree falls, or when an animal excretes its waste products, the nitrogen compounds pass into the soil or into the water. Second, certain bacteria begin to break down these organic nitrogen compounds. In this process, organic nitrogen is converted into ammonia. Even in this form the nitrogen is of little use to the plants. In the third step, the ammonia is converted into soluble ammonium compounds. The ammonium compound ionize giving ammonium ions (NH_4^+) as well as some ions with negative charge (NO^-_2). Recent researches have demonstrated that many higher plants are able to absorb and utilize ammonium ions as the major source of nitrogen. The fourth step, is carried out in the soil by nitrifying

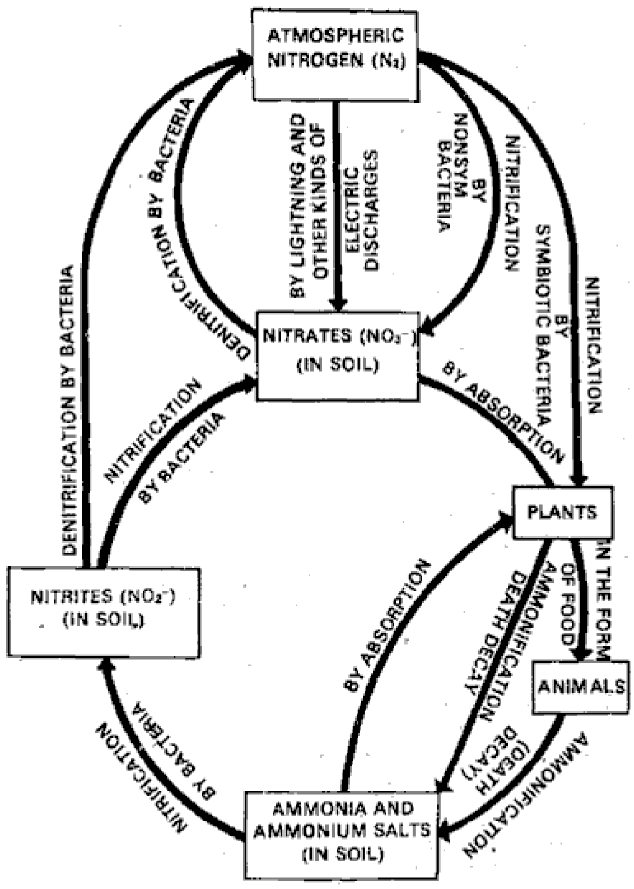


Fig. 15.5 Nitrogen cycle

bacteria. Some of these, like Nitrosomonas, convert ammonia into nitrite, whereas others, like Nitrobactor, act on nitrites and convert them into nitrates. These nitrifying bacteria are all chemosynthetic autotrophs. In the fifth step the highly soluble nitrates dissolved in soil water are taken up by the roots of the plants.

Another way in which nitrogen is made available to the plants for protein synthesis is by nitrogen fixation. All photosynthetic, chemosynthetic, and heterotrophic micro-organisms play a role in nitrogen fixation. Nitrogen fixing bacteria, such as Rhodospirillum, live freely in the soil.Other nitrogen fixing bacteria, like Rhizobium, grow in the roots of plants called legumes. These are symbiotic bacteria, which take carbohydrates and oxygen needed by them from the plant roots and fix nitrogen into nitrates for the use of plants.

The process of nitrification in the open ocean and its sediments is very poorly understood at present. Some blue green algae, such as Anabaena and Nostoc, are reported to play a significant role in the fixation of nitrogen in the aquatic medium,

Other blue-green algae which can fix nitrogen include Gleotrichia, Enchinulata, Trichodesmium, Nostoc, etc. to name a few.

Some nitrogen is also returned to the atmosphere by denitrification to gaseous nitrogen. However, most of denitrifying organisms reduce nitrate to nitrite, and still others to ammonia, Denitrification to molecular nitrogen occurs under anaerobic or partially anaerobic conditions.

There are yet other aspects of the cycling of nitrogen which could be assessed, among others, the role of volcanic action or sedimentation. Thus we find, the movement of nitrogen is by no means unidirectional, unregulated, nor energy-independent. There are various routes available, each route is biologically and/or non-biologically regulated and energy is released or consumed in each process these numerous self regulating, energy dependent, feed back mechanisms result in a steady state of nitrogen balance.

15.6. OXYGEN CYCLE

Oxygen is the life supporting portion of the earth's atmosphere. Our atmospheric air contains about 21 percent oxygen. It is also present dissolved in water. Oxygen is given out as a byproduct of photo-synthesis. Plants and animals utilize oxygen in respiration and return it to the atmosphere and water in the form of carbon dioxide. The carbon dioxide is utilized by green plants as an essential raw material for carbohydrate synthesis. In such a simple yet cycle, oxygen is replenished and maintained in the ecosystem.(Fig. 15.6).

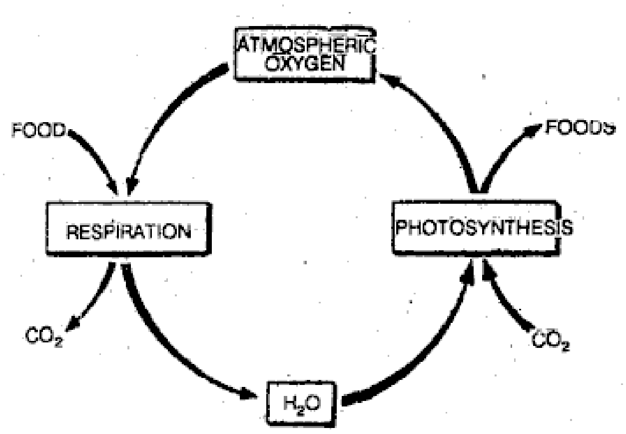


Fig. 15.6 Oxygen Cycle

15.6.1. RESERVOIR

The main reservoir of oxygen is the atmosphere, which contains about 21 per cent of volume. This is equivalent to about 1.2 x 1018 kg of oxygen. Since this oxygen has been provided by green plants through photosynthesis, and because carbon dioxide transfers between the atmosphere and the biosphere correspond stoichiometrically to oxygen transfers in the opposite direction, the oxygen present in the atmosphere represents the carbonaceous material present in the sediments as graphite, coal, oil, gas and other carbonaceous compounds which have not been oxidized through respiration. The other two non-living sources of oxygen are water, and carbon dioxide. In fact, a large amount of it the locked up as sulphates, carbonates, organic matter, and ferric ions. However, these represent non-utilizable forms.

15.6.2. TRANSFER PATHWAYS

15.6.2.1. Withdrawal of oxygen

a) Respiration: The main withdrawal of oxygen from the atmosphere by the biota is through the process of respiration. It is used for the biological oxidation of organic molecules such as carbohydrates for the release of energy. Since free oxygen is potentially destructive to all forms of carbon- based life, the early organisms were all anaerobc, obtaining energy through the process of fermentation. In the anaerobic process, organic molecules erve as hydrogen acceptors, so that in the oxidation of some organic compounds, simultaneous reduction of some organic compounds, simultaneous reduction of others occur. However, the energy released is very low, about 50 kilocalories per mole.

   It has been estimated that the total oxygen requirement of the biosphere for respiration is about 246 billion tons annually.

b) Decay: A large amount of oxygen is also used up for the decay and decomposition of organic compounds by various decay bacteria such as the nitrogen, sulphur, and phosphate bacteria. This accounts for about 150 billion tons annually.

c) Oxidation of rocks: A varied amount of oxygen is consumed in the oxidation of rocks.
   Weathering rates of elemental carbon to carbon dioxide, suiphide rocks to sulphate, and iron (II) rocks to iron (III) roughly match the leak rate. Oxidation of reduced volcanic gases (H2 or CO) is a smaller but not negligible additional process.

d) Ozone formation: A part of the oxygen is used up for the formation of ozone, but-the rates formation and break down are not available.

15.6.2.2. Return pathway

The main return pathway is the photosynthetic process occurring in plants and microorganisms. From the point of view of generation of organic material, the overall photosyntheric process consists of the formation of carbohydrates by the reduction of carbon dioxide, and oxygen is a by-product.

This molecular oxygen is derived from the splitting (photolysis) of the water molecule. It has been estimated that all the earth's water is split (during photosynthesis) by plant cells and reconstituted (during respiration) by animal and plant cells every two million years.

Since photosynthesis and respiration occur simultaneously it would appear that all the oxygen released through photosynthesis is consumed during respiration and decay. However, a part of it is not consumed due to organic sediment deposition. This process buries carbon without decay and contributes to the formation of fossil fuels in time. It has been estimated that this leak through deposition marine sediments is about 0.32×10^9 tons. The overall photosyntheric process releases about 400 x 100 tons of oxygen annually into the atmosphere.

SUMMARY

Biogeochemical cycling is the movement of materials from global bioshpere through biochemical reactions including exchange of elements between the biotic and abiotic portions of the biosphere. The cycling system involves well-defined reservoirs, exchange pools and transport pathways, driven by various chemical and physical processes. The flux rates provide data for calculating time-residence 'equations defining local as well as global dynamics.

There are two main types of biogeochemical cycles, gaseous in which the atmosphere is the major reservoir, and sedimentary in which the lithosphere serves as the reservoir. These are closely tied to the water cycle. Each cycle may gain be divided into a large slow-moving geologic or global cycle that results into global change, and a relatively faster local cycle. The prime force in the movement of these cycles are the solar radiation which moves the water cycle through evaporation and precipitation processes, and the biotic cycle via the food chain.

The water cycle is driven by heat received from the solar radiations, and regulated by evaporation and precipitation. Water vapour passes to the atmosphere through evapotranspiration from the land, and evaporation from the ocean. Precipitation balances the output and maintains the soil moisture, as well as the water level of streams, rivers, lakes and the ground water. The cycle may be differentiated into global and local cycles. The water cycle drives the biogeochemical cycles of elements and nutrients, controls the climatic features of the earth, and modulates the salinity and hydrodynamics of the oceans.

The reservoir ofoxygen is the atmosphere which contains about 21 per cent of oxygen by volume. Withdrawal of the gas from this reservoir occurs through respiration, decay, oxidation ofrocks, and ozone formation. The main return pathway is photosynthesis. The oxygen thus produced comes from the photolytic splitting of water.

The carbon cycle is the simplest and the most perfect gaseous cycle since carbon is returned as fast as it is withdrawn. It moves from the producers, to consumers, and then to decomposers which return it to the reservoir. The main reservoir of the carbon is the atmosphere. Withdrawal occurs through photosynthesis, calcium carbonate precipitation and deposition ofinarine organic sediments. Return of carbon dioxide to the reservoir is brought out by respiration, decay of organic matter etc.

Nitrogen cycle is a typical gaseous cycle. The major reserve of nitrogen is the atmosphere. It is an essential element for the biosphere, because it is necessary in the formation of nucleic aacids, aminnoacids and proteins. Since dinitrogen cannot be used directly, various microorganisms convert it in a step-wise manner, into utilizable forms. These are taken up by plants and channelled through the food chain. The return of dinitrogen to the atmosphere from dead material and wastes is also controlled by microorganisms.

QUESTIONS

1) Define biogeochemical cycle? Explain the role of water in regulating the other cycles?
2) Describe the nitrogen cycle?
3) Give an account on carbon cycle?

16

POPULATION DYNAMICS

Population ecology is a specialized branch of ecology dealing with the numerical impact of various interaction (both biotic and abiotic) on a specific set of individuals. Population is defined as "a collective group of organisms of the some species occupies a certain area at a specific time". The word population is derived from a latin word "Populus", which means a group of people in a place.

Demography is the study of the population changes and their course throughout the life cycle. 4 demographic parameters are determine the total numbers in a population change at a particular time. They are the Birth (B), Death (D), Immigration (I) and Emmigration (E). If a population increases in size, this may be due to either birth of new individual (or) due to immigration of individuals from adjoining areas. If the population declines, then the reason in simply either death and emigration. These four demographic parameters occurs simultaneously and can be represented in an algebric equation, where the change in a population between two points in time, then

$$N_{t+1} = N_t + B - D + I - E.$$

Whereas N_{t+1} - Population size at time (t + 1)

N_t - Population size at time t

B - No.of individuals born between time to and t + I

D - No.of individuals died between time t and t + 1

I & E - No.of immigrants and emigrants.

16.1. POPULATION CHARATERISTICS

Population is termed as the naturally occurring stock (a group of individuals) of races or of a certain race of fish which occupies a certain area of space, which behaves as an 'biological units.' Population density is the population size per unit of space. This density is also called as 'abundance'.

When expressed interms of number of individuals in the stock or weight of the stock per unit of an ecosystem. To an fishery management, comprehensive knowledge of abundance in a population of a given species is essential for the success of fishery of that species of fish. A variety of technique are generally used to obtain the estimates of 'population abundance, which serves the basis for the study of population dynamics. There are

16.1.1. NETREPRODUCTIVE RATE (Ro)

Net reproductive rate (Ro) is an useful indicator in the success of a population's life history pattern, This can be defined as "the rate of multiplication per generation of the population (or) equivalently, as the average number of daughters produced per female born in a population".

16.1.2. POPULATION PRODUCTION:

Production is a measure of the total amount of tissue synthesized by a population over a defined time intervals. It gives an information on the rate at which fish flesh is becoming available to exploiters of that population. It can be defined as,

$$P = g\,B$$

whereas g- specific growth rate

B - mean biomass of the population for the time interval over which production is estimated,

The biomass (B) of a population at a given time is calculated as

$$B = N.\ W$$

whereas N - abundance of the population

W - mean weight of an individual in a population at that time.

16.1.3. DENSITY DEPENDENCE

The pattern of changes in abundance and production by a population will partially reflects up on the mortality rate, fecundity and growth of its own densities.

16.1.3.1. Density dependent recruitment

The abundance of the adult stock in a population affects recruitment to the population. If adult density is low, the recruitment will below, if it is high, the recruitment will also be high Reproduction tends to increase the abundance in a population from one generation to other. In fishery, the abundance of a population received a great importancy. This is due to 2 reasons. First, the catch depends upon fishing efforts and also on the abundance of population at a given time. Secondly the fishing, which has an effect on the population.

16.1.3.2. Density dependent growth

The more the density of a population, slower is the rate of growth. At low density the growth is faster, over population often leads to stunted individuals.Individual growth of a fish is linked with the *growth* of the entire population, which represents a change in numbers with time. Individual growth in an population forms the basis for the population dynamics. Growth patterns, along with fecundity, rate of survival and rate of modality, influence on the population dynamics.

16.1.3.3. Density dependent mortality

In case of young fish or eggs natural mortality is found to be linearly related to numbers. However the density will not have any effect as natural mortality.

16.2. POPULATION STRUCTURE: YEAR-CLASSES

A population has a definite structure with respect to its species composition andlor age-composition of its individuals. Separate populations are indicated by differences in rate of growth during the life span of fish or during a particular part of it such as early stages, and by differences in the years of periodic abundance and scarcity. At any given moment, a population is characterized by species dominance, age dominance and year-class dominance. A *year-class* denotes the fish stock of a particular species at any given time belonging to the spawning of a particular species at any given time belonging to the spawning of a particular year. The number of eggs produced year after year may remain the same. In certain years the rate of survival is high and the abundance is substantial. The fishery of a population depends for its success on its year-class dominance, it will be good in the dominant year- class, it will decline with subsequent weak year-classes, and will be good again with a new dominant year-class. If a substantial portion of fish stock belonging to any one particular year-class (say 2-year class) is removed by fishing, recruitment in the population may be delayed by one or several years due catches in subsequent years. Whereas fecundity (number of eggs) does not influence seriously on year-class abundance, but the spawning stock does influence by its fluctuation from year to year. Also, the favorable conditions or the adverse conditions met by developing stages largely influence the density of the year-class. Wider distribution of these stages, meaning lesser competition, has a similar effect. Extended spawning and hatching periods help in wider distribution. The makeup of population of a certain species by the age-groups gives a clue to different racial stocks present therein. The racial stocks within a population have different morphometric characters, such as the length of head, of the snout, the interorbital width, the distances from the tip of the snout to the jnsertions of the various fins. Comparison between these morphometric measurements also gives clue to the racial stocks within a population.

16.3. DYNAMICS OF FISH POPULATION

Generally the size of the total stock of a race, species, (or) group of species vary from year to year and from one region of the world to the other. These fluctuations in abundance are caused by natural factors and also by mans activity. In general, the population dynamics are considered to the biological characteristics of a given species and its adaptations.

16.3.1. NATALITY VS MORTALITY

For instance, if natality is equal to the mortality, the stock abundancy will be constant, if it is more, the population increases in size and if it is less, the size of the population declines. Such a cases, the expanding population dominated by young ones, whereas the *regressing* one with aged adults.

16.3.2. STOCK- RECRUITMENT RELATIONSHIP

The young fish is considered to be the recruit stage of fishery and it can be actual contributor in increase the adult population size. Several studies reveals that, a population remains stationary, under a particular stock - recruitment relationship. However in working out this relationship, prerecruit stages (from egg to recruit) should also be taken into consideration. For the addition of the recruits, the stock intern depends upon the survivals of the pre recruit stages. This leads to a success of an year - class (the annual recruitments) or success of an separate year class which greatly influences on the dynamics of the stock, specially on its age composition.

A number of factors affects on the survival of a year - class strength from egg to recruit stage. Among all, *(emperature* and *food* are important factors. The survival of an year - class strength is also related to the population fecundity, which determines the reproductive capacity of the species. The population fecundity is generally expressed as the specific fecundity of a species.

16.4. POPULATION DYNAMICS AND FISHERY CATCHES:

To fishery biologist more important aspect is to know whether a population is chaning, increasing or regressing. The indices of relative abundance are more useful than actual abundance. These inidices are time Population Dynamics and Ecological Succession relatives, for example the number of fishes caught per day, or the percentage of sample plots occupied by a species of fish. Catch per unit effort reflects best the fluctuations. Fluctuations in catches are often serious obstacles influencing the fishing industry at all levels. The worst is when the factors are *unstable* hydrographic conditions-something beyond one's control.

From fishery considerations, three types of fluctuations in catches are recognized. They are *irregular, short range* and *long range.* The *irregular fluctuation* is one which occurs from years to year. It is caused by the effect of weather upon the fishing activity. The *short range fluctuation* occurs over a period of a few years, rising for 2 or 3. years and then declining for a similar period. This type arises due to a shift in the age composition or a variation in the size of the individual year classes influencing the catch. Other factors include indiscriminate catches (with regard to year class). Distribution and feeding conditions available for the younger stages (eggs. fry etc), presence of fish enemies, competitors for *food,* outbreak of epidemic diseases and parasitic infection among fish or its food organisms. *Long range fluctuations* occur over long periods of several years showing changes from good to poor catches. Climate changes are thought to be the chief reasons. Strong year-classes appeared of such species as were heat-loving. The reverse of this happended for the cold-loving species.

Cyclic fluctuations seen in some fisheries, like the fishery of the Indian sardines and that of the North sea herrings, are found to be directly influenced by the cyclic fluctuations in the availability of particular food organism such as the diatoms and copepods, respectively.

16 .4.1.INDICATORS OF FLUCTUATING POPULATIONS

Various criteria, such a changes in age composition in the catches, shifts in areas of fishing, changes in catches etc, may indicate nature and extent of fluctuation in abundance. The following act as good indicators:

a) Sustained decrease in age and size of the individuals indicate that the population is regressing.

b) Sustained stunting of the individuals is a sign of expanding population.

c) Sustained changes in the species composition of the catches is regarded as indication of fluctuating populations. The relative numbers of the different species in the catches, by the change in proportion, would indicate which population is regressing.

d) Sustained decline in the catch per unit effort is a reliable indication of regressing population.

e) The necessity to shift the fishing grounds, in view of the falling numbers in catches, is an indicator of the declining abundance in the pojiulation

f) For schooling pelagic species, contraction of the area in which the

g) For schooling pelagic species, contraction of the area in which the buoyant eggs and larvae are collected. i.e., shrinkage of the spawing areas is an indication of the declining adult abundance.

16.4.2. FLUCTUATIONS IN THE CATCHES

Serious economic handicaps are felt I the fishing industry owing to large fluctuations in the catches particularly in the event of severe decline in the catch from the previous year(s). these fluctuations may arise from very different and unrelated factors operating. Three main kinds of these are generally accepted. The first is the fluctuation in the size of the population, as discussed above. The second one is the variation in the availability of fish to the fishing efforts on account of the movement of the fish showing changes at various times of the day *or* night, or during different seasons of a year or under the influence of the migratory urge. If the direction or the path of migration undergoes deviation, catches decline considerably, unless this was detected by modem devices like use of echosounders aeroplaces or electronic transmitters for following the route of migration. The third factor is the difference in the intensity of fishing.

SUMMARY

Population ecology is the specialised branch of ecology. Demography is the study of the population change and their course throughout the life cycle. The four demographic parameters like birth, death, immigration and emmigration determines the change in number of total population at a particular time. Each population is having its own characteristics features. For fishery point of view, the abundance of fish population of a given species is important and the population dynamics serves the basis of the abundance. Various techniques assessing the net productivity rate and population production are employed to study the abundance of population. The population production is inturn dependent on density, growth, mortality, recruitment etc.

QUESTIONS:

1. Define the population and add a note on. the characteristics features of a population ?
2. Critically comment on the influence of various factors governing on the production of a fish population?
3. Write short notes on a) stock recruitment relationship b) fish catchpopulation dynamics.

17

AQUATIC POLLUTION

Environment pollution is a global problem and is common to both developed as well as developing countries. Environmental pollution is the result of urban - industrial technological revolution and speedy exploitation of every bit of natural resources. The ôraze of progress in agriculture, industry, transportation and technology is taken as the general criterion of development of any nation. Such activities of man has created an adverse effects on the survival of man himself and other living organisms in the 'biosphere'. Thus pollution is generally defined as "the addition of the constituents to water, air or land, which adversely alter the natural quality of the environment".

17.1. DEFINITION

The word 'Pollution' derived from the latin word 'Pollutionem' (meaning to defile or make dirty). The term pollution is defined in various ways, like

Pollution means the addition of any foreign material such as inorganic, organic, biological or radiological or any physical change occurring in nature which may harm or affect living organisms directly (or) indirectly, immediately (or) after a longtime.

17.2. POLLUTANT

In general, pollutants are residues of substances made by us, used by us and even thrown away by us as a waste products, which pollute the environment in one way or the other. The pollutants can be classified in a number of ways. Either they may be classified on the basis of their forms they exist in the environment after their release or from ecosystem point of view.

1) *Basing up on the basis of their forms of existence in the environment*, they are

a) Primary pollutants: Those substances emitted directly from an identifiable source

b) Secondary pollutants: These are the substances, derived by primary pollutants by chemical reactions.

2) *Basing on the ecosystem point of view,*

a) Biodegradable pollutants: It includes domestic sewage, heat etc. that can be readily decomposed under natural circumstances. However, if the rate of production of such waste is higher than the rate of break down of these materials, they tend to accumulate in the system, disturbing the balance between natural cycles, which intern give rise to pollution.

b) Non - biodegradable pollutants: The substances, that are not degraded by micro organisms.

These include substances like heavy metals, aluminum cans, plastics, synthetic compounds such as pesticides, detergents and others.

17.3. AQUATIC/WATER POLLUTION

Modern civilization with its rapidly growing industrial units and an increase in the population, has led to an occelerated degradation of the freshwater resources. The water bodies are subjected to a wide variety of human activities such as washing, Swimming, bathing and waste disposal, disposal of industrial effluents etc., these modifies the environment of the natural waters, in a way that leads to a potential health hazard. Water resources are said to be polluted, when because of man's activity in adding or causing the addition of matter to the water or altering the temperatt!re, the physical, chemical (or) biological characteristics of the water are changedio such an extent that its utility for any reasonable purpose or its environmental value is demonstrably depreciated.

17.3.1. TYPES OF POLLUTION

Kendeigh (1975) classified the pollution of aquatic bodies into four main types. they are:

a) Natural - Pollution brought about by naturally.
b) Silting - resulting from excessive erosion of the surrounding upland.
c) Industrial - Produced by inorganic chemical wastes from tarmeries, breweries, paper and pulp mills, gas plants, mines, metal industries, petroleum industries etc.,
d) Organic - Principally municipal sewage and drainage of agriculture land.
e) Thermal - As hot water effluent from industries and atomic power plants.

17.4. MAIN SOURCES OF WA TER POLLUTION

Discharge of solid or liquid waste products containing pollutants into surface or coastal waters, or on to the land surface is the main cause of water pollution. Main sources are identified as follows:

17.4.1. Sewage and Domestic Wastes:

About 75% of water pollution is caused by sewage and domestic wastes. *Organic pollution* originates from incompletely digested sewage, which usually has some remaining biochemical oxygen demand (BOD) when it is released. Swage originates from domestic and commercial premises, land drains, some industrial plants, and agricultural site.

17.4.2. Industrial Wastes:

All industrial plants produce some organic or inorganic chemical wastes, which cause water pollution. Sometime major part of the industrial waste is discharged directly into rivers, canals, and the sea, and not into the sewerage system. The largest volume *of* discharged waste is in the form of an "effluent", which may be any solid, liquid, or gaseous product, in a treated or untreated condition. Industrial effluents may contain water, origanic solvents, oils, suspended solids, and dissolved chemical compounds.

17.4.3 Pesticides, Fertilizers and Detergents:

Major souce of pesticides in the rivers, streams and lakes is run-off from agricultural fields. The optimum condition for run-off is when there is heavy rainfall soon after the pesticide application. Pesticides also reach aquatic systems from discharge of industrial effluents into water. Pesticides can reach water in such effluents, either as waste from pesticide factories, or as discharge from factories.

The use of organic synthetic detergents has been responsible for considerable increase in the phosphorus released in sewage effluents. Detergents are composed of complex phosphates (alky 1 benzene sulfonate or alkylate sulfonates) which eventually breakdown into phosphates usable by aquatic plants. Several studies also indicate the toxic effects of detergent to fish. Fish exposed to household detergents exhibit abnormal behaviour like frequent surfacing, air engulfing, jerking movement and loss of body balance.

17.4.4. Toxic Metals:

Toxic metals are often described as the heavy metals, and these includes iron, lead, mercury, cadmimum, zinc, copper, nickel and arsenic. Very small quantities or traces of some metals are required for normal growth and metabolism, for example, copper, iron, nickel and zinc. However, if the threshold limit value (TLV) is exceeded, these metls may cause variable deleterious effect on plants and animals.

17.4.5 *Thermal Pollution:*

Thermal pollution may be defined as the warming up of an aquatic ecosystem to the point where desirable organisms are adversely affected. A large number of industrial plants (electric power, steel and chemical industries) use cold water from the rivers and discharge it hot. A single 1000 MW power plant may use one- half million gallons of cooling water per minute. At some places atomic energy plants have become a major source of thermal pollution, which is harmful to fishes and aquatic invertebrates.

17.5. EFFECTS OF WATER POLLUTION ON FISH

Effects of water pollution on the different components of the biosphere are too many as are the sources of water pollution. The effects of water pollution may be consideren under the following six headings. However, many factors including the quantity and composition of the effluent, the value of water, and weather conditions govern the overall effects of pollution.

17.5.1. Physical Effects

a) ***Turbidity**:* Various types of suspended solid particles, discharged into water bodies, cause water turbidity and reduction of the dissolved oxygen in water. The natural turbidities are seldom, directly lethal to fish. But the turbidity may affect the productivity of an aquatic ecosystem. And also hampers spawning and growth of fish. Fish and some invertebrates suffer from such pollution because their gill surfaces are clogged with suspended matter.

b) ***Heat:*** Other physical effects of water pollution include cooling water discharge from power stations, causing a rise in water temperature or the so-called thermal pollution. The rise in water temperature will lower the dissolved oxygen content, and speedup the biodegradation of pollutant organic matter. The biological effects of thermal pollution depend upon how much the temperature is raised, for the metabolic rate of physiological processes is speeded up by heat. Since each species has its own metabolic rate, most aquatic animals can only exist within a specific temperature range. For example, trout are killed by temparature of over 25^0C and their eggs will not develop in water above 14^0C. Rivers affected by thermal pollution support onlycoarse fish. Raised water temperature increase vulnerability of fish to disease.

c) ***Oxidation Effects:*** Oxidation effects are caused by (a) *bacterial action upon organic pollutants,* and (b) *through chemical oxidation of inorganic and organic substances present in industrial wastes.* Both types of oxidation require the use of dissolved oxygen, thereby producing an increased BOD and oxygen deficit in water bodies. Fishes are usually eliminated for long distances by severe organic pollution. Obviously, toxic substances, particularly ammonia, sulphides and cyanides, kill them, as do very low oxygen tensions which enhance the toxicity of most poisons.

17.5.2. Toxic Chemical Effects:

Toxic chemical effects are caused by a range of substances that cause immediate or cumulative physiological changes in plants, animals and humans. Toxins are absorbed into the tissues from polluted water, and their effect varies with the type of chemical substance, the concentration in the tissues, and the metabolism of the organism. Chemical toxins can be broadly described as (i) metals and salts, (ii) pesticides, (iii) acids and alkalies, and (iv) other organic compounds such as polychlorinated biphenyls orPCBs, phenols and cyanides.

a) ***Metallic Pollution:*** One of the most significant effect of metallic pollution is that aquatic organisms can absorb and accumulate concentrations in their tissues. The heavy metals affect the fish tissues concerned with digestion, absorption, respiration, and excretion. Their haematological and pathological effects are well known. They also cause changes in tissue lipid and cholesterol content in fish and their acute toxicity leads to fish mortality.

b) ***Pesticidal Pollution**:* Pesticides also cause water pollution which are considered to be the most harmful. For example, DDT in rivers have an average half-life of 2.5 to 5 years, but it can persist for up to 25 years. Such nondegradable pesticides can accumulate in food chains through biological magnification, and it is known that shrimps and fish can concentrate some pesticides.

Pesticide affect all the vital tissues of the fish body and their effects may be histopathological, biochemical and ecophysiological. Juvenile stages of fish are worst hit by pesticides.

c) ***Pollution by Acids, Alkalies and Other Organic Compounds:*** As acids and alkalie lower or raise the pH value of water, they are considered to be hazardous. Most animals and plants will not survive in water with a pH value below 5 (acid), or above 9 (alkaline). Changes in the pH can also affect the action of other toxins. A number of water pollution toxins such as chromates an chromic acid, beryllium, selenium, cadmium, chlorinated hydracarbons, some rganophosphorus pesticides, and polyvinyl eholoride, have been designated by the WHO. as potential carcinogens, capable of causing cancer in the long term to fish.

17.5.3. Chemical Nutrient Effects

In the context of water pollution, the two most important nutrients are nitrogen and phosphorus, usually present in all natural waters as nitrates and phosphates. The natural process of lake-ageing characterized by nutrient enrichment over a long period of time is called eutrophication. When the process of eutrophication is speeded up by human activity, it is called cultural eutrophication. About 80% of the cultural eutrophication. About 80% of the nitrogen and 75% of the phosphorus added to lakes and streams in developed and developing countries has its source in human activities. When the average concentration of soluble inorganic nitrogen exceeds 0.30 ppm, and the soluble inorganic phosphorus content exceeds 0.01 ppm, algal blooms may appear. During the summer, the algal bloom problem usually become more intense with adverse effects on the whole biota of the lake. Dense algal blooms at the lake surface reduce penetration of sunlight to the lake bottom. As a result, the deeper waters contain less amount of dissolved oxygen, which is further reduced by decomposing algal and organic matter accumulated at the lake bottom. The oxygen depletion is often responsible for the winter kill of fish in many lakes.

17.5.4. Pathogenic Effects Caused by Micro-Organisms

Inland coastal waters that receive sewage discharges and other wastes are a potential health hazard, as they contain pathogenic organisms. At present, sewage effluent is tested only for the presence of *E.coli*, which is a nonpathogenic intestinal bacterium. The so-called colifonu test of water purity is carried out to indicate the presence of absence of faecal matter present in water. This test does not show the presence of pathogenic bacteria and viruses. Although drinking water supplies from rivers are given pre-water supply chlorination treatment, it is not possible to cary out chlorination of sewage effluent before it is discharged into water. This is *because some* free chlorine would enter rivers, and very low concentrations, such as 0.03mg/I, are lethal to fish and interfere with bio degradation, which is essential for resilience of rivers. Fish diseases caused by bacteria are - fin and tail rot, ulcer disease,dropsy, and eye disease. Fish are more prone to diseases in polluted waters and the incidence of diseases in polluted waters and the incidence of disease can be minimized by improving sanitary conditions prevalent in the water and by good pond management.

17.5.5. Effects caused by Accumulation of Radioactive Substances

Radionuclides ultimately become concentrated in bottom living food organisms and produce deleterious effects on human body. However, close monitoring of radioactive pollution in necessary in order to assess their buildup and harmful effects in fish, shell fish and crustaceans, which are used as food.

17.5.6. Industrial Pollution and Fisheries

At present, all the major rivers of India are polluted by a vast array of industrial effluents. Since these effluents have very low DO, high BOD and many types of toxic substances, causing various effects on the aquatic communities, including sudden fish kills and other ecological problems, All river systems of India are polluted by tanneries, textile, wood and jute mill wastes, besides effluents from sugar mills, distilleries, pulp and paper factories, synthetic rubber industry, fry ash from coal washeries and DDT factories. Industrial wastes from oil refineries, steel plants, paint and varnish manufacture plants, and cement and pesticide factories also pollute the inland waters. The distillery wastes of low pH and high oxygen demand created problems causing asphyxiation and mortality of fish. The industrial pollution not only degrades the natural water quality of streams and rivers, it also causes heavy losses of fishery.

Studies on the ecology and pollution states of the Indian rivers indicate that direct disposal of industrial wastes poses serious problem. Since most of the industrial units do not have satisfactorily waste disposal systems or treatment plants,the waste is indiscriminately discharged into nearby water bodies, leading to pollution.

17.5.7. Use of Fish as Biological Indicators of Water Pollution

Besides algae, macrophytes, and benthie macroinvertebrates, fish are considered excellent indicators of the water quality. The presence of a species indicates that the habitat is suitable, and since some of the environmental requirements are known for many species, their presence indicates something about the nature of the environment in which they are found. Thus, the absence of a particular species is less usefull as an indication of environmental conditions than the presence of a species. Based on these criteria several schemes of river zonation have been proposed indicating the presence of one or more dominant fish species usually present in a particular zone. From the headwaters to the mouth, these fish species indicate the unpolluted, less polluted, polluted and intensely polluted zones of the streams, A close examination of the fish species of the river Ganga at Rishikesh-Hardwar, Garhmukteshwar, kanpur, Patna, Bhagalpur, and Calcutta makes this point clear. Fish species which occur in the upland reaches of the Ganga are clean water forms adapted to living in cold waters (5°C to 19°C) having high amount of dissolved oxygen (9 ppm and more). Barilis bendelisis, Puntius chilinoides, Schizothorax richardosnii, and Tor putitora are a few examples of coldwater fish. But as we gradually move downstream, in the potamon zone, the shithsonic fish species are replaced by *Labeo rohita, Carla carla, Cirrhinus inrigala, Notopetrus notopetrus* and *Bagarius bagarius,* etc. Further downstream we find *Channa marulius, Macro gnathus aculeatus, Labeo gonius, Gadusla chapra,* and several other species adopted to resisting low dissolved oxygen concentration and high temperature and pollution load.

Several other parameters such as fish population size, growth rate, condition factor and diversity are also indicative of the overall health of water and prevailing environmental conditions. Fish populations in polluted environments are subjected to a long-term contaminant stress which might affect them in several ways, including modification of reproductive ability, reduced longevity, reduced growth rate, and increased rate of tumor or lesion development.

Pollution of any kind usually affects both abiotic and biotic environment of fishery waters. The interrelationships between the fish and the elements of its abiotic and biotic environment are interdependent, any changes in one system of relationships inevitably produce changes in the other. The interaction of fish with any particular elements of its environment / total environment / the effect oftotal environment is greatly depends upon the condition of the fish itself.

The topic of water pollution and fish will continue to be a subject of zero interest and inquiry for future generations of fish biologists, fishery scientists and limnologists.

SUMMARY

Pollution ha become a general term for the common man because he has become accustomedto.live with it. Environmental pollution has become woven throughout the fabric of our modern life, however, every few years the world is shocked by reports of pollution disasters and it is then that man becomes active and consciousabout the harmfbl effect of pollution, and thinks about the ways and means to keep the environmental clean.

Pollution is defined as the addition or the presence in the environment of one or more contaminants in such quantities and of such duration which tends to alter the physical, 'chemicalor biological characteristics in a way that it becomes injurious to human health or welfare, animal or plant life. Pollutants are grouped into two major categories, primary and secondary pollutants.

Like pollution of air and water, land pollution is slowly increasing. Pollution of water bodies affects all the biotic communities, including fish. Main sources of water pollution are seewage and domestic wastes, industrial wastes and effluents, pesticides, fertilizers etc. The general effects of water pollution on fish may be considered as physical effects, oxidation effects, toxic chemical effects, pathogenic effects and other effects caused by the accumulation of radioactive substances. As fish are excellent indicator of water quality parameter such as fish population size, growth rate, condition factor *and* diversity are also indicative of the total health of water..

QUESTIONS

1) Define the pollution and describe the various types of pollutions?
2) Describe the various sources of water pollution and their effects on aquatic life ?
3) Give an account on the effect of water pollution on fisheries?

GLOSSORY

ABIOCEN : Non-living (abiotic) component of the environment.

ABYSSAL ZONE : Sea bed and sediments at water depth greater than 2000m; also for zone in lake, where no effective light penetration.

ACRODONT: Type of dentition, in which teeth are fused to the outer side of jawbone e.g., teeth in some bony fishes and reptiles. Such a condition in an individual is termed acrodonty.

ADAPTATION : Process of adjustment of an organism in particular set of habitat conditions.

AMENSALISM : Symbiosis in which is inhibited by the other but the latter remains unaffected.

AMMONOTELIC: Ability to excrete ammonia. Large quantities of water would be required to dissolve and carry off ammonia (300 500 ml for one gm of nitrogen as ammonia); fishes (teleosts) have this opportunity so they excrete their urine as ammonium hydroxide.

AMPHIOCOELOUS: Having concavities on both the sides e.g., 8th vertebra of frog, the centrum of which is concave anteriorly posteriorly to articulate with convexities of 7th and 9th veterbra respectively.

AMPHISTYLIC: Upper jaw is attached directly to otic region and hyomandibular is movably attached to otic region and slings upper jaw with cranium. Found in primitive sharks.

APHYTIC ZONE : The area of lake floor, that due to its depth factor is devoid of plants.

ARID ZONE : A zone of very low rainfall with most of the deserts.

ASH : Mineral content of a product that remains after complete combustion.

ASSIMILATION: Changing of absorbed food and other materials from intestine into cytoplasm.

ATMOSPHERE : The gaseous envelope surrounding a planet.

AUTECOLOGY : Ecology of individual organism or species.

AUTOSTLYIC JAW: Type of jaw suspension when lower jaw is articulated with the quadrate bone e.g., in frogs, lizards and birds.

AUTOSTYLIC: Upper jaw is fused with the cranium and lower jaw is articulated with quadrarte. Found in amphibia, reptiles, birds etc. two subtype of this can be differentiated – monimostylic when quadrate is immovable as found in most lizards and streptostylic when quadrate is movable as found in snakes.

AUTOTROPHIC NUTRITION: Process of nutrition in which an organism manufactures its own food e.g., nutrition in which an organism manufactures its own food eg., nutrition found in Euglena where animal synthesizes carbohydrates with the help of its chloroplast from CO2 and water in presence of sunlight as seen in the plants.

BAHTYPELAGIC : Organisms living at water depths between 1000 in and 3000 m.

BATHAYAL : Sea bed and sediments deposited between edge of continental shelf and start of abyssal zone at a water depth of 2000m.

BENTHOS : Organisms living on or at the bottom of a water body.

BIOCIDE : An agent that kills a live organism.

BIOCOEN : Living component of the environment.

BIOCOENOSIS : A community of organisms occupying an area.

BIOMASS : Standing crop (living matter) of living organisms, in terms of weight, present at any given time in the environment.

BIOME : A major ecological community of organism (a complex of several communities, may be under different successional stages) maintained under a particular climate zone.

BIOSPHERE : The planet earth along with its living organisms and atmosphere which sustains life i.e., the earth and atmosphere in which organisms live

BIOTA : The flora and fauna of an area.

BIOTIC (ECOLOICAL) PYRAMID : Graphic representations of the trophic structure and function at successive trophic levels of an ecosystem. This may be shown in terms of number, biomass or energy content.

BIOTIC POTENTIAL : The inherent capability of an organism to increase in numbers under ideal conditions absence of competition, predators, parasites etc.)

BRANCHIA: Gill in an animal.

BULBUS ARTERIOUS: bulb like enlargement at the base of ventral aorta found chiefly in bony fishes.

CANOPY : A leafy portion of a tree or shrub.

CARRYING CAPACITY : Maximum number of individuals that a habitat or its resources can support.

CLASPERS: Pair of hard elongated structures attached to pelvic fins of some cartilagenous fishes. These have a groove internally and are connected with cloaca and are used to transfer sperms into cloaca of female.

CLEAVAGE: Series of sub-divsions of activated egg (zygote) into many cells or blastomeres.

CONUS ARTERIOSUS: Expanded cone-like structure over the ventricle in some vertebrates e.g., fishes that empties blood into aorta. It has valves that check backflow blood.

DECOMPOSERS : Microbes that obtain their nutrition from break-down products of dead organic matter.

DETRITUS : Dead organic matter, mainly of fallen leaves as leaf litter in forests. The microbes decomposing detritus are called detritivores.

DEUTEROSTOMIA: Animals in which blastopore forms anus in gastrula e.g. chordates.

DIGESTION: Chemical conversion of natural food materials (carbohydrates, proteins and fats) body food materials (monosacharides, amino-acids and glycerol + fatty acids)

ECOLOGICAL BALANCE : Maintenance of an equilibrium between living components of an ecosystem, so that it remains stable system.

ECOLOGICAL NICHE : See niche.

ECOLOGICAL PYRAMID : See biotic pyramid.

ECOLOGY: The science of relationship between living organism and their environment.

ECOSPECIES: One or more ecotype in a single coenospecies.

ECOSYSTEM : Ecological system formed by interaction of coaching organisms and their environment. A group of interacting organisms alongwith their environment, that operates as a system.

ECOTYPE : A genetically different population of a species colonising a different specific habitat. Different ecotypes are, however, inter-fertile.

ECTOTHERM: individual which obtains heat directly from environment.

Vast majority of animals excepts birds and mammals are ectotherms.

EMBRLOGY: The study of development of animal.

ENDOTHERM: Animal which produces heat within its body by oxidative metabolism and maintains constant body temperature like bird or mammal.

ENERGY FLOW : The passage of energy through the trophic levels of a food chain.

ENVIRONMENT: The sum of all physical, chemical, biotic and cultural factors that affect life of organism in any way:

EPILIMNION : The warmer uppermost layer of water enough light can penetrate.

EUPHOTIC ZONE : Upper zone of a sea or lake where enough light can penetrate.

EUTHENICS : Science of improving the human race by improving environment.

EUTROPHIC : Refers to lakes that are highly productive in terms of organic matter formed, and well supplied with nutrients.

FECUNDITY: Innate potential reproductive capacity of an individual organism.

FERTILIZATION: Union of mature ovum and mature sperm to form zygote.

FOOD CHAIN : A series of organisms arranged in linear manner with repeated and being eaten.

FOOD WEB: Interlocking pattern of several interlinked food chains.

FORBS : Herbaceous plants, excluding grasses, sedges and other grass like plants.

HABIT: Appearance (external outlook) of an organism.

HABITAT : The place where an organism lives in nature.

HEMIBRANCH: In fishes the gill lamella on each side of gill arch. The two such lamellae belonging to one gill arch and the interbranchinal septum in between them constitute a complete gill. Only a single gill lamella is called half gill or hemibranch. The first gill in fishes like Scoliodon spp. Supports a hemibranch.

HETEROCERCAL TAIL: Type of tail which is a symmetrical internally as well as externally. In such a tall the axis (portion of vertebral column is bent upwards and the two lobes of tail fin epicaudal / upper lobe and hypocaudal / lower lobe) are of unequal size. Such a tail is found in sharks like Scoliodon and bony fishes like sturgeion.

HETERONOMOUS: Condition in which metameres of an animal are not similar metameres specialised in various parts of the body Eg. Chordates.

HOLOPHYTIC NUTRITION: Nutrition in which an animal or organism prepare its own food from carbon dioxide, water etc, in sunlight as seen in the plants. It occurs also in some protozoa like Euglena species.

HOMOCERCAL TAIL: Type of tail which is externally symmetrical but asymmetrical internally. Such a tail is found in most bony fishes.

HUMUS : More or less decomposed finely divided amorphous organic matter in the soil.

HYDROSPHERE: The part of the earth composed of water (ocean sea,

HYOSTALIC: Upper jaw has no direct attachment with cranium but suspended by means of ligaments to it through hyomandibular which is movably attached to otic region. Found in sharks.

JAW SUSPENSION: Splanchnocranium in ganthostomates serves to suspend the lower jaw with cranium and forms jaw suspension.

MEROBLASTIC CLEAVAGE: Egg cleavage in which divisions of egg is incomplete i.e., only occurs in cytoplasm and not in yolk. It is common in eggs with large quantity of yolk like hen's egg.

MESONEPHROS: Vertebrate kidney present in the embryo of most vertebrates, Persists in adult cyclostomes fishes and amphibians but replaced by metanephros in reptiles, birds and mammals.

MORPHOLOGY: Branch of science related to study of form and external structure of an organism.

MYOGENIC HEART: Heart whose activity is not directly controlled by nerves but is controlled directly by muscles e.g., hearts of all vertebrates. Compare with neurogenic heart.

NANNOPLANKTON : The smallest phytoplankton.

NEKTON : Organisms that swim in water

NICHE : The specific physical space occupied by an organism; the functional role of an organism in ecosystem.

OLIGOHYLINE : Slightly brackish waters, of *0.5* to *5* parts per thousand salinity.

OLIGOTROPHIC : Lakes poorly productive in terms of organic matter, and poor in nutrients.

OSMOREGULATION: Maintenance of internal osmolarity with respect to enviroment by an animal. Balance of water and slats within the body of an animal.

PELAGIC: Inhabiting the open water, away from sea shore as in occean necton, plankton.

PHYTOPLANKTON : Floating or freely suspended plants.

PLANKTON: Floatting or dirfting aquatic organisms mostly microscopic; may be phytoplanktons or zooplanktons.

POPULATION DYNAMICS: Study of changes in population densities in an area.

POPULATION: A group of inbreeding individuals of a species.

PREDATION : One organism is eaten by another.

PROFUNDAL ZONE : The zone of a lake lying below the compensation depth.

PROTEROSTOMIA: Animals in which blanstopore forms mouth in gastrula e.g., invertebrates upto mollusca

SCIZOCOLE: Coelom developed from originally solid mesoderm and differentiated on the sides of notochord (also called lateral plate mesoderm) as found in chick. It differs as compared with entercoelic coelom in which mesodermal pouches are formed on both sides of alimetary canal.

SERUM: blood plasma that separates from clot and is free from cells of fibrin.

STANDING CROP : The amount of living matter present in component population at any time in the ecosystem. This may be expressed in terms of numbers of organisms, their weight (biomass) or energy content (by respective pyramids).

THERMOCLINE : The layer of water in a lake lying between epilimnion and hypolimnion. In this zone temperature decreases rapidly with increasing depth.

THROMBOCYTES: Blood corpuscles, like platelets of mammals, found in the blood of other vertebrates. Simple, spindle-shaped, nucleated structures of the size almost of a lymphocyte and produces by haemopoitic tissue. Also called spindle cells.

THROMBOCYTOPENIA: Process of blood clot formation within the ciruclatory system; often seen in area having palques formed as a result of arteriosclerosis. Two major forms are known clinically – one coronary thrombosis which leads to heart attack and other cerebral thrombosis which leads cerebral haemorrhage.

TROPHIC LEVEL : The functional level occupied by an organism 1n any food chain.

ULTRAFILTRATION: Within glomerulus when the blood passes from capilllaries of afferent renal arteriole to efferent renal arteiole then because of pressure difference certain substances from blood are fallen Bowman's capusle and then diffuse to the neck of renal tubule through one called thick wall of capsule. This filtration is called ultrafiltration.

URICOTELIC ANIMAL: Animal that excretes uric acid in urine – reptiles birds and egg-laying mammals.

URIOTELIC ANIMAL: Animal that excretes urea in urine – Mammals.

ZOOPLANKTON : Microscopic animals feeding on the phytoplanktons in aquatic ecosystem.

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