Unit-4.

ADAPTATION IN ANIMAL.

* Terrestrial & Desert ADAPTATIO

16. **Dorso-Ventrally Flattened Body :** Due to huge water pressure the body of marine animals becomes dorso-ventrally flattened. E.g., in Synaptura, Flat fish, both the eyes are situated on the dorsal side of the body. Fig. 108.

TERRESTRIAL ADAPTATIONS

Terrestrial habitat refers to the land, where the organisms live. Earth's land habitat is characterised by a variety of climates and diversity of abiotic factors. Ecologically the terrestrial habitat is subdivided into a number of sub units called : (1) Forest ecosystem, (2) Grassland ecosystem, (3) Tundra ecosystem, (4) Coniferous ecosystem, (5) Cave ecosystem, and (6) Desert ecosystems.

Adaptations in some of the terrestrial ecosystems such as : (1) Forest, (2) Desert, and (3) Cave is given below :

FOREST ADAPTATIONS : Forest animals are arboreal. Naturally, they have adaptations for arboreal life. Some of the arboreal adaptations are, given below :

(1) Opposible toes, (2) Presence of Claws, (3) The tail is prehensile and acts as the fifth limb. e.g. chaemeleon, (4) Digits are fused in groups called syndactyly, (5) Adhesive discs are present on the digits. e.g. Tree Frogs. (6) Development of parachuting method, e.g. Flying squirrel, (7) Limbs are elongated and pectoral girdles are strong, (8) The sense of hearing is well developed. The vision may be average, (9) Forest animals living on land are heavily built : Elephant, Bear, Lion, etc. (10) Reproduction is specially adapted for tree life. e.g. **Phyllomedusa** (Tree frog) of rain forest lays its eggs on rolled up leaves hanging above water. Tadpoles directly fall into the water on hatching. Figs. 109 and 110.

DESERT ADAPTATION : Desert life is adapted to its climatic conditions and scarcity of water : high temperature are the main limiting factors of desert. Desert animals develop adaptations for following purposes : (1) Water conservation. (2) Water getting. (3) Tolerance of heat, and (4) Protection.

1. **Procurement and Preservation of Water :** Animals of desert obtain water from various sources

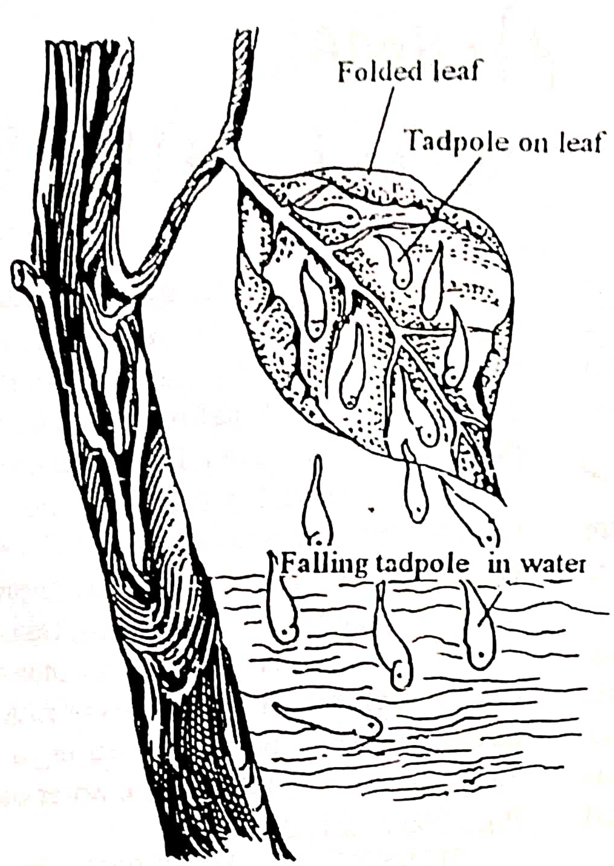


Fig. 110. Leaf nest of Phyllomedusa (Tree frog of rain forest).

and try to preserve them as it is a very scarce item. Tortoise and rabbit compensate their requirement of water taking fleshy plants instead of drinking water directly. Ants and rats of desert depend on water produced in body carbohydrate metabolism. They excrete urine in the form of solid substance. Carnivorous animals satisfy themselves with the water taken with the flesh. Some animals use dew drops placed on plants. Some lizards absorb atmospheric water through their skin, i.e. their skin is hygroscopic.

Many adaptations are found in the body of desert animals to preserve water. (i) Skin of desert animals are very thick to check the loss of water by sweating. (ii) Scales and spines are found on the body of many animals and plants, to check transpiration. (iii) Uromastix stores water in large intestine. (iv) Camels store water in the water cells present in first stomach. It can retain the water for many days. Fig. 111/3. (v) To prevent evaporation, certain desert animals are nocturnal.

2. **Protection :** Many protective devices are found in desert animals, as they have to lead a very adverse climatic condition and fierce struggle for existence, (i) Nocturnal habit, (ii) Skin covered by thick coating (moloch-lizard), (iii) Sole of limbs of desert animals become thick, which help them to run on sand comfortably, (iv) Desert snakes have deadly poison in their poison gland.

3. **Protection From Sandy Wind :** Nostrils of desert animals are provided with valves. Camel can close the nostrils with the helps of valve, like eye lids. Eyes of camel are placed upward and are provided with long and dense hairs. So that, sand may not enter into the eye. Lower eye lid of some desert lizards is transparent and remains attached with upper eye lid. Ear remains protected with scales or hair.

4. **Fast Runner :** Desert animals are fast runners which protect themselves from predators. Following adaptations are there to run faster. The desert Lizard **Callisaurus** runs with the body raised above the ground. Fig. 113.

(i) Sole of leg are wide and thick. (ii) Fingers of **Phrynocephalas** and **Teratoscincus** bear long grooves, which help them to run fast. (iii) Fleshy cushions are found on the sole of legs of camel and ostrich.

5. **Sensory Organ :** Optic, Olfactory and auditory sensory organs of desert animals remain very sensitive.

6. **Mimicry :** Most of the desert animals have great power of mimicry. They can change their body colour according to the surrounding. This helps them to protect from any predator.

7. **Poison :** Most of the desert animals have poison glands. **Rattle snake, Heloderma punctatum, Tarantula spider, Trapdoor spider,** etc. are poisonous.

Thus we find that animals inhabiting desert bear many peculiar adaptive features, which help them to live in desert, which is very adverse condition of life.

CAVE ADAPTATIONS

Natural hollows on the earth is known as caves. The animals living in caves are called **Cavernicolous animals** and their adaptations are called **Cavernicolous adaptations.** Cave habitat is very different from other terrestrial habits. Light is absent, temperature is low and constant through out the year, humidity is high. These cause, following adaptations in animals living in cave permanently.

Freshwater Adaptations

(For figures refer to Lotic Adaptations)

The freshwater habitat is formed of the running water system and the standing water system. Organisms living in these habitats have special adaptations. They are as follows:

1. Attachment : The plants and animals of the lotic habitat are permanently attached to some substratum for not being washed away by the flowing water. Eg. *Green algae, blue green algae, water moss, Hydra, sponges, leeches, snails*, etc.

2. Hooks and Suckers : Hooks and suckers help the animals to attach themselves to the substratum or to the water plants of lotic habitat. Eg. Blackfly larva *Simulium*, the larvae of *Blepharoceras* and caddisfly *Hydropsyches*.

3. Sticky Ventral Surfaces : Snails and flatworms have sticky ventral surfaces by which they adhere to the objects.

4. Stream-lined Bodies : A stream-lined body offers minimum resistance to the water flowing around it.

5. Flattened Bodies : Flattened body helps the organism to find shelter under stones and in crevices. Eg. *Nymphs of mayflies and stone flies.*

6. Positive Rheotaxis : Lotic animals have the inherent ability to move upstream.

7. Positive Thigmotaxis : Lotic animals have the inherent property to keep close contact with the substratum. Thus lotic animals are prevented from being washed away by the moving water. Eg. *Stone fly nymphs.*

8. Osmoregulation : The body fluids of freshwater animals are hypertonic to freshwater. Hence endosmosis occurs. As a result freshwater continually enters the body. Hence the freshwater animals are continuously pumping out the excess of water. This is done by *contractile vacuoles* in Protozoa, *glomerular kidney* in fishes and *green glands* in crustaceans. The kidney and green glands remove the excess of water in the form of urine. A certain amount of salt is also lost through urine. This loss of salt is compensated by the absorption of salts from the external medium by ***chloride cells*** present in the gills.

9. Encystment : During summer certain freshwater systems dry up. Hence the freshwater animals develop heat *resisting cysts* to tide over the dry seasons. Eg. *Protozoans, Copepods, Annelids*, etc. *Sponges develop Gemmules.*

10. Respiration: Many freshwater animals develop special respiratory organs. Eg. *Rectal gills* in dragon fly larva; *Abdominal gills* in mayfly larva and *Respiratory siphons* in *Ranatra* and *Nepa.*

11. Ammonotelism : Freshwater animals excrete their nitrogenous waste product in the form of *ammonia*. Ammonia is easily diffusible through the body and readily soluble in the surrounding medium. Hence all freshwater animals are *ammonotelic.*

12. Creeping : Flatworms, segmented worms and nymphs avoid exposure to currents by *creeping* down among the stones and gravel. This is possible because they have elongate and supple bodies.

13. Stone-cases: The case-bearing *caddis worms* make their cases on heavy stones or coarse-sand in contrast to the light vegetable material used by their pond-living relatives.

The caddis worm, *Silo* even add large *anchor stones*. Hence they cannot be washed away by the currents.

14. Flat Foot : The limpet *Ancrylastrum fluviatile* and the snail *Limnaea pereger* have large flat foot which attaches them firmly to the stones.

15. Remaining close to the Substratum : Mayfly nymphs of the family *Ecdyonuridae* are flattened and apply themselves closely to the stones, onto which the current holds them.

In the case of the mayfly *Rhithrogena* the broad flattened gills are spread out round the body like a *flange* and the anterior pair is bent round under the thorax and closely fitted to the substratum. This device enables the nymphs to cling very tightly to smooth surfaces and they are very difficult to dislodge even from a sheet of glass.

16. Silken Threads : Some of the caseless caddis worms use silken threads for anchoring themselves.

The larvae of the blackfly *Simulium* has a most remarkable method of attachment. It spins a small mat of silken threads on some solid object and then moves its broad backside onto the mat and engages a complex circlet of little hooks in the mesh. It also provides itself with a safety-line, rather in the manner of spider, so that if it does break free it can clamber back again to its original position.

17. Stout Claws: Some lotic water animals are provided with strong stout claws, with which they can cling to small irregularities on stones. Eg. Cased and caseless caddis worms, midge larvae, mayfly nymph such as *Baetis* and the sluggish beetle *Helmis*.

18. Fast Swimming: The mayfly nymph *Baetis* has a stream-lined body. It swims against quite fast currents.

The maggot of *Limnophora* has long fleshy hooks in its tail. They help it to maintain its position in the water current.

19. Feeding Habit: Most of the lotic organisms depend on the water current for their food. The water current carries with it small particles of detritus, detached algae and animals which have lost their grip. This source of food is exploited in various ways.

1. The larvae of *Simulium* hangs out into the water from its silken mat. It has a pair of large collapsible comb-like structures on its head. With the help of these structures the larva sifts the water by making continuous grasping movements. It thus catches small particles carried by the water current.

2. The small midge larva of the genus *Rheotanytarsus* builds a tube on the surface of a stone, from which radiate a number of oblique *struts*, making the tube resemble a small *Hydra*. The larva then spins a string of sticky saliva between the struts, turning the structure into a little net supported by poles. This net filters the food from the water (*Walshe*, 1950).

3. The nets made by caseless caddis worms for filtering food from water are more striking. They spin conical silken nets which are directed upstream and which are attached along one side to a stone at a point where it is raised off the bottom. The

force of the current keeps the net open, in the same way as the wind keeps open the wind-sock on an air field. The larva lives in the tail-end of the net. It collects the food at intervals from the bottom of the net (*Wesenberg-Lung*, 1943).

20. Accessory Respiration : Certain freshwater fishes develop accessory respiratory organs to respire atmospheric

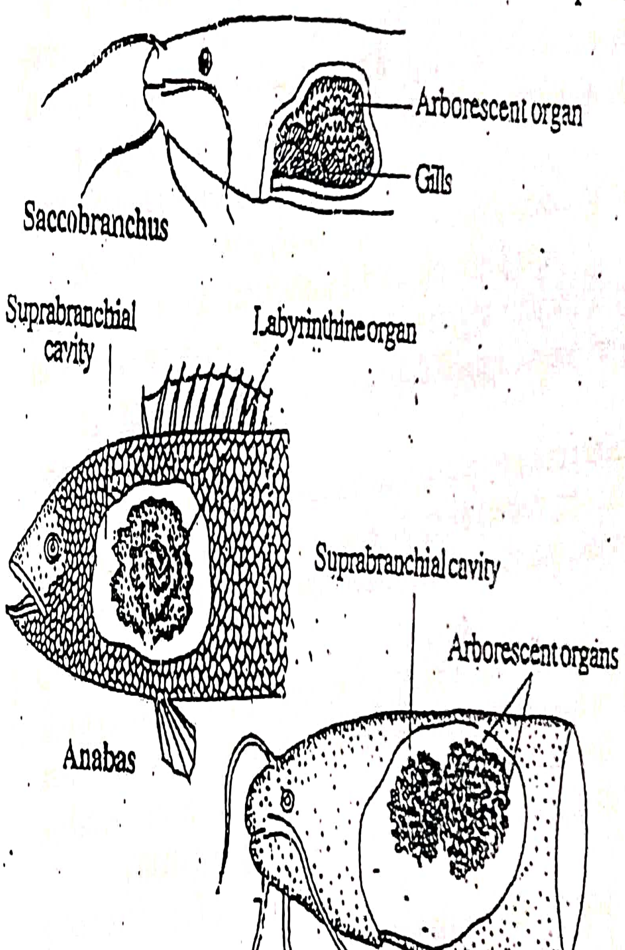


Fig.14.27: Accessory respiratory organs.

air, when the freshwater dries up. Eg. *Ophiocephalus*, *Saccobranchus*, *Clarias*, etc. The accessory respiratory organs are the *labyrinthine* organs in *Anabas*, *arborescent organs* in *Clarias*, *tubular sacs* in *Saccobranchus*, etc.

21. Aestivation : The lung fish *Protopterus* undergoes aestivation when the ponds dry up in summer. It makes a burrow and secrete a *cocoon* around itself. In the burrow, it remains in a dormant condition throughout the unfavourable season.

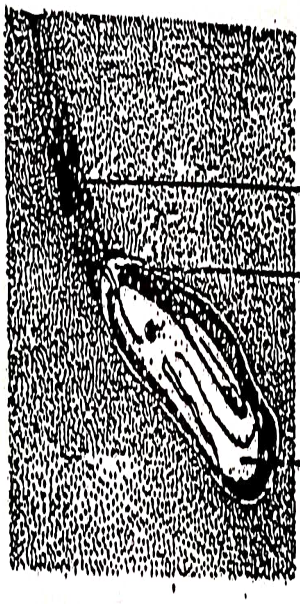


Fig.14.28: Aestivation in Protopterus.

22. High Oxygen Content and Small Gills : Swift currents make good aeration in running water. Hence running water has high oxygen content. The running water animals are adapted to water with high oxygen content. The stone fly larvae live in such waters and have very small gills.

23. Migration: All organisms make effective attempts to complete their life history. Often this requires change of habits and habitats. The fish *Anguilla* (eel) has to oscillate between breeding and feeding grounds. It lives in freshwater. But for breeding it travels thousands of miles in the sea. This migration of the freshwater fish is called *catadromous migration.*

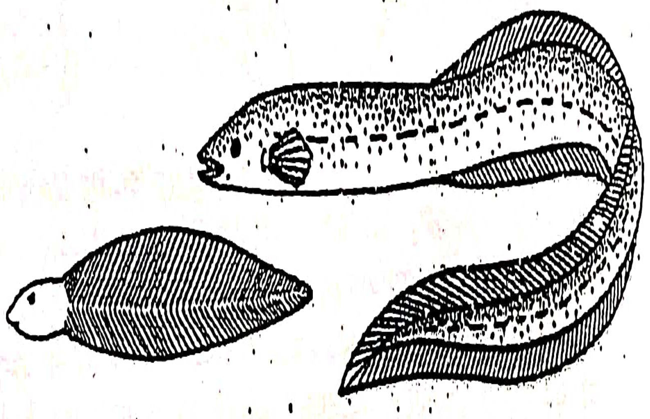


Fig.14.29 : Eel and Leptocephalus larva.

A *Salmon* feeds in the sea; but breeds in freshwater. The migration of *Salmon* from sea to freshwater is called *anadromous migration.*

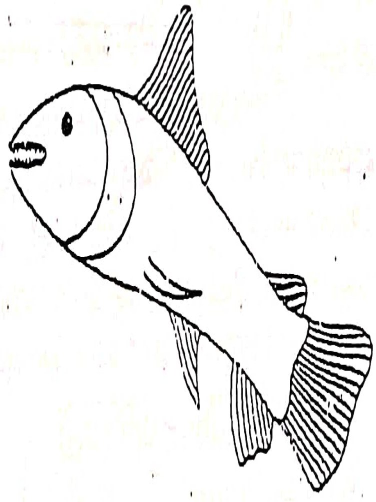


Fig.14.30: Salmon exhibiting anadromous migration.

24. Parental Care : Freshwater organisms regularly produce lesser number of eggs. As they produce lesser number of eggs, extensive care is taken to protect them. The eggs are carried by their parents until they hatch. Eg. *Rotifers, cladocerans, copepods, amphipods, isopods,* etc.

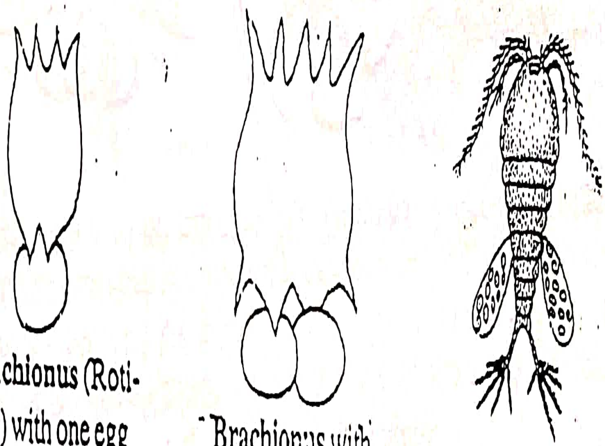


Fig.14.31: Parental care in freshwater animals.

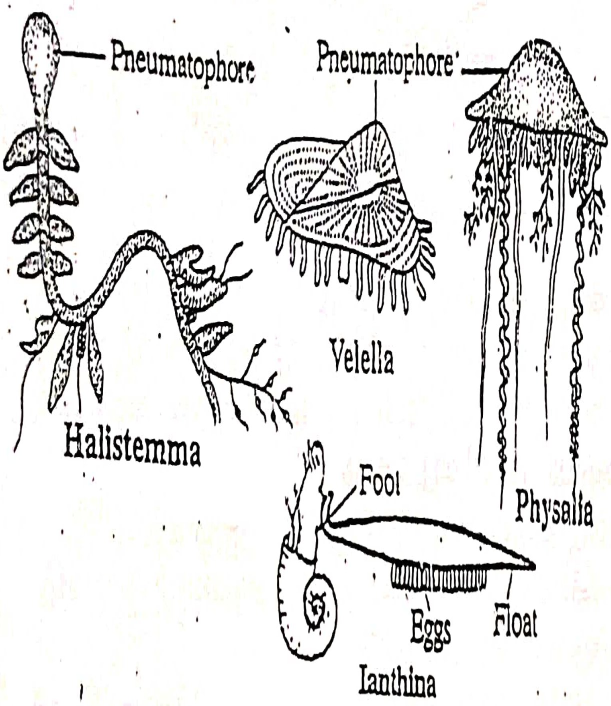


Fig.15.14: Plankton have pneumatophore for floating.

8. Air Bladder : Air bladder is a gas-filled sac, arising as a dorsal outgrowth from the gut in fishes. The fish can alter the amount of gas in the air bladder by secretion or reabsorption. This helps to change the specific gravity and thus regulates buoyancy at different depths.

9. Body Shape : The pelagic animals avoid sinking from the surface by changing their body shape. In some cases the body is flattened. Eg. *Medusae, Haplodiscus* (turbellarian), *Phyllosoma larva, Glochus, Tomopteris*, etc. Planktonic forms assume a ribbon-like, needle-like or chain-like shape.

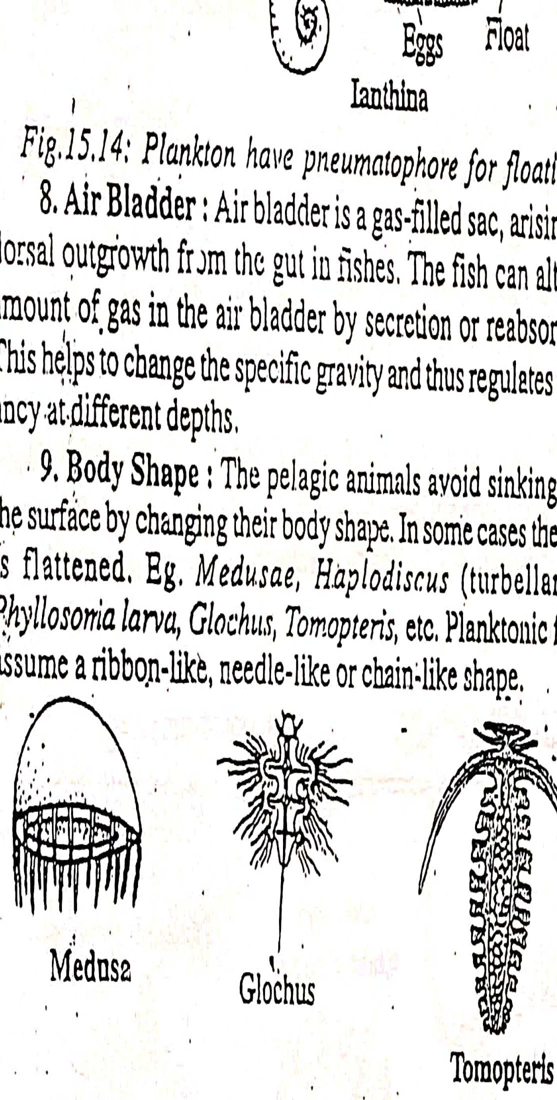


Fig.15.15 : Flattened body helps plankton to float.

10. Elongated Appendages : In many planktonic organisms, the appendages are elongated and branched helping them to prevent sinking. Eg. *Copepods, Megalopa, Phyllosoma, Tomopteris, Polychaete larvae*, etc.

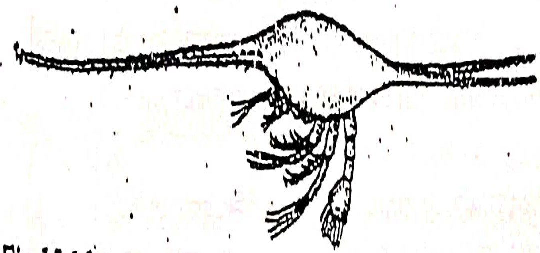


Fig.15.16: Zoea of Petrolisthes, Long horns help floating.

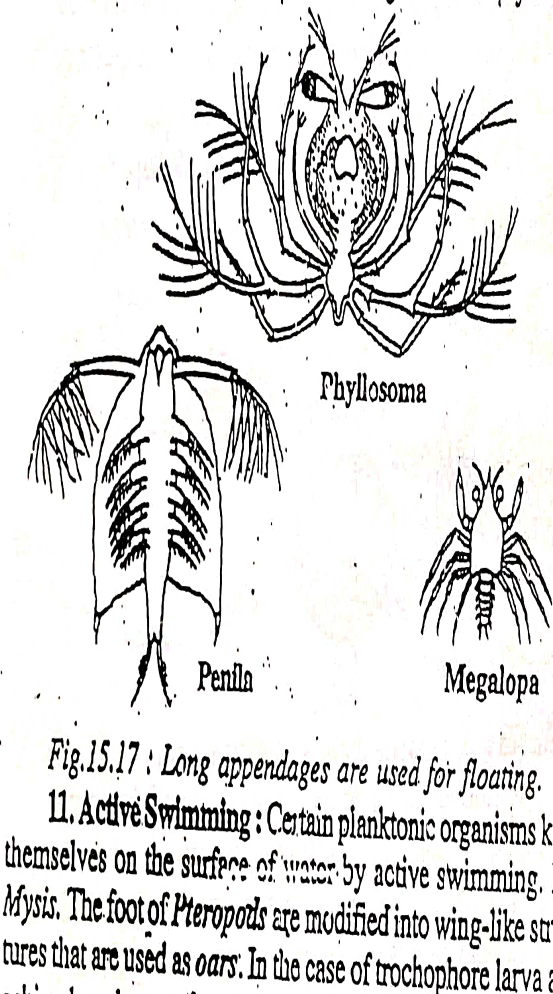


Fig.15.17 : Long appendages are used for floating.

11. Active Swimming : Certain planktonic organisms keep themselves on the surface of water by active swimming. Eg. *Mysis*. The foot of ***Pteropods*** are modified into wing-like structures that are used as ***oars***. In the case of trochophore larva and echinoderm larvae, the ***cilia*** are used for swimming.

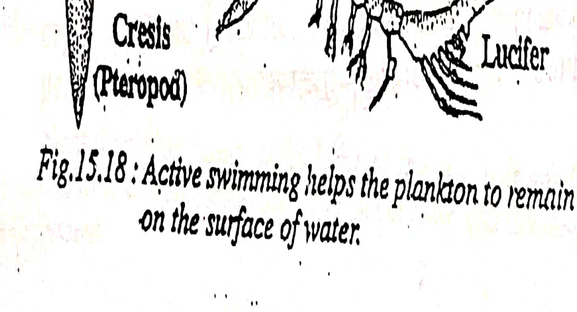


Fig.15.18 : Active swimming helps the plankton to remain on the surface of water.

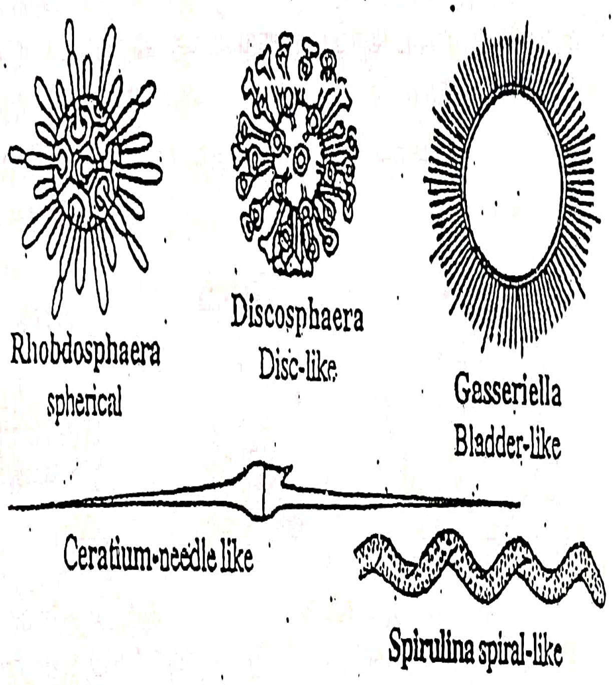


Fig.15.10 : Shape is adapted for floating.

2. Thin Shells : The foraminiferans *Orbulina* and *Globigerina* have thin shells when compared to their benthic relatives. Thin shells reduce weight and the planktonic organisms are prevented from sinking.

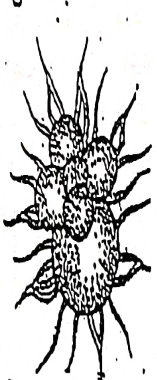


Fig.15.11: Globigerina with thin shells.

3. Pores : Some pelagic foraminiferans contain pores on the shells and the openings of the shell are enlarged in some cases. Pores reduce body weight.

4. Uncalcified Exoskeleton : The pelagic crustaceans have either weakly calcified or uncalcified exoskeleton. The pelagic lamellibranch *Planktomya* has an uncalcified shell. Among the Cephalopods, the pelagic *Loligo* and *Oigopsidae*

Fig.15.12 : Loligo has uncalcified shells.

have delicate narrow uncalcified internal shells, commonly called *shellpens*. These are thin when compared with the heavy calcified cuttle bone of the benthic *Sepia*. Among heteropods (gastropods) there is progressive reduction in the shell.

5. Water Storage : Reduction in the specific gravity has been attained in many pelagic animals by storing large amount of water. The water is stored in the tissues. In the jelly fish *Cynae*, the amount of water may reach up to 90%. Large amount of water is also stored in siphonophores, heteropods, pteropods, chaetognaths, *Alciopa* and *Tomopteris*. In the case of *Leptocephalus* larva of eel, *Salpa* and *Pyrosoma* the body is watery and transparent. *Noctiluca, Beroe* (Ctenophore) and radiolarians reduce their weight by storing water of low salinity.

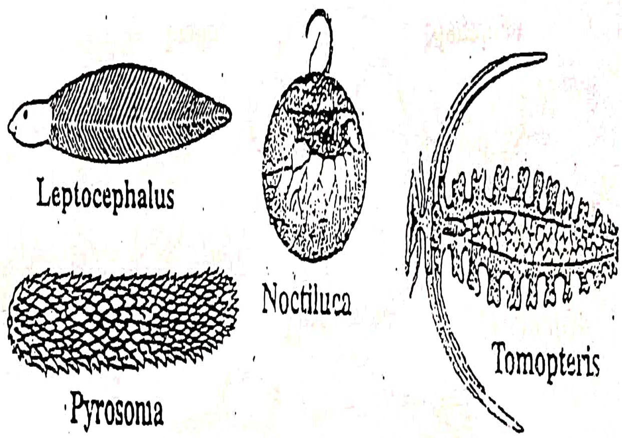


Fig.15.13 : Some plankton store water for floating.

6. Storage of Fat and Oil Drops : In many planktonic organisms, the specific gravity is reduced by the accumulation of fats and oil drops. Pelagic crustaceans such as cladocerans and copepods contain fat. Fishes like cod and many selachians store their food materials in the form of fat in their liver. The sun fish *Mola mola* and basking shark *Cetorhinus maximus* have a thick layer of fat.

The radiolarians store oil drops in the intracapsular protoplasm. The zooplanktonic eggs have oil drops.

7. Pneumatophore : Pneumatophores are specialized zooids meant for floating in siphonophore coelenterates such as *Halistemma, Physalia, Velella*, etc. Pneumatophores are filled with air or gas.

12. Jet Propulsion : A number of pelagic animals maintain themselves on the surface of water by *jet propulsion*. By this method, the animal takes in water and ejects it with force which enables the animals to propel either forwards or backwards. Eg. *Hydromedusae, scyphomedusae*, the swimming bells *(nectocalyces)* of *siphonophores*, and *cephalopods*.

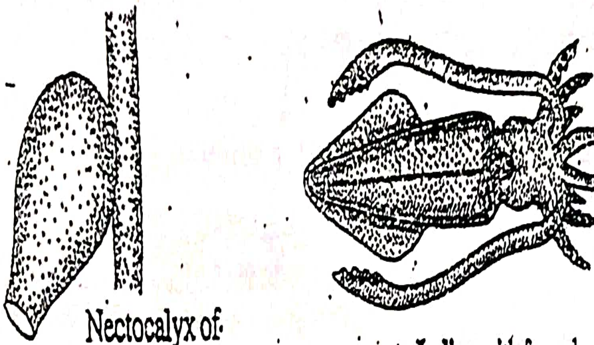
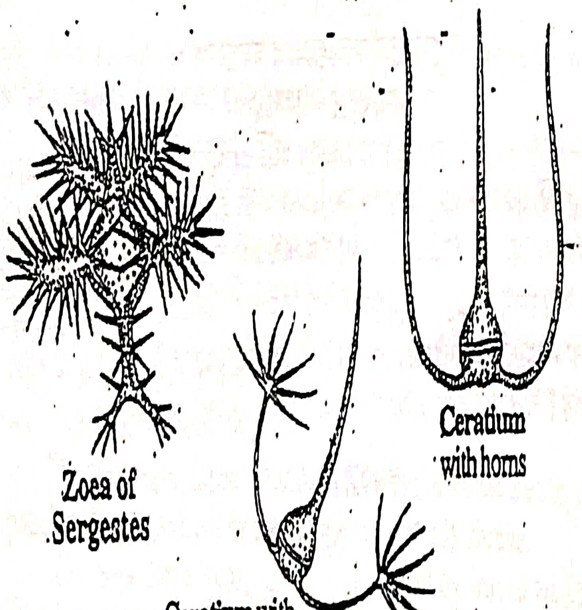


Fig.15.19: Jet propulsion makes the plankton remain on the surface of water.

13. Special Processes : Planktonic organisms prevent themselves from sinking by developing special outgrowths of the body. These outgrowths include horns of *Ceratium*, spines of *Globigerina*, feathery setae of copepods, fleshy arms of echinoderm larvae, etc.



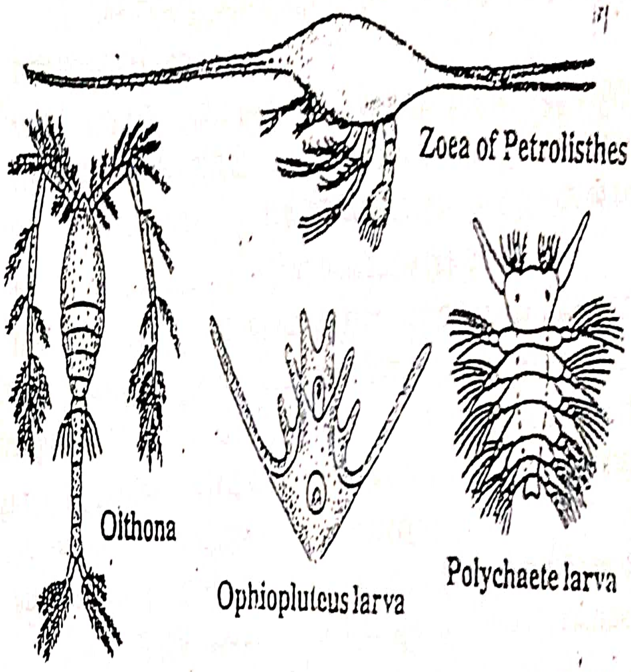


Fig.15.20: Special outgrowths of the body help in floating.

14. Diurnal Migration : Many planktonic organisms such as amphipods, copepods, ostracodes, decapod larvae, pteropods, chaetognaths, polychaetes, siphonophores, tintinnids, etc. migrate to the surface water at night and to deeper water at the break of the day. It is an adaptation to avoid the scorching heat of the sun.

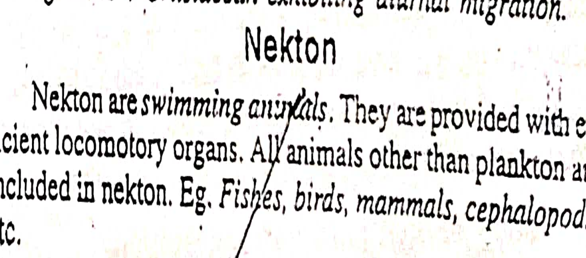


Fig.15.21 : Crustacean exhibiting diurnal migration.

Nekton

Nekton are *swimming animals*. They are provided with efficient locomotory organs. All animals other than plankton are included in nekton. Eg. *Fishes, birds, mammals, cephalopods*, etc.

Benthic Region

Benthic region refers to *the floor of the sea*. It is subdivided into two regions, namely the *littoral zone* and the *deep sea system*.

abundant in vegetation and animals. It has representatives drawn from almost all the phyla of the animal kingdom. The flora and fauna of the rocky shore are as follows:

Flora : *Sargassum, Ulva, Polysiphonia*, etc.

Sponges : *Grantia, Sycon*, etc.

Coelenterata : *Sea anemones, Zoanthus, Lobophytum Sertularia, Plumularia*, etc.

Platyhelminthes : *Planarians.*

Annelids : *Nereis, Eunice, Tubifex, Serpula, Polynoe, Sabella, Eurythoe*, etc.

Arthropods : *Palinurus* (lobster), *Hyas* (spider crab) *Carcinus* (shore crab), *Hermit crab; Balanus, Lepas, Cyprea* (amphipod), *Matuta, Gelasimus, Maia, Gammarus*, etc.

Molluscs : *Mytilus, Littorina, Patella, Trochus, Cyprea, Haliotes, Turritella, Chiton, Nerita, Fissurella, Murex, Pholas, Teredo, Lithodomus, Octopus*, etc.

Echinodermata : Star fishes, Sea urchins, Brittle stars, Sea lilies, Sea cucumbers, etc.

Prochordata : *Herdmania, Ascidia, Botryllus.*

Fishes : *Petrachus, Epinephelus, Gobius, Cyclopterus, Liparis*, etc.

3. Adaptation to Intertidal Rocky Shore

Intertidal rocky shore is rich in flora and fauna. They are provided with following adaptations:

1. Organs of Attachment

In the rocky shore, tides and waves dash against the rocks. If the animals living in this habitat are not firmly attached to the rocks, they will be washed away. Hence the rocky shore forms have adaptations for attachment.

Examples : 1. Sea anemones are attached with the help of a *pedal disc.*

2. Ascidians produce an *adhesive secretion.*

3. Balanus is provided with *cement glands.*

4. Molluscan forms have *broad muscular foot.*

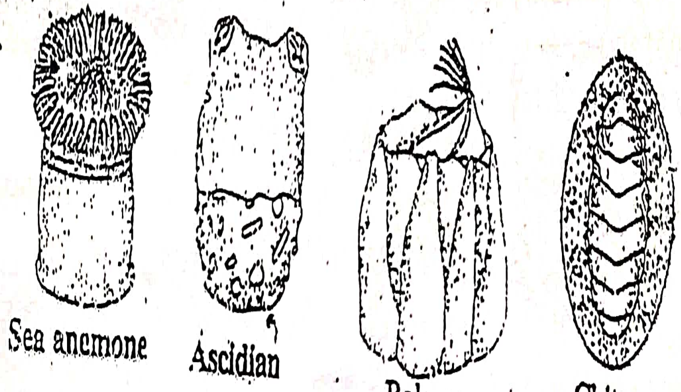


Fig.15.27 : Rocky shore animals with organs of attachment.

2. Sedentary Life

The rocky shore forces its inhabitants to lead a sedentary life. Eg. *Sea anemone, Zoanthus*, etc.

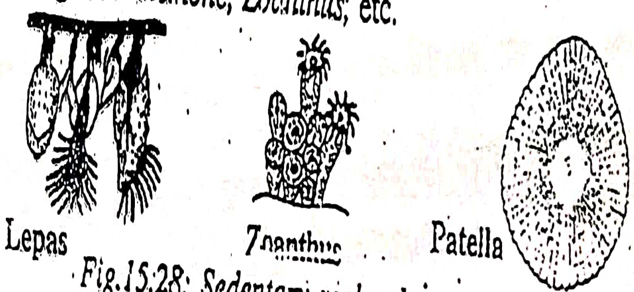


Fig.15.28: Sedentary rocky shore animals.

3. Loss of Locomotory Organs

Locomotory organs are reduced. Eg. *Lepas, Balanus*, etc.

4. Desiccation

The animals living on rocks are very often exposed to atmosphere. Hence desiccation is a problem. It is avoided in various ways. The following are the important ones:

1. Balanus is protected by shells.
2. Ascidian is covered by a test.

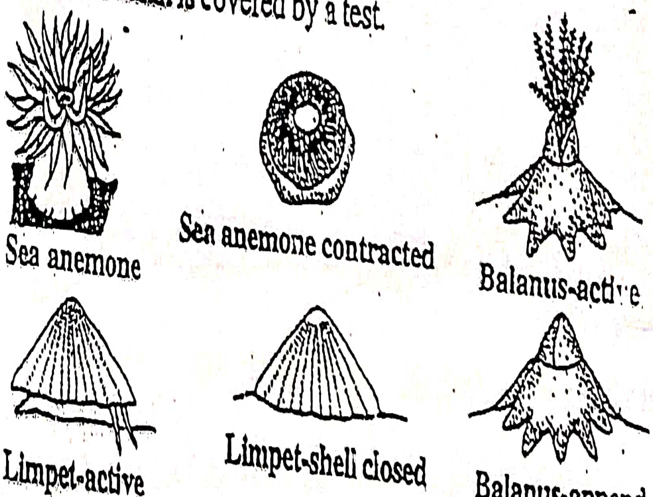


Fig.15.29: When intertidal rocky shore animals are exposed, they protect themselves by contraction or withdrawal.

3. Certain organisms protect their exposed organs by contraction and withdrawal. Eg. *Sea anemones, Zoanthus, Balanus, Tubicolous Polychaetes*, etc.

4. Certain animals have tube-dwelling habit. Eg. *Tubifex*.

5. Certain organisms avoid desiccation by suspending their activities.

6. Molluscan forms close the shells tightly.

5. Defensive Mechanisms

As rocky forms are sedentary and exposed very often, they develop defensive mechanisms.

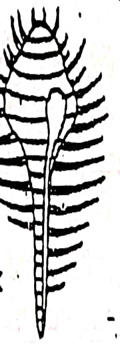
Examples : 1. Molluscan shells are provided with spines. Eg. *Murex*.

2. Crustaceans bear spines on their body. Eg. *Rock lobster*.

3. Sea anemones are provided with nematocysts.

4. Sponges and Ascidians are provided with spicules.

5. Adaptive colouration is seen in *Octopus*.



Murex

Fig.15.30 : Rocky shore animals are protected by spines.

Rock lobster

Fig. 15.31: Sea anemones are protected by nematocysts.

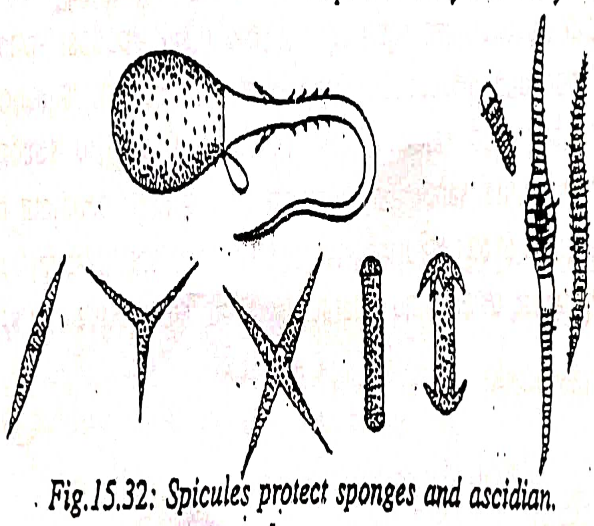


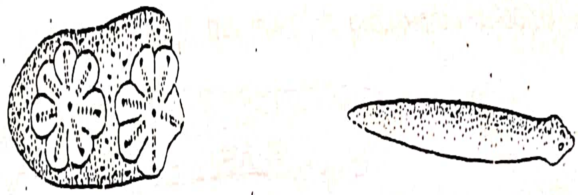
Fig.15.32: Spicules protect sponges and ascidian.

6. Hiding

Certain rocky forms escape from the bounding action of tides by living in the crevices of rocks. Certain animals live among sea weeds.

7. Flattened Body

To reduce friction, the body becomes flattened. Eg. *Botryllus, Planaria*, etc.



Botryllus

Planaria

Fig. 15.33: Rocky shore animals have flattened body to reduce friction.

8. Regeneration

The regeneration capacity is high as the parts of the body of these animals are frequently broken by the dashing of winds and stones.

Fig.15.34 Brittle star, the rocky shore animal has tremendous powers of regeneration.

Intertidal Sandy Shore

Intertidal sandy shore contains sand grains of various sizes. Erosion of continental land masses results in the formation of sandy beaches. Rocky areas of the shore also contribute to sandy beaches when they are worn out by waves, tides and action of boring animals. The intertidal sandy shore has the following salient features:

1. Shifting Substratum : In the sandy shore, the substratum is not static. It is labile. Wind transports dry sands and wave occurs not only in marine environments but also in brackish waters, lakes, ponds, streams, rivers and springs. The interstitial fauna includes ciliates, turbellarians, nematodes, cnidarians, bryozoans, rotifers, archiannelids, oligochaetes, polychaetes, gastrotrichs, kinorhynchs, tardigrades, harpacticoid copepods, ostracods, isopods, gastropods, nudibranchs, echinoderms and ascidians. The newly discovered group *Mystaco caridia* has been reported from this habitat only.

Majority of interstitial organisms are small, elongate, vermiform with transparent bodies and are generally devoid of eyes. Sense organs and adhesive structures show remarkable development. They are *negatively phototactic* and *gregarious* in habit. Herbivores, carnivores, omnivores and detritus feeders are all represented here.

According to *Swedmark* (1964) *the interstitial system is the most dynamic environment with special biological conditions.*

Adaptations for Intertidal Sandy Shore

The sandy beach is unfavourable for animal life because of shifting substratum and ceaseless pounding of breaking waves. However, the sandy beach is very suitable for animal life because it takes prolonged time for drying. The animals of the intertidal sandy shore possess the following adaptations:

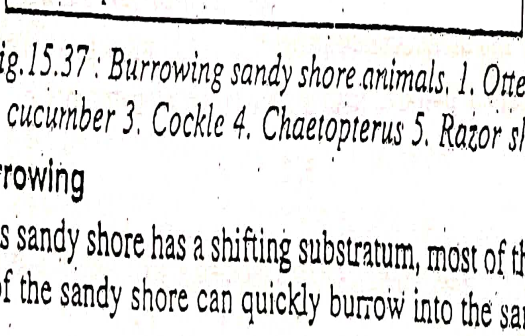


Fig.15.37 : Burrowing sandy shore animals. 1. Otter shell 2. Sea cucumber 3. Cockle 4. Chaetopterus 5. Razor shell.

1. Burrowing

As sandy shore has a shifting substratum, most of the animals of the sandy shore can quickly burrow into the sand. So

they have adaptations for burrowing. The following are the burrowing structures found in sandy shore animals:

1. Proboscis : In *Balanoglossus* the proboscis is conical in shape and it is used for burrowing.

Fig.15.38: Balanoglossus with conical proboscis for burrowing.

2. Prostomium : In *Glycera* the prostomium is muscular and pointed and it is used for burrowing.

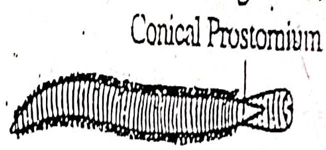


Fig.15.39: Glycera with conical prostomium for burrowing.

3. Shell : The flattened nature of the shells of *Donax, Solen, Dentalium*, etc. helps in burrowing.

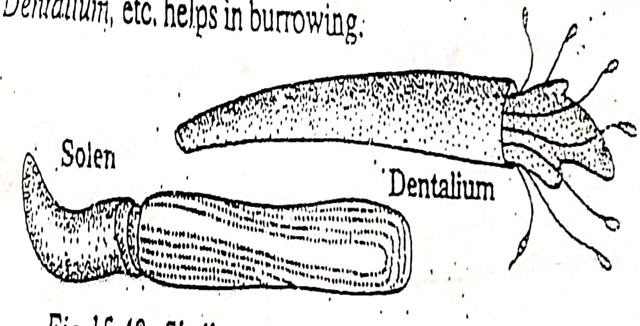


Fig.15.40: Shells are used for burrowing in some sandy shore animals.

4. Foot : The foot of *Solen, Cardium, Dentalium, Natica, Oliva, Ensis*, etc. are pointed and are used for digging.

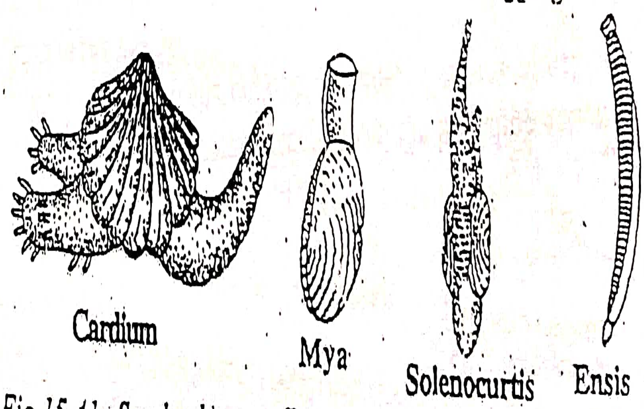


Fig.15.41: Sandy shore molluscs use their foot for burrowing.

5. Appendages : The appendages of crabs and other crustaceans help them to bury quickly into the sand.

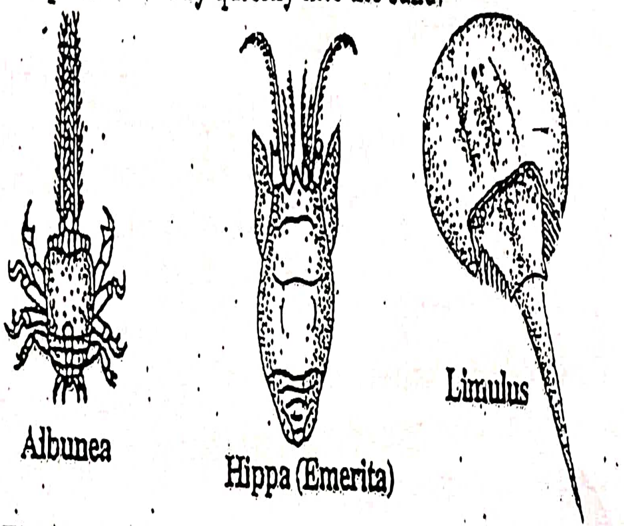


Fig.15.42: Sandy shore arthropods use their appendages for burrowing.

2. Tubicolous Life

Many annelids, inorder to protect themselves from the harshy environment, live in permanent or semipermanent tubes within the sand. Eg. *Arenicola.*

3. Mucous

Certain soft bodied annelids secrete mucous around their body. The mucous assists in keeping moisture around their body. The mucous assists in keeping a cover of sand grains over the body for the purpose of protection against the pounding action of waves. Eg. *Prionospio krusadiensis, Aricia* and *Lumbriconereis.*

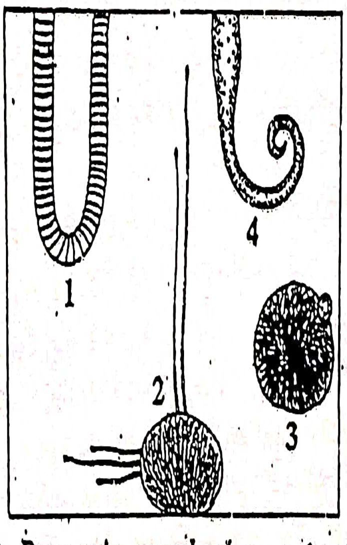


Fig.15.43: Burrowing sandy shore animals; 1. Arenicola 2. Sea potato 3. Heart urchin 4. Amphitrite

4. Terrestrial Life

During low tide, vast stretches of sandy beach is exposed to terrestrial factors. So certain intertidal sandy shore animals lead a temporary terrestrial life. Eg. *Ghost crabs* (Ocypoda), *hermit crabs, fiddler crabs,* etc. They return to the water only occasionally to moisten their gill chambers.

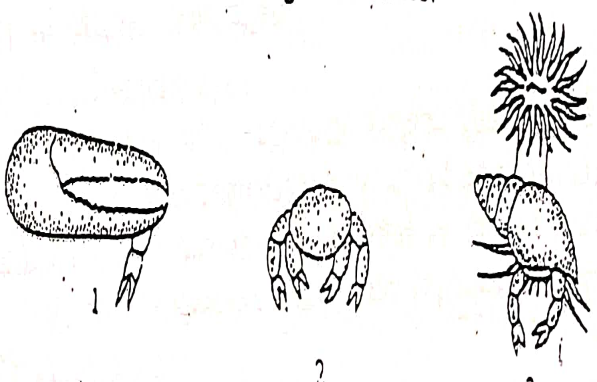


Fig.15.44: Sandy shore crabs: 1. Male and Female fiddler crabs 2. Ghost crab 3. Hermit crab.

5. Filter Feeding

Filter feeding is a characteristic feature of burrowing life. Filter feeding is exhibited by sandy shore animals like *Emerita, Albunea, Terebella, Donax, Mactra, Timoclea,* etc.

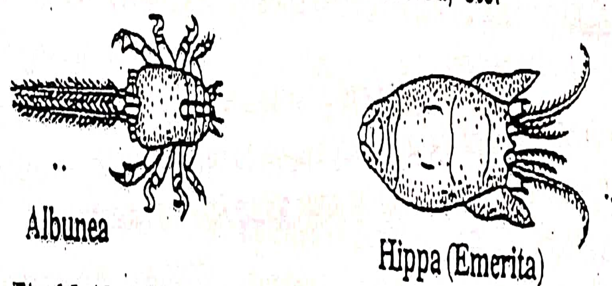


Fig.15.45: Filter feeding sandy shore crustaceans.

Emerita and *Albunea* burrow backwards facing the sea and lie buried. When the wave recedes, they extend their setose antennae into the retreating water. The antennae act as passive filters in the current. Then each antenna is drawn alternately through the mouth parts to scrap the plankton and other organic particles collected. The mouth parts of these forms are so arranged that the entry of sand grains is effectively prevented.

The bivalves *Donax, Mactra* and *Timoclea* also exhibit filter feeding. These molluscs burrow beneath the surface with their muscular foot. They extend their long *siphon* to the surface of the sand to take in a current of water which brings in suspended food particles. They are provided with complex rings of tentacles around the inhalent siphon, to prevent same grains from entering the mantle cavity.

Terebella is a sandy shore tubicolous polychaete. It develops a special mechanism to collect the micro-organisms from the sand.

Terebella lives in a tube. The head bears numerous, long, hollow muscular tentacles. The tentacle can be turned in a variety of ways. One side of the tentacle from the base to the tip is ciliated. This side of the tentacle can be folded to form a ciliated groove along which the food is propelled into the mouth.

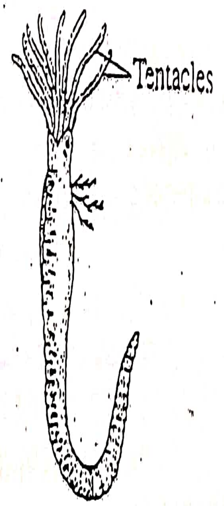


Fig.15.46: *Terebella*.

The tentacles are beautifully adapted for exploring and transporting the food. Their shape as in cross section, varies at different points at any particular moment according to the use to which they are being put. At one point a tentacle will be flattened to form a zone of attachment; distal to this flattened point, the tentacle explores the mud; proximal to the point of attachment the surface of the tentacle will be folded to form a ciliated groove along which the food is propelled.

6. Deposit Feeding

Arenicola marina is a deposit feeder. It depends on the organic materials deposited in the sand. It collects food by *filter feeding* and *sand feeding* methods.

It lives in a '*J*'-shaped tube. The head lies towards the small limb of 'J'. The worm swallows sand continuously by the proboscis. As more

Fig.15.47: Arenicola with filter feeding mechanism.

and more sand is swallowed, a funnel-like depression is formed on the surface. Water enters the tube through this funnel, percolating down through the sand which filters food materials (micro-organisms). This organically rich sand is swallowed by the worm. Now and then, the worm moves to the top of the vertical limb and defaecates in the form of castings.

7. Detritus Feeding

A number of sandy shore animals depend on detritus, which includes broken pieces of plants and animals and decaying organic materials. Eg. *Arenicola, Balanoglossus*, etc.

8. Carnivores

Many sandy shore animals capture and devour other animals. These animals are called *carnivores*. Eg. *Ocypode crabs, Isopods, Glycera, Nephthys*, etc.

9. Scavengers

Scavengers feed on dead seaweeds, dead animals and plant and animal debris. Eg. *Ocypode crabs* and *tabitrid amphipods*.

10. Respiration

When the sandy shore animal remains buried respiration is carried out in various ways. When *Albunea* remains buried in the sand, the two long antennae are closely held together to form a tube. This tube projects above the surface. Through this tube respiratory water is taken in.

11. Protective colouration

Certain sandy shore animals are resembling the sand. Eg. *Albunea*.

12. Breeding Ground

Sandy beach forms a suitable breeding ground for many marine animals. Eg: *Marine turtles, grunions*, etc.

1. Marine turtles migrate to the sandy shore during breeding season. On the sandy shore, they dig small pits and the eggs are laid. The mother covers the eggs with sand and goes away. The eggs are hatched by sun's heat and the young ones crawl to the sea.

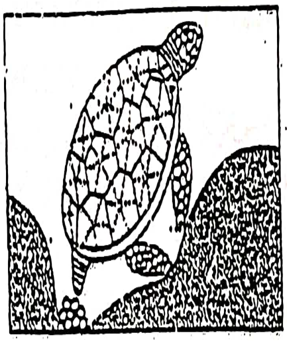


Fig.15.48: A marine turtle laying her eggs on a sandy beach.

2. The grunion, *Leuresthis tenuis* (fish) of the California coast visits the intertidal sandy shore for breeding. Thousands of these move towards the shore and the females on reaching there quickly burrow into the sand, tail first. Lying half buried, they lay the eggs and during this time the males curl around them on the surface of the sand and deposit the milt which run down the sand and fertilize the eggs. After breeding the fish return to the sea. The eggs are covered with sand by the receding tide. It has been found that the breeding migration of this fish is well correlated with the lunar cycle and that they lay the eggs only along the highest spring tide level, so that the developed eggs may be washed back into the sea by the next spring tide.

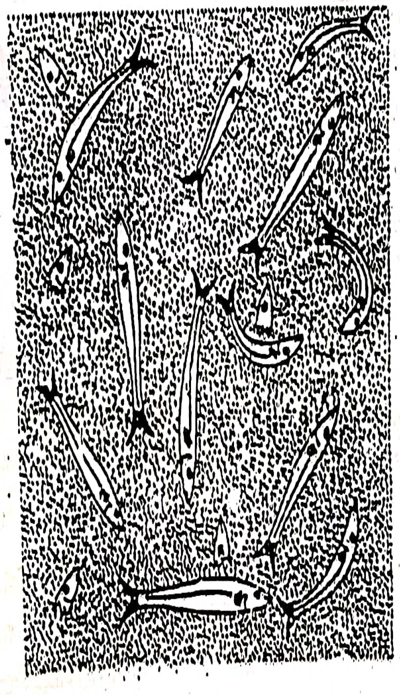


Fig.15.49: Grunions breed on a sandy beach.

regions. As the muddy shores contain salt marshes and mangrove swamps, the inhabitants possess a wide variety of adaptations. They are the following:

1. Burrowing

The muddy shore has a soft substratum. Hence most of the muddy shore forms have burrowing adaptation. The following are the burrowing structures found in muddy shore animals:

1. **Prostomium :** In *Arenicola* and *Dendronereis* a muscular conical prostomium is present. It is used for burrowing.

2. **Foot :** The foot of *Cardium* is pointed and it is used for digging.

3. **Appendages :** The appendages of *Uca* (fiddler crab) and *Albunea* are used for burrowing.

2. Tubicolous Life

Many polychaetes live in permanent or semipermanent tubes within the mud. Eg. *Arenicola* lives in a J-shaped tube; *Chaetopterus* lives in a U-shaped tube.

3. Mucous

Certain soft bodied annelids secrete mucous around their body. The mucous assists in keeping a cover of sand grains over the *body* for the purpose of protection. Eg. *Chaetopterus.*

4. Terrestrial Life

During low tide vast stretches of muddy shore is exposed to terrestrial factors. So certain intertidal muddy shore animals lead a temporary terrestrial life. Eg. *Hermit crabs, fiddler crabs, Periophthalmus, Boleophthalmus,* etc. They return to the water only occasionally to moisten their gill chambers.

5. Filter Feeding

Filter feeding is a characteristic feature of burrowing life. Filter feeding is exhibited by muddy shore animals like *Albunea, Arenicola, Chaetopterus,* etc.

Albunea burrows backwards facing the sea and lies buried. When the wave recedes, it extends its setose antennae into the retreating water. The antennae act as passive filters in the current. Then each antenna is drawn alternately through the mouth parts to scrap the plankton and other organic particles collected. The mouth parts are so arranged that the entry of sand grains is effectively prevented.

6. Deposit Feeding

Arenicola marina is a deposit feeder. It depends on the organic materials deposited in the mud. It collects food by *filter feeding* and *sand feeding* methods.

It lives in a 'J'-shaped tube. The head lies towards the small limb of 'J'. The worm swallows sand continuously by the proboscis. As more and more sand is swallowed, a funnel-like depression is formed on the surface. Water enters the tube through this funnel, percolating down through the sand which filters food materials (micro-organisms). This organically rich sand is swallowed by the worm. Now and then, the worm moves to the top of the vertical limb and defaecates in the form of castings.

7. Detritus Feeding

A number of muddy shore animals depend on detritus, which includes broken pieces of plants and animals and decaying organic materials. Eg. *Arenicola.*

8. Carnivores

Many muddy shore animals capture and devour other animals. These animals are called *carnivores.* Eg. *Ocypode crabs, hermit crabs*, etc.

9. Scavengers

Scavengers feed on dead seaweeds, dead animals and plants and animal debris. Eg. *Ocypode crabs.*

10. Respiration

When the sandy shore animal remains buried, respiration is carried out in various ways. When *Albunea* remains buried in the mud, the two long antennae are closely held together to form a tube. This tube projects above the surface. Through this tube respiratory water is taken in.

11. Protective Colouration

Certain muddy shore animals are resembling the mud. Eg. *Albunea.*

12. Broad Foot

The muddy shore animals have broad foot. This prevents sinking into the soft mud. Eg. *Aplysia.*

13. Accessory Respiration

Muddy shore animals are very often exposed to atmospheric air. Hence they have accessory respiratory organs. Eg. *Periophthalmus, Boleophthalmus,* etc.

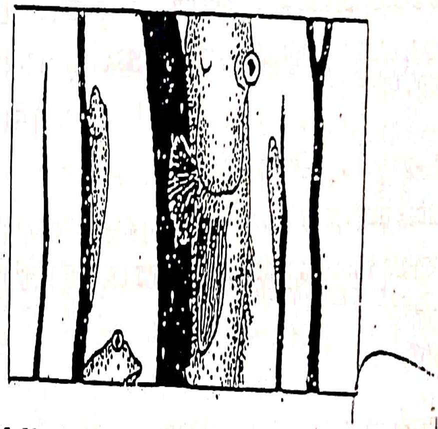


Fig.15.52: Mudskipper has large bulging eyes. It can climb on trees and is provided with accessory respiratory organs.

Coral Reef Ecosystems

Coral reefs are highly productive marine ecosystems. *Johannes* (1970) stated that *coral reefs are the most biologically productive, taxonomically diverse and esthetically celebrated of all communities.*

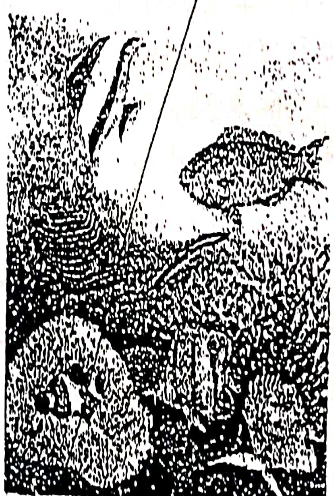


Fig.15.53: A part of coral reef ecosystem.

5. Arthropods : *Crabs, Barnacles, Lobsters, Shrimps, Limulus*, etc.

6. Molluscs : *Nautilus, Spirula, Pecten*, etc.

7. Echinoderms : *Crinoids, Starfishes, Sea urchins*, etc.

8. Fishes : *Chimaera, Harriota, Photostomias, Photocorynus, Photoblepharon, Saccopharynx, Eurypharynx, Macropharynx, Gastrostomias*, etc.

Deep Sea Adaptations :

The deep sea has a unique environment with limiting physico-chemical factors. The faunal composition is typically adapted. The following are the adaptations:

1. **Predatory Habit :** Deep sea system is away from the reach of sun's rays. Hence the deep sea environment is pitch dark. The absence of light prevents the growth of plants and photosynthetic organisms. So deep sea animals feed on other animals and are ***carnivorous*** in habit. Eg. *Gastrostomias*.

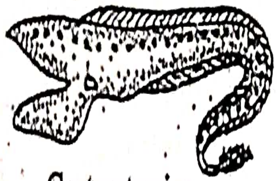


Fig.15.58: Gastrostomias, a predator of deep sea.

2. **Scavengerous Feeding :** Most of the deep sea animals feed on the bodies of surface forms that sink to the bottom. Some even feed on the excreta of the surface water animals. As low temperature prevails in the deep sea, decomposition of bodies falling from above is retarded and the deep sea animals enjoy an almost fresh diet. The food missed by the deep sea inhabitants accumulate at the bottom constituting the food supply of deep sea sedentary forms such as echinoderms and foraminiferans.

3. **Large Mouth and Distensible Stomach :** Deep sea animals are equiped with large mouth, wide buccal cavity, well developed dentition and distensible stomach. These features help the deep sea animals to swallow prey larger than themselves. For example *Chiasmodon niger* (great swallower) and

Saccopharynx ampullaceus (gulper) have distensible stomach. *Gastrostomias* has a wide mouth. In the case of *Photocorynus, Photostomias* and *Linophryne*, the dentition is well developed.

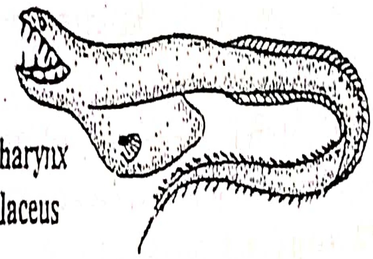


Fig.15.59: A deep sea fish with distensible stomach.

4. **Weak Endoskeleton :** In deep sea animals, the skeleton is fragile, weak, light and flexible. This is due to the uncalcified and weakly calcified skeletal system. This is caused by the *low temperature* prevailing in the deep sea. Eg. *Chimaera*.

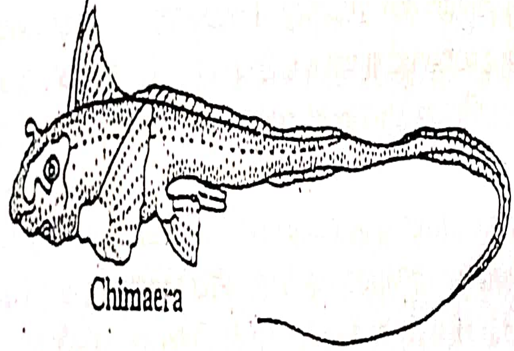


Fig.15.60: Chimaera with weak skeleton.

5. **Small Body Size :** Small body size is almost an universal character of deep sea animals, although gigantic forms have also been recorded.

Fig.15.61: Deep sea fish.

6. **Lateral-line System :** Lateral-line system is well developed in all deep sea fishes. This sense organ enables the deep sea animals to live successfully in the lightless environment inspite of the absence of eyes.

7. **Muciferous System :** The muciferous system of many deep sea fishes is developed in an extraordinary degree. They have the ability to secrete large amount of mucous. The whole body is covered with a layer of mucous. Eg. *Macruridae*. The

exact physiological use of this secretion is unknown, but it has been observed to have phosphorescent properties.

8. Eyes : The eyes of deep sea animals are well developed even though they live in an environment of constant darkness. In the fish *Gonostoma denudata* the eye is so large that it occupies nearly 2/3rd of the length of the skull.

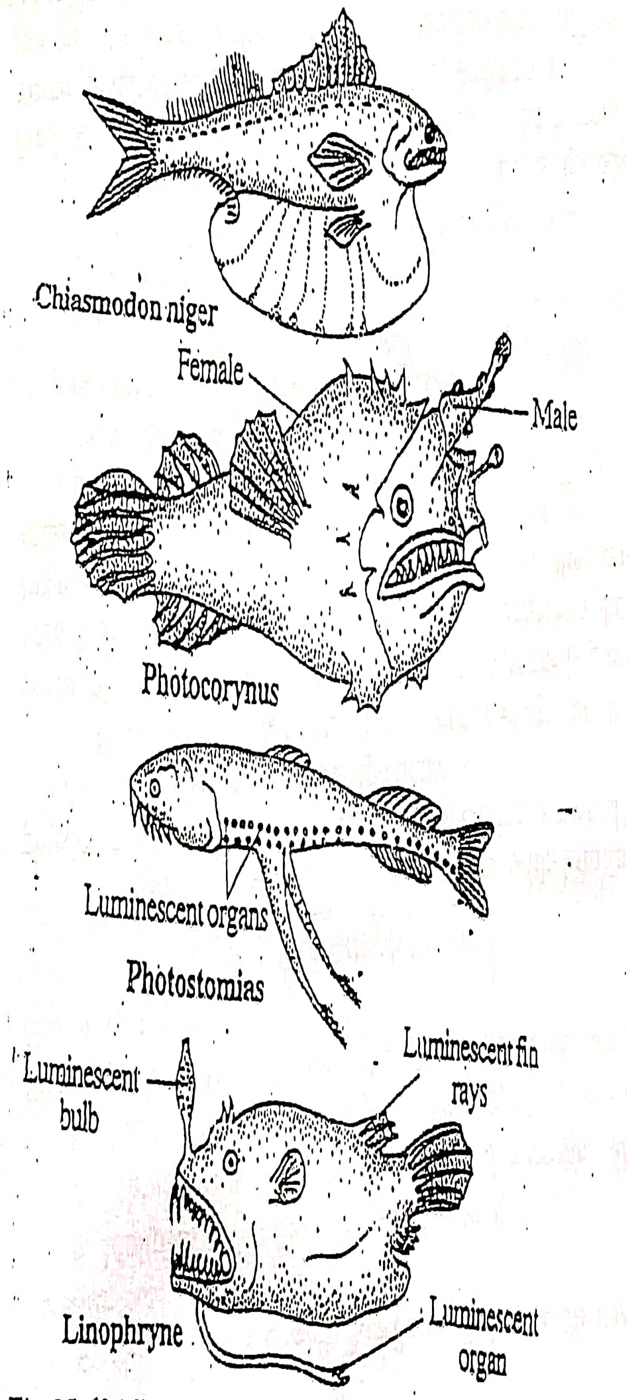


Fig.15.62: Deep sea fishes with large mouth, powerful teeth and distensible stomach.

Fishes like *Bramma longipinnis* and *Regalecus* have large eyes. Deep sea amphipods and schizopods and sergestids have also large eyes. Telescopic eyes with enlarged lens is found in *Gigantura chuni*. In deep sea fishes, *rods* are well developed and found in large numbers. Cones are either reduced or absent.

Eyeless animals of the deep sea are also equally common. Some deep sea crustaceans have reduced eyes. Deep sea cephalopods and other molluscs have no eyes. Eg. *Pecten*. In some crabs also, the eyes are reduced.

9. Sensory Organs : In deep sea animals, sense organs like antennae are well developed to compensate for the absence of eyes. The antennae are extraordinarily long. They measure 4 to 5 times the length of the body. In the shrimp *Aristaeus* the antennae are 10 to 12 times longer than the body. In *Munnipsis longicornis* (isopod crustacean) the antennae measure about 8 times the body length.

In deep sea fishes *fin rays* are considerably elongated. In *Bathypterois*, one fin ray of the pectoral fin is produced into a sensory filament. In *Stylophorus parodoxus*, the caudal fin is produced into a long filament. These structures are sensory to touch and perceive the disturbances in the surrounding water.

10. Hydrostatic Pressure : The hydrostatic pressure in the sea increases by one atmosphere for every 10 metre depth. But the deep sea animals are unaffected by the enormous pressures acting upon them in the great depths of the ocean for their tissues possess the same pressure of the surroundings.

11. Swim Bladder : A swim bladder is lacking in many deep sea fishes. This is to escape the high stress of pressure that may be experienced as depth increases.

But some species of gonostomatidae possess well developed bladders. In such fishes special structures like *retia mirabilia* capable of secreting gas are found attached to the swim bladder.

12. Sexual Adaptations : In the deep sea, it is difficult to get a mate because of the absence of light and of thin population. Hence in some cases the male is found attached to the body of the female. In angler fish, the male is very small and it is attached to the body of the female. In *Edriolynchus*, the attachment between the male and female is so close that tissues and blood vessels are interconnected.

13. Colouration : Deep sea animals have a riot of colours. Red colour seems to predominate over others. In addition, dark, violet, black and brown are quite common. Deep sea foraminiferans are known for their dark reddish and violet colouration. Starfishes, crustaceans and hydroid polyps are red in colour many copepods are dark violet.

14. Bioluminescence : *'Living light'* is a remarkable feature of deep sea animals. The living light is ***blue*** or ***green*** in colour. It is commonly called ***cold light*** because it does not produce heat. The light may be emanated in three ways, namely ***intracellular*** production, ***extracellular*** production and ***bacterial action***. The light producing organs are called *Photophores*. The photophores are located in some regions of the body or all over the body. Bioluminescence is common among fishes, crustaceans, cephalopods, coelenterates, starfishes and annelids.

Photoblepharon has a light organ under the eyes. The lantern fish *Linophryne* has fin rays studded with luminescent organs. *Gastrostomias* has two longitudinal rows of photophores. Photostomias has four longitudinal rows of luminescent organs. In angler fishes such as *Linophryne, Lophius*, etc. The light organ is situated at the tip of a movable lure and the lure can be used to draw the prey towards the mouth.

Lophius

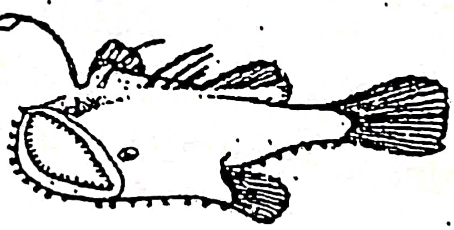


Fig.15.63: Deep sea fish.

The main function of bioluminescence is to aid vision in the abyssal darkness. It is also used to identify the mate and to attract the prey. Many fishes utilize this cold light to drive away enemies by a sudden flash of light.

ഓഓഓ

becomes sufficiently rare to be advantageous again. Moreover, any new pattern can be at an advantage because it is rare. Thus there is selection for variability and no one form will be excessively common.

The variability will be limited by the available patterns which are cryptic in the circumstances likely to be encountered by the species. If the colour forms are controlled by single major genes, this type of selection will lead to *polymorphism*. If they are controlled by genes having small additive effects, there will be variability with an array of forms intermediate between the extreme patterns. There can, of course, be a combination of both if there are some major genes and some with less distinct effects. This type of selection may well account for some of the extreme variability found in many very common cryptically coloured animals.

It is advantageous for an organism which is relatively inedible or dangerous to advertise this fact as widely as possible so that it is not repeatedly attacked and damaged. Consequently colours and patterns which are conspicuous and easily remembered are evolved.

2. Mimicry

Mimicry is defined as *"the resemblances of one organism to another or to any natural object for the purpose of concealment, protection or for some other advantage"*.

Mimicry is a kind of *adaptation*. The term mimicry was introduced in biology by *Bates* (1862).

The organism which exhibits mimicry is called a *mimic*. The organism or the object which is mimicked or imitated is called a *model*.

Mimicry is classified into two ways. On the basis of the role of mimicry, it is classified into three types, namely 1. Protective mimicry 2. Warning mimicry and 3. Aggressive mimicry. Secondly mimicry is divided into two types based on the views of two scientists. They are, 1. Mullerian mimicry and 2. Batesian mimicry.

Protective Mimicry

When mimicry offers protection to the mimic, the mimicry is called *protective mimicry*.

Examples of Protective Mimicry: 1. The leaf insect *Phyllium* lives among green leaves on trees. Its wings and legs are green like the colour of leaves. Again its legs are flattened and the wings have a venation similar to leaves. Thus the insect cannot be distinguished from the leaves and it helps the insect to escape from its predators.

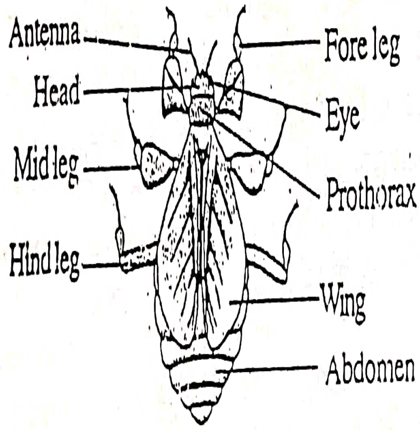


Fig.30.8: Phyllium, a leaf insect resembles a leaf.

2. The stick insect or walking stick mimics exactly the twigs.

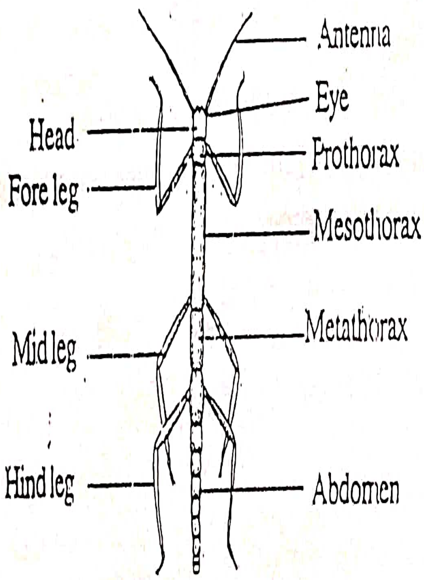


Fig.30.9: A stick insect resembles a stick.

3. The dead leaf butterfly *Kallima* mimics the dried leaves. The under surface of the wings are dull brown in colour. When it settles on the dried leaves, the wings are folded and kept vertically upwards and the dull brown colour is exposed. Thus the butterfly looks like a dried leaf.

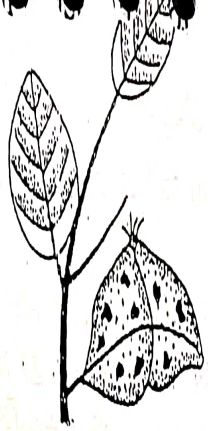


Fig.30.10: Indian leaf butterfly resembles a green leaf.

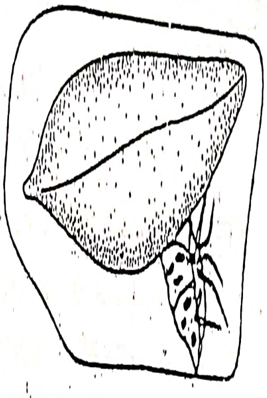


Fig.30.11: Dead leaf butterfly resembles a dried leaf.

4. The stick caterpillars of geometric moth *Solenia tetralunaria* resembles young twigs in colour and shape. Again its posture on the twig is fantastic. It is attached to the main twig by its posterior end and the entire body stands oblique to the twig so that it appears like a small branch; its pointed head resembles the terminal bud.

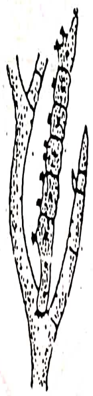


Fig.30.12: Stick caterpillar.

5. The sea-horse *Phyllopteryx eques* resembles sea-weeds because it bears numerous leaf-like outgrowths.

Fig.30.13 : Phyllopteryx eques, the sea-horse resembles sea-weeds because it bears numerous leaf-like outgrowths.

Warning Mimicry

There are some harmless or palatable animals which mimic the harmful or non-palatable animals. By this, the mimics warn the enemies and protect themselves.

Examples of Warning Mimicry : 1. The non-poisonous snake *Lycodon* mimics the poisonous krait *(Bungarus)* in its colour pattern.

2. The non-poisonous *Ptyas* mimics the poisonous cobra by producing a hissing sound.

3. The palatable viceroy butterfly *Limenitis* mimics the non-palatable monarch butterfly *Danaus* (Ref. to *Batesian mimicry*).

Aggressive Mimicry

In this mimicry, the mimics possess some lure to attract the prey. For example, if a predator resembles its prey, the predator may be able to approach its victim more easily than it could otherwise do.

Examples of Aggressive Mimicry : 1. The *bee flies* belonging to the family *Asilidae* resemble the bees. These flies lay their eggs in the colonies of bees. When the larval flies emerge, they feed upon the bees in an immature stage. This was observed by *Brower* and *Westcott* (1960). They concluded that because of their resemblance the fly can easily enter the bee colonies without any suspicion and capture and devour them.

2. In angler fish *Lophius*, the first fin ray of the dorsal fin is produced into a fleshy appendage ended with a *bait*. The bait hangs infront of the mouth and swings in all directions. If another fish tries to capture this bait, the angler fish swallows it in no time.

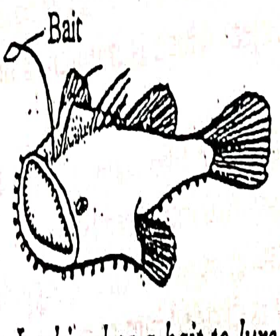


Fig.30.14: Lophius has a bait to lure the prey.

Batesian Mimicry

Batesian mimicry was explained by *Bates* (1862). It states that *an edible or harmless species resembles an inedible or harmful species for protection.*

It is an *adaptation.*

The salient features of Batesian mimicry are summarized below:

1. The model must be inedible or protected.

2. It (model) must have a conspicuous colour pattern.

3. It (model) must be very common.

4. Both model and mimic must be present in the same area at the same time.

5. The mimic should bear a very close resemblance to the model.

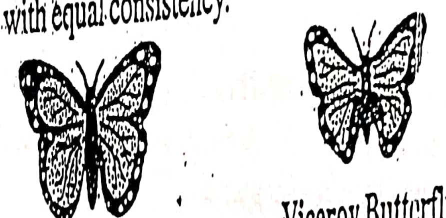
Examples for Batesian Mimicry: 1. The *Krait* (*Kattu viriyan in Tamil*) is a deadly poisonous snake. It is steel blue in colour with dominant cross bands. This dangerous snake is imitated by *Lycodon* (Vellikkol varian in Tamil) *Lycodon* is non-poisonous. So it imitates krait in its colour and possession of cross bands, *Lycodon* deceives an artist and not a biologist. A biologist can distinguish a *Lycodon* from a krait. In krait, the colour bands are absent from the head, neck and the following region. In the anterior region, the bands are pale and become prominent as they go backwards. On the tail also they are conspicuous. But in *Lycodon*, the cross bands start from the head itself. These bands are prominent in the anterior region and become pale as they go backwards. The tail is free from cross bands.

2. A very good example of Batesian mimicry is provided by the monarch butterfly *Danaus plexippus* and the viceroy butterfly *Limenitis archippus* of North America.

These two butterflies belong to two different species; but their colour pattern is strikingly similar.

The monarch butterfly is *inedible* and the viceroy butterfly is edible. Both of them are living in the same area. The monarch butterfly forms the *model* and the viceroy butterfly is the *mimic.*

The effectiveness of the mimicry possessed by the viceroy butterfly was tested by *Brower* (1958) by means of experiments with Florida scrub Jays *Cyanocitta coerulescens.* Young jays were first fed with viceroy butterflies which they ate in every test. They were then given monarch butterflies which they tried to eat but rejected violently after the first taste, and thereafter avoided them consistently. After having been presented with fifty monarch models the jays were again viceroys, which they now avoided with equal consistency.



Monarch Butterfly

Viceroy Butterfly

Fig.30.15: Batesian mimicry. The monarch butterfly is inedible and the viceroy butterfly is edible.

Thus in natural populations when an young predator bird happens to capture the monarch butterfly for the first time, it tries to avoid the viceroy butterfly. Thus the mimic is protected at the expense of the model.

The model is non-palatable and the mimic is palatable. When the number of mimics in a population is lesser, a predator bird is likely to get a distasteful model and it tries to avoid this pattern afterwards. As the mimic resembles the model, it is also avoided; thus the fitness of the mimetic form will be high. When the mimics are more in number in a population, the birds are likely to get palatable mimics. Birds then will begin their attacks on the mimic-model pattern and fitness of the mimetic form will be greatly decreased.

3. Another well known example of Batesian mimicry is provided by *bees* and *bee flies* belonging to the family *Asilidae.* Bee flies resemble bees both in colour pattern and behaviour. Bees have sting and hence harmful; bee flies are harmless and hence they mimic bees.

L.P. Brower and *J.V.Z. Brower* (1958) experimentally proved the importance of mimicry exhibited by bee flies. In an experiment, some toads were kept in a jar; bees were dropped in; the toads tried to capture the bees; the bees stung the toads on the tongue; this gave discomfort to the toads. Hence the toads not only avoided the bees but crouched motionless in a corner of their cage whenever these insects were placed in it.

Similarly, toads avoid bee flies also.

On the other hand when dragon flies are introduced into the cages, these same toads readily capture and eat them. Control toads which have never been, exposed to bee stings, readily eat both bee flies and the bees from which the stings have been removed.

Similar types of observations were made on the African species of swallow tail butterfly *Papilio dardanus* by *Dr. C.A. Clarke* and *Dr. P.M. Sheppard.*

These experiments and observations clearly show that warning colouration and mimicry are highly effective adaptations for organisms to escape from predators.

4. The black drongo *Dicrurus adsimilis* (*Karrunguruvy* in Tamil) is distasteful and aggressive. It is a savannah-inhabiting species and is often found in company with a black flycatcher *Melaenornis pammelaina*. The black flycatcher is palatable and hence is a mimic (*Cott, 1940*).

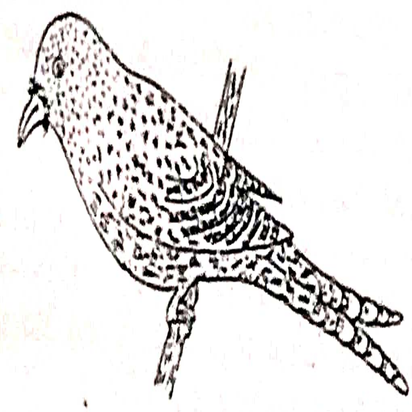


Fig.30.16: Black Drongo, inedible. It is mimicked by the edible black flycatcher.

5. Friar birds of the genus *Philemon*, living in South East Asia are gregarious, conspicuous, noisy and aggressive. *Orioles* often accompany flocks of friar birds and the two are sometimes very difficult to tell apart. The friar birds vary in appearance from region to region; the Orioles always mimic the local form with which they are co-existing. The conspicuousness, aggressiveness of the friar birds, as well as the parallel geographical variation in the two groups makes it almost certain that this is an example of Batesian mimicry in birds and that the friar birds are the models.

Mullerian Mimicry

Mullerian mimicry is based on the observations made by *Muller* (1879). In Mullerian mimicry, two or more species with an unpleasant or dangerous attitude resemble each other for the purpose of protection.

The salient features of Mullerian mimicry are summarized as follows:

1. All the species are warningly coloured and protected.
2. All the species can be equally common.
3. The resemblance between the forms is not necessarily very exact, because neither species relies on deceiving a predator, but only on reminding it of dangerous distasteful qualities.
4. The species are rarely polymorphic.

A Ctenuchid Moth resembles a Wasp : Both moth and wasp are inedible. In this case, both mimic and model are protected. The advantage of Mullerian mimicry is based on a reduction on the number of *'trials'* required by a young predator in learning to avoid inedible species. Once a bird has learned not to eat wasps, it automatically also has learned not to touch the ctenuchid moth. Thus both individuals are not destroyed by the bird. On the other hand, if a bird learns that the moth is unpalatable it will avoid wasps also and thus wasps are benefited.

Conditions Necessary for Mimicry

For successful mimicry certain conditions should be satisfied. They are

1. The mimics and models should occur in the same area.
2. Mimics should be lesser in number than the models.
3. The models should be unpalatable or harmful and
4. The imitation should be clear and visible.

protection against predators. Comouflage could also have a connection with light, heat or other forms of radiation. If this is so, certain apparently meaningless camouflage may in fact serve a purpose which is still unknown.

CAMOUFLAGE

Before concluding our survey of protective colouration and the various forms it takes, the question of camouflage in general must be considered. The object of camouflage is, by one means or another, to make the animal as indistinguishable as possible from its background.

Conspicuous markings breakup the animal's silhouette and in this way make it hard to see. An animal's outline is accentuated when the contour is repeated by its colouration, for colouration then acts as an additional outline or frame. But if it cuts the contour perpendicularly the outline is broken and the animal camouflaged. The zebra with its stripes is strikingly visible from a short distance, but in the Savannah at a distance of some fifty yards it vanishes, and game-hunters report that its perpendicular black and white stripes merge into the landscape. This is ture of all those animals which, like the tiger, have their contour broken up by perpendicular stripes. Contrasting blotches of black on a white background similarly conceal the animal. The larger snakes have various markings in which contrast is emphasized by white edges bordering dark patches. The chicks of numerous coloured species which, like the ringed plover, the woodcock, the quail, and the bittern, are hatched on the ground profit from this principle of broken contours and in consequence are hard to see against the earth or sand.

Protective Colouration may also serve to disguise an animal's appendages. A good example of this is provided by a small frog of the lower Zambesi, *Megalixalus fornasinii*. The frog, very conspicuous, has a brown band separated by two white bands in the middle of its back and on its flanks; there is also a brown band and a white band on its legs. When the frog is resting the bands of the legs from a prolongation of the bands of the body, so that the familiar silhouette of a frog is no longer noticeable. Colouration similarly designed to mask the animal's shape is not uncommon among insects, fishes, and reptiles.

The vertebrate eye, with its brightness and the regular form of the pupil and iris, is generally very visible, and efforts are made of camouflage it. Often it is lost in a black irregular band which seems to form part of a design—for example in fishes, frogs, snakes, birds, and antelopes. Often a coloured band is disposed in such a way that it crosses the eye and tends to make the black depths of the pupil disappear. Many vertebrates instinctively close their eyes in full daylight or when in danger; the lid which protects the eye is often camouflaged and exactly resembles the region above the eye-sockets. The eyelids may be covered with scales or with feathers. In the Australian lizard *Molach* the eyelids are not only scaly but are crossed by a coloured band perpendicular to the palpebral fissure.

The presence of an inconspicuous animal may be betrayed by its shadow, which is sometimes more obvious than the animal itself. Thus many crepuscular moths which spend the daylight hours on tree trunks flatten themselves against the bark to avoid casting a shadow. The *Satyridae*, in response, raise their wings and press them together so that only the dull under-surfaces can be seen. But as well as this they face in the direction of the sun so that the thin line of their shadow is as inconspicuous as possible. Many lizards lie flat against the ground and the shadow they throw is masked by lateral fringes.

As animal's presence is betrayed not only by its outline but being three-dimensional by its relief. Most invertebrates and almost alll fishes, amphibians, reptiles, and mammals have more highly coloured backs than bellies. The more intense lighting to which the back is normally exposed reduces this contrast of pigmentation and, when the animal is seen at a certain distance, creates the illusion of a flat surface. In this way small marine animals, swimming over a sandy bottom, are invisible. Sometimes this colour scheme is reversed: in certain animals which swim upside down the belly is more highly pigmented than the back. A Nile catfish, and the pelagic Nudibranchiate mollusc (*Glaucus atlanticus*) have silvery backs on which they swim, and dark blue bellies which ae visible from above. The caterpillar of *Sphinx ocellata* lives on a willow; its back is pale green and its belly a dark greyish green. But very frequently the position the caterpillar takes up is the reverse of normal. It then seems to merge into the leaf. Its rear pair of legs is fixed to a branch, and its pale back is turned towards the ground, its darker belly towards the light; its oblique line give an impression of the play of light and shade on the veins of a leaf.

Colouration designed to lower the animal's relief sometimes takes the form of a gradation of colours. The cheetah, seen from a distance, appears to be greyish and flat, thanks to a yellow skin dotted with black patches which are dense on its back and increasingly spaced out as they approach its underside. The brilliant colours of most coral-reef fishes are super-imposed on a tinted background in shaded designs.

Objections to the Adaptive Value of Colouration

1. Animals which lack concealing colouration equally fare well the mimicking forms. The *Raven* fares well like the mimicking forms. The *Raven* for example wears the same black plumage from arctic zone of tropics. It may be noted that it is not a defenceless bird because it has a strong beak and powerful claws and so it--required no protective colouration.
2. Keen-sighted enemies are not deceived by cryptic colouration. This objection is over-ruled because birds show selection in feeding and they avoid unpalatable insects.
3. Cryptic mimicry depends on colour vision and most animals lack colour vision. But bees and birds show colour perception of flowers they visit.
4. Experience and memory, are required by the enemy, of the dangerous nature of the model which the harmless forms imitate. Such memory is not proved. However, some animals possess association memories.
5. Cryptic colouration cannot ensure safety because animals hunt by scent and sound. This is true but eye-sight is important in close range and colour vision is present in some animals.
6. It is based upon anthropocentric conception.

Unit-V. ADAPTATION in Animals

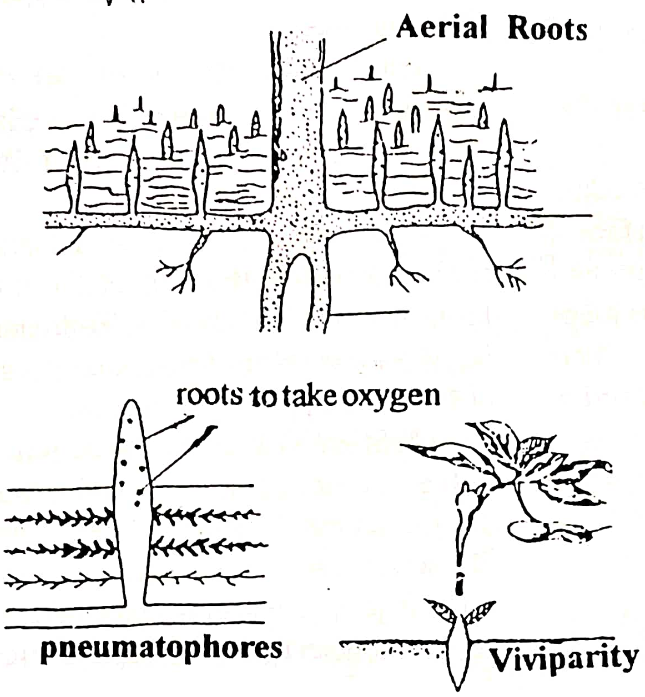


Fig. 89. Mangrove plants have pneumotophores.

As a result, the estuarine orgnism has the adaptation to survive at low oxygen (O_2) concentrations. Burrowing animals can tolerate low concentration of oxygen (anoxic conditions).

(7) Estuarine cat-fishes carry their fertilized eggs in their mouth cavity till hatching, to prevent the eggs from being washed away by current. Fig. 88.

(8) **Mangrove :** Mangrove plants are found in muddy sea and are well adapted to muddy habitat. Some adaptations are given in Fig. 89.

(i) **Aerial Roots :** This habitat is poorly aerated. Therefore, mangrove plants have aerial roots called **pneumatophores** to take oxygen from the surface.

These pneumatophores also produce a number of small nuritive roots which serve a nutritive function. Fig. 89.

(ii) **Viviparity :** In many mangrove plants, the zygote once formed develops uninterruptedly into the seedlings without the intervention of a resting stage. The seeds take root even when they are on their parental plants. Seedling is planted when they fall on the ground. Mangrove communities (Rhizophora, Avicennia, Brugulera, Gymnorhiza, Xylocarpus, Granatus, etc.) are viviparous. Fig. 89.

Terrestrial, fresh water and marine animals are found in this zone. **Barnacles, Oysters, Hermit crab, Fiddler crab and many molluscs (Littorina melanostoma, L. scabra,** etc.) are common in Mangrove swamps.

MARINE ADAPTATIONS

Marine habitat is the largest in earth. It covers about 71% of the earth's surface. The oceans offer about 300 times the habitable space provided by both the fresh water and terrestrial habitats. The

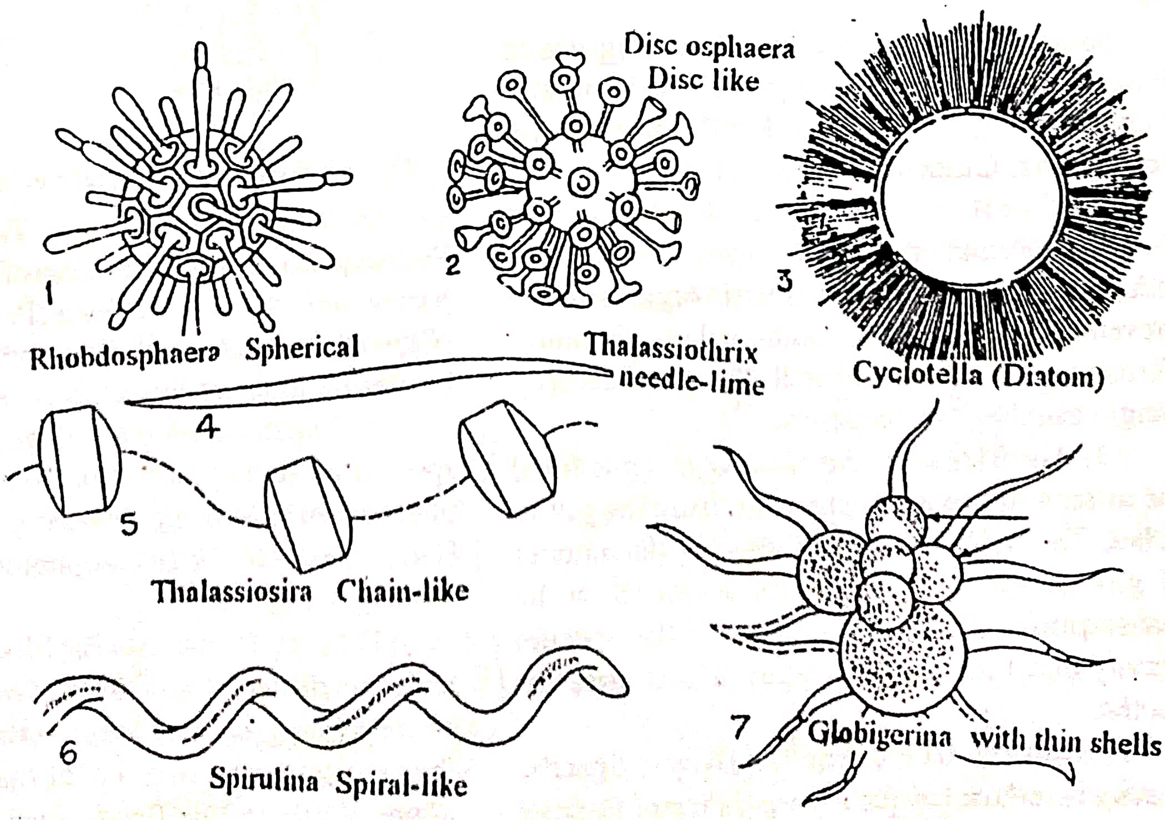


Fig. 90. Different shape of planktones well adapted for floating.

marine habitat is vast and can be divided into many zones. The physical characteristics of each zone is so varied that animals living in that area have different kinds of adaptations.

Different kinds of animal adaptations in major marine habitats are given below :

Pelagic or Planktonic Adaptations : Planktonic animals are specialized to live on the surface of the water. They have the following adaptations:

(1) **Shape :** The shape of the plankton helps them to float on the surface of the water. Their shape may be bladder-like, needle-like, hair-like, ribbon-like or branched.

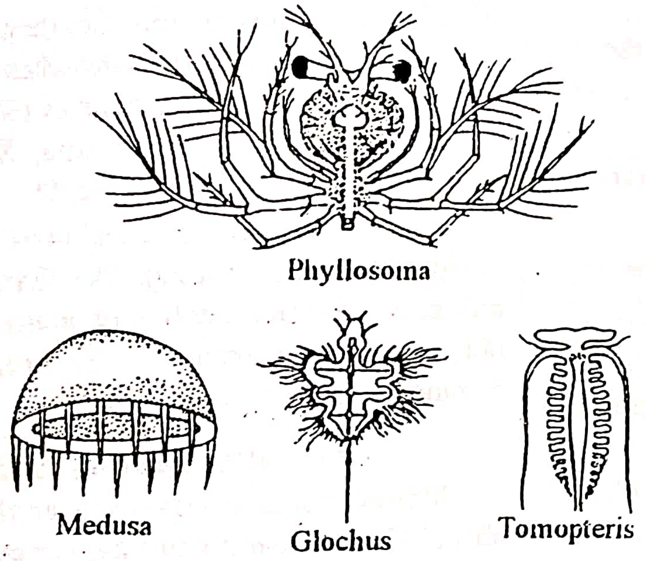


Fig. 91. Some planktons flattened body helps plankton to float.

Some pelagic animals avoid sinking due to flattened body. e.g. Medusae of coelenterates haplodiscus (turbellarian), Phyllosoma Larva, Tomopteris, Glancus, etc. Fig. 91.

(2) **Shell :** Orbulina and Globigerina (Forameniferans) have thin shells because this reduces weight and the planktonic organisms are prevented from sinking. Some pelagic foraminiferans bear pores on the shell. Pores reduce body weight and help in buoyancy.

(3) **Air Bladder :** Air bladder is a gas filled sac arising as a dorsal outgrowth from the gut in fishes. The fish is capable of altering the amount of gas in the air bladder by secretion or by reabsorption. This helps to change the specific gravity and thus regulates buoyancy at different depths.

(4) **Storage Of Fat And Oil Drops :** Specific gravity is reduced by the accumulation of fats and oil drops in many planktonic organisms. Pelagic crustaceans (Cladocerans and Copepods) contain fat in the body.

The radiolarians store oil drops in the intracapsular protoplasms. The zooplanktonic eggs have oil drops which keep them floating on the surface of water.

Code fish and many selachians store their food materials in the form of fat in their liver in large quantity. The sun fish **Mola mola** and barking shark **Cetorhinus maximus** have a thick layer of fat in the upper layer of skin.

(5) **Store Water for Floatation :** Reduction in the specific gravity has been attained in many pelagic animals by storing large amount of water. The water is stored in the tissues. The amount of water in jelly fishes may reach up to 90%. Siphonophores, heteropods, pteropods, chaetognathus,

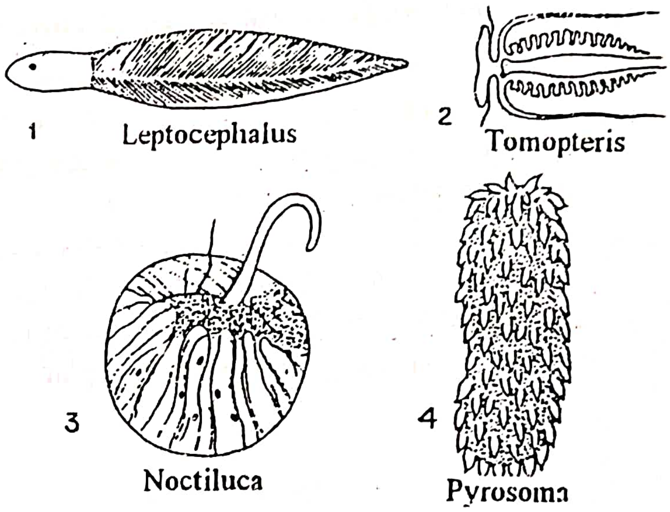


Fig. 92. Some plankton store water for floating.

etc. store large amount of water. The body of Salpa, Pyrosoma, Leptocephalus larva of eel, etc. is transparent and watery. Noctiluca (Protozoan), Berva (Ctenophore) and radiolarians reduce their weight by storing water of low salinity. Fig. 92.

(6) **Pneumatophore :** Pneumatophores are specialised zooids meant for floating in siphonophore coelenterates. e.g. Physalia, Velella, Porpita, Helistemma, etc. Pneumatophores are filled with air or gas. Fig. 93.

(7) **Special Processes for Floatation :** Planktonic organisms prevent themselves from sinking, by developing special outgrowths of the body. These outgrowths may be horns of Ceratium, spines of gobigerina, fleshy arms of echinoderm

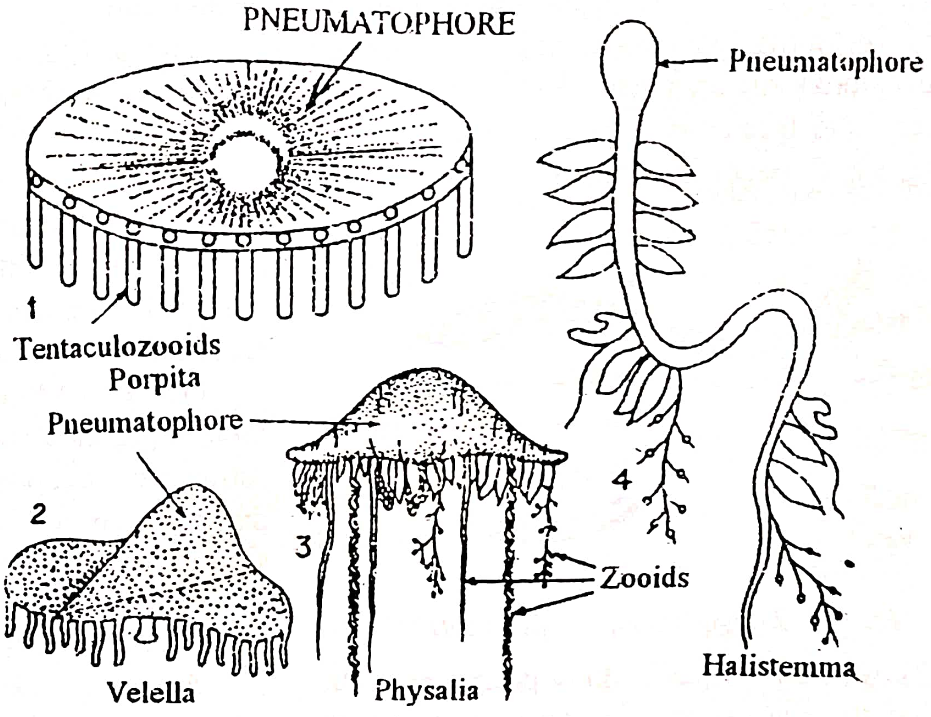


Fig. 93. Planktons bearing pneumatophores for floating on the surface of water.

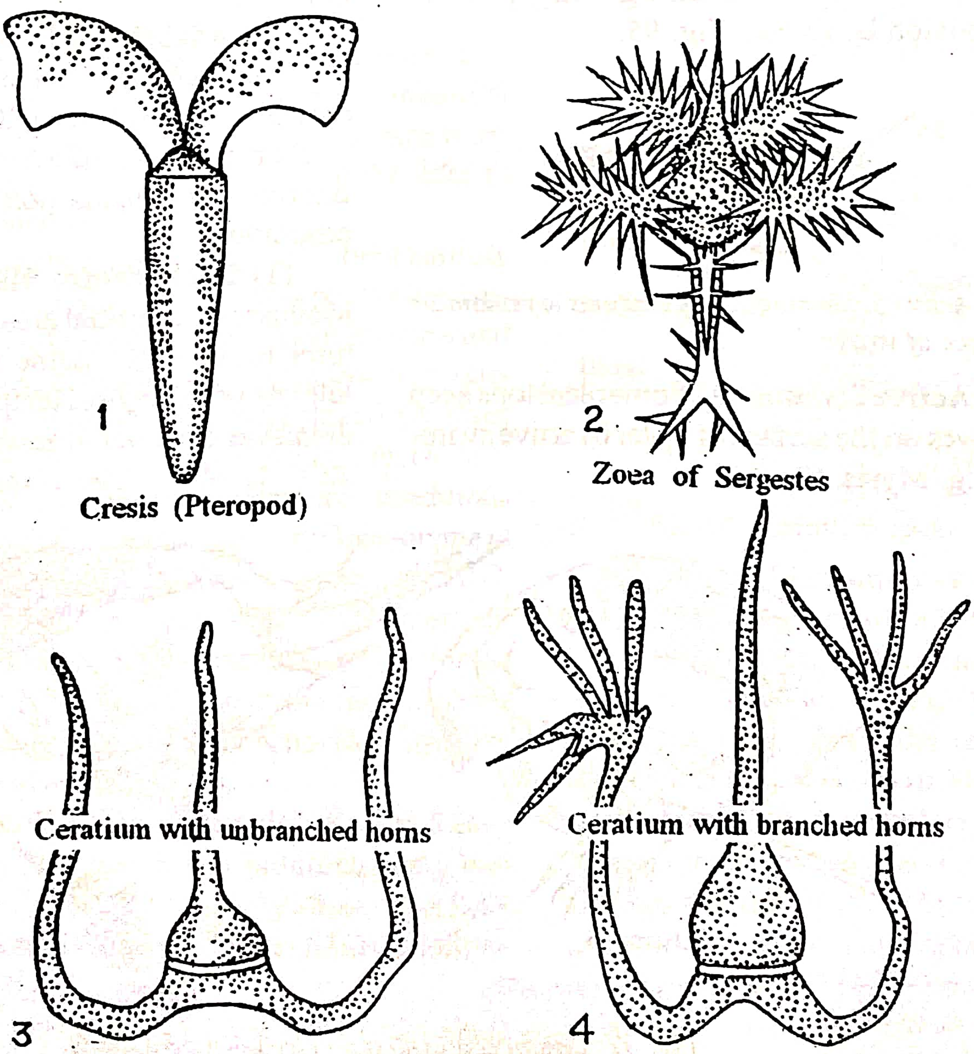


Fig. 94. Special outgrowth of the body to help in floating.

larvae, feathery setae copepods, etc. The foot of Pteropods are modified into wing-like structures that are used as oars. In the case of trochophore larva and echinoderm larvae, the cilia are used for swimming. In many planktonic organisms the appendages are elongated and branched helping them to prevent sinking. e.g. Copepod, Megalopa. Fig. 94.

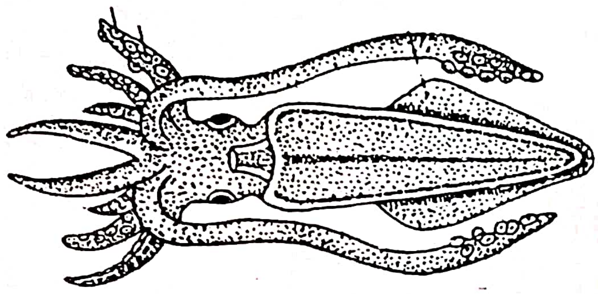


Fig. 95. Loligo has uncalcified shells.

(8) **Jet Propulsion :** Many pelagic animals maintain themselves on the surface of water by jet propulsion. The animal takes in water and ejects it with force, which enables the animals to propel either forwards or backwards. e.g. Loligo perform jet propulsion by funnel. Fig. 95.

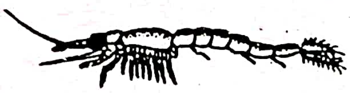


Fig. 96. Active swimming help planktons to remain on the surface of water.

(9) **Active Swimming :** Some planktons keep themselves on the surface of water by active swimming. e.g. Mysis. Fig. 96.

(10) **Uncalcified Exoskeleton :** The pelagic crustaceans have uncalcified or weakly calcified exoskeleton.

The pelagic lamellibranch Planktomya has an uncalcified shell. Among the Cephalopods, the pelagic Loligo and Oigopsidae have delicate narrow uncalcified internal shells, commonly called shellpens. These are thin when compared with the heavy calcified cuttle bone of the benthic Sepia. Among heteropods (gastropods) there is progressive reduction in the shell.

(11) **Circadian Periodicity :** Many planktonic organisms such as amphipods, copepods, ostracodes, decapod larvae, pteropods, chaetognaths, polychaetes, siphonophores, tintinnids, etc. shift to the surface waters at night and to deeper waters at the break of the day. It is an adaptation to avoid the scorching heat of the sun. Fig. 97.

Nekton : Nektons are swimming animals such as fishes, turtles, birds, mammals, cephalpods, etc. They are provided with efficient locomotory organs. All animals other than plankton are nekton.

Adaptation In Intertidal Animals

Intertidal zone is adjoining the shores. It is the area between low tides and high tides. This area is — characterised by the coming and going of tides. Intertidal organisms possess following general adaptations :

(1) **Temperature Fluctuation Tolerance :** Molluscs of intertidal areas can tolerate temperatures up to 50° C. Some intertidal animals can tolerate wide range of temperature, e.g. **Modiolus demissus** can tolerate temperatures ranging from 22°C to 40°C. The invertebrates (**Gastropod-**

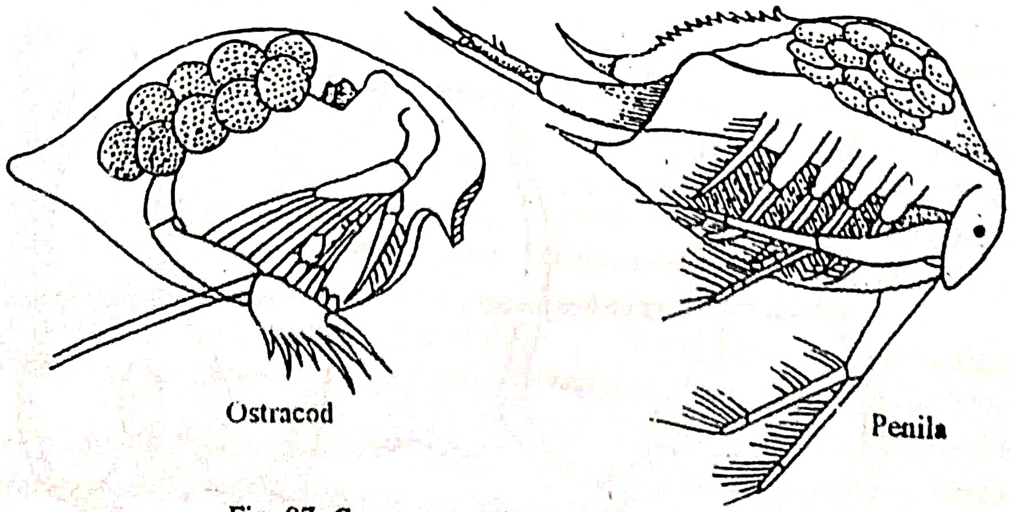


Fig. 97. Crustacean exhibiting circadian periodicity.

Nerita tesselata; Limpet — Fissurella barbadesis; Barnacle — Tetraclitea squamosa) living in the intertidal areas have limited power of thermoregulation. The Australian gastropod **Ceredium** decreases temperatures by clustering on falling tide.

The fiddler crab (**Uca pugmax**) is attracted to light in the morning, but it avoids light during hotter part of the day by retiring into the burrow. Through this diurnal phototropic rhythm, they avoid high temperature.

(2) **Tolerance To High And Low Salinity :** Intertidal animals can tolerate wider ranges of salinity. **Uca rapax** (crab) can even survive in extremely high saline (salinity 90%) water. This condition is found on the salt flats.

Many intertidal animals can survive prolonged periods of time in low salinity water. For this, they have some adaptations such as : (i) The animals transport salts actively from the medium, to the body fluids. (ii) They secrete hyposmotic urine. (iii) The permeability of the body surface to the salts to water or to both is reduced.

(3) **Drying i.e. Desiccation :** Drying is a serious hazard for intertidal animals. Intertidal animals are tolerant to desiccation for some time. They also move up and down along the tides to prevent desiccation.

(4) **Less Oxygen Supply :** Intertidal animals have to face oxygen stress. Mud-burrowing animals may be exposed to low oxygen tensions and even anaerobic conditions during low tide. Barnacles, clams, oysters, etc. tightly close themselves off from the external environment during low tide. In fact they are subject to anaerobic conditions during this period. The fiddler crab (**Uca pugmax**) is capable of surviving anoxia for 24 hours at 21°C.

(5) **Pelagic Larvae :** Most of the intertidal organisms have pelagic larval stages. The larvae are guided to the right place at the right time for setting through orientational behaviour, which is of great survival value.

Adaptations In Intertidal Rocky Shore Animals : The sea-shore containing rocks and stones is called Inter-tidal rocky shore. This zone is rich in flora and fauna. They exhibit the following adaptations :

(1) **Sedentary Life :** Intertidal rocky shore inhabitants are forced to lead a sedentary life. e.g. Sea-anemone, zoanthus, etc.

(2) **Organs Of Attachment :** In the intertidal rocky shore, tides and waves dash against the rocks. If the animals living in this habitat are not firmly attached to the rocks, they may be washed away. Hence, inhabitants of this zone develops organs for attachment. Sea anemones remain attached with the help of a pedal disc. Balanus is provided with cement gland. Lepas is provided with stalk. Molluscs (Chiton, Patella) bear broad muscular foot. Ascidian remain attached with the help of adhesive secretion. Fig. 99.

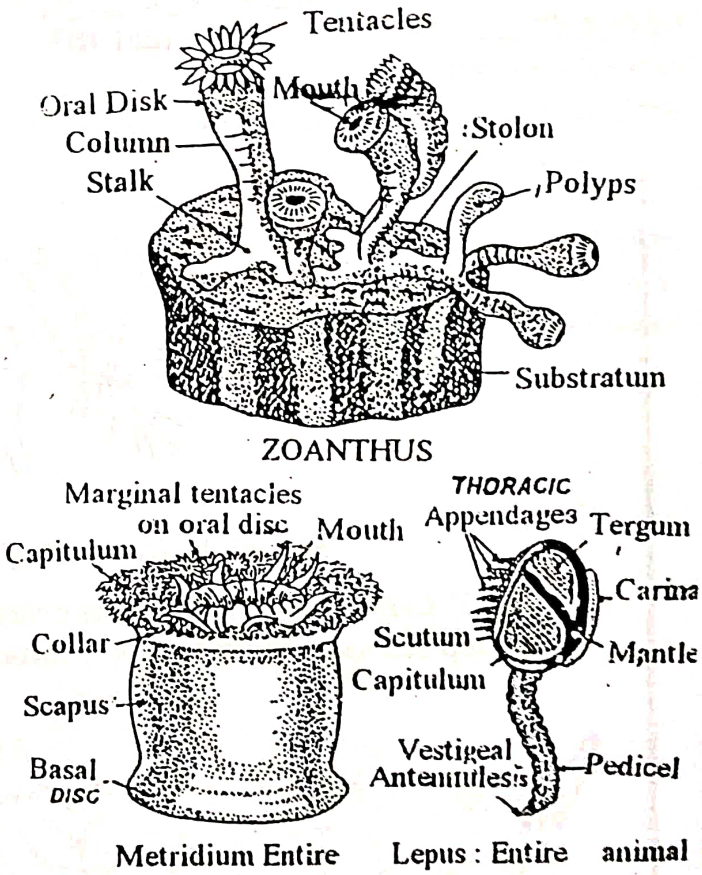


Fig. 98. Sedentary rocky shore animals.

(3) **Loss of Locomotory Organs :** Locomotory organs are absent or reduced due to sedentary mode of life, e.g. Sea-anemone, Balanus, Lepas, Ascidian, Zoanthus, etc. Fig. 98.

(4) **Drying :** Intertidal rocky shore animals face desiccation. It is met in different ways. (i) Sea anemone, Balanus, zoanthus, tunicolous polychaetes, etc. avoid desiccation by contraction. (ii) Balanus avoid desiccation by shells. (iii) Ascidian avoid it by a thick test around body. (iv) Tube dwelling animals (Tubifex) avoid desiccation due to living in tubes. (v) Molluscans close the shells tightly and protect desiccation of body.

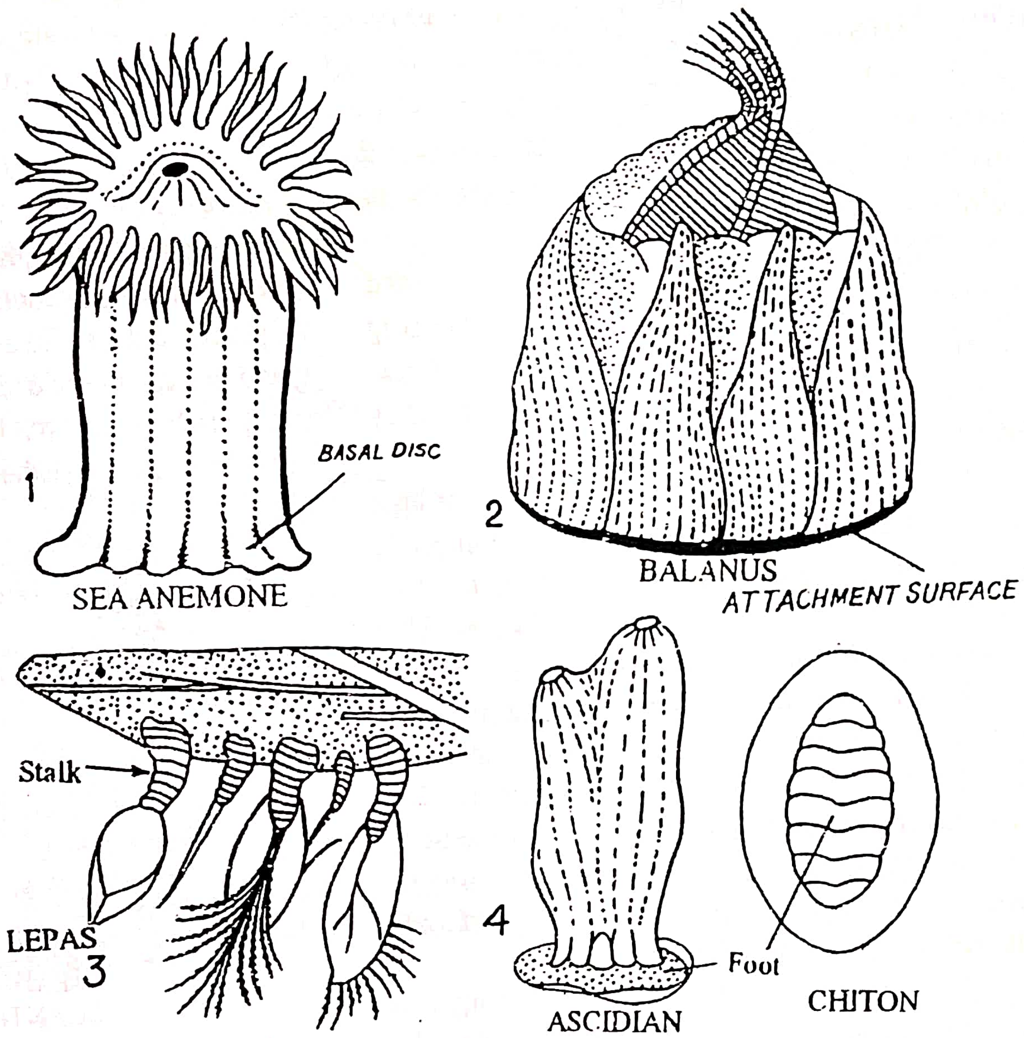


Fig. 99. Various kinds of attachment organs in intertidal rocky shore habitat.

(5) **Defensive Organs :** Rocky shore animals develop defensive mechanisms. Crustaceans bear spines on their body. e.g. Rock lobster. Shell of Murex are provided with spines Fig. 100. Tentacles of sea-anemones bear a defensive organ nematocysts. Sponges and Ascidians are provided with spicules.

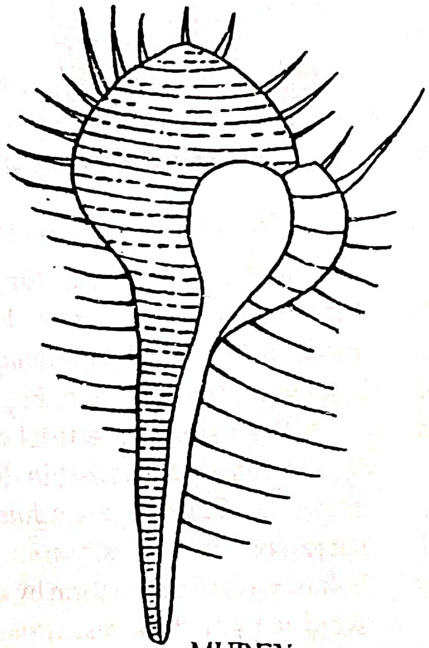


Fig. 100. Rocky shore animal are protected by spines.

(6) **Hiding :** Some rocky shore animals take the advantage of their habitat for hiding. They escape from the bounding action of tides by living in the cvreices of rocks. Some animals live among see-weeds.

(7) **Flattened Body :** Planaria, Botryllus have flattened body which reduces friction.

(8) **Regeneration :** The body of animals (Brittle star), inhabiting rocky shores, is frequently broken by the dashing of winds and stones. Therefore, they have great power of regeneration.

Adaptations For Intertidal Sandy Shore : Intertidal sandy shore is vast land of sand grains of various sizes. It is unfavourable for animal life due to shifting substratum and ceaseless pounding of breaking waves. Animals of the intertidal sandy shore bear following adaptations :

(1) **Burrowing Habit :** Most of the animals of the sandy shore can quickly burrow into the sand. Many burrowing structures are found in them :

(i) Proboscis of Balanoglossus helps in burrowing.

(ii) Prostonium of Glycera is muscular and conical. It help in burrowing.

(iii) Shells of some molluscs (Dentalium, Solen, Donax) helps in burrowing.

(iv) Foot of some animals (Dentaium, Solen, Cardium, Mya, Solencurtis, etc.) helps in burrowing.

(v) Appendages of crabs and other crustaceans help them to dig holes and bury into the sand.

(vi) Some annelids live permanently in tubes within the sand. e.g. Arenicola (J-shaped burrow). Fig. 101.

(2) **Mucous Secretion :** Some annelids (Lumbriconereis, Aricia, Prionospio, etc.) secrete mucous around their body to keep the body moist.

(3) **Terrestrial Life :** Some intertidal sandy shore animals (Ghost crab — Ocypoda, Hermit crabs, Fiddler crabs — **Uca pugmax**) lead a temporary terrestrial life. They return to the water only occasionally to moisten their gill chambers.

(4) **Filter Feeding :** Filter feeding is exhibited by sandy shore animals leading burrowing life. e.g. Terebella, Donax, Albunea, Emerita, Mactra, etc.

Albunea and Emerita burrow backwards facing the sea and lie buried. When the wave recedes, they extend their antennae into the retreating water. The antennae act as passive filters in the current.

Some molluscs (Donax, Mactra, Timoclea) also exhibit filter feeding. These molluscs burrow beneath the surface with their muscular foot. They extend their long siphon to the surface of the sand. The siphon takes in a current of water laden with suspended food particles. Around the inhalent siphon, complex rings of tentacles remain present. These tentacles prevent sand grains from entering the mantle cavity.

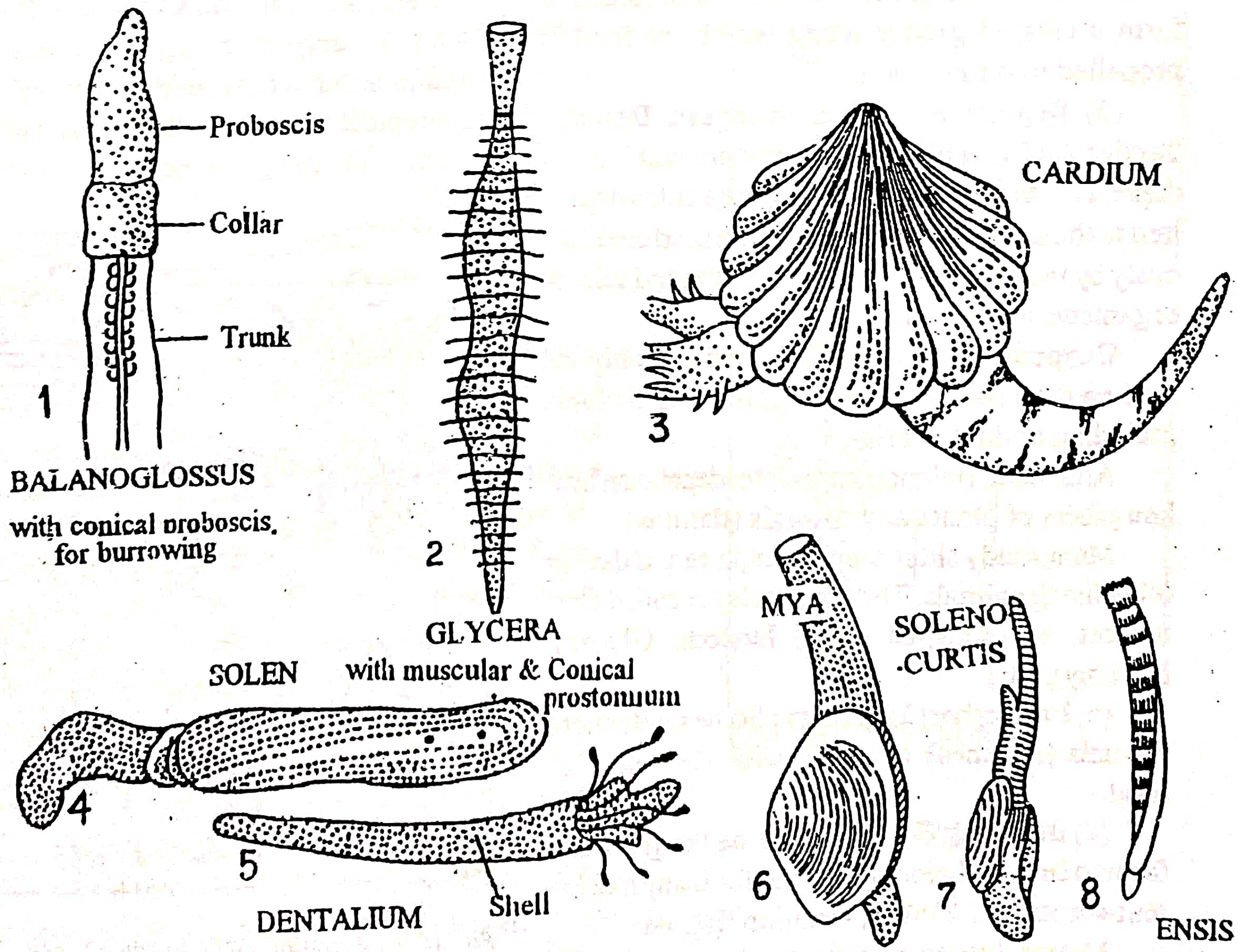


Fig. 101. Sandy shore animals with burrowing structures.

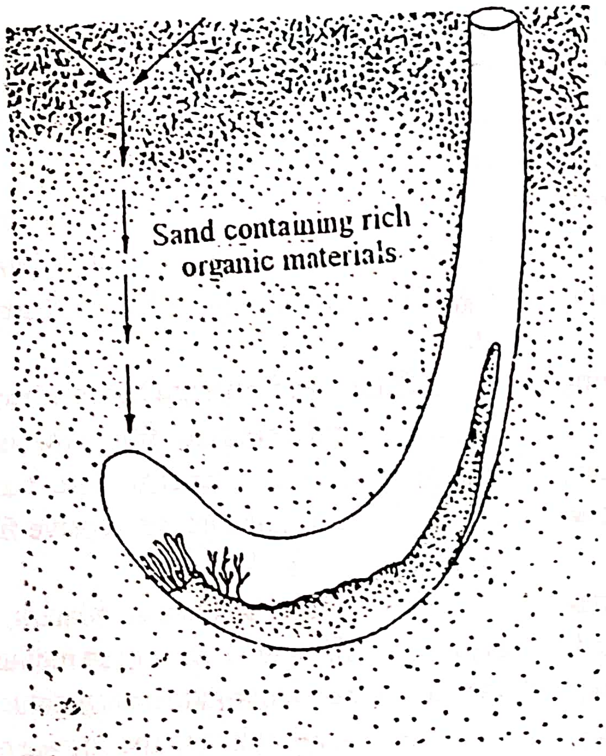


Fig. 102. Arenicola with filter feeding mechanism.

Terebella has developed a novel method to collect the micro-organisms from the sand. It lives in tube and is a filter feeder. The head bears numerous tentacles. One side of the tentacle is ciliated. This side of the tentacle can be folded to form a ciliated groove along which the food is propelled into the mouth.

(5) **Deposit Feeder, Scavengers, Detritus Feeder And Carnivores : Arenicola marina** is a deposit feeder. It feeds on micro-organisms deposited in the sand. The worm swallows sand continuously by the proboscis and along with sand micro-organisms are also ingested.

Ocypods Crabs and **Tabitrid** amiphipods feed on dead sea weeds, dead animals and plants including animal debris.

Arenicola, Balanoglossus, etc. depend on broken pieces of plants and animals (detritus).

Many sandy shore animals capture and devour other living animals. These animals are called Carnivores. e.g. Ocypod crabs, Isopods, Glycera, Nephthys, etc.

(6) **Protective Coloration :** Some sandy shore animals (Albunea) resemble with the colour of sand.

(7) **Breeding Ground ;** Marine sandy habitat forms a suitable breeding ground for many marine animals such as Turtles, Grunion fish, etc.

Marine turtles migrate to the sandy shore during breeding season. Females dig small pits on the sandy shore where tides do not reach. Now female lays her eggs in pit. She covers the eggs with sand and returns to sea. The young ones at once start crawling to the sea. This is an instinctive behaviour. Fig. 103A.

The grunion fish (**Leuresthes tenuis**) of the California coast, visits the intertidal sandy beach for breeding. They breed in a very interesting way and exhibit lunar periodicity in this act. Thousands of grunion fish reach sandy shore riding on tides. Females on reaching there quickly burrow into the sand. They sink into the sand through tail. Lying half buried, they lay the eggs and during this time the males curl around them on the surface of the sand and deposit the milt pass down the sand and fertilize the eggs. After breeding they return on lunar tidal wave. The eggs are covered with sand by the receding tide. On hatching, young grunion fish are carried back into the sea by the next spring tide. Fig. 103B.

Adaptations To Muddy Shore : Intertidal muddy shores occur in beaches, where wave action is less. Many muddy beaches are occupied by salt marshes and mangrove swamps. Salt marshes are found in temperate regions while Mangrove swamps occur in the muddy shores of tropical and sub-tropical region. Adaptations in animals of muddy shore are given below :

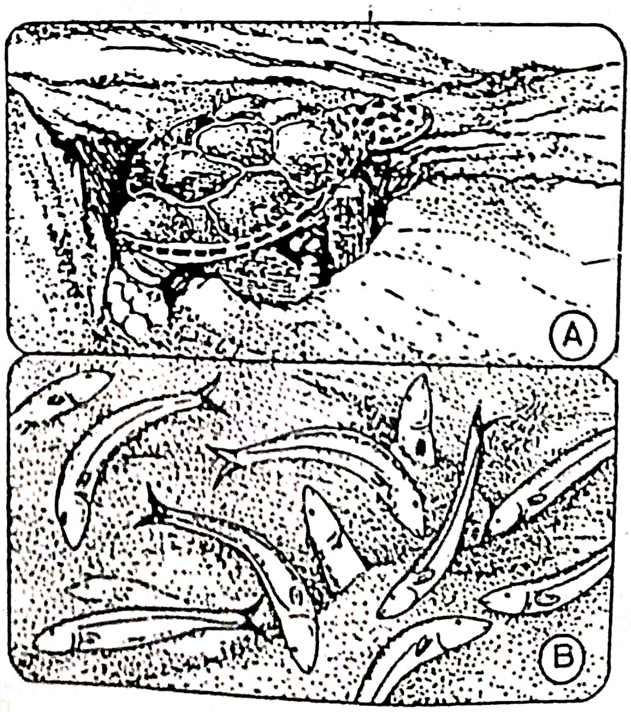


Fig. 103A. A marine turtle laying her eggs on a sandy beach. 103B. A Grunions breed on a sandy beach.

(1) **Burrowing :** Muddy shore has a soft substratum. Hence, most of the muddy shore animals has burrowing adaptations. Burrowing structures are Prostomium, foot, appendages, etc. (See Arenicola, Cardium, Uca in sandy shore adaptations).

(2) **Tubicolous Life :** Chaetopterus lives in U-shaped tube (Fig. 104), Arenicola lives in a J-shaped tube (Fig. 102).

(3) **Filter Feeding :** (Consult intertidal sandy shore adaptations).

(4) **Protective Colouration :** (same as sandy shore).

(5) **Broad Foot :** The muddy shore animals have broad foot. This helps in locomotion on soft substratum and prevents them sinking into the mud. e.g., **Aplysia.**

(6) **Accessary Respiratory Organs :** Periophthalamus, Boleophthalamus, etc. respire through skin and other accessory respiratory organs bcause these are less exposed to air.

Deep Sea Adaptations

Marine habitat is the largest habitat of our planet. Sea water contains high concentrations of salts. Adaptive features of sea fauna are as follows :

1. **Shape and Size :** Marine animals have a stream-lined body. This minimises the resistance of water in movement. Due to pressure **Torpedo, Sawfish, Pleuronectus, etc.** have become dorso-ventrally flattened. Figs. 106 & 108. The size of marine animals is usually small except that of chimaera, sharks and whales.

2. **Skeleton :** Temperature of water in deep sea always remains low. In low temperature, animals are less capable of synthesizing calcium. As a result of which, skeleton of deep sea animals are soft and non-calcareous. Calcareous sponges are completely absent in deep sea. Exoskeleton of deep sea corals and protozoans are made up of silica. The shells of molluscs are brittle. Endoskeleton of fishes are non-calcareous.

3. **Pigmentation :** Lack of light in deep sea causes lack of pigmentation in the body of animals.

4. **Food and Nutrition :** For food, (i) They kill and eat others, (ii) Use the wastes removed by the body of surface dwellers, (iii) Depend on plants and animals living on the surface of water. Deep sea fishes are predators hence, their mouth is wide, jaws and teeth are strong. Stomach is long and elastic. Chaetopterus live in U-shaped tube and get food from one end of the tube.

5. **Number :** Lack of the limiting factors of environment restricts the density of population in deep sea.

6. **Eye :** Some deep sea animals lack eye (crabs), some have vestigial eye (Pectene) while some have well-developed eye (Torpedo). Some fishes, for example **Gigantura,** have telescopic eyes.

7. **Sensory Organs :** Long sensory antenna compensates the absence of less developed eyes. **Munnipsis longicornis** crustaceans have eight times longer antenna than its body. **Aristeas** (Shrimps) have 10 - 12 times bigger antenna than his body. Fin rays present in the body of animals of this region is also very long. One fin ray of pectoral girdle modifies in sensory fibre in Bathypterois.

8. **Lateral Line System :** Lateral line system is found on both lateral sides of the body. It function as chemo and thermo receptors.

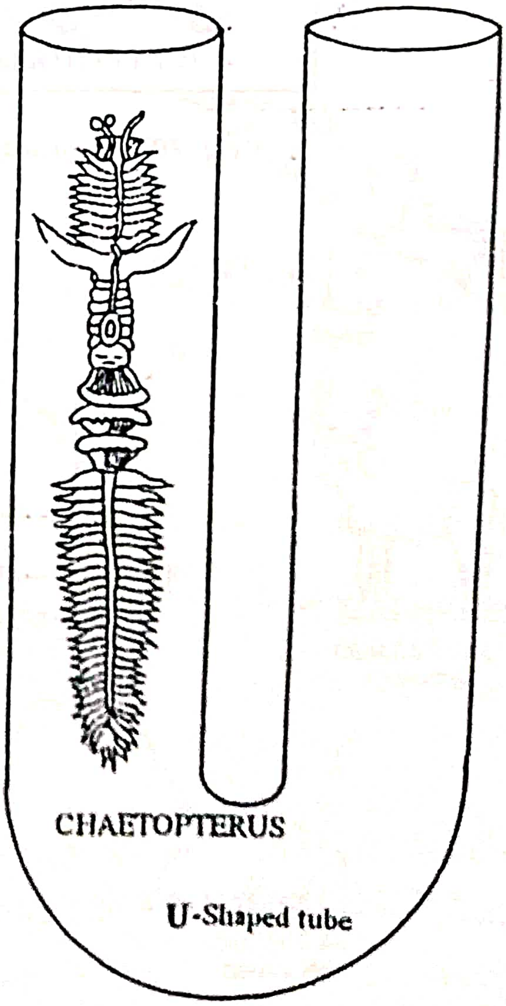


Fig. 104. U shaped burrow of chaetopterus.

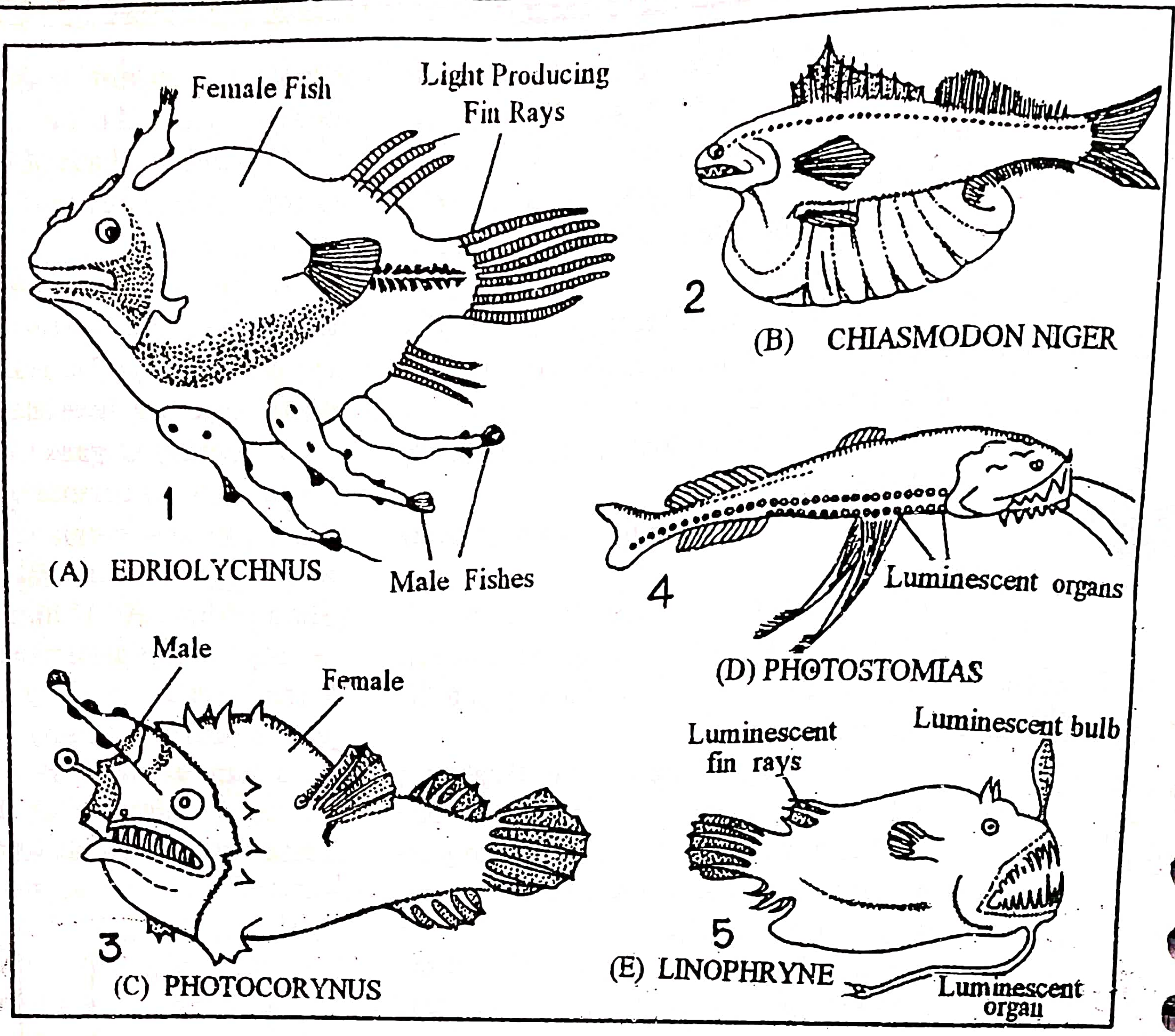


Fig. 105. Deep sea fishes with large mouth, powerful teeth and light producing organs.

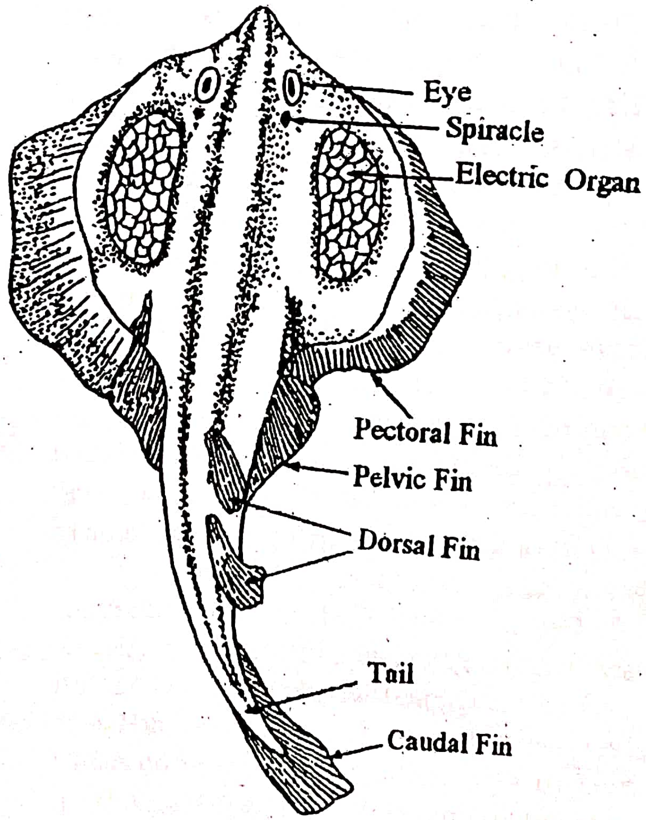


Fig. 106. Torpedo (Electric ray) with electric organ.

feeders. The spined loach has sensory barbels around its mouth. A strange fish is *Gigrinocheilus*, from south East Asia. It is vegetarian and grazes algae from rocks with special rasp like folds inside its lips.

TYPES OF ADAPTATIONS

According to *Lull* the animals show different types of adaptations and some important types are mentioned below:

(i) Cursorial adaptation
(ii) Fossorial adaptation
(iii) Aquatic adaptation
(iv) Scansorial adaptation
(v) Volant adaptation
(vi) Cave adaptation
(vii) Desert adaptation

Cursorial Adaptation

There are many vertebrates which are adapted for running. These are also called *speed adaptations* as they are meant for fast locomotion for searchng the food and for escaping their enemies. Various snake lizards, dinosaurs, ornithischia, flightless birds like emus, noas, rheas etc and mammals for example kangaroos, bandicoots, wolf, hares, dogs, cats and leopards etc. exhibit cursorial adaptations. They are characterized by the following changes. For running or speed they develop following features:

Body Contour

Animals coming under this category whether terrestrial, aquatic or aerial have the body mouided extrenally in such a way as to offer the least resistance to the medium through which they pass. Thus the body is streamlined with head and neck extended forward and ears thrown back to offer least resistance to air.

Limbs

Lengthening of the limbs is the basic feature in cursorial adaptation that has been done without the elongation of bone by being changed from plantigrade to digitigrade condition and in some to the unguligrade where there is reduction of digits. Fibula and ulna of the limbs tend to reduce and in exclusively locomotory limbs these bones are mere vestiges. These modification, however, affect the rotatory movement of the limbs which in these cases is restricted in one plane.

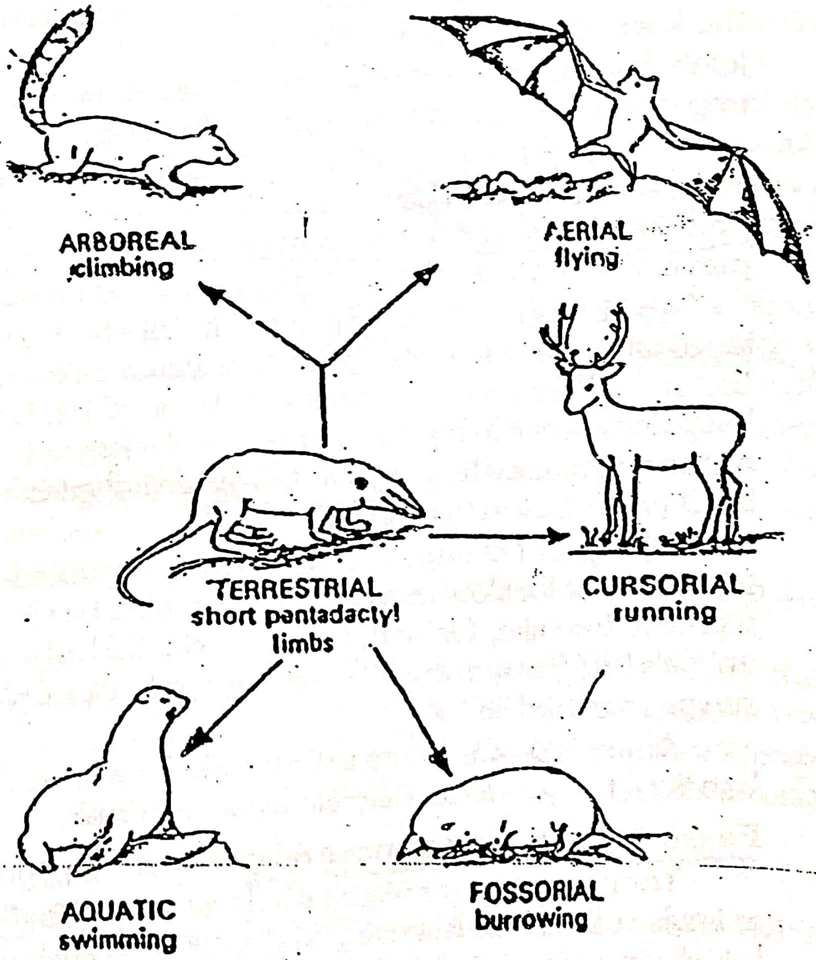


Fig. 16.6. Showing various types of adaptation in mammals.

(a) *Indetermining digital reduction* : It is feasible to avoid interference between forelimbs during running as dogs hind limbs come forwards and outside of the forelimbs at high speed. Besides this, there is a tendency toward rigid limitation of movement in the bones of the ankel and wrist, knees and elbow between the digits in unguli grade animals.

(b) *Lengthening of distalia of limbs* : Distal elements of food and skin, and hand and forearm become lengthened for the purpose of increasing the length of stride and speed of movement. The powerful muscles are attached at the proximal end of the limbs. Muscles are shortened and thickly which increase their power and speed of contraction.

(c) *Loss of digits* : Plantigarde means that the entire palm or sole rests on the ground. Wrist and ankle are not raised from the ground Bear, racoon are plantigrade. Plantigrade animals are generally five toed with a few exceptions; digitigrade animals are four toed, while unguligrade are four, three, two or even one toed. *Chlamydosaurus* (frilled lizard of Australia) is five toed, but when it runs on its hind feet, the outer and inner toes are raised off the ground and the animals makes a three toed track. Hence speed adaptation has its influence in determing digital reduction. Kangaroo Forelimbs are also often used as efficient organs of prehension.

(d) *Reduction of ulna and fibula* : In cursorial animals the ulna in the forelimbs and fubula in the hindlimbs are reduced as an adaptation to fast running. The clavicle bones of the pectoral girdle also tend to reduce. In horse the ulna and fibula are represented by splint bones.

(e) *Loss of universal movement* : The free movement of limb segments at the joints is lost except at the ball and socket joint of hip and shoulder. The limbs neither bent at the knee joint or elbow joint nor at the ankel and wrist joints. It avoids bending of the food and helps in a powerful impact on the ground and to get a better speed.

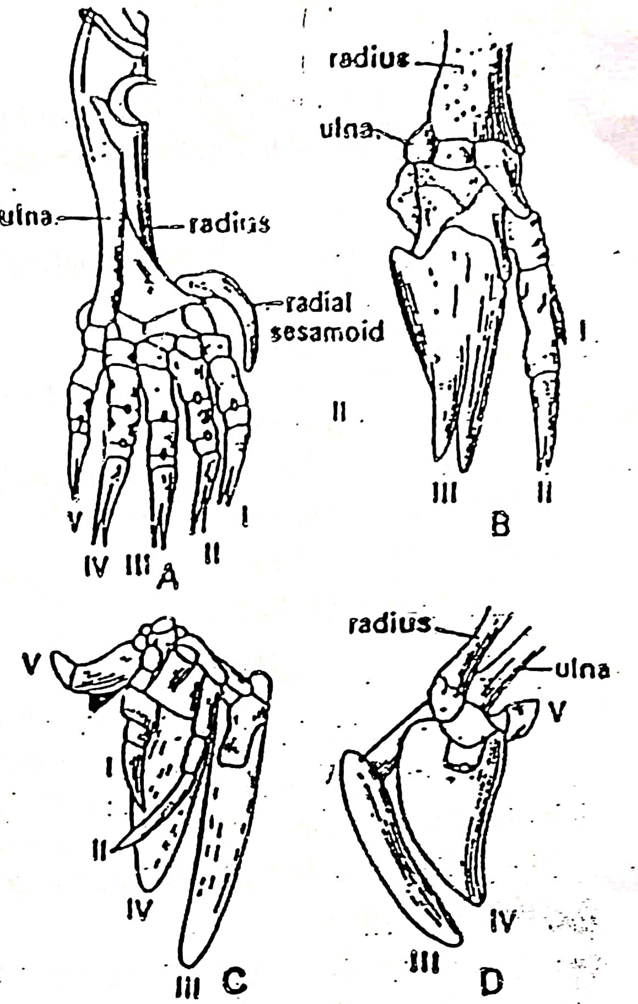


Fig. 16.7. Fossorial adaptations in the hands of moles. A—Common mole, B—Golden mole, C-D—Marsupial moles.

(f) *Musculature of limbs and development spring ligaments* : In cursorial forms the muscles of limbs are powerful. These are shortened and thickened restricted in the proximal part of the limbs. Their power and speed of contraction is markedly increased, because the muscles are attached to the proximal part of the limbs, a set of spring ligaments is developed on the posterior surface of the foot.

(g) *Tail as a balancing organ* : The tail when present acts as an organ of conterpoise. In semi errect biped tail is used as counterpoise. In kangaroo and in dinosaurs, tail serves as a prop like a third limb, when the animal rests without coming down on all four limbs. Tail is short and heavy in larger forms (i.e. kangaroo), while in lightly built creatures it is long and slender (e.g. Jerboa, dinosaurs). It includes also the shortening of neck (e.g. Jerboa, though cervical vertebrae are seven) and prevalence of mental precocity. A tail is present even in running birds.

(h) *Bipedal changes* : In bipedal forms cursorial adaptation include reduction of forelimbs (role is used for resting or for slow movement while feeding. Fore limbs are also used efficient organs of preheusion. In flightless bird like, Ostrich, Emi, Rhea etc. the hind limbs have become more efficient drivers. In some animals like Kangaroo and other marsupials, the tail plays an important role. Being a powerful organ it serves as a thrid limb.

Animals showing cursorial adaptations are Ostrich, Emu, Rhea, Kiwi and Casswary among birds, and bandicoot, tiger, horse, deer etc. among mammals.

Fossorial or Sub-terranean Adaptations burrowing Adaptation.

There are many animals which are adapted to dig the burrows either for food or retreat. Those animals, whose food is above ground, are not so perfectly modified as those whose food is found underground. Initially the fossorial adaptations are seen in the primitive and unambitious animals which are defenceless. This category includes *Caecilians, Ophiosaurs, Sphenodon, Uromastix*, desert snakes etc. The fossorial modifications are given in the following lines :

dig- to make a hole

1. Body contour

Body is somewhat fusiform or spindle shaped to offer a little resistance to subterranean passage. However, snakes and caecillians have cylindrical body for burrowing. The head tapers anteriorly to form a sort of snow that helps in burrowing.

Neck : In burrowing mammals neck is often absent or it is very short, so that their conical head directly passes into the trunk.

Limbs : Forelimbs as well as hindlimbs are very short and stout in wholly fossorial forms and the former are specially modified for digging. The hand is broad and stout with long claws. In the common mole (*Condylura*) the hand is as broad as the height of the body and hence digging is very rapidly accomplished. The broadening of hand in mole and echidna occurs by the addition of another bone (osfalciforme) to the originally fully developed five fingers, which increases the breadth of the palm. In the golden mole (*Chrysochloris*) there are four fingers, of which the two middle ones are elongated with powerful claws of digging. The bones of forelimbs are very strong and bear prominent tuberosities for muscular attachment. The proximal end of the humerus bears ridge for te insecrtion of powerful shoulder muscles and those help in rotating the hand.

The *olecranon process* is specially large in fossorial forms as it is for the insertion of the powerful triceps muscles that serve to straighten the arm. The shoulders are narrow and their sockets are near to each other. They are strengthened by short clavicles and large T-shaped *episternum* as well as paired coracoids which extend from shoulder socket to presternum. In other mammals these bones do not reach the breast bone.

In the *Hind limb*, the femur is not so much robust as the humerus. Tibia and fibula are partially fused and the calcaneium (heel bone) is very prominent. In talpa there is a large sesamoid bone at the side of the tibia like os falciforme of the hand. In monotremes the proximal end of fibula is anteriorly prolonged.

Skeleton : The shoulder girdle is a strong forwardly placed. Scapula and sternum are lengthened and shift the forelimbs still forward. The clavicles are thick and articulate both with acromian process of scapula and the humerous. The union strengthens the shoulders and enables them to withstand immense muscular strain involved during the process of digging. The shoulders are also strengthend by the large T shaped episternum and the coracoid.

Skull : The skull of subterrane animals is compact and roughly conical. The suture between the bones of the skull are obliterated. The jaw bones are reduced. In burrowing mammals the zygomatic arch is absent and auditory region is reduced. The dentition is also reduced and jaw muscles are poorly developed.

Vertebral column : The vertebrae of the cervical, sacral and lumbar regions are fused to give firmness and strength in pushing the animal through the earth. In moles, talpa and hedge hogs, intercentral ossicles are present between lumbar vertebrae which strengthen the vertebral column. In Armadillos an extra pair of zygopophyses are present in the lumbar vertebrae.

Skin : Skin of burrowing animals is protected with mucus (annelids), chitin (arthropods), scales (reptile, and caecilians) and fur or spines (mammals).

Hibernation : Hibernation or winter sleep is another feature of burrowing forms, living beyond the limits of the tropics. It is due to the absence of green vegetation which supports insects and worms. It is a device to tide over unfavourable climate. An exception to this is the lemmg (*Myodes lemmus*), which feeds on vegetable (grass roots and stalks, shoots of dwarf birch, reindeer, lichens and mosses); they form long gallies through the turf or under the snow.

Tail

Long tail is unconvenient for subterranean life, it is short in hedge hog, ratel and wood chuck. Tail is short in *Talpa* and other burrowing forms. It serves as a valuable tactile organs.

Eyes and ears

The eyes tend to become reduced as they are of no use in dark habitat as in caecellian and desert snakes. The external pinnae also tend to disappear as in moles. These ae probably obstructions to burrowing life. However in *Otter* and *Geomyidae* external pinnae ae small. In monotremes these pinnae are absent.

Desert Adaptation

Digging Mechanism

A small and stout help in digging and is truncated and upturned at the tip as in hog-nosed snake (*Heterodon*). In *Talpa* a prenasal bone is found at the tip of the nose. The incisor teeth are forwardly directed as in pocket gophers e.g., tusks of elephants are suited for digging. In some cases even the canines are also effective organs as in swine.

Desert Adaptations

Desert has got problem of water conservtion, defence from animals and escape from the hot sand particles which might injure the sense organs. The primary need of desert forms is to get adequate quantity of moisture. *Molach*, a desert lizard, having hygroscopic skin, absorbs water like blotting paper. Camel stores the water in stomach in its special water storing cells, Hump helps in the production of metabolic water in greatest proportions. The water conservation into plants is done by reservoir of large masses of water pulp and thickened bark to hold water. To avoid the evaporation the plants are usually baflers.

For self defence from the extreme heat of the sand and and climate, the sense organs are protected either by developing scales, abundant long lashes along with long neck and hair. In plants, the important defensive needs are: anchorage and spinescence. Venomous nature of desert plants is also helpful.

The fauna and flora of desert is pecularily adapted to these drastic conditions and the modifications are mostly associated with the conservative and avaliability of water, protection against extreme heat and cold and obtaining food.

1. Obtaining water

Higher animals connot live long without drinking water and need water at frequent intervals. But scarcity of water is the primary cause of desert conditions. Free water is not avaliable for miles together. The main source of moisture of the animals are the juices of food, whether plant sap or the blood of the prey. The desert animals try to utilize water from every avaliable source.

Terrestrial animals lose water their body in three ways:

(a) By evaporation through the body surface,

(b) By exhailing moisture during respiration, and

(c) By expelling water or liquid urine during excretion. Animals living in desert have developed no means to avoid water loss by all these ways.

(a) To avoid evaporation through body surface

Desert animals have developed protective measures to avoid loss of water by evaporating through general body surface :

1. Desert animals develop thick hide which avoids water loss by perspiration.
2. Number of sweat glands in the skin of desert animals is very much reduced or in some cases these are totally absent.
3. Scorpions and reptiles have developed almost impermeable outer covering. Scales and spines are developed on the exposed surfaces. Examples are sand lizard (*Moloch*) and horn toad (*Phyrnosoma*).
4. Some desert animals produce epighrams and secretions to prevent loss of water. Desert insects are wax proof.
5. Certain animals like camel have developed more tolerance to heat. Their body temperature fluctuates more with the atmosphere and thus reduce the amount of moisture lost through sweating and panting. Camel can loose 30 percent its body weight without showing signs of distress and protein deficiencies. Mostly animals loose water from the blood which becomes thick or dehydrated causing death. In camel water is lost from the tissue and not from blood.

(b) To avoid loss of moisture during respiration

Many desert mammals cool the exhaled air in their nose, before it is expelled out through nostrils. As a result mositure condenses in the nose and is not lost as water vapours along the exhaled air.

(c) To avoid loss of water during excretion

This is brought about by excerting concentrated urine or urine in semisoid state. Desert rats and kangaroo rats excrete urine which contains 24% urea, where as man urine contains 6% urea. Even reptiles, insecis and birds pass their body wastes in such concentrated state as uric acid that little or no moisture is lost in the process. Uric acid can be crystalized in the body. In camel also the amount of urea in the urine increases and the amount of urine decreaes with the reduction in the amount of water conserved in the body.

(d) Other methods of conserving water

1. Desert animals are mostly burrowing and nocturnal. They come out of their burrows either late in night or early in the moming, when percentage of moisture in air almost equal to the moisture in their burrow. The burrow protects them against scorching sunlight and avoids in excessive water loss due to evaporation. *Schmdit* and *Nielsons* have found that relative humidity in the burrows was 30-50%, where as outside the burrow in the air it was 0-15%. Certain animals are found to plug the mouth of their burrows during day time.
2. Desert animals are active only for a brief period during those part of the year where water and food are available for rest of the time. They remain dormant lying hidden in some burrows or holes.
3. *Uromastix* is said to store water in large intestine and in camel water is stored in the rumen along with fermenting food in a pocket like structure. But the recent investigation suggest that the liquid present in rumen in not actually water but its composition is similar to digestive juices and its amount is for less than present in the stomach of other animals.

Protection against sand stroms

The desert are often found to have dust stroms in the afternoon and these are sometimes so strong that heaps of sand are washed away very swiftly. The important organs affected by the drifting sand and the nostrils, ears and eyes. Several mechanisms have been evolved to protect these structures:

1. Nostrils in majority of desert animals are either reduced to small pinholes or they are protected with complicated valves. For example, in camel, the nostrils can be closed in the same way as eyes are closed by the eyelids. In sand swimming lizards the nostrils are turned upwards and are thus protected from sand.
2. Eyelids exhibit various modifications and are capable of closing the eyes without hindering the vision. In *Mabuya* the lower eyelid is much enlarged and transparent and can be drawn on the eye like the nictitating membrane. It spreads over the complete eye thus protecting it against the sand but permitting vision. In certain other lizards (*Ablepharus*), the lower eyelid is permanantly streched over the eye and fused with the lower margin of upper eyelid. It is wholly transparent thus their eyes are permanantly losed but are able to preceive vision. In camel the eyes are high on the head and are protected by long and thick eye lashes.
3. Ears are often protected with fringers of scales or hairs. In *Phrynocephallus* and *Pharynosoma* the air apertures are absent. Nocturnal animals need a sharp sense of hearing. Jack rabbits, hares etc. have large ears.

Colour

The colouration in desert animals is found to match with the sand dunes. The body hues are often grey, brown or red, which is often in harmony with the ground. Often the colour is dull which blends with the surroundings. Thus blending colouration furnishes protection from the attack of predators by camuflaging. In the absence of definite places for concealment, the colour blending is the only measure of protection and the animals cannot be easily detected in moonlit night. Warning colouration is exhibited by poisonous animals like lizards, *Heloderma*, rattle snake, spiders and red ants. In general, desert animals are less heavily pigmented and are comparatively small size.

65

Example of desert flora

Date palm having long deep exploring roots and horizontally spreading roots; plants with thin salty encrustations or hairs over the leaves.

Examples of desert fauna

Moloch (desert lizard) having hygroscopic skin, absorbs water like blotting paper. Its surface is covered with thorn like scales.

A few animals absorb dew drops along the vegetation food. Desert rabbit, turtles and wood rat (*Neotoma*) eat succulent plants for their water need. Jerboas, Kangaroo rat (*Dipodomys*), pocket mouse (*Pesognathus*) and other desert rodents eat dry seeds and vegetation and quench their thirst. Carnivorous animals feed on their prey for food and water Grasshopper mice of western North America, long eared hedgehog of Sahara and a *Marsupial mulgara inhabit* the arid zone eat insects and small rodents.

Self defence against scroching sun

For self defence from the extreme heat of the sand and arid climate, the animals adapt themselves as follows:

In digging species of reptiles, the *nostrils* are directed upward instead of forward. In most snakes they are protected by complicated valves or they reduced to pin holes. Camel's nostrils are capable of being closed like eyelids.

The eyes of *Typhlops* (burrowing desert snake) are overhung by the head sheath. In camels, eyes are covered by abundant long lashes. These are further protected by reflecting heat of the sand by possessing the long neck e.g. ostrich camel.

In lizard *Mabuya*, the lower lip becomes enlarged with a transparent window in it.

The ear opening is either small or protected by fringes or scales or they may be abolished. In camel it is protected by hairs.

Camel has the power of moisture conservation, eyes are covered by abundant eyelashes; nostrils are being closed like eyelids, ears are protected by hairs; and possession of only two toes.

Possession of venom is another desert adaptation (self defence). All the snakes have poisonous fangs or stings e.g., rattle snake.

All the poisonous spiders are found in desert. Scorpions are also present.

Gazelle resembles the general colouring of landscape (white on sand, dark grey on valcanic rocks). It is a good example of self defense.

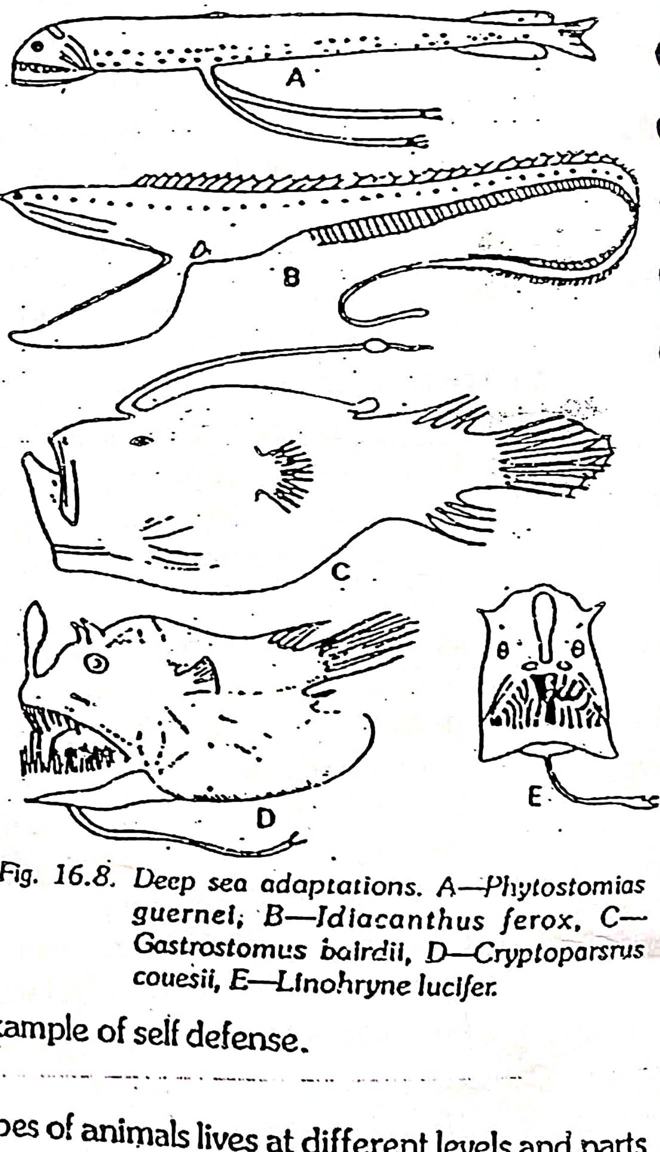


Fig. 16.8. Deep sea adaptations. A—Phytostomias guernei; B—Idiacanthus ferox, C—Gastrostomus bairdii, D—Cryptoparsrus couesii, E—Linohryne lucifer.

Deep Sea Adaptations

The seas occupy the major part of earth Different types of animals lives at different levels and parts of the seas. Many of them are sessile and some are creeping. Both these categories are collectively called *epifauna*. Some burrowing animals which are also called the *infauna*, are also found in seas. The characteristics of the deep sea are intense cold, utter absence of movement, profound darkness, enormous pressure, the absence of phytoplankton, scarcity of food and resulting competition, and soft bottom.

Gunther enumerated the following adaptations in deep sea forms.

(i) Fragile and weak body

Since there is no motion in deep sea water, the animal forms are delicate, landslender and possess stile like legs. Examples are the fragile glass sponge-the *Hexactinellida,* long legged crab-the *Kaempfferia,* the fishes like *Macrurus* and *Chimaera* with tails drawn out into long points.

(ii) Colouration and Biolumniscence

The deep sea forms are more or less unifrom as far as their colouration is concerned. They have simple, dull brown or gray body colour. In some forms like *Macrurus,* the belly is black and the top silvery because of lumniscence coming from below. This lumniscence is an important feature of deep sea forms belonging to fishes, cephalopod molluscs and crustaceous. In this, the animals produce their own light by means of their specialized organs the lumniescent organs as in "*lanternfish*" and "*hatchet fish*". The bioluminescence is basically used as a bait to attract their prey, and secondly gives recognition of the sex as in *Photostomias* fish. In some invertebrates, light producing organs are scattered over the body and in others there are special luminscent organs as stated above.

(iii) Receptors

Some deep sea fishes exhibit greatly enlarged eyes or the so called *telescopic eyes* which are highly effective in visioning lights of very low intensity. Examples are *Arggropelens, Pandulus, Cyritsome longlpinnis* and *Regalecus.* Some other forms have very small eyes of little apparent use, and still others lose their eyes completely. Examples of eyeless forms forms are *Eulima* and *Pecteus.* In those forms where the eyes are small there is a reciprocally large development of olfactory organs in higher forms like fishes. The deep sea forms also have a well developed pressure sense. In water the turbulence is created by nearby animals which are recognized by the nature of turbulence created by them.

(iv) Food

Most of the forms living in deep sea are scavangers or predators. The scavanging forms are foraminifera, holothurians, crustaceans and molluscs. Similarly predaceous forms are *Melanocetus, Saccopharynx* and *Eupharynx.* The forms have wide mouths, strong dentition, destensible stomaches and the ability to swallow prey larger than themselves. Due to the scarcity of food in the deep sea there is "eat-or be-eaten" mode of existence.

(v) Soft bottom

Due to the soft substratum, msot animals living at the bottom of sea develop long appendages, abundant spines, stalks or other means of support, as illustrated by the tripod fish, limb shells, and crinoids. These appendages are sensory and act as tango-receptors as well as chemoreceptors.

Adaptation in Fishes

The fishes live in an astonishing variety of habitats from the perpetual night of the abyss to the lighted surface spaces of the Oceans. They are found along wave battered rocky shores and coral reefs, on sandy bays and muddy estuaries and in the mid depths of the ocean where there is no bottom, no surface, no shore. They are to be found in great rivers and vast lakes, in rushing torrent and in still canals, in stagnant ponds and farm ditch and in caves deep under ground and as deep as the abyss. They live happily beneath the pack ice of polar seas and in tropical swamps. They are to be found in hot springs of Arabia where the water temperature may reach as high as 40°C and even more astonishing in the thermal soda springs of lake Magadi in Kenya where the temperature of the water or rather of the soda liquor, ranges from 27°C to 49°C. With very few exceptions the Dead sea, which is too salty to support any form of life, is a notable one, wherever, there is water, there will be fish. As is only to be expected, there is within this huge group, conditioned by this fantastic variety of habitats, a vast diversity of fishes we are accustomed to think of the cigar shaped fishes : the typical fish. But adapted to particular surroundings or to specialized ways of life, there are flat fishes, round fishes, ribbon fishes, tubular fishes and so on. There is, in fact, no such thing is a typical fish at least far as shape is concerned.

66

Adaptation in shape and symmetry

The flat fishes or *Pleuronectidae* habitually lie on the ground upon on side of the body, some species on the left side some on the right. In adaptation to this abnormal position the symmetry of the two side in many respect altered. If a flat fish is held in a vertical position and compared with any ordinary fish many of the paired organs will be seen to be present in their usual position, on each side there is a lateral line, a pectoral and pelvic for and a gill cover or operculum.

There are three chief pecularities which a flat fish resting on the ground with its original plane symmetry in a horizontal position, differs from an ordinary fish which swims with its plane of symmetry vertical : (1) the position of both eyes on the upper side, (2) The absence of pigments from the lower side of body (3) the extension of the dorsal fin along the line outside the dorsal eye instead of between the eyes as in ot fishes.

The flat fishes are evidently descended from ordinary symmetrical ancestors which swam in a vertical position, and in the course of evolution their structure has undergone the modificaions which are mo suitable for their peculiar position and habits. To have a flattened shape and to lie upon the sand or gravel at the sea bottom, is a mode of life which offers distinct advantages to a fish in the way of food concleament from enemies, and has been adopted by other fishes as well as flat fishes. *Skates* for instance, and the *Anglers* have adopted this mode of life, but they have always rested on the ground in the verti position and either were originally or have become flattened dorsoventrally without alternation of their original symmetry.

Rounded fishes

An excellent example of the rounded shape is the huge sun fish which may grow to a length of 10 ft and attain a weight of more than 1000 kg. The body is slightly compressed and is a very deep oval shape. The sun fish which is quite well known in British waters in summer is sometimes called the *Headfish*, this is an appropriate name, for it does have the appearance of being composed of an enormous head t two fins, and no more. There is a large and high dorsal fin and immediately opposite to it, a large and deep anal fin. The body ends abruptly behind these fins, giving the impression that the tail has been amputated.

Other fishes with shortened rounded bodies are the *puffer fish* and the *Porcupine fish*. These too a slow swimmers and would be easy prey for swift predators because of no bodily armour of spines. The sunfish lacking spines, has an armour of tough bristle some 7.5 cm thick.

Tubular fishes

At the opposite extreme to the shortened rounded fishes are those with long narrow tubular bodies. The best known of these is undoubtedly, the common *Eel*. The ribbon fishes are also basically tubul fishes, but their bodies have been so laterally compressed that the original tube has been superceeded by the ribbon from which they derive their name. This body shape has been evolved to suit particular livir conditions and has resulted in a loss of speed, but nothing like the same extent as in the shortened rounded fishes.

Cigar shaped fishes

The typical cigar shaped fishes occupy a position midway between these two extremes. But between them and the extremes at either end, there is very conceivable body shape. Perhaps the most extraordinar is that of the *sea horse*, another very popular aquarium exhibit. In the sea horse, the head is bent at right angle to the body giving the impression of a definite neck. The body is curved and bears a number of membranous projections giving it a broken outline. The tail is prehensile-a feature unique among fishes and is used by the fish to attach itself to plants. The sea horse swims in an unright position, propelling itself by means of its fins, and is, therefore, a very slow swimmer. It possesses nothing that can be described a armour and is completly defence less. But the upright position and the broken outline do help to render i inconspicious among the upright swaying water plants amongs which it lives and to which it attaches itse by its tail.

Scansorial Adaptation

Animals developing the ability to live on tree that is why this type of adaptation is also called the *arboreal* or *climbing adaptation*. The animals of this kind are categorized into following types:

(i) Wall or rock climbers
(ii) Terrestrio-arboreal forms
(iii) Arboreal forms

(i) Wall or Rock climbers

There are some animals which are adapted to cling on wall and rock and for this purpose they develop adhesive and vaccum pads in the limbs. The excellent example of this category comes from the wall lizard-*Hemidactylus*.

(ii) Terrestro-arboreal forms

Some animals can climb on the tree but they prefer to live on ground under the trees. Such animals have prehensile limbs for the purpose. The excellent example is *Funambulus*.

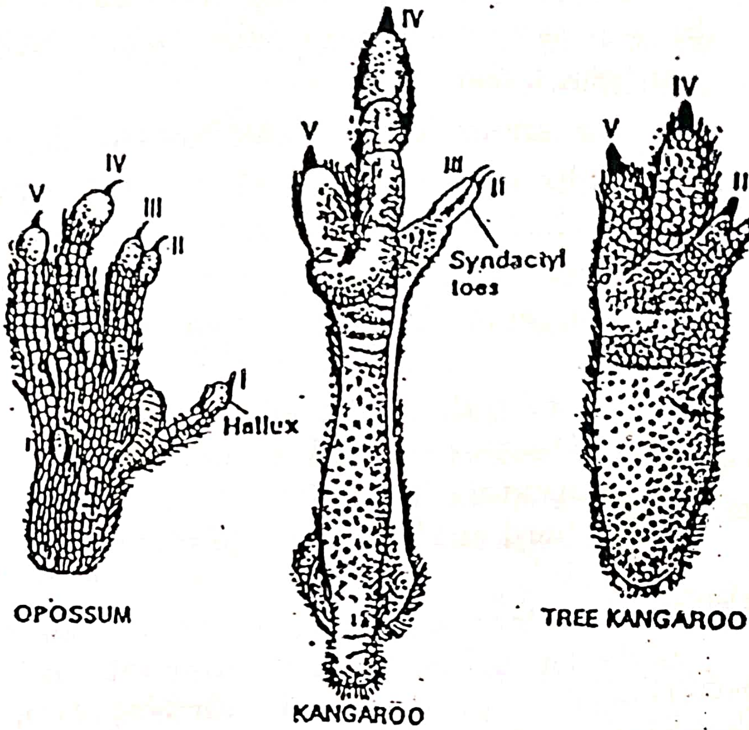


Fig. 16.9. Hind feet of Marsupials.

(iii) Arboreal forms

Animals living on trees and rarely coming down to ground are the arboreal forms. Animals like calotes, chameleon, lemur etc. usually move on the upper surface of the branches that is why these animals are also called *branch runners*. There are some forms like sloths, flying lemur and bats that rest hanging by powerful claws of their limbs. These animals are constituted in such a manner that they cannot walk up on the branches but rest and move suspended from them by powerful recurved claws of their limbs. Bats hang themselves by the claws of hind limbs and sloths by forelimbs claws. Sometimes, sloth takes rest by keeping its back on the nearby branch and relaxes the hold of one more of its feet, but the inverted position

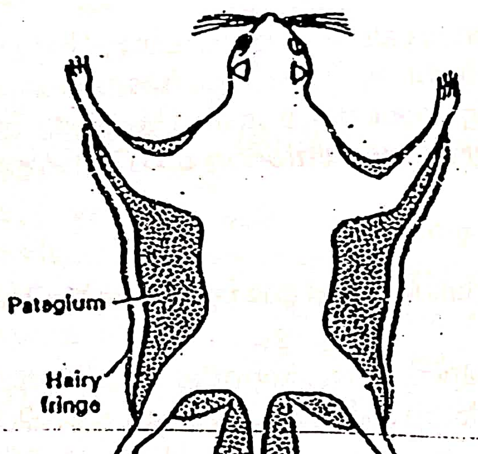


Fig. 16.10. Flying Squirrel.

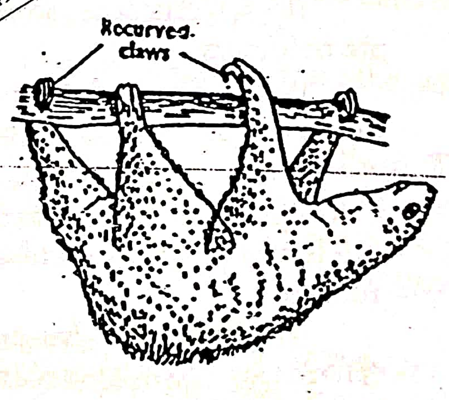


Fig. 16.11. Two toed sloth suspended on a branch.

Aquatic Adaptations.

feathers. The feathers provide an insulation, thereby preventing the loss of heat and maintaining a constant temperature of the body.

Flight Muscles and keeled sternum : In birds there is well developed keeled sternum to provide space to flight muscles for their attachment and smooth functioning. There are many types of flight muscles in birds, but two of them are very common—*Pectoralis major* and *pectoralis minor.* Pectoralis minor is for the upstroke and major for the down stroke and propulsion of the body.

Beak and Teeth : In birds, the teeth are absent, basically to make the body light. At to compensate it they develop a sharp, light but strong beak. It also assists in prehension.

Perching ability : In birds, forelimbs are modified into wings. Hind limbs develop perching ability to rest on the trees which are supposed to be safer than the ground. This ability is seen in all flying birds.

Tail : The tail is short in birds and a bears a series of tail feathers or rectrices arranged in a fan like manner and serves as a ruddar in steering and as a counter balance in perching.

Pneumatic bones : In birds, the bones are hollow, pneumatic and less ossified. The basic purpose of these changes is to make the body light. Most of the bones are fused and articulated bones are restricted to the parts where mobility or movement is required. Some bones develop air spaces in them.

Air sacs : In birds, thin membranous air sacs are associated with lungs to store the additional amount of air and to make the body light. Air sacs also cool down the temperature around gonads.

Single ovary : In birds, only one ovary is functional and other one is rudimentary. The ovian eggs are large, calcareous and megalecithae. This stage also helps in reducing the body weight. It is the left ovary that remains functional.

Urinary bladder : Urinary bladder is not found in birds, as the urine cannot be stored, and the excretion is almost solid or semisolid. This is also the water conserving ability that helps in flying in one way or the other.

Brain and sense organs : Brain is well developed and specially the cerebellum which is concerned with equilibrium and co-ordination is greatly developed. Eyes bears characteristic sclerotic plates to resist variable air pressure during flight. Eye are large and quick focussing.

Aquatic Adaptations

Aquatic adaptations develop in the animals due to their ancestors or permanently water living forms are called *primary aquatic adaptation.* If they show terrestrial ancestry then the adaptations are said to be the *secondary aquatic adaptations*:

Primary aquatic adaptations

These adaptations are seen in fishes as they were evolved in water and never had terrestrial ancestory. They show the following features :

Body Contour : Body contour is spindle shaped with wedge shaped head, and offers little or no resistance in swimming.

Fins : Fins are the main swimming organs in fishes. The fins may or may not be paired. Paired fins are the pectoral and the pelvic whereas unpaired fins are middorsal, ventral and caudal fins.

Gills : Most fishes respire by means of the gills they develop. The gills may be external i.e. without operculum or internal. i.e. with operculum.

Lateral line organs : The presence of lateral line organs is the important feature of fishes. These organs detect the changes caused by mechanical disturbances in the surrounding water. Recently, *Lowenstein* has suggested the role of these organs other than balancing. According to him, these organs may help in *echolocation* to make the fish able to swim even in darkness or in turbid water. These lateral line organs are not developed in terrestrial forms.

Swim bladders or air bladders : Most of the bony fishes prossess swim bladder that serves as a hydrostatic organ. With the help of a swimbladder a fish can float at any level in the water. In some fishes, it is also associated with the production of sound.

Box 28.2 : Echolocation in bat

Many animals are known to have more sensitive sense organs than human beings. One of such abilities is highly developed acoustical mechanism of some mammals and birds. The ability of an animal to emit high frequency sound pulses and to use the return echoes for detecting the distance, direction, size and texture of an object in its environment is referred to as echolocation. In simple words, the process for locating distant or invisible objects by means of sound waves reflected back to the sound emitted by the animal. Human ear can hear sound frequencies within range of 20 to 20,000 Hertz (= 20 KHz). Beyond 20,000 Hz sound is inaudible to human ear and called ultrasonic sound. Most animals having the power of echolocation can emit sound with frequencies higher than 20 KHz. This sonar-like use of auditory signals is most developed in microchiropteran bats and some cetaceans (see Box 28.3). Only two genera of birds are known to use echolocation, the Asian cave swift (*Collocolia*) and the South American oil bird (*Steatornis*).

A special feature of bats is the flying ability but they are also known for their activity in total darkness. Lassaro Spallanzani (1799), an Italian naturalist curiously sought the answer to how bats avoid obstacle in darkness. He found that blinded bats could find their way home and could catch flies like normal bats. At that time, a paper published by Louis Jurine, a Swiss surgeon, indicated that a bat with ears plugged failed to navigate in darkness. Spallanzani came to the conclusion that bats navigate by detecting the echoes of sound, but whether the animal itself emits the sound or not was unknown to him. In 1920 Hartridge, a physiologist suggested that bats navigate and capture prey using their sense of hearing. In 1938, Griffin and Galanbos with developed acoustical instruments proved that bats emit the ultrasonic sound themselves and use the echoes of that sound to "see in the dark". Their further investigations revealed the phenomenal capacity of microchiropteran bat for echolocation, which mainly feed on insects. Among megachiropteran bats, rousette bat (*Rousettus*) is known to use echolocation, which nest in caves and employ echolocation to navigate out of the caves.

Modifications for producing high frequency sound

Larynx of bat is typically mammalian and capable of producing sound of complex frequency and temporal modulation. Situated behind the hyoid bone, bat larynx is a box of cartilage and muscles with a central opening through which both inspired and expired air passes. Pair of deep tissue folds by the side of central opening are vocal cords, which are connected with strong cricothyroid muscles. Sound is produced by forcing air through the central opening between these tensed vocal cords. Loudness and modulation of frequencies is produced by alteration of tension on the vocal cords by these muscles. Other modifications are -

(i) Laryngeal cartilages are ossified to form a strong framework.

(ii) Sound is emitted by mouth or nose. The bats producing nose call have an epidermal nose-leaf (Fig.28.15.a) acting like a megaphone. The nose-leaf may modify, direct and focus the sound in a more concentrated beam.

(iii) In some bats extra-laryngeal resonating chambers help in modulation of sound.

Number of morphological and neuronal modifications help in detecting echoes

(i) Usually pinnae are very large (Fig.28.15.b) to receive echoes. But for fast flying bats, there is compromise between size of pinnae and flight speed.

(ii) Tympanic membranes and ear ossicles are especially small and light; thus provide high accuracy in receiving high frequency sound.

(iii) Cochlea is large, and basilar membrane is narrow and tightly stretched, hence responsive to faintest pulse of sound.

(iv) Middle ear muscles like tensor tympani and stapedius are much powerful. Their contraction briefly blocks the ears in each sound emission, so that the animal does not deafen itself.

(v) A padding of blood sinuses, connective tissues and fatty tissues isolate the inner ear from the skull, reducing direct transmission of sound from the mouth to the inner ear.

(vi) Auditory centers of brain occupy a very large portion of the relatively small brain of bats. Many regions of bat's brain receive auditory signals, which are processed through neuronal computation and help to construct a spatial idea of external world.

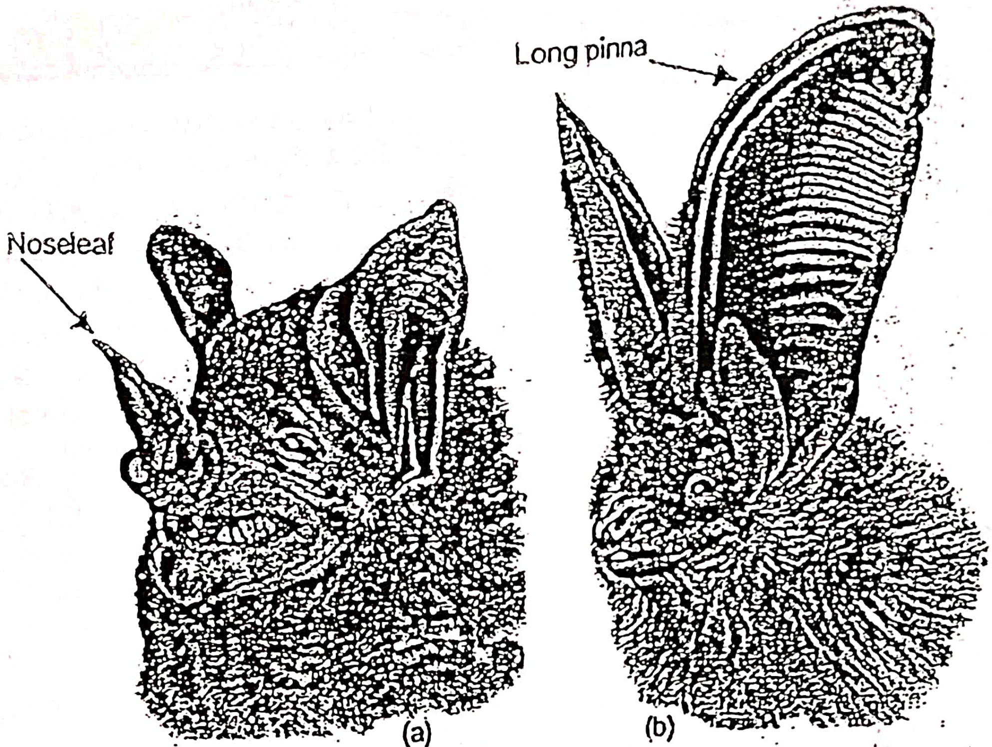


Figure 28.15 : (a) Spear-nosed bat, *Uroderma* with nose-leaf and (b) long-eared bat, *Plecotus*, with long ears.

Characters of sound waves

Sound vibrations travel through air in pressure waves and the distance between successive peaks is called wavelength. Sound also vary in intensity from loud to low, which reflects the energy or amplitude of each wave. The intensity of sound is recorded in decibels. Animals can produce sound simultaneously comprising of different frequencies and amplitudes. Of these differing sound waves, one has lowest frequency, called basic or fundamental. If the higher frequencies are double, triple or quadruple of the basic, they are called **harmonies** – second, third or fourth respectively.

Most insectivorous bats use pulses that sweep down through a range of frequencies – referred to as frequency-modulated (FM) calls. They can be produced in two ways – a shallow sweep of long duration or a steep sweep of short duration. It is believed that steep FM pulses improve object discrimination and this can be further improved by producing harmonies. Yet some species like horseshoe bats are known to emit constant frequency (CF) pulses, though they terminate in short FM sweep.

It is already stated that sound produced by larynx is emitted through mouth or nose, according to bat family. Bats of family Vespertilionidae emit mouth calls with wide angle of dispersion (≥ 180°). Bats of family Rhinolophidae emit sound through nose and broadcast the sound through nose leaf with a narrow angle of dispersion (≤ 90°).

During echolocation, bats emit sound with discrete pulses of high intensity and up to 150 KHz frequency. Patterns of sound also vary according to bat family. In Vespertilionidae, short pulses are emitted with 1 – 4 millisecond duration. Their pulse repetition rate varies from 10/sec at rest to 100/sec during hunting. These bat are able to detect insects at 50 cm. to 1 meter distance. Rhinolophidae, on the other hand, emit much longer pulses with 40 – 100 milliseconds duration. Their pulse repetition rate is less than 10/sec and with this efficiency they can locate an insect at a distance of 6 meters.

Information conveyed by echoes

Sound produced by microchiropteran bats is highly energetic, with intensities about 200 dynes/cm^2 close to the mouth of bats. It is as intense as the noise made by a jet plane taking off. Nevertheless, the sound energy that returns as echo from a small object is very weak, because sound travels in radially expanding waves and amount of energy drops as the square of distance. This reduction in energy with distance occurs in both ways – when the cry travels out and

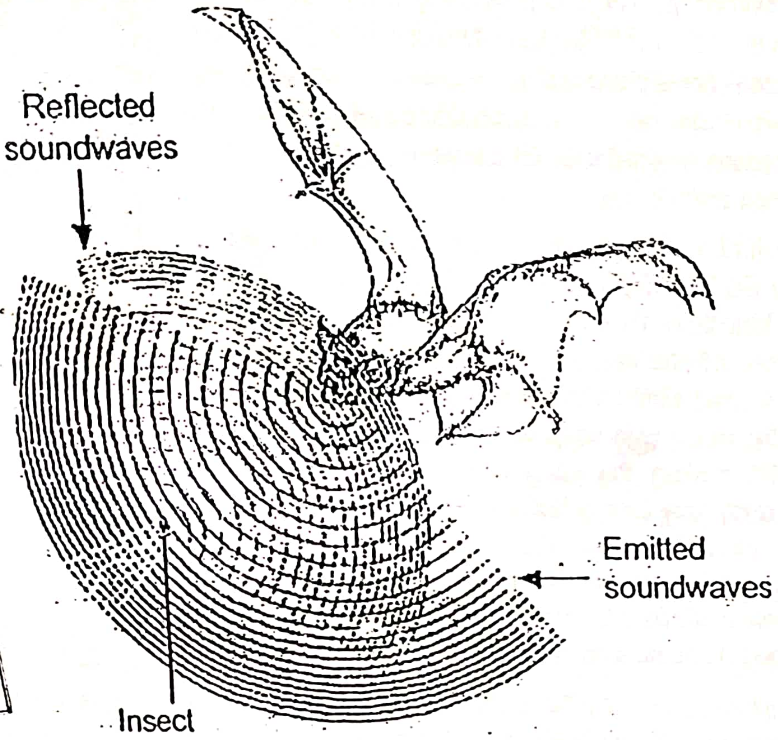


Figure 28.16 : Only a small portion of emitted sound is reflected back to the bat. Again, a small portion of reflected sound is actually intercepted by a bat.

when the tiny fraction of it returns as echo. Initial energy of sound emitted by a bat may be very high but that of returned sound is very low (Fig.28.16). Still a bat can gather enough information about direction, distance, size, texture, relative movement etc. about the reflecting object.

(i) Returned echo is received by large pinnae and a neuronal mechanism called contra-lateral inhibition help to find the direction of reflecting object. Stimulation of sensory cells of inner ear of one side desensitizes the cells of the other ear. It increases the contrast between two ears and permits to determine the direction from which the echo is coming.

(ii) The time required for an echo to return is directly proportional to the distance from the bat to the target. The change in return time between two successive calls indicates the relative movement of the bat and its target.

(iii) Frequencies of reflected echo indicate the object size. Larger objects reflect longer wavelength hence lower frequencies and vice versa. Therefore, to detect a very small object, a bat produces very high frequency sound waves.

(iv) Texture of reflecting surface is indicated by the character of the echo. A sharp echo indicates a smooth surface like the exoskeleton of a beetle. A blurred echo indicates a rough surface, such as the body surface of a moth.

Capturing a prey involves three phases of echolocation

When an insectivorous bat, such as little brown bat (*Myotis*) captures insects by echolocation, there are three phases of acoustical orientation.

(i) The first phase is searching, when the bat flies straight and emits pulsed sound separated by silent period of at least 50 millisecond. The rate of pulse is 10/sec and duration of each pulse is about 2 millisecond. Each pulse of sound is frequency modulated (FM), sweeping downwards through a frequency spectrum between 70 KHz and 30 KHz. Other bats may use different length of pulses and frequencies, which vary from family to family.

(ii) The second phase is approaching a prey and begins when the bat detects its prey. Flies or mosquitoes can be detected from a distance of 1 to 6 meters. Pulses produced in this phase shorten in intervals, about less than 10 millisecond. It produces 100 cries/sec., each lasting only 0.5 to 1 millisecond.

(iii) The third and final phase is capturing. The bat emits a buzz like sound pulsed up to 200/sec, in which intervals are less than 10 millisecond, duration is less than 0.5 millisecond and frequency drop to 25 - 40 KHz. When the bat reaches within a few millimeter of the insect, it scoops up the insect with wings or interfemoral membrane (Fig. 28.17) guiding the insect into its mouth. Exact details obviously vary among families or even among species but the general actions are almost same. High-speed photography shows that a bat performs two distinct captures within 0.5 second. Therefore, they are efficient enough to capture as many as 10 – 12 insects per minute.

Figure 28.17 : A horseshoe bat swoops on a moth, just before capturing.

A hunting horseshoe bat (*Rhinclophus*) produces long calls with constant frequency (CF), each with 50 millisecond duration and a rate of 10 sec. But when the bat closes on the insect, the CF component of each pulse is suppressed in amplitude and reduced to less than 10 millisec. While capturing the prey, it uses FM sweep.

Sonograms of three phases of echolocation during hunting an insect prey by two types of bats are shown in Fig.28.18.

More about echolocation in bats

Why bats emit ultrasound? High frequency sound waves have shorter wavelengths hence travel in straight line. Again,

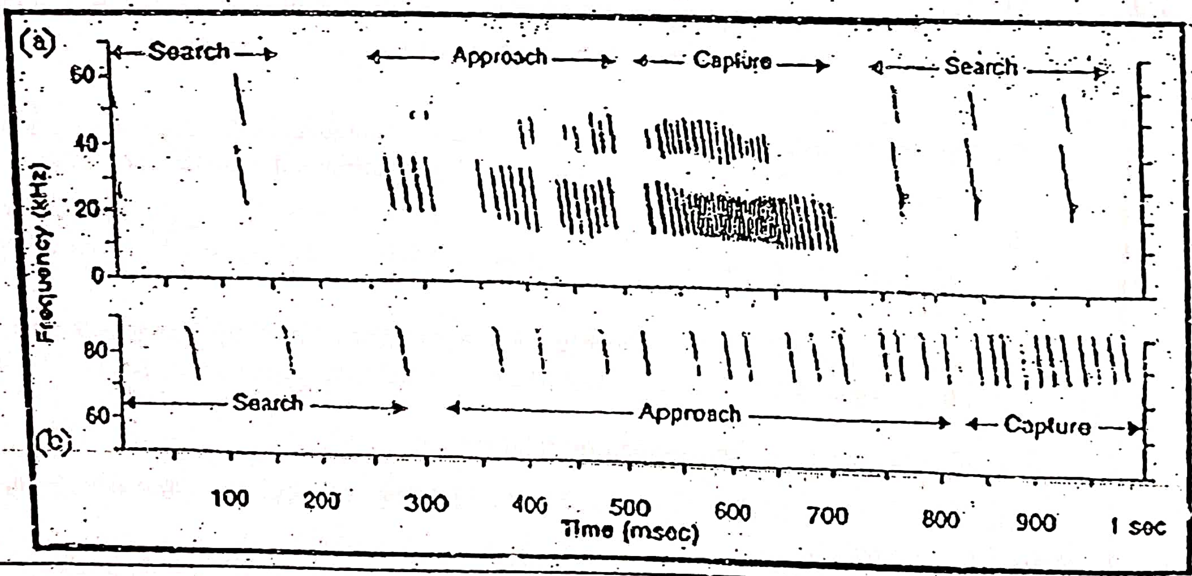


Figure 28.18 : Sonograms of three phases of echolocation during hunting an insect prey of two groups of bats. (a) Little brown bat (*Myotis*) is a vespertilionidae bat and produces FM calls. Its pulse rate increases and duration shortens toward capturing prey. (b) Horseshoe bat (*Rhinolophus*) is a Rhinolophidae bat and produces CF calls. As the bat coming nearer to prey, CF compoent is suppressed and FM sweep is used to capture the prey.

an object reflects only those sound waves, which match to its own size. Then to detect very small objects, high frequency (hence very short wave length) sound should be emitted for accurate echolocation.

Horseshoe bats (*Rhinolophus*) often use echolocation to search around but they themselves remain stationary. It is suggested that they introduced a velocity factor – a Doppler shift (change of frequency of echo relative to the original sound) by rapid movement of ears. One question still puzzles – how bats discriminate between own call and those of others flying around. The probable answer is that, a brief neural sensitization follows the emission of a call with definite wavelength. Bats have moderately large eyes but they have little use in darkness. So there is no doubt that microchiropteran bats rely mostly on their echolocation ability for flying freely in night avoiding any obstacle and for hunting insects. A blinded bat can avoid a wire less than 0.5 mm in thickness in total darkness. Fish-eating bats use echolocation to locate and capture fishes from water by detecting ripples produced on the water surface by the swimming fishes. Cave-dwelling bats detect cracks or crevices in the rock in the caves by echolocation, from which they hang during roosting.

Echolocation in bat (in other animals also) is an exceptional device that puzzles scientists. It is suggested that bats can perceive a three-dimensional geometry around itself by using echolocation and therefore, can assess more than one target at any one time. In simple words, bats know the image of their world by echolocation as we do with our visual ability. It is also certain that they make this phenomenal sense more perfect through learning.

Advantages of living in aquatic habitat :

(i) Aquatic habitats constitute about 70% of this planet. Naturally, aquatic animals, particularly marine, have a wide home range.

(ii) Aquatic animals enjoy access to a wide variety of food, which include planktons, plants, various invertebrates and fishes.

(iii) Aquatic animals escape from terrestrial carnivorous and also aquatic predators through various ways of life.

(iv) Aquatic animals have greater avenues for dispersal and migration, which allow them to seek favorable living conditions.

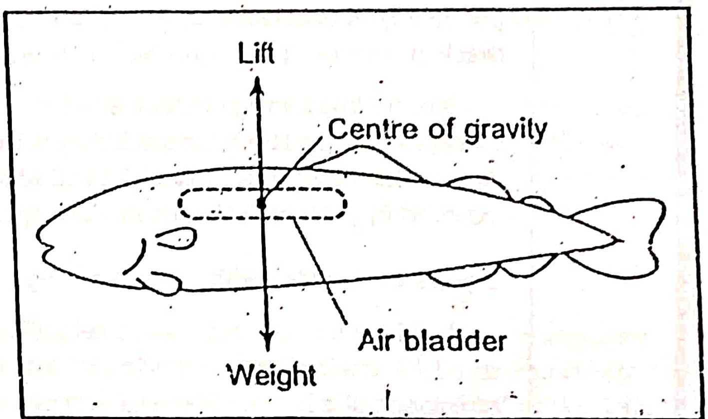


Figure 28.19 : A fish can generate lift by pectoral fins and/or swim bladder, hence can keep floating.

28.3.1 Prerequisite for Aquatic Life

An aquatic adapted animal must has the following qualities—

1. It must have the ability to swim and overcome the resistance of the medium during locomotion.
2. It must have necessary body organization for floating.
3. It has to overcome the problem of osmoregulation.
4. It must have necessary protection of sense organs and respiratory structures for water. Thermoregulation, proper mode of reproduction are also of great importance, particularly in secondary aquatic animals.

Aquatic vertebrates are broadly grouped into two categories—primary and secondary; and their adaptations are named accordingly.

28.3.2 Hydrodynamics of Swimming

Animals swimming in water need little support or none for their own body. Many have swim bladder (Fig. 28.19) or large amount of fat in body that enables them to suspend themselves in certain depth with little energy expenditure. Although high density of water allows them to be neutrally buoyant, it also produces high drag. Spindle-shaped body wonderfully helps to overcome the problem of drag and it has a good relation with flow pattern of water

Box 28.3 : Echolocation in Cetaceans

Like bats, cetaceans are specialized mammals living in water. Living lineages of cetaceans are two – Mysticeti (baleen whales) and Odontoceti (toothed whales). Baleen whales are filter feeders by their baleen plates and are known to produce elaborate vocalizations called whale songs. These whale songs are mostly within the range of human ear. Though their sound can travel hundreds of kilometers in sea, baleen whales are not known to use echolocation. Toothed whales are smaller than baleen whales, and feed on squids and fishes. Most toothed whales live in the coastal areas, which are very productive zones. This area is turbid, so vision is limited. Again, some toothed whales (like sperm whale, Physeter) dive into deep water up to 1000 meters depth where sunlight is very poor. So toothed whales that catch preys in turbid coastal areas or in deep sea face a problem of unclear vision and they solve this problem by using echolocation.

Organs associated with sound production

Sound production underwater is a problem. Diving secondary animals submerge with limited supply of air. Therefore, using this reserved air for sound production is a waste of valuable oxygen, which can reduce the time of submergence. So, it has been suggested that sound production in cetaceans has shifted from larynx to complex nasal passage (Norris, 1974). The nasal passage is extended from glottis to blowhole (the single nostril on the top of head) and has many blind pockets or diverticula. Sound is forced back and forth in this passage to produce sound, which is reflected from the broad surface of skull. Ultimately, the sound is focussed in a narrow beam by a fatty tissue in the head region – known as melon (Fig.28.25). Melon is known as a flexible acoustic lens and can change its shape to beam the sound energy in different direction. Bones of skull and melon are adjusted to function like a parabolic reflector for focussing sound (Fig.28.26).

When sound energy leaves whale's head, it passes from one medium to another. Acoustic coupling between oil and water is good, so little sound is lost by reflection. Some scientists forward that sound is produced by the larynx, which is situated far forward. Larynx of toothed whales have complex folds and muscles but no vocal cords. But the sound is focussed by parts of the forehead. Some species can produce two types of sound simultaneously and this support this view.

Organs associated with echo-receiving

Middle ear in cetaceans does not perform as sound receiving and transmitting organ. Norris (1974) first proposed that sound is received and conducted to inner ear via a special fat body extending from lower jaw to auditory bulla – the intramandibular fat body (Fig.28.26). In fact, an area of very thin bone on the side of mandible is known as acoustic window.

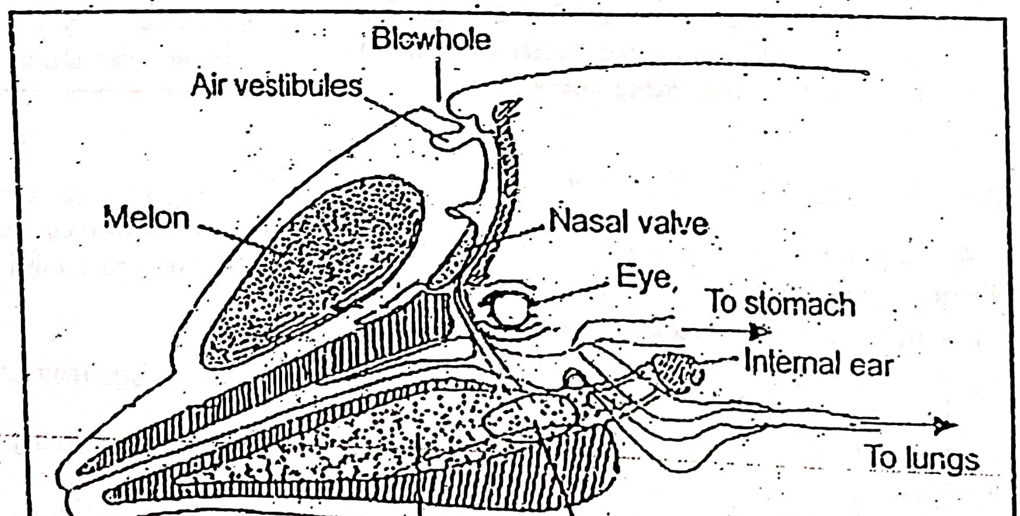


Figure 28.25 : Organs associated with sonar device of a dolphin.

Through this window, echoes enter the fat body and is conducted to the bulla.

High proportion of sound energy is received by body tissue are conducted to inner ear with no directional information. Therefore, inner ears of cetaceans are isolated from the sound transmitted via body tissues. Auditory bulla is made up of thick bone and separated from skull by fat and connective tissue like a soundproof chamber. At where the intramandibular fat body touches the bulla, the bone of that point is thin. Thus, cetaceans perceive reflected sound through lower jaw, experiments support this view.

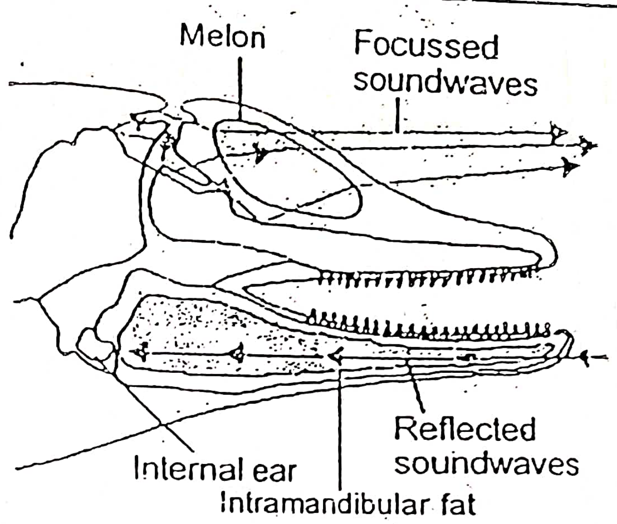


Figure 28.26 : Acoustic focussing of ultraroundwaves through melon and receiving echos through intramandibular fat.

Properties of sound produced by cetaceans for echolocation

Velocity of sound in water is five times greater than that in air. Hence wavelength of any sound frequency is five times longer in water. An object reflects only those wavelengths, which are shorter than or equal to their diameter. Therefore, cetaceans must emit very high frequency sound to detect smaller objects like fishes or squids.

Echolocation of toothed whales includes frequencies from 20 to 220 KHz, higher than that of bats. They emit intense, short pulses of clicks with very short duration and high repetition. In some species the clicks are longer in duration with less repetition. While emitting high frequency sound waves, cetaceans direct them forward in a narrow beam but lower frequencies are dispersed in wider vertical and horizontal arcs.

Purpose of echolocation

Cetaceans use echolocation for two purposes – for navigation and for searching prey. For navigation, low frequency sound waves are emitted to detect large obstacles in their swimming path. To locate a small fish, they use narrow beam of very high frequency sound. The swim bladder of fishes is the best sound reflecting object; therefore, whales face problem in detecting fishes with reduced swim bladder.

During rest, dolphins employ their combined echolocation ability of all individuals in their school to scan their surrounding. Consequently, they build up a sound picture of their environment. In this way, the school remains aware of potential danger in their surrounding.

28.4 DEEP SEA ADAPTATION

Light-less sea-bottom is usually referred to as deep sea that extends from the lower limit of littoral zone (200 meters deep), to the ocean floor. In the benthic division, this limit includes Bathyl (200m-4000m.), Abyssal (4000m. - 6000m.) and Hadal (6000m. and below) zones. In pelagic division, the limit includes Mesopelagic (200m.-1000m.), Bathypelagic (1000m.-4000m.) and Abyssopelagic (4000m and below) zones.

Characteristics of deep sea

Light : Limit of penetration of sunlight is about 200 meters. Beyond that, diffused light may be present but the amount decreases with depth. Blue-green wavelength may penetrate further (up to 750m.). But at greater depth, there is only darkness, no day or night.

Temperature : Temperature of water decreases with depth. Below 1000m., average temperature is 37°F; there are no diurnal or seasonal fluctuations.

higher O_2 affinity than other mammals and this facilitates the uptake of O_2 in the lungs. Birds native to high altitude or which fly over high mountains during migration are conspicuously more tolerant to the problems of high altitude. The reasons are various—

- high O_2 affinity of their blood,
- great effectiveness of their respiratory system,
- their exceptional tolerance to alkalosis, and
- their ability to maintain a normal blood flow to the brain at low PCO_2 and remain free from brain anoxia.

31.4 Adaptations for Thermoregulation

Temperature has profound influence on living organisms and their metabolic processes. Active life is limited to a narrow range of temperatures compared to cosmic temperature. Except some thermophilic bacteria, the tolerance level of organisms is between a few degree below the freezing point of pure water and approximately +50°C.

Animals which maintain a high body temperature and remain active in cold surroundings are called **homeothermic** (warm-blooded), such as birds and mammals. They also have the ability of internal heat production and are referred to as **endothermic**. On the other hand, those whose body temperature fluctuates with that of their surrounding are **poikilothermic**. They also depend on external sources of temperature (such as solar radiation) and are called **ectothermic**. They include reptiles, amphibians and fishes.

Temperature limits to life

Temperature tolerance of animals differs greatly. Some have very narrow tolerance range; others have a wide tolerance range. Again, temperature tolerance may change with time and certain adaptations may help to extend the limits. An animal can survive an exterme temperature but it cannot remain active. Again, an extreme temperature can be tolerated for a short exposure but for long it is lethal. Generally, two extreme temperatures are nearly equal for all aquatic animals but differ greatly for terrestrial animals.

Upper temperature limit for animals is around +50°C but some can tolerate much higher in resting condition. A fly larva *(Polypedilum)* can tolerate dehydration and in that state it can survive +102°C for 1 minute. Eggs of fresh water crustacean *Triops* can survive the dry mud of temperature up to 80°C. Aquatic animals are not exposed to very high temperatures. The most heat tolerant fish, the desert pupfish *(Cyprinodon)* lives in warm springs in California and Nevada, where usual temperature is around 34°C. In contrast, some Arctic and Antarctic animals have a surprisingly low upper heat tolerance. Antarctic fish, *Trematomus* lives in nature at an average of -1.9°C and has an upper lethal temperature of about 6°C. Thermal death may happen due to denaturation and coagulation of protein, inactivation of enzymes, inadequate O_2 supply, alteration of membrane structure etc.

Effects of low temperature on organisms are also perplexing. Animals of cold and temperate regions are often exposed to prolong winter temperatures far below the freezing point of water. Survival at such subzero temperatures depends on physiological and biochemical characters known as hardiness. Cold hardiness is possible through two strategies. The first is to become freeze-tolerant i, e, to survive extensive freezing and ice-formation in body. Fully aquatic invertebrates have no problem with freezing because their osmotic concentration equals that of their medium. But many intertidal animals can tolerate more than 90% of body water frozen into ice and therefore able to tolerate an exceptional increase in osmotic concentration. High concentration of glycerol and other polyhydric alcohols in body fluid protect them from injury due to freezing, such as gall fly *(Eurosta)*, parasitic wasp *(Bracon)* etc. Nucleating agents in hemolymph of a number of beetles actually aid in ice formation, thus the damage due to freezing is avoided. Among vertebrates, tree frog *(Hyla versicolor)*, wood frog *(Rana slyvatica)* are freeze tolerant. Hatchlings of painted turtle *(Chrysemys picta)* may survive when more than 50% of their extracellular water is frozen to ice. No fish, bird or mammal is known to be freeze-tolerant.

Second strategy of cold hardiness is **freeze-intolerance**, i.e. they avoid ice formation in body even if exposed to –40°C or less. They remain super cooled i.e., freezing point is much lowered. Here also, glycerol is found to play an effective role. An extreme example is willow gall fly *(Rhabdophaga)* that survives the winter in Alaska at –60°C by supercooling and is found to contain 50% glycerol in their body fluid.