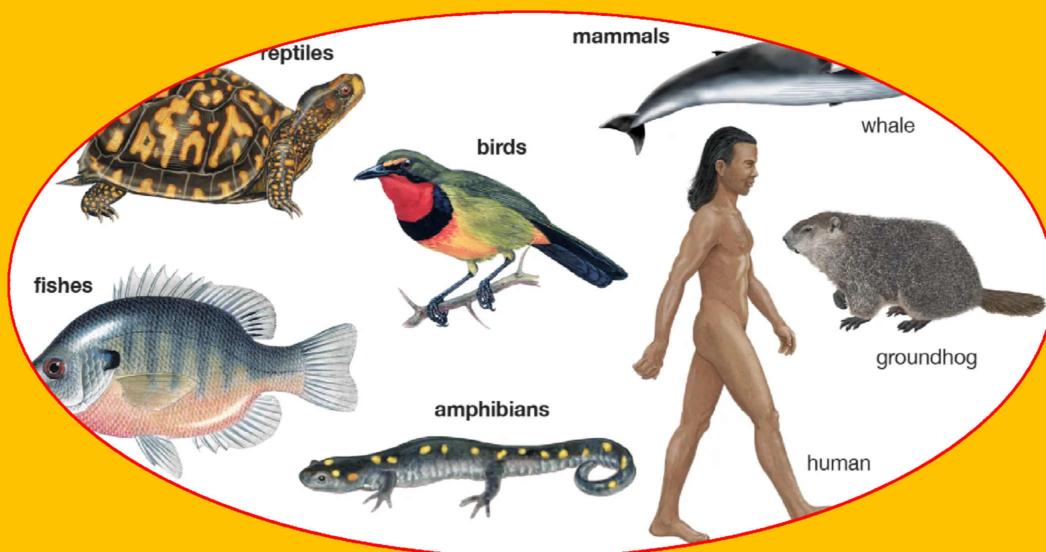
MSCZO-601

M.Sc. III Semester

VERTEBRATE ZOOLOGY



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CONTENTS

COURSE: VERTEBRATES

COURSE CODE: MSCZO601 **CREDIT: 3**

UNIT 1: TAXONOMY AND ORIGIN OF CHORDATES

1.1 OBJECTIVES

We shall comprehend the fundamental traits, history, and ancestor of chordates. After reading this chapter, we will also be familiar with the general traits, taxonomy, and order-level classification of chordates.

1.2 INTRODUCTION

Chordates **evolved from some deuterostome ancestor (echinoderms, hemichordates, pogonophorans etc.)** as they have similarities in embryonic development, type of coelom and larval stages. Fossils of the earliest vertebrates are known from the Silurian-Devonian period, about 400 million years ago. Phylum Chordates belongs to the **Kingdom Animalia** and includes all the vertebrates, i.e., animals with a backbone, and several invertebrates, i.e., organisms without a backbone. They possess a bilaterally symmetrical body and are divided into three different sub-phyla. Chordates contain five classes of animals: **fish, amphibians, reptiles, birds, and mammals**; these classes are separated by whether or not they can regulate their body temperature, the manner by which they consume oxygen, and their method of reproduction.

1.3 CLASSIFICATION OF THE CHORDATES UP TO ORDER LEVEL

PHYLUM CHORDATA

ACRANIA Group (=PROTOCHORDATA) (Primitive chordates without head and vertebral column)

Example: Balanoglossus, Cephalodiscus, and Rhabdopleura are subphylum HEMICHORDATA; these primitive and dubious chordates are now categorized as non-chordates, following echinoderms. Subphylum **UROCHORDATA,** Example- **Herdmania***, Salpa, Doliolum, Pyrosoma, Oikopleura.* These are *sedentary* or planktonic tunicates in which chordate characters manifest in the larval stage.

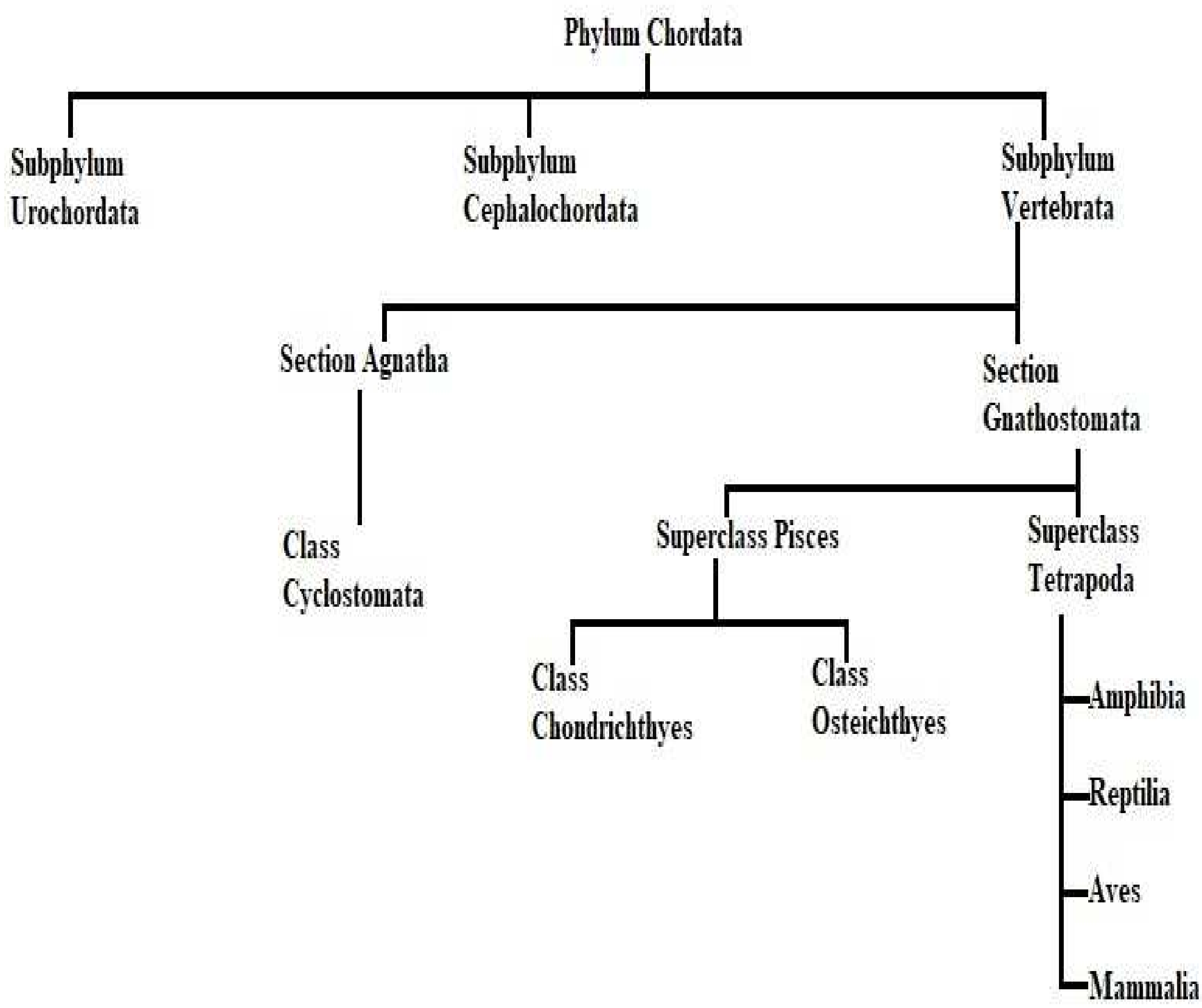
Subphylum **CEPHALOCHORDATA,** Example- **Amphioxus**, *Asymmetron.* These are typical chordates having chordate characters in the larval as well as adult stages.

Group CRANIATA (=EUCHORDATA)

(Chordates with skull, with 54,000 species of true chordates)

Subphylum **VERTEBRATA,** chordates with head or skull, brain and vertebral column.

- Division **AGNATHA**, 90 species of paraphyletic group of jawless fishes, which were the first vertebrates. Living forms are elongated, scale less, slimy parasites and scavengers that include lampreys and hagfishes. They have no paired fins.
- Class **OSTRACODERMI,** extinct shelled jawless fishes of Ordovician period. For Example- *Cephalaspsis.*
- Class **CYCLOSTOMATA,** jawless fishes of today, without scales and paired fins.
- Order **Myxinoidea**: the hagfish's containg 40 species. *Myxine, Bdellostoma, Eptatretus* are good examples.
- Order **Petromyzontia**: lampreys, 41 species, parasitic on other fishes. **For Example-** *Petromyzon.*
- Division **GNATHOSTOMATA,** vertebrates with jaws that are modified gill arches and paired appendages. They include cartilaginous fishes, bony fishes and tetra pods.


Phylum Chordata
Subphylum Urochordata
Subphylum Cephalochordata
Subphylum Vertebrata
Section Agnatha
Section Gnathostomata
Class Cyclostomata
Superclass Pisces
Superclass Tetrapoda
Class Chondrichthyes
Class Osteichthyes
Amphibia
Reptilia
Aves
Mammalia

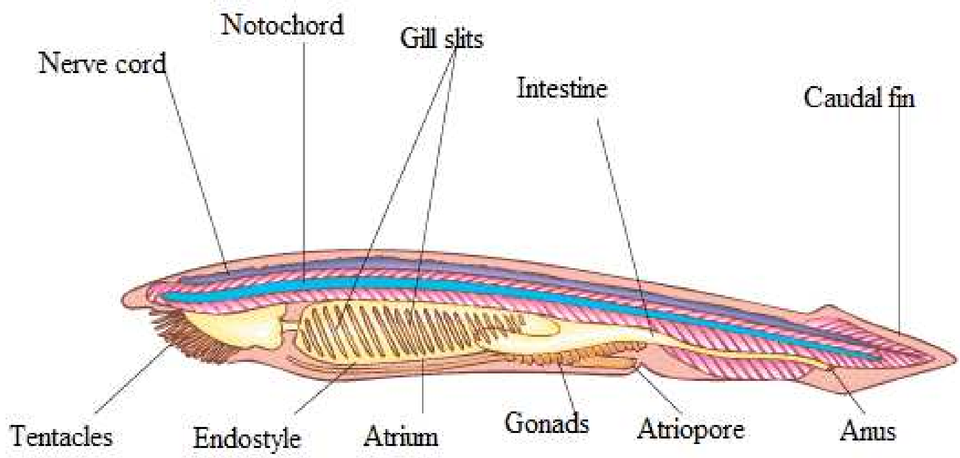


Fig.1.1 Primitive chordate character

SUPER CLASS I: PISCES

Class PLACODERMI, extinct group of spiny sharks. For Example- *Climatius.*

Class **CHONDRICHTHYES:** cartilaginous fishes that have cartilaginous skeleton, ventral mouth, placoid scales, heterocercal tail fin and 5 pairs of gill slits.

- Subclass **Elasmobranchii**— 850 species of sharks, rays and skates.
- Subclass **Holocephali**— 30 species of ratfish *(Chimaeras)*.

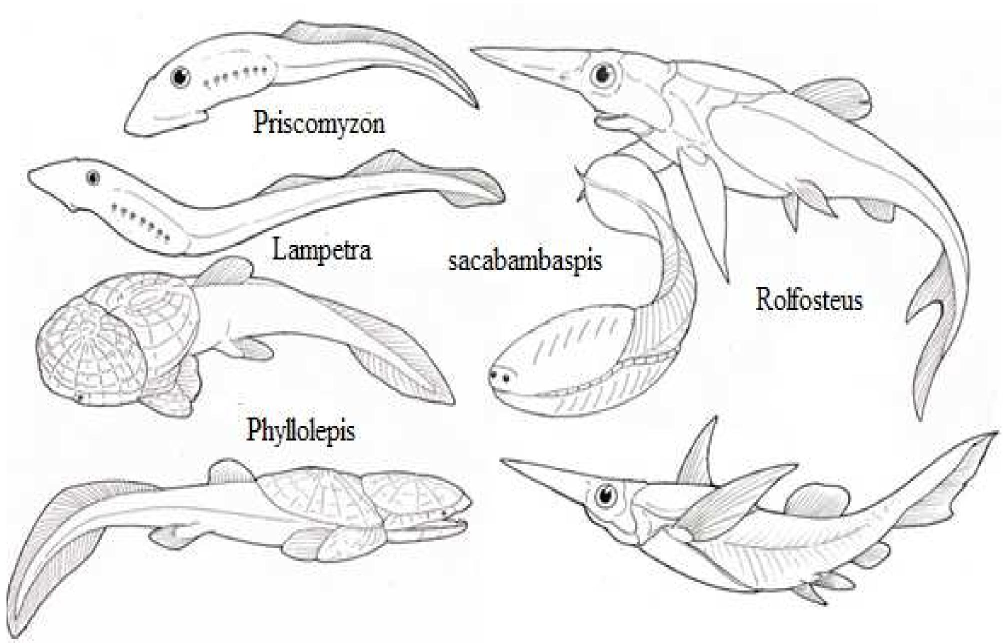


Fig.1.2Super class Pisces

Class **OSTEICHTHYES** 20,000 species, bony fishes. Skeleton bony, four pairs of gills, covered with operculum, possess swim bladder or lung.

- Subclass **Actinopterygii**, ray-finned fishes.
- Super order **Chondrostei**, 25 species of sturgeons, bichirs and paddlefish.
- Super order **Holostei**, which includes *Lepistosteus (*7 species) and *Amia (*1 species)
- Super order **Teleostei** includes 20,000 species of bony fishes, such as tarpon, herring, perch, etc.
- Subclass **Crossopterygii** includes 2 species of coelacanth *(Latimeria).*

Class **CHOANICHTHYS (=DIPNOI)**, has 6 species of lungfishes under three genera, namely, *Protopterus, Lepidosiren* and *Neoceratodus.*

SUPERCLASS CTETRAPODA: Two pairs of paired appendages

Class **AMPHIBIA**

- Order **Gymnophiona** (Apoda) —165 species of burrowing caecilians, elongated bodies, and limbless, dermal scales embedded in annular folds of skin.
- Order **Caudata** (Urodela) —425 species of salamanders, tailed amphibians, usually with two pairs of limbs.
- Order **Anura** (Salientia) —4300 species of frogs and toads, tail-less amphibians, long hind limbs for jumping, head and trunk fused. They have sound producing and hearing organs.

Class **REPTILIA,** 7800 species, turtles, crocodiles, lizards, snakes, etc. These are the true land vertebrates and never come return breeding in water.

They have internal fertilization and produce large cleiod eggs with leathery shells and are ectotherms. Bodies covered with epidermal scales and vertebrae are procoelous.

- Order **Chelonia**, 300 species of turtles and tortoises having bony shell on the body.
- Super order **Lepidosauria,** lizard-like with acrodont or pleurodont dentition.
  - Order **Rhynchocephalia (=Sphenodontia**), 2 species of tuatara *(Sphenodon)* in New Zealand. They have acrodont teeth, amphicoelous vertebrae and a parietal eye.
  - Order **Squamata,** with pleurodont teeth, procoelous vertebrae, without third eye.
  - Suborder **Lacertilia** includes 4000 species of lizards.
  - Suborder **Ophidia** includes 2700 species of snakes.
  - Superorder **Archosauria** includes modern crocodiles and extinct dinosaurs.
  - Order **Crocodilia**, 23 species of alligators, crocodiles and gavials

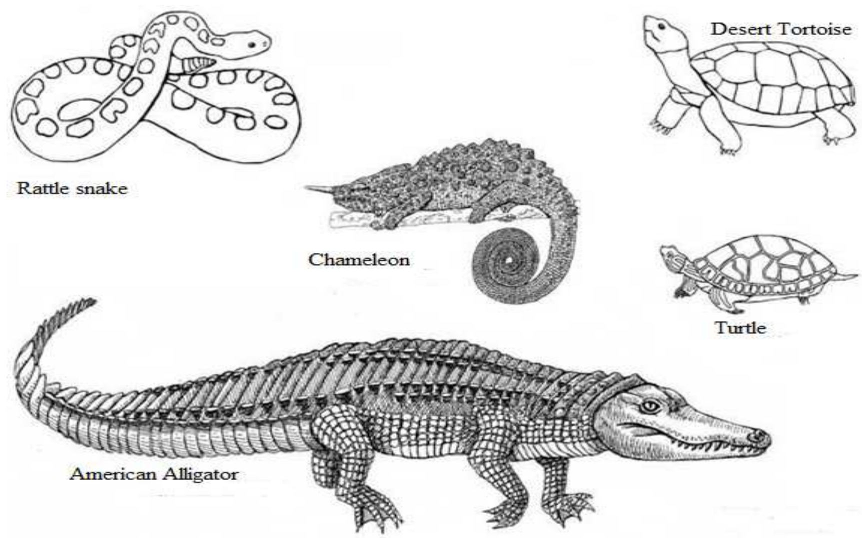


Fig.1.6 Different types of Reptiles

Class **AVES,** 9100 species.

Birds being feathered bipeds have internal fertilization and lay hard-shelled eggs and are endotherms. Nearly every anatomical feature is related to ability to fly. They are the only animals with feathers that are modified from reptilian scales.

Class **MAMMALIA,** 4,500 species.

Mammals evolved in the late Triassic, the time dinosaurs first appeared and diversified greatly following the extinction of dinosaurs during the Cenozoic. Characteristics include hairs for protection and from heat loss; mammary glands; heterodont teeth; endothermy; 4 chambered hearts etc.

- Subclass **PROTOTHERIA, Order Monotremata,** egg laying mammals having 6 species in Australia and New Zealand. No teeth and true mammary glands.
- Subclass **METATHERIA, Order Marsupialia,** 275 species of marsupials that have brief gestation period after which the embryo develops in a pouch. They have prolonged lactation and parental care. Marsupials include: opossum, kangaroo, koala, Tasmanian devil, wombat, etc.
- Subclass **EUTHERIA**, **16 orders** which include 4700 species of placental mammals that are truly viviparous, with a placenta for gas and nutrient exchange between the mother and foetus. They also have true mammary glands.

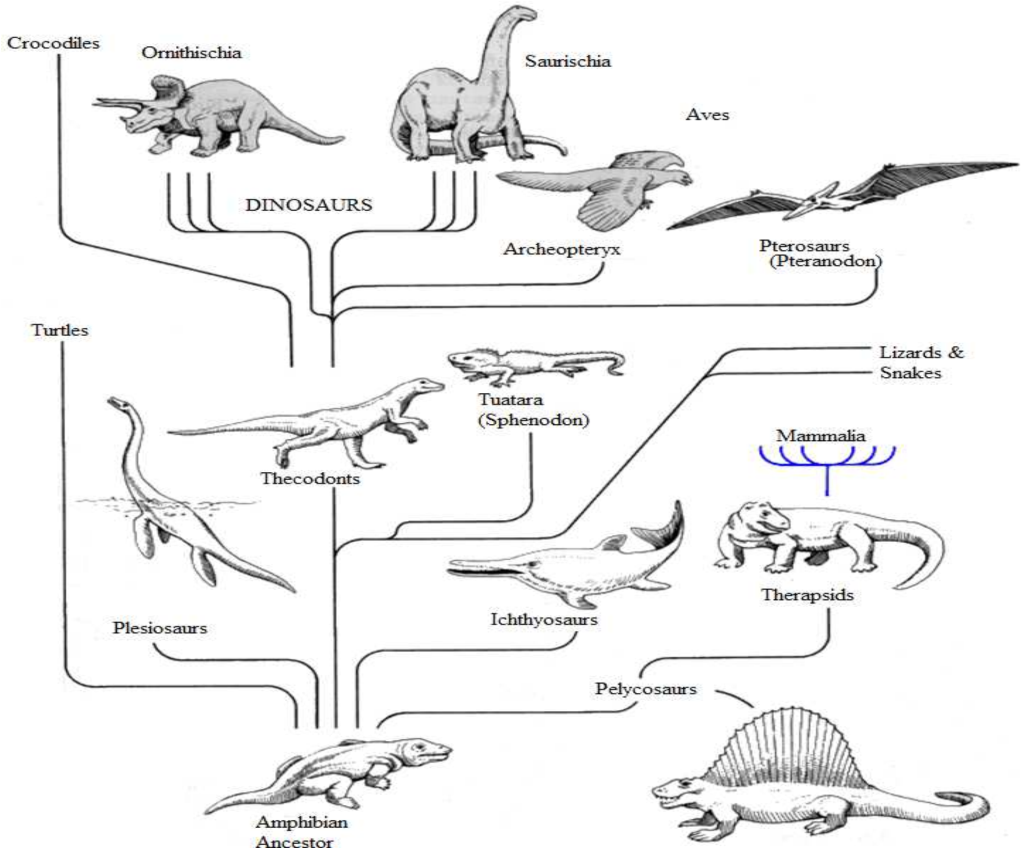


Fig.1.7 Different class of chordate

1.4 HABIT & HABITATS

Animals of this phylum are found in almost all habitats of world. Some species live in land. Among the aquatic chordates some live in fresh water and some in marine water. Many species are arboreal, desert dweller, polar, cave dweller and carsorial.

Chordate, any member of the phylum Chordata, which includes the vertebrates (subphylum Vertebrata), the most highly evolved animals, as well as two other subphyla—the tunicates (subphylum Tunicate) and cephalochordates (subphylum Cephalochordata). Some classifications also include the phylum Hemichordata with the chordates.

As the name implies, at some time in the life cycle a chordate possesses a stiff, dorsal supporting rod (the notochord). Also characteristic of the chordates are a tail that extends behind and above the anus, a hollow nerve cord above (or dorsal to) the gut, gill slits opening from the pharynx to the exterior, and an endostyle (a mucus-secreting structure) or its derivative between the gill slits. (A characteristic feature may be present only in the developing embryo and may disappear as the embryo matures into the adult form.) A somewhat similar body plan can be found in the closely related phylum Hemichordates.

General features

Tunicates are small animals, typically one to five centimeters (0.4 to 2.0 inches) long, with a minimum length of about one millimeter (0.04 inch) and a maximum length slightly more than 20 centimeters; colonies may grow to 18 meters (59 feet) in length. Cephalochordates range from one to three centimeters. Vertebrates range in size from tiny fish to the whales, which include the largest animals ever to have existed.

Tunicates are marine animals, either benthic (bottom dwellers) or pelagic (inhabitants of open water), that often form colonies by asexual reproduction. They feed by taking water in through the mouth, using the gill slits as a kind of filter. The feeding apparatus in cephalochordates is similar. They have a well-developed musculature and can swim rapidly by undulating the body. Cephalochordates usually live partially buried in marine sand and gravel.

Vertebrates retain traces of a feeding apparatus like that of tunicates and cephalochordates. The gill slits, however, ceased to function as feeding structures, and then later as respiratory devices, as the vertebrate structure underwent evolutionary changes. Except in some early branches of the vertebrate lineage (i.e., agnathans) a pair of gill arches has become modified so as to form jaws. The fishlike habitués that evidently began with cephalochordates became modified by the development of fins that were later transformed into limbs. With the invasion of the vertebrates into fresh water and then onto land, there was a shift in means of breathing—from gills to lungs. Other modifications, such as an egg that could develop on land, also emancipated the vertebrates from water. Elaboration of the locomotory apparatus and other developments allowed a diversification of structure and function that produced the amphibians, reptiles, birds, and mammals.

1.5 CHARACTERISTIC FEATURES

- Aquatic, aerial or terrestrial all free living with no fully parasitic forms.
- Bilaterally symmetrical and metamerically segmented.
- Exoskeleton often present well developed in most vertebrates.
- Body wall triploblastic with 3 germinal layers: ectoderm, mesoderm and endoderm.
- Coelomate animals with a true coelom, enterocoelic or schizocoelic in origin.
- A skeletal rod, the notochord, present at some stage in life cycle.
- Digestive system complete with digestive glands.
- Blood vascular system closed. Heart ventral with dorsal and ventral blood vessels. Hepatic portal system well developed.
- Excretory system comprising proto –or meso-or meta-nephric kidneys.

Animals in the phylum Chordate share four key features that appear at some stage during their development (often, only during embryogenesis).

1. a notochord
2. a dorsal hollow nerve cord
3. pharyngeal slits
4. post-anal tail

NOTOCHORD

The notochord, a flexible, rod-shaped feature present in all chordates' embryonic stages as well as in certain species' adult stages, is where the chordates get their name. It provides skeletal support over the entire length of the body and is situated between the nerve cord and the digestive tract. In certain chordates, the notochord serves as the body's main axial support during the animal's whole existence.

When present during embryonic development in vertebrates, the notochord stimulates the growth of the neural tube, which acts as a support for the growing embryonic body. But in most adult vertebrates, the vertebral column (spine) takes the role of the notochord.

DORSAL HOLLOW NERVE CORD

Ectoderm rolls into a hollow tube during development to form the dorsal hollow nerve cord. It is dorsally (at the top of the animal) from the notochord in chordates. Other animal phyla, as opposed to the chordates, are characterized by solid nerve cords that are situated ventrally or laterally. The central nervous system is made up of the brain and spinal cord, which develop from the nerve cord that is present in the majority of chordate embryos.

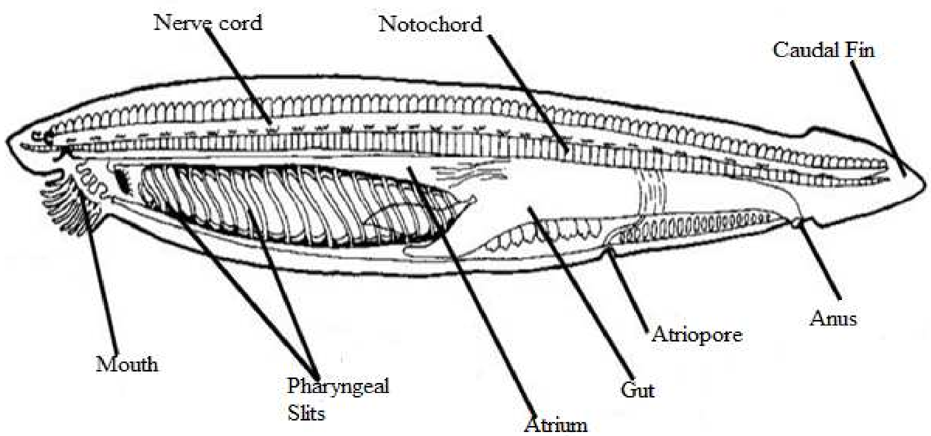


Fig 1.8 Pharyngeal slits dorsal nerve cord & notochord

PHARYNGEAL SLITS

Pharyngeal slits are openings in the pharynx (the region just posterior to the mouth) that extend to the outside environment. In organisms that live in aquatic environments, pharyngeal slits allow for the exit of water that enters the mouth during feeding. Some invertebrate chordates use the pharyngeal slits to filter food out of the water that enters the mouth. In vertebrate fishes, the pharyngeal slits develop into gill arches, the bony or cartilaginous gill supports.

In most terrestrial animals, including mammals and birds, pharyngeal slits are present only during embryonic development. In these animals, the pharyngeal slits develop into the jaw and inner ear bones.

POST-ANAL TAIL

The post-anal tail is a posterior elongation of the body, extending beyond the anus. The tail contains skeletal elements and muscles, which provide a source of locomotion in aquatic species. In some terrestrial vertebrates, the tail also helps with balance, courting, and signaling when danger is near. In humans and other apes, the post-anal tail is present during embryonic development, but is vestigial as an adult.

1.6 ORIGIN, EVOLUTION AND ADAPTIVE RADIATION OF CHORDATES

It is believed that chordates originated from invertebrates. However, it is difficult to determine from which invertebrate group of the chordate developed. It is almost constant that chordate ancestors were soft bodied animals. Hence, they were not preserved as fossil.

Many theories have been put forward to explain the evolution of chordates, few of them are as follows:-

(a) **COELENTERATE THEORY:** According to this theory chordates developed from coelenterates. It is believed that radial symmetry coelenteron, cnidoblasts etc, disappeared and advanced characters developed to giverise the chordates. This theory infers that chordates might have acquired higher characters independently. This theory is not acceptable.

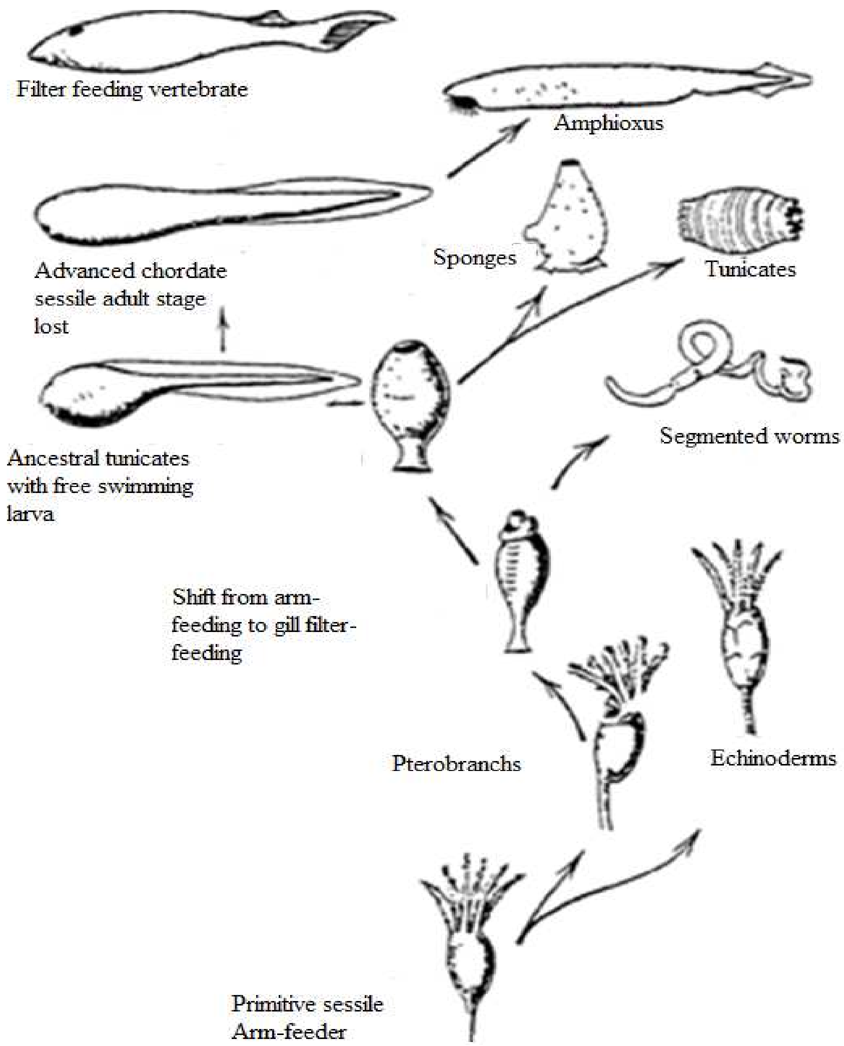


Fig.1.8 Origin of chordates

(b)ANNELID THEORY: This theory suggests that the chordates have evolved from an annelid stock, like many chordates the annelids show bilateral symmetry, metasmerism, head, lateral coelome complete digestive tract, closed circulatory system, haemoglobin, etc. The resemblance is enhanced, if an annelid is turned upside down. But the mouth would be dorsal which is unlike that of chordates. Metamerism and appendages of annelids differ in nature from those of the chordates. Bilateral symmetry, head and complete digestive tract occur in other non-chordate phyla also. Coelome is schizocoelic in annelids and enterocoelic in lower chordates. Haemoglobin is dissolved in the plasma in annelids but it is present in the red blood corpuscles in chordates. Annelid nerve cord is double and ventral in contrast to single, hollow, dorsal nerve cord of chordates. Some striking differences exist between the annelids and the chordates in their embryology too, hence it is difficult to accept this theory.

(c) ECHINODERM -HEMICHORDATE THEORY-ORIGIN OF CHORDATES: This theory infers origin of chordates, hemichordates and echinoderms from a common ancestor. This theory is based on the following evidences.

1. **EMBRYOLOGICAL EVIDENCE:** Both echinoderms and chordates have enterocoelic coelome, mesoderm and deuterostomous mouth. There is resemblance between the bipinnaria larva of certain echinoderms and the tornaria larva of hemichordates. In echinoderms chordates the central nervous system develops from a dorsal strip of ectoderm.

2. **SEROGICAL EVIDENCE:**
   Similarity exists between the proteins of the body fluid of chordates and echinoderms. Hence the chordates and echinoderms are closely related. The radial symmetry of adult echinoderms will disapprove their relationship with the bilaterally symmetrical chordates. In echinoderms radial symmetry is secondarily developed from a basically bilateral symmetry. Both the primitive and the early echinoderm larvae show bilateral symmetry.

ADAPTIVE RADIATION OF CHORDATES

Mammals were small, widespread, and few throughout the Mesozoic era, the time of the reptiles (dinosaurs). The dinosaurs had disappeared by the end of the Mesozoic or the beginning of the Cenozoic, and mammals had quickly spread and undergone numerous evolutionary changes. Placental mammals began to diverge from marsupials towards the beginning of the Cretaceous epoch.

Most mammal orders evolved throughout the Eocene and Oligocene, settling in the habitats and ecological niches left vacant by the dead dinosaurs. Divergent evolution or adaptive radiation refers to this process of development from a single ancestral species to a range of forms that occupy various habitats.

H.F. Osborn created the idea of adaptive radiation in evolution in 1898. Examples frequently cited as proof include Australian marsupials, Darwin's finches from the Galapagos Islands, various limb structures in animals, etc.

***A*. Radiation in Limb Structure of Mammals:**

Pentadactyl limbs are modified into mammalian limbs. It is thought that early, ancestor mammals were short-legged, five-fingered ground dwellers. They did not have any form of locomotion-specific modification to their limbs. These creatures lived on land. The forerunners of contemporary mammals were these terrestrial forebears.

These mammal species with simple limb structures are positioned in the middle of figure 33.10. As a result, adaptive radiation took place in five distinct lines or habitats with altered limb structures.

From these terrestrial mammals the different lines radiated in the following manner:

1. One evolutionary line radiates to form arboreal forms which have adapted limbs for life in trees (e.g., squirrels, sloths, monkeys, etc.).
2. Another line leads to aerial representing mammals adapted for flight (e.g., bats) Only bats occupy the position at the terminus of this line, since they are the only truly flying mammals Somewhere along this line we can place for gliding mammals such as "flying squirrel. "

The arboreal and aerial forms not arose independently from the terrestrial forms as shown in the diagram It is believed that the ancestral aerial forms were previously lived in trees having gliding type of locomotion which later gave rise to true flight. Hence, perhaps the gliding formed transitional type of locomotion between climbing and true flight.

3. Third line of radiation gave rise to cursorial forms (e.g., horses and antelopes). They have developed limbs suitable to rapid movements over the surface of the ground. Along this line also developed other mammals with less strongly modified limbs, such as wolves, foxes, hyenas', lions.

4. Fourth line of radiation formed the burrowing mammals, the fossorial mammals. Some of the fossorial mammals, like the moles, have modified their forelimbs for digging but they are poorly

adapted for locomotion on the ground. While others like pocket gophers and badgers are expert diggers but they have retained structures enabling them to move readily on the surface of ground.

5. **Fifth line of radiation leads to the aquatic mammals:**

(i) Whales and porpoises having limbs strongly adapted for aquatic life, but they cannot move about on land.

(ii) While seals, sea lions and walruses have also strongly modified limbs for aquatic life but they are also able to move about on land.

(iii) The third group includes accomplished swimmers such as others and polar bears which are equally at home in water or on land.

Thus, all the mammals of different radiating lines have limbs more or less adapted for some particular mode of locomotion. All the lines start from a common centre representing the short, pentadactyl limbs of terrestrial mammals. From the centre, evolutionary lines radiate out in various directions. Hence, adaptive radiation is evolution in several directions starting from a common ancestral type.

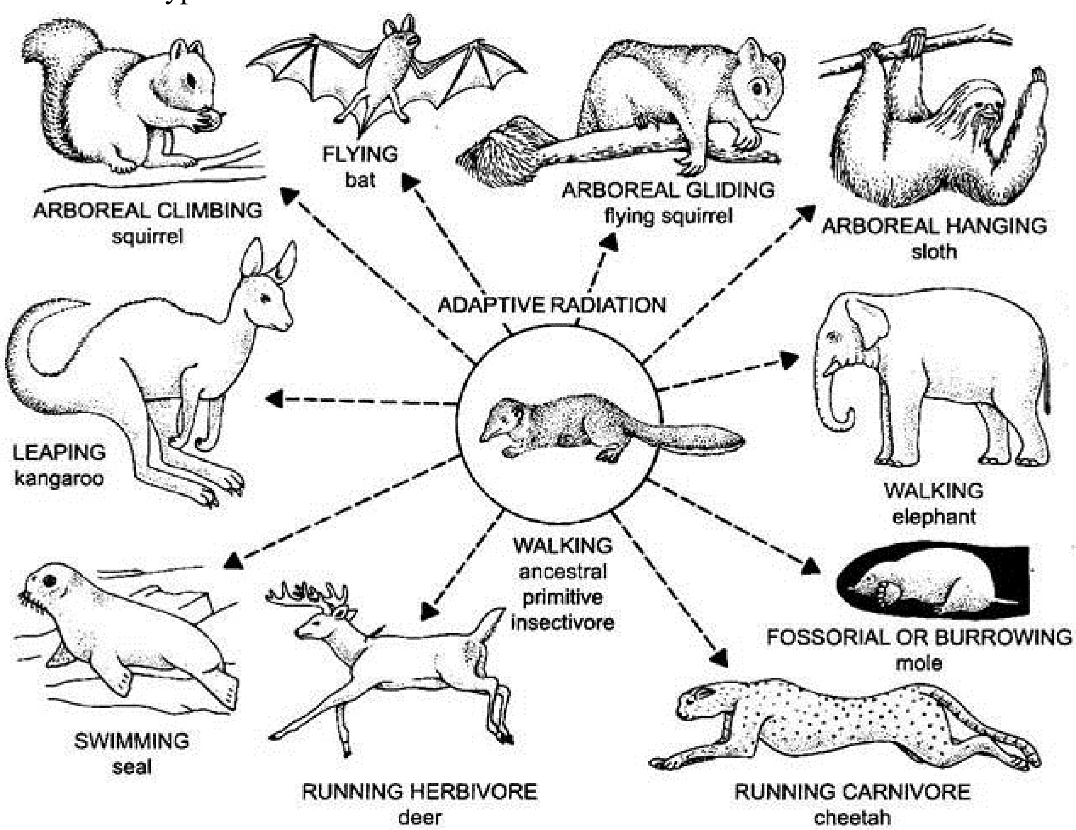


Fig.1.9 Adaptive radiation or Divergent evolution in mammals based on locomotion

Evolutionary Relationships:

All the mammals included in the diagram have modified Pentadactyl limbs; hence, they must be related to each other. Possession of this common limb pattern indicates close relationship not only among mammals but also by birds, reptiles and amphibians – by all vertebrates except fishes.

B. Tooth Radiation in Mammals:

The mammals with few exceptions (Cetacea, ant-eaters etc.) possess heterodont dentition, i.e., the teeth in contrast to those of reptiles, are differentiated into different forms with very distinct functions. The different types of teeth are incisors for biting, canines for grasping, tearing or for defense or offence, premolars and molars are for grinding. The premolars and molars show greatest structural modification for different types of food.

In insectivorous type (stem form in mammals), premolars and molars are low-crowned simple with few cusps, generally sharp pointed and suitable for crushing feeble prey. In carnivorous type, premolars and molars are high crowned, trenchant, shearing structures (carnassials). The jaws have little or no lateral movement. Cats have no grinding teeth, while dogs have more of grinders. In Odontoceli (e.g., toothed whales) there is no tooth differentiation and the teeth are practically alike.

In sperm whale, Physeter, no teeth in the upper jaw, but germs of upper teeth are present, while in whalebone whales (Mystaceti) upper teeth are totally absent and their place is taken by curious baleen or whalebone which hangs from the palate.

In herbivorous types, incisors are for seizing and cutting the vegetation. In ruminants, they are absent in the upper jaw, but a horny pad is present there. Canine teeth are of little importance for herbivores, but in musk deer they are used for defense and in swine they are used for uprooting the vegetation.

Grinders (premolar and molars) may be short-crowned and brachydont adapted for succulent leaves and twigs or long-crowned and hypsodont adapted for harsh grasses. In myrmecophagous type teeth have disappeared, jaws reduced and mouth opens at the extreme anterior end of tubular snout with a highly extensible and prehensile adhesive tongue for eating ants.

1.7 SUMMARY

The chordates are of various body forms but they all have notochord, dorsal tubular nerve cord, pharyngeal slits and a post anal tail at some stage of life .Various theories have been proposed to explain the origin and evolution of chordates but none of them is completely satisfactory, However, it is believed that they evolve sometimes before Cambrians. The most advanced forms of chordates are mammals.

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UNIT 2: PROTOCHORDATES

2.1 OBJECTIVES

We will understand the general characters of Hemichordates, Urochordates & Cephalochordates' and the affinities & Interrelation between them.

2.2 INTRODUCTION

Protochordates are an informal category of animals (i.e.: not a proper taxonomic group), named mainly for convenience to describe invertebrate animals that are closely related to vertebrates. This group is composed of the Phylum Hemichordate and the Subphyla Urochordata and Cephalochordate.

They are generally found in marine water. Their body is bilaterally symmetrical, triploblastic, and Coelomated. At a certain stage of their lives, their body develops a long, rod-like structure for support called the notochord. They exhibit organ system level of organization.

The Phylum Hemichordates consists of marine worms that share some, but not all of the characteristics of chordates. These animals have pharyngeal gill slits and a dorsal nerve cord, which is usually solid. The three body parts are proboscis, collar and trunk. What was once thought to be a notochord is no longer considered homologous. Acorn worms are examples of hemichordates.

The Urochordates and Cephalochordates are protochordates, but belong to the Phylum Chordata. Therefore, these animals will be discussed in the chordate section.

2.3 SALIENT FEATURES OF PROTOCHORDATES

The Name Protochordates laterally means 'the First Chordates'. These are the heterogeneous group of animal of phylum Chordates, related to the vertebrates, which they resembles in possessing gill slit, notochord and dorsal hollow nerve chord or at least traces of these.

The organisms belonging to the Protochordata are generally known as the lower chordates. They don't form a "proper" taxonomic group and are only classified as such for convenience purposes. However, they do form a major group of Chordates. They are also known as Acraniata because they lack a true skull. They are divided into two subphyla- Urochordata, Cephalochordates.

Characteristics of Protochordata

1. They are generally found in marine water.
2. They are relatively small sized Animals.
3. Their body is bilaterally symmetrical, triploblastic, and coelomated.
4. Sexes may be separate or united.
5. Solitary, Marine, Free living, Pelagic Burrowing or tube-like living forms.
6. At a certain stage of their lives, their body develops a long, rod-like structure for support called the notochord.
7. They exhibit organ system level of organization.

E.g., Herdmania, Amphioxus.

2.3.1HEMICHORDATE

GENERAL CHARACTERS OF HIMICHORDATA

- Bilaterally symmetrical and exclusively marine, worm- like and soft bodied animals.
- Body cavity a true coelom (enterocoel).
- Body divided into three sections, Proboscis, collar and trunk. Numerous paired gill-slits are present.
- Digestive tube complete, straight or U-shaped.
- Nervous system normally diffuses, but variable and partially open circulatory system.
- Possesses Glomerulus as an excretory organ and reproduction normally sexual, sexes usually separate but few acorn worms also exhibit asexual reproduction.
- Fertilization external in sea water .Development direct or indirect with a free swimming tornaria larva. Feeds on fine particles in the water.

  Etymology: - From the Greek Hemi for half and the Latin chord

Not familiar creatures to most people, hemichordates form a small phylum (only a few hundred species). Their importance for the study of vertebrate evolution, however, cannot be underestimated. The fossil record of one group of hemichordates, the graptolites, is very well known and is often used to correlate rocks.

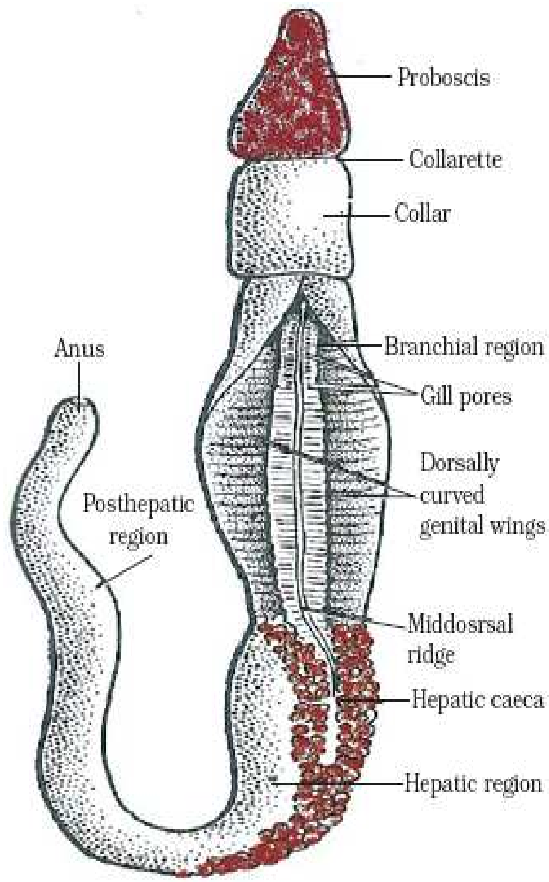

Fig.2.1 Balanoglossus (External Feature)

Hemichordata (Gr.hemi-half ; chorde-cord) till recently treated as a subphylum of the phylum Chordates is now regarded as an independent phylum of invertebrates, close to Echinodermata, Hemichordates or Acelochordata are tongue worms .It includes a small group of soft, vermiform, marine and primitive chordates, most of them live in tubes. Hemichordates are distinguished by a **tripartite** (threefold) division of the body. At the forward end of the body is a **pre oral lobe**, behind this is a collar, and in the posterior side there is the word “hemichordate" means "half chordate,". They share some (but not all) of the typical chordate characteristics.

The body and enterocoelous coelom are divided into three unequal regions: Proboscis, collar and trunk.

Acorn worms also have multiple branchial openings, as many as 200 in some species. They are slow burrowers like earthworm, using the proboscis to burrow through sediment. They may either be **deposit feeders** (consume sediment and digest the organic matter like earthworms in soil) or **suspension feed**ers (collect suspended particles from the water). Some of these worms may be very large; one species may reach a length of 2.5 m (almost eight feet), although most of them much smaller. Development is direct in some, while is found in a tornaria larva.

Hemichordates are dioecious (i.e., males and females, although they cannot be distinguished externally) with external fertilization and are development is indirect (i.e., there is a distinct larval form). Asexual reproduction occurs in at least some acorn worms and in most pterobranchs. Acorn worms fragment small pieces from the trunk, each of which can then grow into a new individual. Pterobranch colonies are derived by budding of a single sexually produced individual. Sexual reproduction in pterobranchs produces non-feeding larvae that are brooded in the colony.

2.3.3 CEPHALOCHORDATA

GENERAL CHARACTERISTICS

These animals are known as ‘sea squirt’. The tunicates were first regarded as sponges. Lamark in 1816 placed Tunicata in between the Radiata and Vermes in his system of classification. Later, they were included in Mollusca. In 1866 Kowalevsky kept them in chordates. Their chordate features are clearly seen in the larval stages. All Urochordates are marine and occur in all the seas. Majority of them are sedentary and some are pelagic. The life-history of urochordates passes through a dramatic change. Their chordate characters are more pronounced during larval period. While in adults they are more like invertebrates than chordates. Therefore, the characters are described in two heads — larval characters and adult characters.

1. Body shows variation in size and form.
2. The body is unsegmented and has no tail
3. The body is covered by a test. It is formed by tunicin which is rallied to cellulose. Hence the name Tunicates.
4. Body wall shows one-layered epidermis, dermis is made by connective tissue and muscles, and atrial epithelium.
5. Coelom is absent.
6. Atrial cavity surrounds the pharynx, into this cavity the gill slits, anus and genital ducts will Open. It opens through atrial aperture.
7. Larva has notochord in the tail. It disappears during metamorphosis.
8. Respiratory system contains gills in the pharyngeal wall.
9. Ciliary mode of feeding is common.
10. Open type of Circulatory system is seen.
11. The heart is ventral and it periodically reverses its function.
12. Nervous system is represented by a single dorsal ganglion in the adult.
13. Excretion is carried on by nephrocytes.
14. Asexual reproduction is by budding.
15. Bisexual animal and cross fertilization is favored.
16. Fertilization is external.

CLASSICFICATION UP TO ORDER LEVEL

Subphylum Urochordata is divided into three classes.

CLASS 1. ASCIDIACEA

CLASS 2. THALIACEA

CLASS 3. LARVACEA (APPENDICULARIA)

CLASS 1. ASCIDIACEA:

i. These are sedentary tunicates.
ii. The body is covered by a test.
iii. Pharynx is large and contains gill-slits.
iv. Notochord, nerve-cord and tail are absent in adults.
v. These are bisexual animals.
vi. Life-history includes a typical tadpole larva.

The class is divided into two orders.

Order 1. Enterogona

these ascidians bear one gonad in the intestinal loop. Neural gland is ventral to the ganglion. Tadpole larva is seen.

Ex: *Ascidia* and *Ciona.*

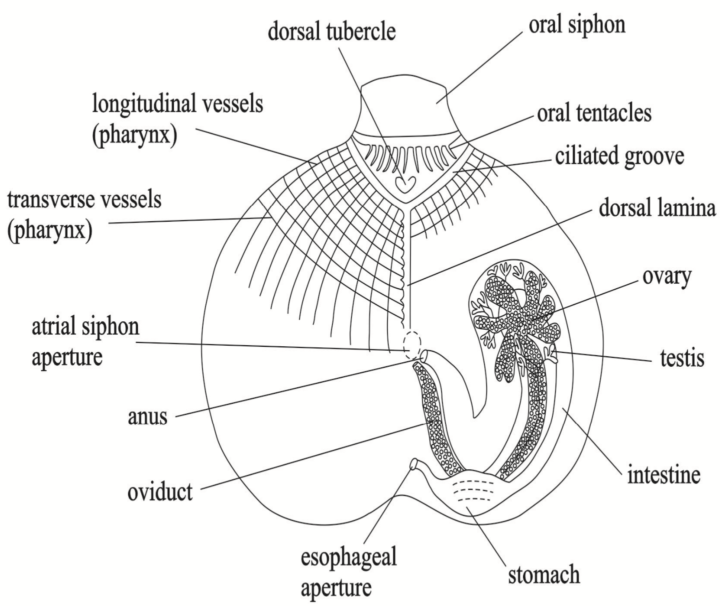

Fig. 2.2: Internal Structure of Ascidia

Order: 2. Pleurogona.

In these ascidians, gonads are paired and are present in the atrial wall. Neural gland is dorsal to the ganglion:

Ex: Herdmania, Botryllus.

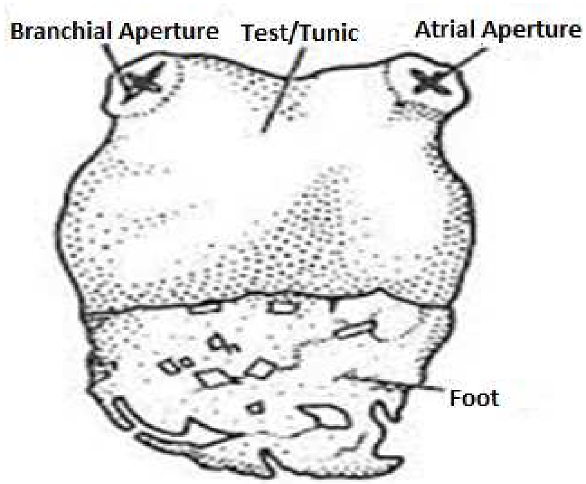

Fig 2.3 Test of Herdmania

CLASS 2.THALIACEA:-

i. These urochordates are free-swimming and pelagic forms.
ii. They are covered by transparent test.
iii. The brachial and atrial apertures are placed at anterior and posterior ends.
iv. Pharynx is small.
v. Notochord, nerve-cord and tail are absent in the adult.
vi. Asexual reproduction is by budding.
vii. These are bisexual animals.
viii. Tailed larva may be present or absent.
ix. Alternation of generations can be seen in the life history.

The class Thaliacea is divided into three orders.

Order1. Doliolida (Cyclomyarla)

- Barrel shaped body is completely covered by muscle bands,
- Pharynx is small.
- Number of gill slits is less.
- Tailed larva is seen.

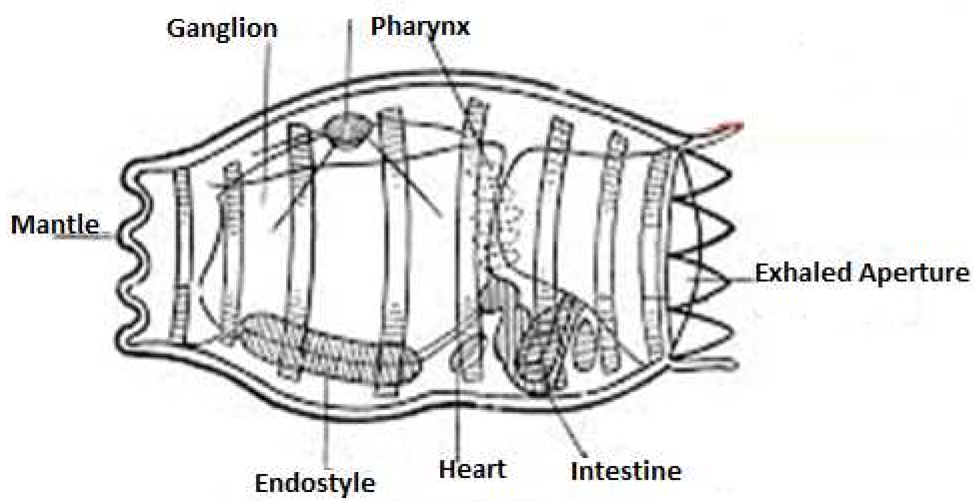

Fig 2.4: Doliolum

- Sexual Blasto-zooid and asexual oozooid stages will alternate in the life cycle. Ex: Doliolum.

Order2. Pyrosomlda:

i. This order includes colonial forms.
ii. Muscle bands are small and present at the ends.
iii. Gill-slits are many.
iv. Tailed larval stage is absent.
Ex: Luminescent colonial form.

Order 3. Salpida (Hemimyaria):-

i. Muscle bands are complete dorsally and incomplete ventrally.
ii. This order includes organisms whose body prism is like.
iii. Only one pair of lateral gill slits is present.
iv. Tailed larval stage is absent.

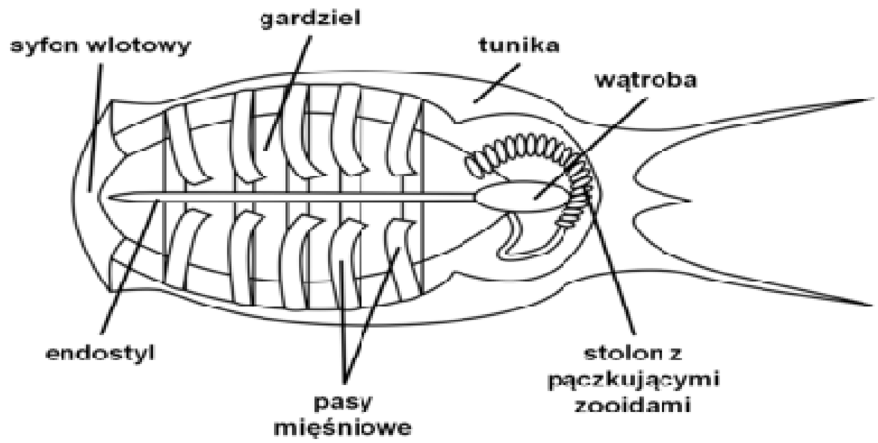

Fig: 2.5 Salpa

CLASS: 3. LARVACEA (APPENDICULARIA)

- These are free – swimming pelagic tunicates.
- True test covering is lacking.
- They show loose gelatinous house.
- This house is useful for filter feeding.
- Two gill slits are present.
- Atrium is absent.

2.4AFFINITIES AND INTERRELATIONS

AFFINITIES OF BALANOGLOSSUS

Affinities of Balanoglossus with Annelida & Echinodermata:-

Spengel (1893) suggested **affinities of Hemichordata (Balanoglossus) with Annelida** as follows:-

1. Bodies of both are vermiform and coelomate.
2. Both have Burrowing habits and tubicolous life. Both ingesting mud which is passed out as castings through anus.
3. Collar of *Balanoglossus* is similar to clitellum of earthworm.
4. Proboscis & prostomium is similar & preoral.
5. The arrangement of blood vessel is similar.
6. Position of heart in both is dorsal.
7. Tornaria larva of *Balanoglossus* shows several structural resemblances with the Trochophore larva of Annelida in being pelagic, ciliated, with apical plate, eye spots, and sensory cilia & well developed alimentary canal with similar parts.

Affinities of *Balanoglossus* with Echinodermata:-

Adult resemblances:-

Adult *Balanoglossus* and echinoderms are structurally quite different. So it is difficult to draw their phylogenetic relationship between themselves. However some resemblances are:-

1. Enterocoelic origin of coelom.
2. Heart vesicles and glomerulus of *Balanoglossus* are considered homologous to the dorsal sac and axial gland of echinoderm.
3. Nervous system poorly developed and forms epidermal nerve plexus.
4. Proteins & phosphagens present in *Balanoglossus* closely resemble those of echinoderms.
5. Both have common habits, and remarkable power of regeneration.

Larval resemblances:-

Tornaria larva of *Balanoglossus* has striking, structural similarities with Bipinnaria larva of echinoderms as follows:-

- Both are small, pelagic, transparent and oval.
- Identical ciliated bands taking up a similar twisted course.
- Enterocoelic origin & similar development of coelom.
- Proboscis coelom of Tornaria is comparable to hydrocoel of echinoderm Dipleurula.
- Deuterostome & digestive tract and complete are in both.

Chordates affinities of Balanoglossus:-

Inclusion of *Balanoglossus* under phylum chordate is not universally accepted. Among 3 fundamental chordate character the nature of notochord is really questionable. Recent workers do not accept the notochord nature of buccal diverticulum.Beside the nervous system, in general, is typically non chordate type excepting the presence of lumen in collar nerve cord. The only important chordate feature is the presence of gill slits.

Affinities with Urochordata:-

Similarity is present in the pharynx and branchial apparatus of both. Development of the Central part of the nervous system is quite similar in both

Affinities with Cephalochordata:-

Similarity is found in the structure and function of branchial apparatus in both. Arrangement of coelomic sacs is also similar in both. The typical tunicate looks like a non-chordate animal. If the life history of such animal is studied, the larval form reveals the chordate characters of that animal.

Urochordate's-resemblance with Chordate. :-

Urochordates resemble the chorates owing to the following features-

- Presence of dorsal tubular nerve cord.
- Presence of notochord.
- Well developed pharynx with gill-slits.
- Presence of endostyle on the ventral side of the pharynx.

- Presence of atrium around the pharynx.
- Presence of post - anal tail with tail fin.

  Because of these chordate features tunicates are included in chordate's group.

Urochordate's-resemblance with Amphioxus (Cephalochordate):

- Presence of notochord.
- Presence of dorsal tubular nerve cord.
- Presence of large pharynx with gill slits.
- Presence of atrium and atriopore.
- Presence of muscle band.

  Thus, the urochordates show close relation with Cephalochordates.

Urochordates differ from other chordates owing to the following characters:

- Presence of retrogressive metamorphosis.
- Absence of segmentation.
- Because of these characters zoologists included these animals in a Separate sub-phylum Urochordata.
- During recent years many zoologists regarded the tunicates as primitive and ancestral forms of chordates as a whole.

2.5 SUMMARY

The hemichordates are bottom-burrowing animals, solitary, particularly marine and cosmopolitan that inhabit soft sediments (Mandal, 2012). They are deposit feeders with a great importance in the food chains and also to recycle nutrients, break algae mats and mix marine sediments (Eco Marines 2013).They have bilateral symmetry, worm-like body divided into three regions,(Mandal, 2012).Mainly due to the presence of stomochord and character of the larvae, They are believed to be an connecting linked between a chordates and non-chordate (Mandal,2012).Although they are important for the whole marine environment balance and maintenance, there are only a few studies about it.

The urochordates are exclusively marine animals living on the substratum. The most familiar member of the group is *Hardmania;* it possesses two siphons for the entry and exit of water.

Characteristically they have a larval stage which undergoes retrogressive metamorphosis giving rise to the adult animal.Urochordates show all the basic characters of chordata at one or the other stage of life, they are supposed to be lower than Cephalochordata but higher than hemichordates from evolutionary point of view.

2.6TERMINAL QUESTIONS AND ANSWERS

Q1. Give the general characters of Hemichordata?

Q2. Give the classification of Hemichordates?

Q3. Describe the habit, habitat and external morphology of Balanoglossus?

Q4. Why the comman name of herdmania is sea squid?

Q- 5 Give the general characters and classification of Urochodata?

Q- 6 Give the systematic position of Herdmania?

Q- 7 Explain why a living organism required food? Describe the process of feeding and digestion in Herdmania?

Q- 8 describe the external features and habitat of Herdmania?

Q- 9 Give specialized characters of Urochordates and discuss its affinities?

Q-10 Explain the retrogressive metamorphosis in Herdmania larva?

Multiple Choice Questions

1. Balanoglossus belongs to the group:

(a) Platyhelminthes
(b) Annelida
(c) Cephalochordata
(d) Hemichordata

2. Balanoglossus is commonly known as:

(a) Snake worm
(b) Acorn worm
(c) Corn worm
(d) Earth worm

3. Larval form of Hemichordata:

(a)Tornaria
(b) Crinoidia
(c) Nauplius
(d) Caterpillar

4. Advanced chordates originated from:

(a) Amphioxus
(b) Tachoglossus
(c) Balanoglossus
(d) Starfish

5. Musculature in Balanoglossus is:

(a) Smooth
(b) Cardiac
(c) Striated
(d) Transverse

6. Coelom in Balanoglossus is:

(a) Scizocoel
(b) Entercoel
(c) Holocentric
(d) Metacentric

7. Balanoglossus is:

(a) Surface feeder
(b) Bottom feeder
(c) Column feeder
(d) Ciliary feeder

8. Which of the following is true for blood vascular system of Balanoglossus?

(a) Closed
(b) Absence of central sinus
(c) Blood is colorless
(d) Arteries and veins are absent

9. Body in hemichordate is:

(a) Segmented
(b) Radially symmetrical
(c) Diploblastic
(d) Triploblastic

10. Fertilization in Hemichordates is:

(a) Internal
(b) External in freshwater
(c) External in sea water
(d) External in air

Answers

1(d) 2 (b) 3 (a) 4(c) 5 (a) 6(b) 7 (d) 8 (c) 9(d) 10 (c)

UNIT 3: AGNATHA & GNATHOSTOMES

3.1 OBJECTIVES

- To understand the systematic and functional morphology of various groups of Cyclostomata.
- To study their affinities and adaptations to different modes of life.
- To describe and explain the basic biology, evolution and development system of Cyclostomata.
- To impart knowledge in comparative anatomy and development of Cyclostomata.
- To understand the ecological terms.

3.2 INTRODUCTION

Agnathan, (super class Agnatha), any member of the group of primitive jawless fishes that includes the lampreys (order Petromyzoniformes), hagfishes (order Myxiniformes), and several extinct groups.

Hagfishes are minor pests of commercial food fisheries of the North Atlantic, but lampreys, because of their parasitic habit, have been a serious pest of food fisheries in the Great Lakes in North America, where they have reduced the numbers of lake trout and other species. Agnathans are otherwise of little economic importance. The group is of great evolutionary interest, however, because it includes the oldest known craniates' fossils and because the living agnathans have many primitive characteristics.

Cyclostomata is a group of chordates that comprises the living jawless fishes: the lampreys and hagfishes. Both groups have round mouths that lack jaws but have retractable horny teeth. The name Cyclostomata means "round mouths”. Their mouths cannot close due to the lack of a jaw, so they have to constantly cycle water through the mouth.

3.3 ORIGIN AND EVOLUTION OF AGNATHA: OSTRACODERMS AND CYCLOSTOMES

Agnatha 'without jaws') is an infraphylum of **jawless fish** in the phylum Chordates, subphylum Vertebrata, consisting of both present (cyclostomes) and extinct (conodonts and ostracoderms) species. Among recent animals, cyclostomes are sister to all vertebrates with jaws, known as gnathostomes.

Recent molecular data, both from rRNA and from mtDNA as well as embryological data, strongly supports the hypothesis that living agnathans, the cyclostomes, are monophyletic.

The oldest fossil agnathans appeared in the Cambrian, and two groups still survive today: the lampreys and the hagfish, comprising about 120 species in total. Hagfish are considered members of the subphylum Vertebrata, because they secondarily lost vertebrae; before this event was inferred from molecular and developmental data, the group Craniates was created by Linnaeus (and is still sometimes used as a strictly morphological descriptor) to reference hagfish plus vertebrates.

While a few scientists still regard the living agnathans as only superficially similar, and argue that many of these similarities are probably shared basal characteristics of ancient vertebrates, recent taxonomic studies clearly place hagfish (the Myxini or Hyperotreti) with the lampreys (Hyperoartii) as being more closely related to each other than either is to the jawed fishes.

EVOLUTION OF AGNATHA

Although a minor element of modern marine fauna, agnathans were prominent among the early fish in the early Paleozoic. Two types of Early Cambrian animal apparently having fins, vertebrate musculature, and gills are known from the early Cambrian Maotianshan shales of China: Haikouichthys and Myllokunmingia. They have been tentatively assigned to Agnatha by Janvier. A third possible agnathid from the same region is Haikouella. A possible agnathid that has not been formally described was reported by Simonetti from the Middle Cambrian Burgess Shale of British Columbia.

Many Ordovician, Silurian, and Devonian agnathans were armored with heavy bony-spiky plates. The first armored agnathans—the Ostracoderms, precursors to the bony fish and hence to the tetrapods (including humans)—are known from the middle Ordovician, and by the Late Silurian the agnathans had reached the high point of their evolution. Most of the ostracoderms, such as thelodonts, osteostracans, and galeaspids, were more closely related to the gnathostomes than to the surviving agnathans, known as cyclostomes. Cyclostomes apparently split from other agnathans before the evolution of dentine and bone, which are present in many fossil agnathans, including conodonts. Agnathans declined in the Devonian and never recovered.

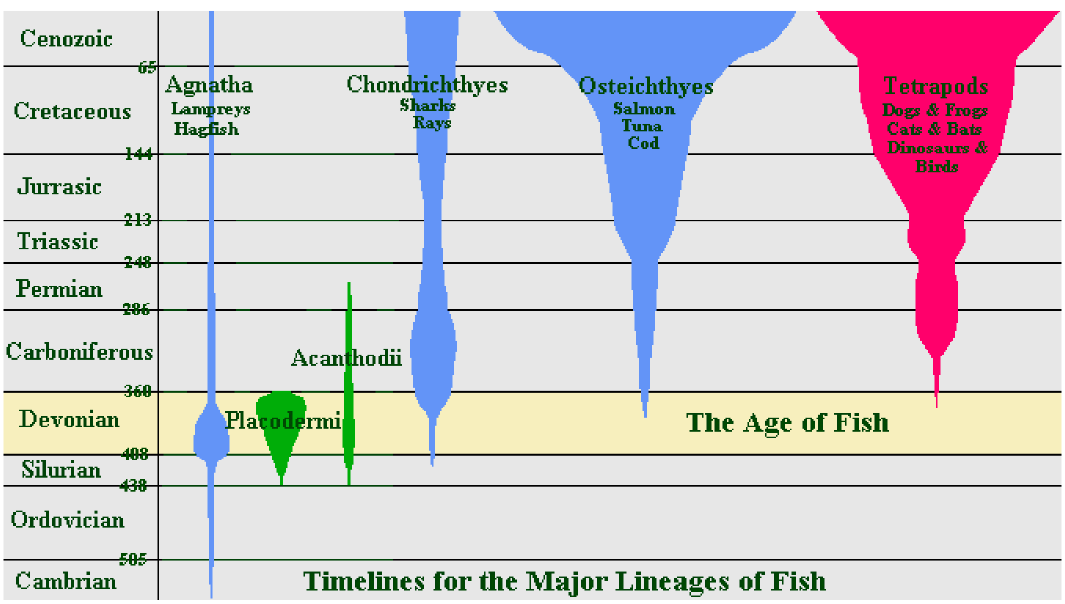

Fig.3.1 Evolution of jawless fishes

Approximately 500 million years ago, two types of recombinatorial adaptive immune systems (AISs) arose in vertebrates. The jawed vertebrates diversify their repertoire of immunoglobulin domain-based T and B cell antigen receptors mainly through the rearrangement of V(D)J gene segments and somatic hyper mutation, but none of the fundamental AIS recognition elements in jawed vertebrates have been found in jawless vertebrates. Instead, the AIS of jawless vertebrates is based on variable lymphocyte receptors (VLRs) that are generated through recombinatorial usage of a large panel of highly diverse leucine-rich-repeat (LRR) sequences. Three VLR genes (VLRA, VLRB, and VLRC) have been identified in lampreys and hagfish, and are expressed on three distinct lymphocytes lineages. VLRA+ cells and VLRC+ cells are T-cell-like and develop in a thymus-like lympho-epithelial structure, termed thymoids. VLRB+ cells are B-cell-like, develop in hematopoietic organs, and differentiate into "VLRB antibody"-secreting plasma cells.

General study of Petromyzon

Systematic position

Phylum Chordates

Sub phylum Vertebrata

Group Agnatha

Class Cyclostomata

Order Petromyzontiformes

Family Petromyzontdae

Type Petromyzon (Lamprey)

External Feature:

Lampreys are eel-like in appearance, but have a soft, cartilaginous skeleton. They lack paired fins but have well developed dorsal and ventral finfolds. In the adult, the jaws are so rudimentary that apparently they are wanting; the mouth is a longitudinal slit when closed, but forms an elliptical disc at the tip of the snout when open, and is armed with many horny, hooked teeth arranged in numerous (11 to 12) rows, the innermost the largest. There are two dorsal finfolds, and seven open gill slits on each side. The sea lamprey (the only member of its group known from our salt waters) can hardly be mistaken from any other fish its eel-like appearance coupled with two dorsal fins and the jawless mouth locate it at a glance.

Colour:

Small specimens (whether on their way downstream or in salt water) are white below and uniformly colored above, usually described as blackish blue, or as lead colored, and more or less silvery. But large specimens usually are olive brown above, or of varying shades of yellow-brown, green, red, or blue, mottled with a darker shade of the same color, or sometimes nearly black if the dark patches are confluent. The lower surface is whitish, gray, or of a pale shade of the same hue as the ground color of the back. During breeding season, the landlocked form takes on more brilliant hues, with the ground tint turning bright yellow.

Size:

The length at the time of transformation from the larval stage is about 4 to 8 inches (100-200 mm.). Sexually mature individuals, taken [page 13] in American rivers, average 2 to 2½ feet long, up to a maximum of about 3 feet. One of 33 inches weighed 2¼ pounds.

Habit and Habitats:

It has been known since a longtime that the sea lamprey breeds in freshwater. However, it does not enter all the streams within its range indiscriminately. As an illustration, we may cite outer Nova Scotia and the Bay of Fundy, where lampreys run in the St. Marys, Sackville, Annapolis, Shubenacadie, Petit Codiac, and St. Johns Rivers, but not in the Moser or Apple Rivers, although these last also are "salmon" rivers. Their requirements are a gravelly bottom in rapid water for their spawning beds, with muddy or sandy bottom in quiet water nearby, for the larvae.

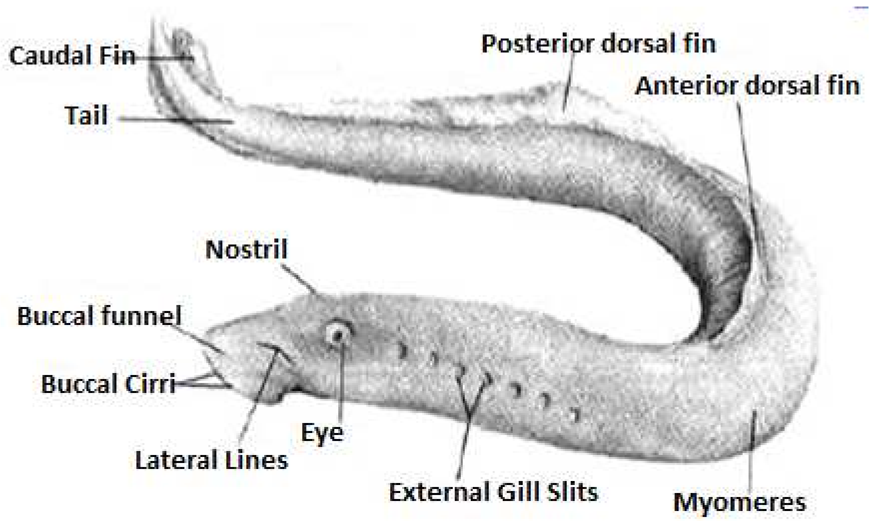

Fig 3.2 Adult Lamprey

STRUCTURAL FEATURES

1. **External Gill Slits** - openings that lead to the internal gills that are used to extract oxygen from the water. Lampreys have seven distinctive gill slits (fig.3.2).

2. **Buccal Funnel** - is the beginning of the mouth cavity. It contains numerous teeth in the adult lamprey. It is surrounded and supported by the oral disc.

3. **Buccal Papillae** - finger-like projections that surround the buccal funnel.

4. **Lateral Line System** - a system consisting of lines of pores that sense water currents, water pressure changes, and movements and vibrations in the water. The visible external pores of the lateral line system lead to an internal canal, which connect with specialized sensory cells. This system is believed to be related to the sense of hearing in other vertebrates.

5. **Median Nostril** - The median nostril is a primitive feature unique to the lamprey. Other vertebrate animals have paired nostrils. The nostril is responsible for detecting scents and leads to a nasal tube in the dorsal region of the head. A lamprey can "smell" by perceiving chemicals in the water. These scent particles can be detected from great distances. Chemical scents enter the medial nostril, pass through the nasal tube triggering the olfactory nerve cells along the way, and send electrical signals to the brain via the olfactory nerve.

6. Pineal Organ - The pineal organ is located under the skin immediately posterior to the medial nostril. Evidence of its presence is shown by a generalized round bump on the dorsal side of the head. In the lamprey, the pineal organ is sometimes referred to as a “third eye” due to its role in perceiving light and dark. The pineal organ contains a light sensitive retina that does not interpret visual images.

7. Eye - The eye is a sensory organ responsible for receiving visual input. It leads to the optic nerve, which sends visual impulses to the brain. In the brain the images are deciphered. The adult lamprey eye is structurally very similar to the eyes of other vertebrates consisting of a cornea, iris, lens and retina. There are no eyelids present in the lamprey.

8. Anterior Dorsal Fin - A fin used to maintain an upright orientation in the water while moving about.

9. Posterior Dorsal Fin - This fin has the same function as the anterior dorsal fin.

10. Caudal Fin - A powerful fin used to thrust the lamprey’s body through the water.

11. Cloaca - The common opening of the urinary and reproductive systems. It receives waste from the kidneys and fluids from the reproductive organs and transfers them to the external environment via the opening of the cloaca. The urogenital papilla is a protrusion that may be extending from the cloaca.

12. Anus - The anus is located immediately anterior to the cloaca. It is an extension of the intestine through which solid waste is expelled from the body.

The Digestive System

The digestive system consists of the alimentary canal, which runs from the mouth to the anus. Food enters the food enters the mouth and moves through the pharynx into the esophagus. The adult lamprey is an ectoparasite and its food is in the form of fish blood. A lamprey does not have a stomach. Rather, food passes directly from the esophagus to the intestine, which absorbs the bulk of the nutrients. The intestine becomes the site of the emulsification, digestion, and absorption of nutrients. The latter portion of the intestine digests bacteria, reabsorbs water, and forms feces. The last section of the intestine narrows to form an exit called the anus. The resulting solid wastes leave the body at this point.

Nervous system

Lampreys have a primitive nervous system; the brain structure is fairly simple compared to other vertebrate animals. System consists of the brain and a hollow spinal cord–Situated above the alimentary canal. –Vertebrate nerve cord and brain contain a cerebrospinal fluid which contains mineral salts and traces of protein and sugar. The fluid helps to support the nervous tissue and probably plays some part in its nutrition. The nerve fibers are not covered by the myelin sheath (a fatty insulating layer) found in all higher vertebrates–Therefore nervous conduction is slow. The complex nervous connections found in higher forms are impossible in these early vertebrates**.**

Circulatory System:

Blood flows through a series of vessels to supply oxygen and nutrients to the body and to remove carbon dioxide and other wastes.–Arteries and arterioles carry blood away from the heart–Veins and venules carry blood back towards the heart–Capillaries are the smallest vessels where the gases are exchanged with the cells of the body

Respiratory Systems:

A lamprey "breathes" by extracting the oxygen present in the water in which it lives. Within the respiratory tube are seven gill pouches, each containing the finer feather-like gill lamellae. The gill lamellae increase the surface area of the respiratory structures and contain the small capillary beds that extract oxygen Problem, when a lamprey is feeding and attached to a fish the mouth serves as an attachment organs, it is no longer available for use in respiration. Under this situation Water can be drawn directly into the respiratory tube through the external gill slits. Muscular contractions change the volume of the respiratory tube and thus control the movement of water over the gill lamellae.

3.3.1 GENERAL CHARACTERS OF AGNATHA

The group Agnatha consists of the jawless fishes, the most primitive group of **extant** vertebrates. While most agnathan species are now extinct, fossil evidence indicates that the group was once highly successful and extremely varied. Two lineages of agnathans have survived to the present, the lampreys and the hagfish.

As the most primitive members of the vertebrates, agnathans differ from all others in several important respects. First, they lack hinged upper and lower jaws and instead have unhinged circular mouths. They also lack the paired appendages (fins or limbs) that are found in other vertebrates. In addition, the internal skeleton of agnathans is not bony but **cartilaginous**. However, many extinct agnathans had extensively developed bony plates directly under the skin. These were most often found in the region of the skull and served as a protective armor. Bony plates are not present in extant agnathan species.

Major Groups of Living Agnathans:

There are two major groups of living agnathans, the lampreys and the hag-fish. Both appear fishlike or eel-like.Lampreys are parasitic species that use their sucker like mouths to attach to a fish host. They use the many teeth in their mouths and on their tongues to rub at the flesh of their prey. Adult lampreys inhabit a saltwater marine environment but swim up rivers to reach freshwater breeding grounds. Lampreys breed only once in their lifetime, in a single tremendous reproductive bout, and die soon after. Lampreys pass through an immature larval stage before metamorphosing into adults. The larval lamprey is always in fresh water. It grows and matures for several years before undergoing metamorphosis and migrating to saltwater habitats. Before it was known that the larva was a larval lamprey, it was thought to be a separate species. The larva is of particular interest to biologists who study vertebrate evolution because it shares many features with the cephalochordate Branchiostoma (formerly called Amphioxus), which is the group believed to be most closely related to the vertebrates. The resemblance between Branchiostoma and the larval form of a very primitive vertebrate is striking, and supports the closeness of the relationship between the two groups.

The second group of living agnathans is the hagfish. Hagfish are scavenger species that feed off dead and wounded organisms in the ocean. They are also well-known for their defense mechanism, when threatened; hagfish ooze out great amounts of foul slime.

Evidence from the fossil record suggests that agnathans reached their peak of diversity between about 500 million and 340 million years ago. During this period, they were plentiful both in the seas and in freshwater habitats. More than 200 fossil species are known. The majority of these species were fairly small, perhaps a few inches long. The species that have survived to the present are but the remains of a group that was once considerably more diverse.

1. Cyclostomes are jawless primitive vertebrates. They may be marine or fresh-water. They include hag fishes and lampreys
2. The body is long, eel like. It has a trunk and a compressed tail.
3. Paired fins are absent. Median fin is supported by cartilaginous fin-rays.
4. The skin i.e. soft and smooth. It is slimy. It is scale less.
5. Z- shaped myomeres are present in the trunk and tail Protractor and retractors muscles

   Move the tongue.
6. In this group a true coelome is seen.
7. These vertebrates do not have jaws, hence called Agnatha.
8. The mouth is circular. It works like a sucker and is surrounded by tentacles.
9. Tongue bears teeth.
10. Stomach is absent and oesophagus leads into the intestine.
11. Endoskeleton is present.
12. Skull is simple and primitive.
13. Notochord persists throughout life.
14. Vertebrae are represented by neural arches, around the notochord.
15. five to sixteen pairs of gills are present in sac like pouches
16. The heart is two chambered. Sinus venousus is present, but conus arteriosus is absent.
17. Blood contains leucocytes and Irregular nucleated erythrocytes.
18. Brain is seen.

19. Ten pairs or less number of cranial nerves are present.

20. Nasal sac is single and median.

21. Lateral line sense organ is present.

22. Excretory system includes a pair of mesonephric kidneys.

23. Sexes are separate.

24. Gonad is single and without a gonoduct.

25. Development may be direct or with a long larval stage.

3.4 THE EARLY GNATHOSTOMES (PLACODERMS)

As early gnathostomes (jawed vertebrates), placoderms were **traditionally viewed as a side branch to the main trajectory of jaw evolution from early osteichthyan fishes to the first tetrapods (land vertebrates)**.

Placodermi (from Greek plate' and skin', literally 'plate-skinned') is a class of armoured prehistoric fish, known from fossils, which lived from the Silurian to the end of the Devonian period. Their head and thorax were covered by articulated armoured plates and the rest of the body was scaled or naked, depending on the species. Placoderms were among the first jawed fish; their jaws likely evolved from the first of their gill arches.

Placoderms are thought to be paraphyletic, consisting of several distinct outgroups or sister taxa to all living jawed vertebrates, which originated among their ranks. In contrast, one 2016 analysis concluded that placodermi are likely monophyletic, though these analyses have been further dismissed with more transitional taxa between placoderms and modern gnathosthomes, solidifying their paraphyletic status.

Placoderms were also the first fish to develop pelvic fins, the precursor to hind limbs in tetra pods, as well as true teeth, 380-million-year-old fossils of three other genera, Incisoscutum, Materpiscis and Austroptyctodus, represent the oldest known examples of birth. The first identifiable placoderms appear in the fossil record during the late Llandovery epoch of the early Silurian. The various groups of placoderms were diverse and abundant during the Devonian, but became extinct at the end-Devonian Hangenberg event 358.9 million years ago.

GENERAL CHARACTERISTICS:

Many placoderms, particularly the Rhenanida, Petalicthyida, Phyllolepida, and Antiarchi, were bottom-dwellers. In particular, the antiarchs, with their highly modified, jointed bony pectoral fins, were highly successful inhabitants of Middle-Late Devonian freshwater and shallow marine habitats, with the Middle to Late Devonian genus, *Bothriolepis*, known from over 100 valid species. The vast majority of placoderms were predators, many of which lived at or near the substrate. Many, primarily the Arthrodira , were active, nektonic predators that dwelled in the middle to upper portions of the water column.

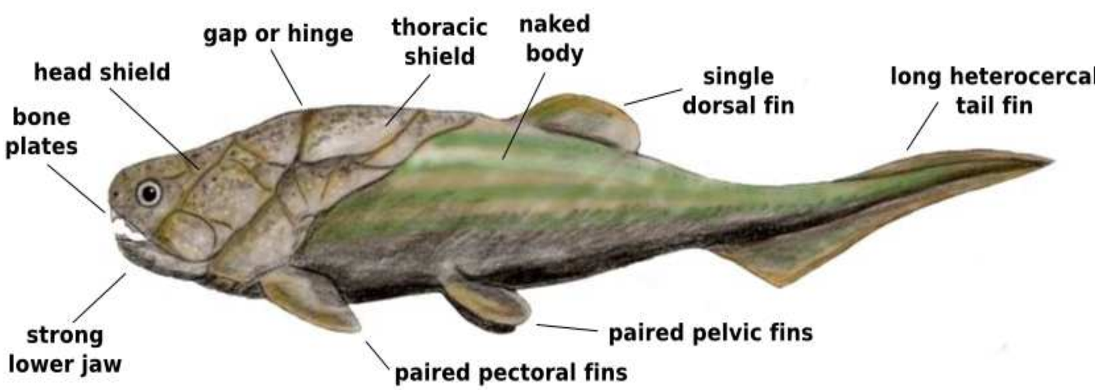

Fig.3.3 External anatomy of the placoderm (Coccosteus decipiens)

A study of the arthrodire *Compagopiscis* published in 2012 concluded that placoderms (at least this particular genus) likely possessed true teeth contrary to some early studies. The teeth had well defined pulp cavities and were made of both bone and dentine. However, the tooth and jaw development were not as closely integrated as in modern gnathostomes. These teeth were likely homologous to the teeth of other gnathostomes.

3.5 SUMMARY

Cyclostomata comprises two families of living jawless fishes: hagfishes (Myxinidae, 44 species) and lampreys (Petromyzonidae, 41 species).Morphological analyses have favored the closer relationship of lampreys to jawed vertebrates (gnathostomes) than to hagfishes. However, most of the recent molecular phylogenetic analyses have supported a hagfish-lamprey relationship. The estimated divergence time for hagfishes and lampreys among several studies averages 482 million years ago (Ma), but varies (520-432 Ma) depending mostly on the assumed timing of the cyclostome-gnathostome divergence. Nonetheless, there is agreement that hagfish and lamprey lineages diverged relatively shortly (within 100 million years) after the divergence of cyclostomes and gnathostomes.

3.6 TERMINAL QUESTIONS AND ANSWERS

Question No.1 Give two example of jawless vertebrate?

Question No.2 Distinguish between Agnatha & Gnathostomata?

Question No.3 Give the General Characters of the Agnathans?

Question No.4 Give the General Characters of the Ganthostomata?

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UNIT 4: PISCES

4.1 OBJECTIVES

- We will studies about the general account of the Elasmobranchii, Holocephali, Dipnoi and Crossoptergii
- We will understand about the Adaptive radiation in bony fishes.
- We will learn about the Affinities and phylogenetic significance of fishes.

4.2 INTRODUCTION

These are true, jawed vertebrates with specific organs for respiration, excretion and blood circulation. The organisms belonging to this class are poikilotherms, meaning that they cannot regulate their own body temperature. Essentially, all the fish come in this category.

Kingdom: Animalia

Phylum: Chordata

Class: Pisces

A fish **(Fig: 4.1)** is any member of a paraphyletic group of organisms that consist of all gill-bearing aquatic craniates animals that lack limbs with digits. Included in this definition are the living hagfish, lampreys, and cartilaginous and bony fish, as well as various extinct related groups. Most fish are ectothermic ("cold-blooded"), allowing their body temperature to vary as ambient temperature changes though some of the large active swimmers like white shark and tuna can hold a higher core temperature. Fish are abundant in most bodies of water. They can be found in nearly all aquatic environments, from high mountain streams Fishes are important resources for humans worldwide, especially as food. Commercial fishermen hunt fishes or farm them in ponds or in cages in the ocean.

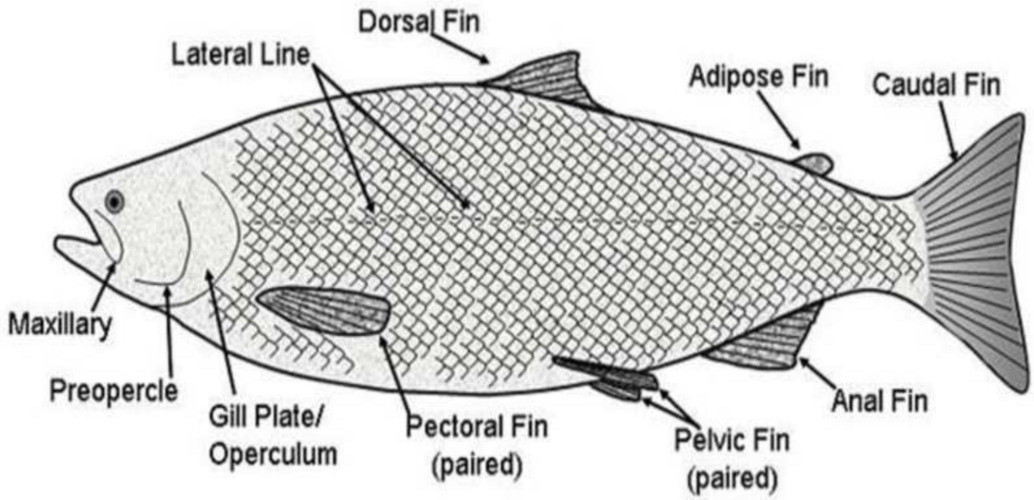


Fig 4.1 a Fish

Fishes are also caught by recreational fishermen, kept as pets, raised by fish keepers, and exhibited in public aquaria. Fish have had a role in culture through the ages, serving as deities, religious symbols, and as the subjects of art, books and movies. Because the term "fish" excludes the tetra pods (i.e., the amphibians, reptiles, birds and mammals) which descend from within the same ancestry, it is paraphyletic and is not considered a proper grouping in systematic biology.

4.3 A GENERAL ACCOUNT OF THE ELASMOBRANCHII, HOLOCEPHALI, DIPNOI AND CROSSOPTERGII

The Chondrichthyes, also called elasmobranchii, comprise sharks, rays, skates, chimaeras, etc. Fishes are essentially aquatic and jaw-bearing true vertebrates. This class is specially known for their unimaginable number (about 40,000 species) and bewildering forms. They are characterized by having streamlined bodies, covered with scales. The presence of gills for respiration and paired fins for swimming. They belong to the super class Pisces which can be sorted out into two distinct evolutionary lines cartilaginous Fishes of Chondrichthyes (Gr. chondros, cartilage + ichthys, fish) and bony fishes or Osteichthyes (Gr. osteon. bore).

GENERAL CHARACTERS

Sharks (sub-order Pleurotremata) are usually somewhat fusiform and slightly compressed laterally. Rays occupy a separate sub-order (Hypotremata), but despite their radical dorso-ventral compression, the migration of the eyes to the dorsal surface, and their apparent dissimilarity from the sharks in other ways, the two groups have many features in common.

The flattened form of the rays is an adaptation to a bottom-dwelling existence. They can commonly be seen gliding along the bottom of all relatively warm seas, and they extend into circumpolar regions as well. Although they are popularly supposed to be confined to shallow waters, some inhabit great depths and are blind.

The elasmobranchii **head** is in many cases produced forwards into a long rostrum. This is of great length and bordered with triangular teeth in the sawsharks (Pristiophorus) and sawfishes (Pristis). In the Hammerhead Shark (Sphyrna = Zygaena) the anterior part of the head is extended transversely and the eyes are carried at the lateral extremities.

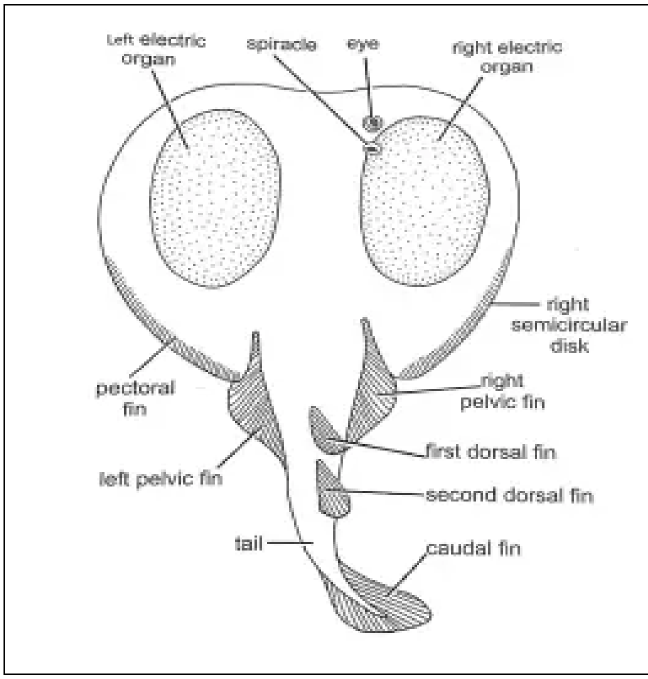
There are well-developed **median and paired fins**. The **caudal fin** is large and, as a rule, strongly heterocercal in the sharks and shark-like rays. It is reduced in most of the latter group. The dorsal and anal fins are large in the sharks, the former completely divided into two. In the rays the dorsal fin is usually small, and the anal fin absent. The paired fins differ widely in the two groups.

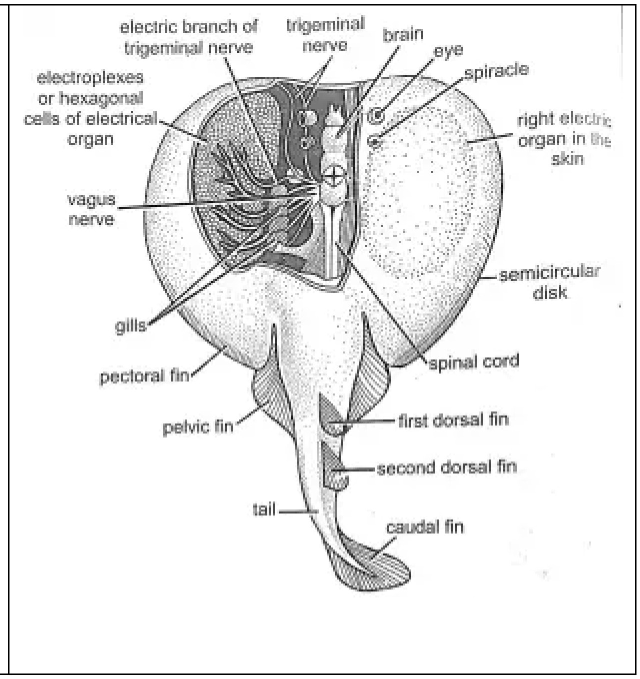
The **mouth** is situated on the ventral surface of the head, usually a considerable distance from the anterior extremity. In front of each angle of the mouth is the opening of one of the olfactory sacs.

The **integument** develops any hard parts as is the case in the majority of the Chondrichthyes; they take the form, not of regular scales, as in most other fishes, but of numerous rough, hard placoid scales. These vary greatly in shape, are usually extremely minute, but are in some cases developed, in certain parts of the surface, into prominent tubercles or spines.

The **endoskeleton** is composed of cartilage, often with a deposition of calcareous matter in special places- notably in the jaws and the vertebral column.

The **skull** is an undivided mass of cartilage, hardened, in many cases, by deposition of calcareous matter, but not containing any true bony tissue. It consists of a cartilaginous case which protects the brain and the organs of special sense.





The **arrangement of the muscles** is simple. The trunk-muscles are divided into a pair of dorsal and a pair of ventral divisions each, composed of many myomeres with intercalated myocommata, following a metameric arrangement. The ventral part, where it forms the muscles of the wall of the abdominal cavity, is composed externally of obliquely running fibres, and represents one of the two oblique muscles of the abdomen of higher forms.

Electric organs occur in several elasmobranches'. They are best developed in the electric-rays, numb-fishes, or torpedoes, in which they form a pair of large masses running through the entire thickness of the body, between the head and the margin of the pectoral fin.

Alimentary Canal and Associated Structures -Teeth are developed on the palatoquadrate and on Meckel's cartilage. They are arranged in several parallel rows, and are developed from a groove within the margin of the jaw. Successive rows come to the front, and, as they wear out, fall off and are replaced by others. In the sharks the teeth are usually large, and may be long, narrow, and pointed, or triangular with serrated edges, or made up of several sharp cusps.

In the rays the teeth are more or less obtuse. Sometimes, as in the eagle-rays, they form a continuous pavement of smooth plates covered with enamel. Thus they are adapted to crushing food such as mollusks, crabs, and other animals.

The respiratory and associated organs of the Chondrichthyes always have the general structure and arrangement already described in the case of the respiratory and associated organs of the Chondrichthyes always have the general structure and arrangement already described in the case of the Dogfish. In the rays the water for respiration is taken in mainly through the spiracles, in the sharks through the mouth.

Blood-vascular System – The heart has, in all essential respects, the same structure throughout the group. The conus arteriosus is always contractile, and contains several rows of valves. The general course of the circulation is the same in all, with some variation in the precise arrangement of the vessels. In some of the rays the ventral aorta and the roots of the afferent vessels are partly enclosed in the cartilage of the basi-branchial plate.

Brain -The fore-brain greatly exceeds the other divisions in size. In Scymnorhinus there are two widely-separated cerebral hemispheres containing large lateral ventricles. In other genera there is at most, as in dogfishes, a median depression of greater or less depth, indicating a division of the anterior end of the fore-brain into two lateral portions.

Urinogenital Organs and Reproduction -The kidneys differ somewhat in the two sexes. In the male the anterior portion persists in the epididymis, and its duct becomes the sperm duct, while the posterior portion, which is the functional kidney, has a duct or ducts of its own. In the female selachian there is no direct connection between the reproductive and renal organs.

The anterior portion of the kidney may be functional, and its duct persists, opening along with those of the posterior portion. In the male the urinary ducts open into a median chamber-the urinogenital sinus-which extends into the cloaca, and receives also the spermiducts. It communicates with the general cavity of the cloaca by a median opening situated on a papilla-the urinogenital papilla. In the female there is a median urinary sinus, into which the urinary ducts open, or the latter may open separately into the cloaca.

Development – Except in one species of Heterodontus, cleavage is meroblastic. It is confined to the germinal disc. A segmentation cavity appears early between the blastoderm cells and the yolk; the floor of the blastocoele becomes covered with a syncytium which probably plays a part in yolk digestion. When cleavage is complete the blastoderm is a lens-shaped disc thicker at one end-the future caudal extremity.

HOLOCEPHALI - GENERAL ORGANIZATION AND AFFINITIES

Introduction

- Holocephali (Gr. Holos = entire + kephale = head), is a very small ancient group of highly specialized marine fishes.
- It comprises of rat-tailed fishes. They appeared first in the lower Jurassic and at present, are represented by a few marine genera only.
- It includes the only cartilaginous fishes having fleshy opercula covering of the gills.
- Like the Acanthodians, they seem to represent divergent and specialized descendants of some primitive elasmobranches' ancestor.

Key Characters of Holocephali

- Endoskeleton cartilaginous often calcified.
- Persistent (unconstricted) notochord; poorly developed vertebrae.
- Holostylic jaw suspension, i.e., the upper jaw is immovably united with cranium, hence the name holocephali.
- Teeth united to form crushing plates, devoid of enamel. This is an adaptation for crushing molluscs, crustaceans and sea urchins.
- The occipital condyles are well developed and are marked better than that of the sharks.
- The gill openings are only four in number and the spiracles cleft is absent.
- A fleshy operculum, supported by branchial rays, is attached to the hyoid arch and forms covering of the gill openings on each side.
- Median and paired fins are well developed.
- No spiracle; no air bladder; no cloaca.
- Absence of stomach and presence of spiral valve in the intestine.
- Kidney is opisthonephric corresponding fundamental pattern of other fishes.
- Sexual dimorphism is well marked. Females attain larger size than the males.
- Mature male with cephalic or frontal clasper on forehead, a pair of pelvic claspers and a pair of prepelvic tenacula.
- Oviparous.
- Fertilization internal and cleavage homoplastic.

General Organization of Holocephali

External Features of Holocephali:-

- Body appearance is shark-like but the head is large and compressed, having a small mouth.
- Operculum is formed by a fold of skin to cover the gill slits so that a single branchial aperture is found.
- Spiracle and cloaca are absent. Two dorsal and a ventral fin present.
- Tail appears to be heterocercal, but in Chimaera, it is whip-like. The pectoral as well as pelvic fins is large in size.
- The anal fin is small. The urinogenital aperture is distinct from the anus.
- Sexes are separate and sexual dimorphism well mark. Females are larger than the males.
- Males having cephalic or frontal clasper on forehead covered with denticles.
- Skin is smooth and silvery.

- Lateral line system has open grooves, with many branches on head.
- The hyomandibular does not participate in the suspension of the jaw.
- Such suspension is often called holostylic, to emphasize, that it probably evolved independently of that in dipnoans and the tetrapods.
- There are 5 gill arches with four gill openings protected by cover.
- The spiracular cleft is completely closed.
- All the pterygiophores of the first dorsal fin are fused into a single plate; the remaining fins and the pectoral girdle are on elasmobranch pattern.
- Each pelvic half consists of a narrow iliac region and a broad pubo-ischial region.
- A fleshy operculum, supported by branchial rays is attached to the hyoid arch and forms covering of the gill openings on each side.

Respiratory System:

- A mandibular pseudobranch is absent and the hyoid bears only a posterior hemibranch.
- The first, second, and third branchial arches have holobranchs but the fourth has a hemibranch.
- The fifth arch is gillless and lacks a cleft between it and its predecessor.

Nervous System:

- Cerebellum is small. Medulla oblongata is produced laterally into restiform bodies.
- The cerebral hemispheres are small and each is connected with an olfactory bulb by means of a narrow peduncle.
- Diencephalon is long and trough shaped.
- The small rounded pineal body is present at the end of a pineal stalk.

Urinogenital System:

- The kidney of holocephalians is opisthonephric having a large number of uriniferous tubules and built upon the basic pattern of other fishes.
- The peritoneal funnels are absent in holocephalians but the abdominal pores are present.
- Unisexual. Clasping organs are remarkable in males only.
- Females attain larger size than the males.
- The male reproductive system consists of testes, vas deferens, epididymis and vesicular seminalis.

- The testes are large oval bodies but contain only immature sperms.
- The sperms become mature in the epididymis and form spermatophores.
- Vesicula seminalis is divided internally into several chambers by means of transverse septa.
- The spermatophores are stored in these compartments and are finally released into the urinogenital sinus.
- The female reproductive organs resemble those of the elasmobranches' and consist of a pair of ovaries, shell glands and uteri.

Fertilization:

- The fertilization is internal and the cleavage holoblastic type.
- The incubation period is fairly long, for example, in Callorhynchus; it extends from 9-12 months.

Eggs and Development:

- The holocephalians are oviparous.
- Their eggs are characteristically spindle shaped and are surrounded by horny egg capsules secreted by the shell glands.
- The capsules of Hydrolagus measure about 15 cm and those of Callorhynchus collie, about 25 cm, in length.
- The eggs are laid in pairs, and contain three compartments.

DIPNOI - GENERAL ORGANIZATION

- The Dipnoi, commonly known as lung fish, are considered to be specialized or degenerate descendants of the more primitive lobe fins which they closely resemble. They were once supposed to be the ancestors of the amphibians, a view no longer held. They are large, bizarre fishes represented only by three living genera and furnishing an example of discontinuous distribution. In all three, the air bladder serves functionally as a lung by which they can breathe air when necessity arises. The endangered monotypic Australian lungfish, Neoceratodus (-Epiceratodus) forsteri, restricted to fresh waters, attains a length of 1.5 meters or more.

- It has a single lung (Monopneumona) and cannot survive out of water. The monotypic South American lungfish is Lepidosiren paradoxa, while the African lungfish, Protopterus, has four or so related species. These two genera have weekly developed gills so that they will drown if prevented from using their paired lungs (Dipneumona). They live on mud swamps or marshes.

- During drought, when the marshes dry up, they aestivate by secreting mucous cocoons in mud, in which they become dormant and breathe atmospheric air through burrow openings. These 1 to 2 meters long, elongated, eel-like or snake-like forms have unique filamentous but highly mobile paired appendages Lung fishes are mostly cartilaginous. They have specialized crushing tooth plates to feed effectively upon shell fish.

- Their embryogeny is more primitive than that of other living bony fishes. Cleavage of eggs is holoblastic and gastrulation occurs by invagination. Their tadpole like larva has external gills as accessory respiratory structures

- The three genera of living Dipnoi are allied in all the essential features of their structure. Therefore it is only necessary to mention here the principal points in which Neoceratodus and Lepidosiren differ from Protopterus. Protop terus and Lepidosiren resemble one another more closely than either resembles Neoceratodus and are placed in the same family, the Lepidosirenida.

- The limbs of Lepidosiren are similar to those of Protopterus, but in Neo ceralodus they are broad and leaf-like, with a correspondingly modified skeleton. The tapering central axis is composed of a stout basal cartilage and a number of short, cartilaginous segments, with serially arranged rows of jointed, cartilage inous radialia projecting on either side. The skull of Neoceratodus differs somewhat from the lepidosirenid type, being an undivided mass, devoid of fontan elles. In many respects it resembles the skull of the fossil dipnoan Ceratodus, and is more primitive than that of lepidosirenids. Furthermore, true splenials and vestigial dentaries are present.

- There are two lungs in Protopterus and Lepidosiren, but only one in Neoccratodus. The monopneumonous condition in Neoceratodus is possibly due to the suppression of the original left lobe (Goodrich). The internal structure of the lung, too, is simpler in this species. In Neoceratodus only four pairs of gills are developed, but each gill arch carries a double row of filaments. The hyoidean gill is a true pseudobranch. A peculiarity in this genus is that the branchial lamellae of each gill arch extend on to the dorsal and ventral walls of the gill cleft, so that the hemibranchs of each cleft are continuous, both dorsally and ventrally. The fifth arch lacks gills.

CROSSOPTERYGIAN GENERAL ORGANIZATION

Crossopterygian, (subclass Crossopterygii), any member of a group of primitive, lobe-finned, bony fishes believed to have given rise to the amphibians and all other land vertebrates.

One major trait of the subclass is the division of the skull into an anterior, or ethmosphenoidal, unit and a posterior, or oto-occipital, unit. These units are remnants of two cartilaginous templates found in the embryonic cranium. A strong joint unites the two regions at each side. The base of the skull and the vertebral column are incompletely ossified, allow the persistence, to various degrees, of the initial skeletal axis, or notochord.

The subclass is made up of three orders: Rhipidistia, Actinistia, and Struniiformes. After being widely distributed around the world in the Devonian to Permian periods (416–251 million years ago), the crossopterygians underwent a rapid decline and then almost became extinct after the end of the Triassic Period (about 200 million years ago).The Rhipidistia, predatory fishes of the Paleozoic, were ancestral to the terrestrial vertebrates and lived predominantly in fresh water. Rhipidistians probably had two respiratory apparatuses, a branchial (gill) system for aquatic respiration and a pulmonary (lung) system for air breathing.

To facilitate air breathing, the nasal cavities were provided with posterior nares (nostrils) homologous with the primary choanae (internal openings to the pharynx) of more-advanced vertebrates. The skeletal structure of the paired fins shows an internal skeleton with elements corresponding to some of the arm and leg bones of land-dwelling vertebrates.

This type of limb foreshadows locomotion both on solid ground and in the water. Thus, in the history of vertebrate evolution, the rhipidistians are credited with having made the great transition in anatomy and physiology involved in the emergence from water and resulting in the evolution of the amphibians.

STRUCTURE OF CROSSOPTERYGII

- The most striking characteristics are those of the head.
- The brain exhibits relatively little outward differentiation and has an extremely small volume with respect to the cranial capacity. (The brain accounts for less than 1.5 percent of the available space within the skull.)
- In addition, the forebrain shows considerable displacement relative to the floor of the skull.
- The snout contains a special sensory organ, the rostral organ, which is lined with electro receptive cells.
- Fibrous connective tissues as well as a pair of powerful longitudinal muscles, the sub cranial muscles that serve to close the intracranial joint, are attached at the intracranial articulation.
- The heart of the Latimeria is very primitive and exhibits almost perfect bilateral symmetry (mirror-image form).
- It lies within a substantial pericardial cavity that retains the primitive continuity with the peritoneal (abdominal) cavity.
- There is a series of small valves near the exit from the heart, and several small contractile organs attached to the branchial arteries apparently fulfill the necessary function of assisting the propulsion of blood.
- An enormous cylinder of adipose (fat) tissue, aligned with a short median diverticulum (a blind pouch) of the ventral wall of the esophagus, lies above the abdominal organs. It apparently is a result of the degeneration of a lung apparatus. The extraordinary size of this cylinder is related to a displacement of the kidneys that undoubtedly occurs in the course of development, these organs occupying an unusual ventral position, posterior to the anus.
- The body is covered with large rough scales. The powerful tail fin has three lobes.
- The posterior end of the notochord extends into the middle lobe, which is by far the smallest.
- Two pairs of fins, the pectoral and the pelvic, are attached to their respective girdles.

- The base of each fin is made up of a fleshy stalk, and each stalk is supported by several successive segments of bone or cartilage that are homologous with the similar parts of the endoskeleton of the paired fins of the Rhipidistia.
- Median fins similarly formed grow from the posterior part of the body, the posterior dorsal (above) and anal (below) fins.
- Finally, there is an anterior dorsal fin which, in contrast to the foregoing, is of ray-finned (actinopterygial) type—that is, lacking the fleshy supportive stalk.
- Modern coelacanths reproduce by internal fertilization, and the mother gives birth to live young.

4.4 ADAPTIVE RADIATION IN BONY FISHES

The adaptive radiation in bony fishes **enables the fish to evolve different methods of locomotion and feeding**. In bony fish, adaptive radiation takes place because of the development of strong jaws, paired fins and a vertebral column.

The purpose of this exercise is to illustrate some of the adaptive radiation and subsequent evolution of fishes. We will make direct observations of living fishes at the Stephen Birch Aquarium museum, located at the Scripps campus of UCSD. We will look at two of the three classes of fishes, the cartilaginous fishes (Chondrichthyes) and the bony fishes (Osteichthyes). The ocean is a stable place to live. The ocean's temperatures are generally uniform over a long period. Water offers support to fish's bodies, so that strong skeletons are not necessary, although the high viscosity of water creates a problem to their locomotion.

The fish’s solution, in response to this problem, is to achieve some degree of streamlining. As a result, fishes from the same habitat look very much alike. It is not that these fishes are closely related because of their similar look, but the solution to the locomotion through the water is a common one. We will first explore the cartilaginous fishes such as sharks, skates, guitar fishes and rays. We will see how they solved the problem presented by their high body density (heavier than water) and underwent adaptative radiation that lead most of them to the bottom habitat. Next, we will look at the bony fishes. These bony fishes, with their specially evolved "swim bladder" solved their body density problem. This allowed the bony fishes to exploit new environments and niches (occupations) not available to the cartilaginous fishes.

LOCOMOTION IN WATER:

Fishes swim by special longitudinal muscles that are attached along the spine and branch out diagonally up and back over the lateral surface. Contractions of these special muscles result in a double curve of the body resembling an "S" shape or sine curve. This curve starts at the anterior end of the fish and travels toward the tail. This wave of motion sends water down along the side of the fish resulting in the fish's forward movement. Some fishes use their body so that the curve is large or has high "amplitude," especially in fishes lacking paired fins. Their efforts result in a strong sideways movement with little forward movement. Other fishes may create rapid, almost vibrational body movements with little sideways movement, but with great forward movement.

SWIMMING IN CHONDRICHTHYES:

The cartilaginous fish's body is heavier than water. If the shark were to quit swimming, it would sink. The shark's pectoral fins probably evolved from folds of skin along its body. Note how these pectoral fins are placed low along the sides of the body and are at right angles to its surface

LOCOMOTION IN THE BONY FISHES:

One key to success in the bony fishes is the presence of a swim bladder. This is a gas-filled sac, located dorsally within the body cavity. This sac, originally evolved as an air bladder or accessory lung, was connected directly to the esophagus. Although some fishes still have the swim bladder connected to the digestive tract, in most modern fishes the swim bladder is a separate organ. The fishes can adjust the amount of gas within the bladder to lighten their body weight. The lighter weight makes it easier for the fishes to maintain a specific depth without an excess expenditure of energy. The bony fishes can browse at one spot without sinking, while the shark must continue swimming. Fishes that hold position in the water for some length of time have a swim bladder, whereas those bony fishes that are fast moving, streamlined and pelagic often lack air bladders.

4.5 SUMMARY

Fishes are a group of aquatic chordates that have gills and lack limbs. The term fish is an informal label that does not refer to a single taxonomic group but instead is used as a general term to refer to various aquatic craniates' animals including hagfish, lampreys, cartilaginous fishes, bony fishes and lobe-finned fishes. Fish do not include tetra pods (four-limbed vertebrates such as amphibians, reptiles, birds and mammals) and for this reason the group is considered to be paraphyletic. Most fish breathe using gills. They take water in through their mouth and push it out through their gills. As the water enters the fishes' mouth, it is rich in oxygen. When it passes through the gills, the oxygen is absorbed from the water as it flows through the capillary-rich gill filaments. At the same time, the waste product of respiration--carbon dioxide--is released into the water before it is then released from the gills through openings on either side of the pharynx. Most fish are cold-blooded animals that have a streamlined body that is adapted for efficient movement in water. There are exceptions to both of these rules though. Tuna, swordfish and a few shark species are warm-blooded, not cold-blooded. Rays are flat-bodied fish that not streamlined. They move through the water at a slower pace by undulating their broad pectoral fins. The development of jaws in the evolutionary history of fish represents an important step. Jaws enabled fish to catch and eat a wide variety of food including marine plants and animals.

4.6 REFERENCES

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UNIT 5: AMPHIBIA

5.1OBJECTIVES

We will learn in this topic about Origin, evolution and adaptive radiation of Amphibian and we also understand the larval stage of Amphibian i.e. Axolotl larva and its evolutionary significance, along with Affinities of Pisces and Amphibia.

5.2 INTRODUCTION

Amphibians are ectodermic, tetrapod vertebrates of the class **Amphibian**. All living amphibians belong to the group Lissamphibia. They inhabit a wide variety of habitats with most species living in terrestrial or aquatic ecosystems. Amphibians typically start out as larvae living in water, but some species have developed behavioral adaptations to bypass this. The young generally undergo metamorphosis from larva with gills to an adult air-breathing form with lungs. Amphibians use their skin as a secondary respiratory surface and some small terrestrial salamanders and frogs lack lungs and rely entirely on their skin. They are superficially similar to reptiles but, along with mammals and birds, reptiles are amniotes and do not require water bodies in which to breed. With their complex reproductive needs and permeable skins, amphibians are often ecological indicators and in recent decades there has been a dramatic decline in amphibian populations around the globe.

The earliest amphibians evolved in the Devonian period from Sarcopterygian fish with lungs and bony-limbed fins, features that were helpful in adapting to dry land. They diversified and became dominant during the Carboniferous and Permian periods, but were later displaced by reptiles and other vertebrates. Over time, amphibians shrank in size and decreased in diversity, leaving only the modern subclass Lissamphibia. The three modern orders of amphibians are Anura (the frogs and toads), Urodela (the salamanders), and Apoda (the caecilians). The number of known amphibian species is approximately 7,000, of which nearly 90% are frogs. The smallest amphibian (and vertebrate) in the world is a frog from New Guinea (*Paedophryne amauensis*) with a length of just 7.7 mm (0.30 in). The largest living amphibian is the 1.8 m (5 ft 11 in) Chinese giant salamander (*Andrias davidianus*), but this is dwarfed by the extinct 9 m (30 ft) *Prionosuchus* from the middle Permian of Brazil. The study of amphibians is called batrachology, while the study of both reptiles and amphibians is called herpetology.

5.3 ORIGIN, EVOLUTION AND ADAPTIVE RADIATION OF AMPHIBIA

Around 370 million years ago, during the Devonian period, lobe-finned fish that were related to modern coelacanth and lungfish gave rise to the first major groups of amphibians. These extinct lobe-finned fish had developed multi-jointed fins that resembled legs and had digits to help them crawl along the sea floor.

During the late Devonian period osteolepid fishes such as Eusthenopteron lived in the freshwater systems. Some of these creatures are thought to have given rise to terrestrial amphibians by initially creeping from pool to pool and subsequently spending more time on land.

They already had lungs and robustly built fins. Since many of the Carboniferous amphibia and the Devonian amphibia still resembled fishes in appearance and behavior, it is known that the pace of evolution was extremely slow. With the exception of a few, almost all of these early amphibians were entirely or mostly aquatic and consumed fish or aquatic invertebrates. Small terrestrial amphibians like Cacops and crocodile-like creatures like Eryops did not evolve prior to the Permian.

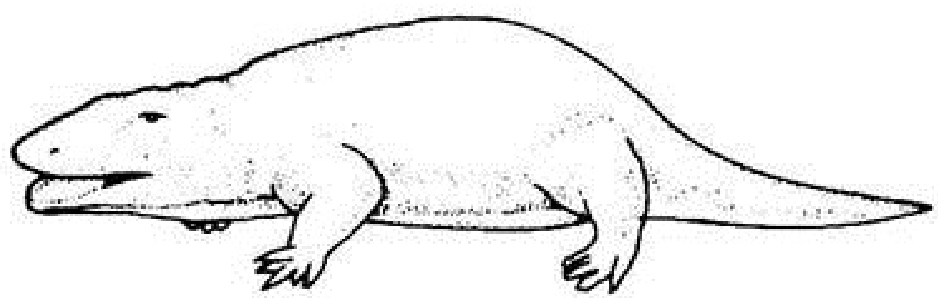

Fig.5.1Eryops An early Permian form having well developed limbs

MOST ANCIENT AMPHIBIANS:

The osteolepids of the Lower and Middle Devonian periods, which date to around 375 million years ago, are the fossils that seem to be most similar to the potential tetra pod progenitor. They were unquestionably fish. Like current lungfish, they might have used air as well as water to get oxygen. Elpistostege is a solitary Upper Devonian cranium that exhibits proportions halfway between those of these fish and those of the first known tetrapods, Ichthyostega and related taxa discovered in Greenland's freshwater deposits. About 350 million years ago, they belonged to the late Devonian or the early Carboniferous.

They are the earliest Labyrinthodontia species, and their teeth have folded dentine. At the tooth's root, the enamel and dentine that encircled the pulp cavity were folded in a labyrinthine pattern. They were all fish eating. This condition was also present in their crossopterygian fish ancestors.

They prospered and created numerous distinct lineages during the course of the following 100 million years of the Carboniferous and Permian periods, one of which gave rise to the reptiles. They were mostly aquatic or semi-aquatic forms, and only a few seem to have been totally terrestrial.

The earliest labyrinthodonts were unquestionably tetra pods and differed significantly from fish in several important ways. While some possessed scales, others had skin that was dry and leathery. Sometimes, ventral plates served as protection for the ventral side of the body.The intercentrum carries a ventral arch and rib. In many other aquatic amphibians the vertebrae are reduced to simple cylinders of bone surrounding the persistent notochord, a condition called lepospondylous, which is found also in modem forms.

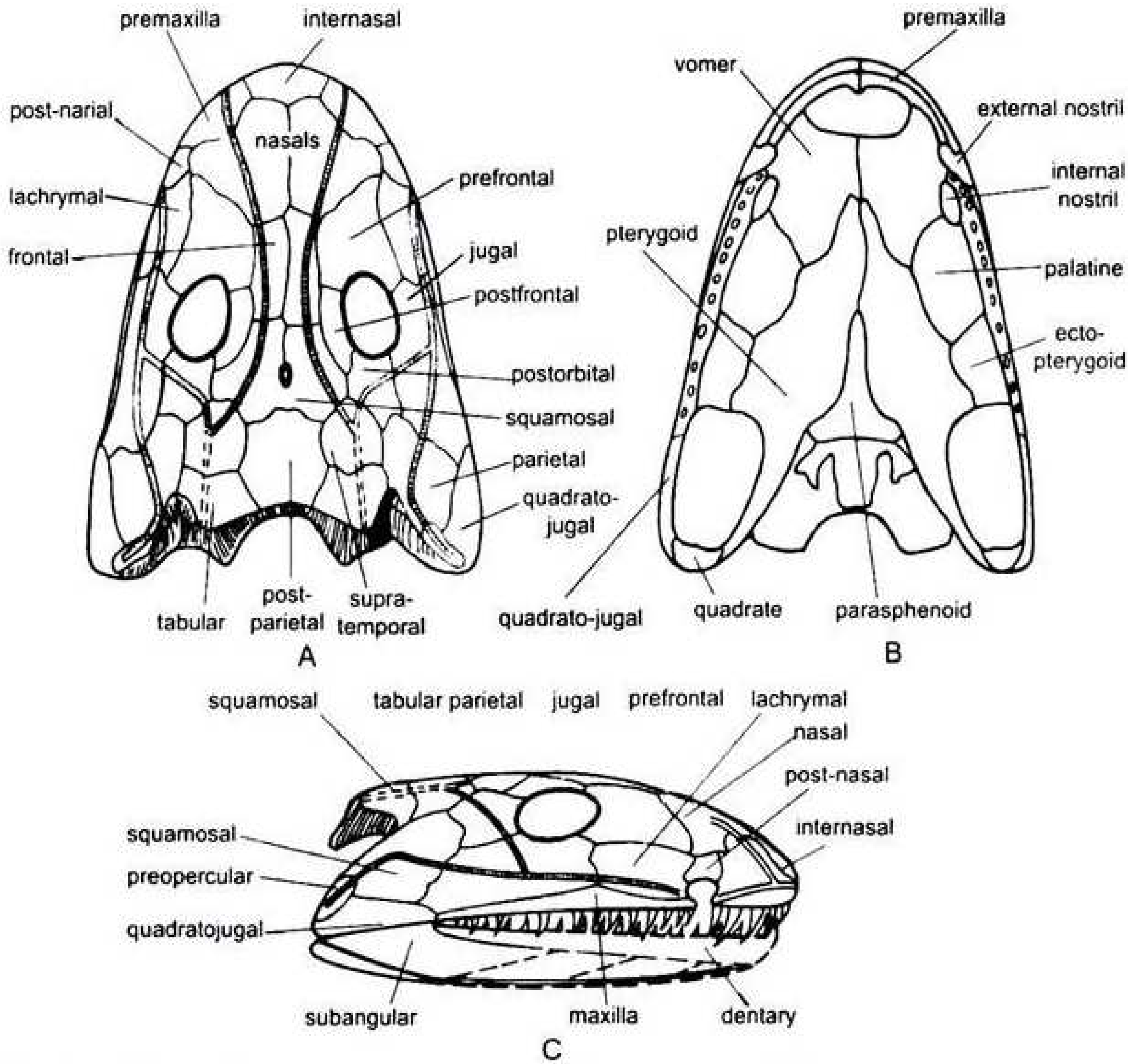

Fig.5.2 Skull of Ichthyostege (labyrinthodont) A. Dorsal View, B.Ventral view, C.Lateral view

The skull of Ichthyostega has amphibian traits, such as a short, wide snout and a long posterior area, but it also has indications of fish heritage in terms of structure. It also has a preopercular bone. The top lip's border is where the nostril rests. Operculum and Gills were missing. These creatures had a long tail with a dorsal fin and were roughly 100 cm long, but they also had powerful legs.

The vertebrae of the oldest Palaeozoic amphibians (Ichthyostegalia) had three sections, a dorsal neural arch, and a centrum made up of an anterior intercentrum and a posterior pleurocentrum. These vertebrae were similar to those of crossopterygians. The majority of Loxomma, a Carboniferous amphibian, were likely aquatic. Later members of the early Permian, such Eryops and Cacops, had strong legs and were presumably able to survive in marshes or on solid ground. The earliest members of Palaeogyrinus, which lived in the Carboniferous, were related to all amphibians. These mainly had long tails and short legs, and the vertebrae still had the two-ringed state of the pleurocentrum and intercentrum.

Although the young of the later Permian amphibia, like Seymouria, possessed lateral line canals that suggested an aquatic larval stage, validating the inclusion of these taxa in the amphibia, they were exclusively terrestrial as adults. They had powerful arms and intertemporal bone in their skulls (absent in reptiles). The coracoid bone and large ilium of the limb girdles give them a reptile-like appearance.

Ophiderpeton and other Carboniferous organisms resembled snakes and were limbless. Homed skulls were present in Permian Diplocaulus.These animals were secondary aquatic carnivores with long bodies and vertebrae adapted for bending movements. They had broad flat heads, upward-looking eyes, and small limbs. Microbrachis possessed bodies and limbs that were more typical. Some may have been the ancestors of the Apoda and were aquatic, while others were entirely terrestrial and made use of burrows.

ORIGIN OF MODERN AMPHIBIA:

Although the modern forms are typically thought to belong to a single monophyletic group, this is not confirmed, and it is also uncertain how they are related to the Amphibia from the Paleozoic. They reveal the skull flattening and loss of ossification in the palate and roof. The temnospondyls' basic, ring-shaped vertebrae (e.g., Loxomma, Eryops, Cacops). Protobatrachus (= Triadobatrachus), the first known anuran from the lower Triassic, having a frog-like cranium but several vertebrae with ribs and a segmented tail. The urodeles resemble early amphibians more on the surface. Modern salamanders resemble Jurassic fossils in appearance. According to Jarvik (1980), they may have descended from the Porolepis fish, which is thought to possess an internal nosfril. Fossil apodes are not known, but their retention of scales suggests an early separation from the rest and they may be derived from the lepospondyls rather than from labyrinthodonts.

ADAPTIVE RADIATION OF AMPHIBIA:

In evolutionary biology, adaptive radiation is the rapid spread of living organisms from a common ancestor into a wide range of novel forms. Phenotypic adaptation and speciation take place with the changes in biotic interactions as a result of new resources being accessible in the environment.

Without the environment, it is impossible for any life to exist. Organisms must adapt to their surroundings, engage in interactions with other organisms, and survive through forming unbreakable bonds with other organisms. The organism must adjust to the altered context when even a small environmental element changes. In other words, the ability to adapt to the environment aids the organism in the battle for survival. In this case, organisms exhibit different physiological and morphological characteristics.

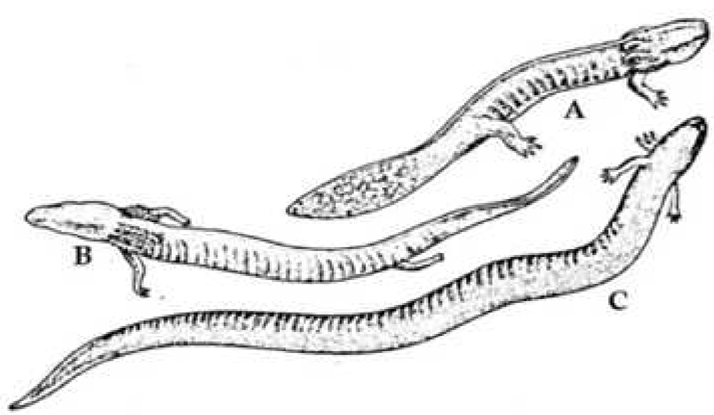

Fig.5.3Showing (A) Necturus (B) Proteus (C) Siren

The capacity for environmental adaptation is known as adaptation. Members of the same ancestral fauna break up into small groups and disperse in search of environments that will help them deal with food, shelter, and security crises. They then adapt to the various ecological niches that exist in their new environments. In this manner, the creatures belonging to the same genus are divided into various groups, and each group develops distinctive features. When various ecological niches are dispersed, this process is known as adaptive radiation.

Amphibians are the first group of vertebrates to transition from aquatic to terrestrial existence. They have adjusted to various settings in search of food, shelter, and safety. Some of these individuals have grown quite accustomed to adaptations found on land. Some members have opted to return to their former aquatic lifestyle. A few amphibians reside in caverns or holes. Others have adapted to Volant or Arboreal characteristics. However, everyone must look for water in adulthood in order to reproduce.

AQUATIC ADAPTATION:

Newts and salamanders, with a few notable exceptions, have made their way back to the water and have become used to their secondary aquatic adaptation. For examples:

- They have eel-like bodies;
- The gill of the larval stage remains functional until adulthood for respiration, and the lungs are significantly diminished;
- Branchial circulatory system development has taken place;
- Fins first appeared on the trunk and tail;
- The state of the skull has become slightly bony;
- Amphiuma, Siren, Proteus, and Necturus are a few animals with aquatic adaptations. Amphiuma has extremely long arms and legs. The Siren's hind arms are severed, and all of the larval characteristics are visible. The bodies of the Proteus, on the other hand, are boat-shaped, with both external gill and gill opening present in their bodies, and skin respiration occurs. Necturus contains external gill.

TERRESTRIAL ADAPTATION

The majority of Anurans and some Urodeles adapt to terrestrial habitats quite well. The Urodela genus of salamanders includes many terrestrial species that go back to the water to lay their eggs. They hide under rocks in corners or under logs made of wood or other materials to dwell. They have a cylindrical tail and no gills. They don't have wings. The Tiger salamander is a superb illustration of such an amphibian (Abystoma tigrinum). Some Salamanders are totally terrestrial. For breeding, they don't require an aquatic environment. They reproduce, and the ovaries are where fertilization takes place. One of these amphibians, known as the spotted salamander (Salamandra maculosa), is widespread throughout Europe and East Asia.

Fig 5.4 Ambyostoma tigrinum

The majority of Anurans and some Urodeles adapt to terrestrial habitats quite well. The Urodela genus of salamanders includes many terrestrial species that go back to the water to lay their eggs. They hide under rocks in corners or under logs made of wood or other materials to dwell. They have a cylindrical tail and no gills. They don't have wings. The Tiger salamander is a superb illustration of such an amphibian (Abystoma tigrinum). Some Salamanders are totally terrestrial. For breeding, they don't require an aquatic environment. They reproduce, and the ovaries are where fertilization takes place. One of these amphibians, known as the spotted salamander (Salamandra maculosa), is widespread throughout Europe and East Asia. They hide in the damp environment for fear of being purified in the bright light of day. As a result, they do not have any difficulty in surviving without water.

Notable terrestrial adaptations of amphibians are as follows:

- Wart/Mole present on skin helps prevent water evaporation.
- They have been suitable for jumping because the hind arm is long.
- Moving to the ground has been facilitated by the growth of strong muscles.
- It has become easier for them to jump because their vertebral column is shorter.
- The lungs have appeared to adapt to aerial respiration.

VOLANT ADAPTATION

Raccophorus is the volant amphibian. However, they do not complete the actual flight; they can only glide from one tree to another. Their fingers look like parachutes in a wide position as they are joined by web feet. The size of web feet is about 75 cm.

Fig.5.5 *Rachophorus maculatus*

Amphibians have developed limbs and lungs to complete airborne respiration in order to live on land. However, their watery environment is better suited for excretion and reproduction. They lay their eggs in water, just like fish, and development also takes place in water. When they are larval, they behave like fish. Thus, they were unable to adapt to the land like reptiles could. Instead, it may be claimed that they are attempting to adapt to land by acquiring some traits necessary for surviving in an aquatic setting.

ARBOREAL ADAPTATION

For simple access to food and secure refuge, some amphibians have chosen an arboreal lifestyle. A well-known arboreal frog from the order Anura is called Hyla arborea. To live in the trees, they have evolved sucking discs on their toes. Due to stickiness, the suction disc's surface is uneven. The suction disc's glandular skin secretes a sticky material.

5.4 AXOLOTL LARVA AND ITS EVOLUTIONARY SIGNIFICANCE

PHYLUM: - CHORDATA (Notochord, dorsal tubular nerve cord present and gill slits present)

GROUP: - CRANIATA (Definite head. Cranium with brain present)

SUB-PHYLUM:- VERTEBRATA (vertebral column present)

DIVISION: - GNATHOSTOMATA (Jaws and paired appendages present)

SUPER CLASS: - TETRAPODA (Paired limbs, lungs, bony skeleton and cornified skin)

CLASS: - AMPHIBIA (Scaleless glandular skin, have 3 chambered heart, cold blooded, 2 occipital condyles, can live in water and land both)

ORDER: - URODELA OR CAUDATA (Scaleless Amphibia having well developed tail, generally with two limbs, with or without external gills and gill-slits in adults).

SUB-ORDER:- . AMBYSTOMOIDEA (Eye lid, present Adults are terrestrial).

GENUS: - ***Ambystoma***

GENERAL CHARACTERSTICS OF AXOLOTL LARVA:

- The Axolotl larva was formerly thought to as the adult form and was given the name Siredon. It was later discovered to be Ambystoma larva.
- It possesses 4 pairs of open gill clefts in addition to 3 pairs of external gills that are colored red. Eyes, nose, and mouth are found in the head.
- Larvae live year-round. A 27 cm long body is separated into the head, trunk, and tail. Caudal fins are present on the tail. Both the fore and hind limbs are present.
- It reaches sexual maturity and begins to deposit eggs.
- In captivity, axolotl larva develops into an adult. Axolotl larva can undergo metamorphosis when given thyroid shots. Axolotls that are six months or older can undergo transformation with ease.

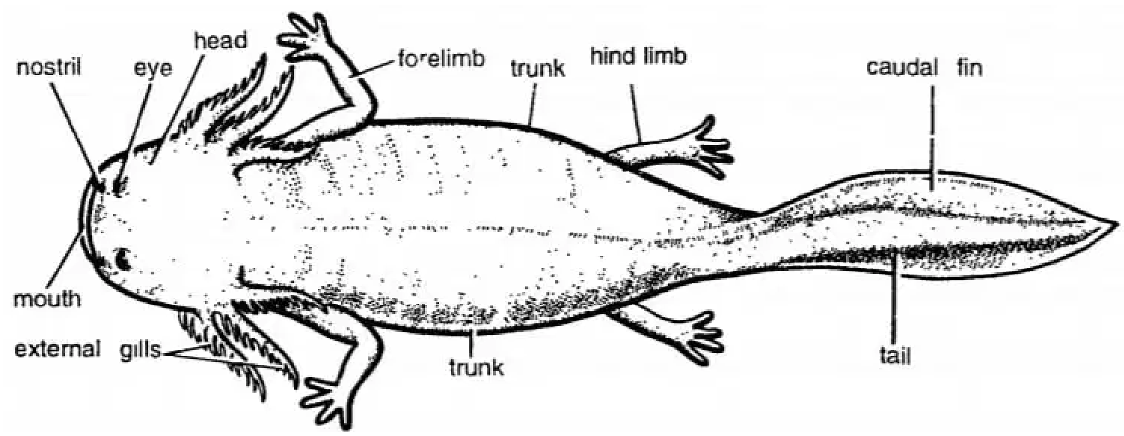

Fig.5.7 Axolotl larva

Special features

Axolotl larvae of *Ambystoma* do not undergo metamorphosis if there is abundance of nutrition and oxygen supply and they develop gonads like adult to breed sexually. The phenomenon of neoteny or paedogenesis is either due to lack of iodine or heredity and environment. A. mexicanus is supposed to be genetically neotenic.

5.5 AFFINITIES OF PISCES AND AMPHIBIA

- Both are ectothermic means cold blooded.
- Both classes are vertebrates mean they have backbone.
- Gills are present in amphibians in larval stage making them capable to live aquatic life and fish have gills too.
- Nervous system is almost similar in Pisces and amphibians.

5.6 SUMMARY

Amphibians are vertebrates of the taxonomic class Amphibia including animals such as frogs and toads (order Anura), salamanders (order Caudata), and caecilians (order Gymnophiona). Thought of as cold-blooded, amphibians are ectotherms, meaning they are unable to regulate their own body temperature independently of the temperature of their surroundings. Amphibians are generally small with thin skin permeable to air and water. With few exceptions, amphibians do not actively care for their young. In general, amphibian reproduction strategy consists of egg-laying and external fertilization of a large number of eggs in a moist or fully aquatic environment. Fertilized eggs develop into amphibian larvae that live part of their lives dependent on an aquatic environment requiring gills and specialized feeding habits. Following a pattern of development unique to amphibians, amphibian larvae undergo marked changes and metamorphose into a terrestrial form that lives on land. Typically, this metamorphosis is demonstrated by loss of gills, changes in overall appearance, and changes in diet. Amphibians live in diverse habitats, often in large numbers, and play several important ecological roles. As consumers, amphibians help regulate populations of the organisms they consume, chiefly invertebrates. As prey items, amphibians are consumed by a variety of larger predators such as reptiles, birds, mammals, fish, predatory invertebrates, and other amphibians. When consumed by larger predators, amphibians transfer the energy and nutrients from amphibian prey items such as small invertebrates to larger predators.

5.7 TERMINAL QUESTIONS AND ANSWERS

Q.No.1 Explain in detail the Adaptive radiation in Amphibians?

Q.No.2. Write a short note on the Axolotls Larva?

Q.No.3.Give the general characters of Axolotls Larva?

Q.No.4.Describe the Origin and Evolution of the Amphibians?

5.8 REFERENCES

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- Some figure and tax material are adopted from Biozoom.

UNIT 6: REPTILIA

6.1 OBJECTIVES

- To understand the systematic and functional morphology of various groups of Reptilia.
- To study their characters and classification upto order level.
- To study a type of reptiles, Uromastyx.
- To get knowledge about the identification of poisonous & non poisonous snakes.

6.2 INTRODUCTION

Reptilia is a group of tetra pod comprising today's turtles, crocodilians, snakes, amphisbaenians, lizards, tuatara, and their extinct relatives. The study of these traditional reptile groups, historically combined with that of modern amphibians, is called herpetology. Birds are also often included as a sub-group of reptiles by modern scientists. Modern reptiles inhabit every continent with the exception of Antarctica. Several living subgroups are recognized:

- Testudines (turtles, terrapins and tortoises): approximately 400 species
- Sphenodontia (tuatara from New Zealand): 1 species
- Squamata (lizards, snakes, and worm lizards): over 9,600 species

6.3 ORIGIN, EVOLUTION AND ADAPTIVE RADIATION OF REPTILES: SEYMOURIA AND COTYLOSAURI

The earliest known proto-reptiles originated around 312 million years ago during the Carboniferous period, having evolved from advanced reptiliomorph terapods that became increasingly adapted to life on dry land. Some early examples include the lizard-like *Hylonomus* and *Casineria*. In addition to the living reptiles, there are many diverse groups that are now extinct, in some cases due to mass extinction events. In particular, the K–Pg extinction wiped out the pterosaurs, plesiosaurs, ornithischians, and sauropods, as well as many species of theropods (e.g. tyrannosaurids and dromaeosaurids), crocodyliforms, and squamates (e.g. mosasaurids).

The oldest unquestionable known reptile was Hylonomus. The origin of these reptiles lies about 300 millions year ago. It was about 8 to 12 inches long about 20 to 30 centimeters, a small lizard-like animal. Hylonomus was reptile with numerous sharp teeth as an insectivorous diet animal. The true reptiles were known as **Anapsids** and **Diapsida**. Turtles are believed to be anapsids.

They were categorized as having a spinal cord, strong solid skull, holes only for nose, eyes, etc. On the other hand, Diapsida has a pair of holes located behind the eyes higher on the skull. They further are divided into lepidosaurs and archosaurs. Lepidosaurs include snakes, tuataras, and lizards whereas, archosaurs include crocodiles and birds.

Reptiles developed from amphibians of Carboniferous period, which relied on water bodies for laying eggs and improvement of larval ranges and as a result couldn't make the most arid habitats far away from water bodies. They invented a huge yolk-weighted down shelled egg that would be laid on land and wherein an amniotic sac contained fluid wherein embryo may want to expand to an superior stage, able to fending for itself whilst hatched. The following anatomical changes converted the ancestral amphibians into land adapted reptiles:

Body developed a covering of epidermal scales to prevent loss of body moisture, and skin glands were lost.

• Skull became monocondylic for better movement and flexibility. Atlas and axis vertebrae together permitted skull movement in all directions.

• Limb bones and girdles became stronger but limbs were attached on the sides of body, and belly touched the ground during creeping mode of locomotion.

• Sacral region involved two strong and fused vertebrae to support the body weight on hind legs.

• Pentadactyle limbs developed claws that helped in climbing on rocks and trees.

• Lung respiration became more efficient.

• As a water conservation strategy, metanephros kidneys excreted uric acid which did not require water for excretion.

• Reptiles continued to be ectothermal since ventricle was not completely partitioned by a septum and blood mixed in heart.

• Internal fertilization evolved as a large cleioid shelled egg was laid on land.

• Embryonic membranes amnion, allantois and yolk sac evolved to enable embryonic development in arid conditions.

Reptiles are tetrapod vertebrates, creatures that either have four limbs or, like snakes, are descended from four-limbed ancestors. Unlike amphibians, reptiles do not have an aquatic larval stage. Most reptiles are oviparous, although several species of squamates are viviparous, as were some extinct aquatic clades-the fetus develops within the mother, contained in a placenta rather than an eggshell. As amniotes, reptile eggs are surrounded by membranes for protection and transport, which adapt them to reproduction on dry land. Many of the viviparous species feed their fetuses through various forms of placenta analogous to those of mammals, with some providing initial care for their hatchlings. Extant reptiles range in size from a tiny gecko, *Sphaerodactylusariasae*, which can grow up to 17 mm (0.7 in) to the saltwater crocodile, *Crocodylusporosus*, which may reach 6 m (19.7 ft) in length and weigh over 1,000 kg (2,200 lb).

ANCESTORS OF REPTILES THE COTYLOSAURS

They were the most primitive stem reptiles that evolved from the labyrithodont amphibians (Embolomeri) in Carboniferous period. Seymoria was a lizard-like animal, with pentadactyle limbs and a short tail. It had homodont labyrinthine teeth on the jaw bones as well as on vomer and palatine bones. Presence of lateral line indicates its amphibious habits. Skull was monocondylic for better movement of head. Seymoria indicates gradual transition from labyrinthodont amphibians to reptiles. Another 5 foot long cotylosaur fossil, Limnoscelis was found in Mexico that had large premaxillary teeth and long tail.

Ancestry through Seymouria:

One of the members of the Cotylosauria was Seymouria (Fig. 6.1) found in the Lower Permian sediments in Texas (U.S.A.), perhaps 250 million years old. It was a lizard-like animal about 60 cm long, with a comparatively thick body, relatively small pointed head with dorsally placed nostrils, and a short tail. It had a few reptilian features like anapsid skull, single occipital condyle, large parietal eye and five digits. Structure of Seymouria was intermediate between the amphibians of that time and the early reptiles.

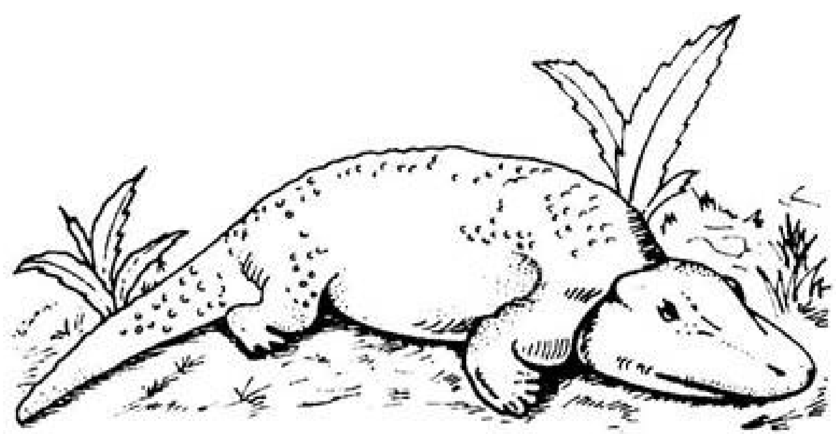

Fig.6.1Seymouria (A Cotylosaur) Anapsid

ADAPTIVE RADIATION IN REPTILES:

One of the many features that make the study of reptiles interesting is what Osborn has called adaptive radiation. By the term adaptive radiation is meant the differentiation of animal form and construction which, form a common starting point, follows lines of adaptations in diverse directions in response to the different needs demanded by different kinds of environment.

The ancient reptiles gave trials to all sorts of haunts and ways of living. Some of them like Pterosaurs became aerial, Ichthyosaurs and Plesiosaurs were aquatic. Amphibians were the Sauropod Dinosaurs. Cursorial adaptation was shown by many Dinosaurs. It is assumed that some of the Mesozoic reptiles became adapted to fossorial and arboreal life.

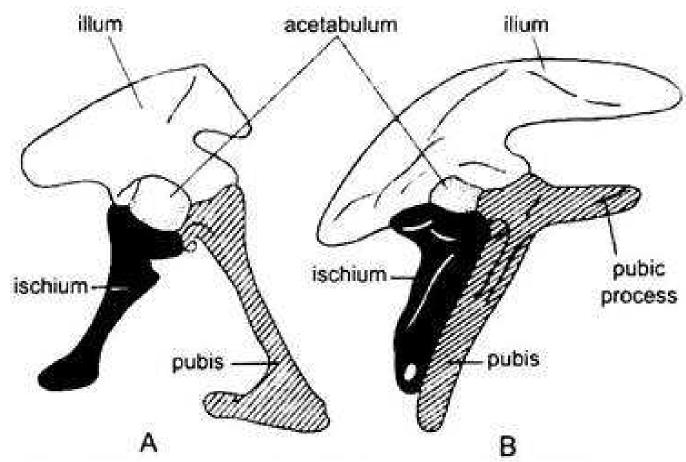

Fig.6.2Structure of pelvis and two orders of dinosaurs

Adaptive radiation is a dynamic aspect of animal existence and as animals branch out into each available environment, they assume characteristic adaptations to meet their specific needs—a fact noticeable in the modifications associated principally with locomotion. The noteworthy feature in the radiation of reptiles is the fact that most of their adventure, especially on land, was successful as there was no vertebrate competitor.

6.3.1 GENERAL ACCOUNT AND AFFINITIES

SIMILARITIES WITH AMPHIBIANS

Reptiles and amphibians share some similarities which create confusion to decide the class of species. Reptiles include turtle, lizard, crocodiles, and snakes while amphibians include frogs, salamander, toads, and newts. They both are ectodermic i.e. cold-blooded. They need external heat sources to maintain body temperature.

For example, **they are both ectothermic and cold-blooded animals**, meaning their body temperature relies on the temperature of their habitat. Reptiles and amphibians also are both vertebrate animals, meaning they have backbones. Reptiles and amphibians also both have excellent eyesight that helps them hunt prey.

Reptiles and amphibians use many common defense mechanisms. Some species of both reptiles and amphibians have the ability to change the color of their skin in order to camouflage in their habitat. Another major defense tactic used by reptiles and amphibians is what scientists call mimicry. Copycat species, some reptiles and amphibians, mimic the bright colors of venomous or poisonous species to ward off predators.

6.4 SKULL OF REPTILES

Reptiles are ectothermic animals with epidermal scales covering their bodies. Their long neck is constructed of the atlas, axis, and other cervical vertebrae, and it is supported by a monocondylic cranium. Their two fused sacral vertebrae allow them to shift their body weight onto their hind limbs. Sharp claws on the pentadactyle limbs aid the animal in climbing and slithering. The first vertebrates to lay a big, shelled, cleoid egg that could grow on land were reptiles. Three membranes—the amnion, allantois, and yolk sac—found in eggs aid in the development of the embryo on land and in arid environments. In most reptiles with huge heads and jaws, the skull weighs too much for the neck to sustain. Therefore, in order to reduce the weight of the skull and to make room for strong jaw muscles, vacuities or fossae originated in reptiles.

The word "apse," which means "arch," is the source of the skull names. The names of the various skull forms are determined by the quantity and variety of arches, enclosed fenestrae, or windows. Animals are able to snap their jaws more strongly thanks to these holes, which actually provide the cranium with additional space for the attachment of jaw muscles.

Osborn, 1903 employed temporal fenestrae to categorise amniotes. After the type of temporal fenestration they possessed, taxa including Anapsida, Diapsida, Euryapsida, and Synapsida were given their names. The sides of the skull have huge openings called temporal fenestrae. The purpose of these holes has been disputed for a while (Case, 1924). Many people think that they permit muscles to stretch and develop, increasing the mass of the jaw musculature. Longer muscle fibres enable an expansion of the jaw's gape to handle larger prey (Pirlot, 1969).

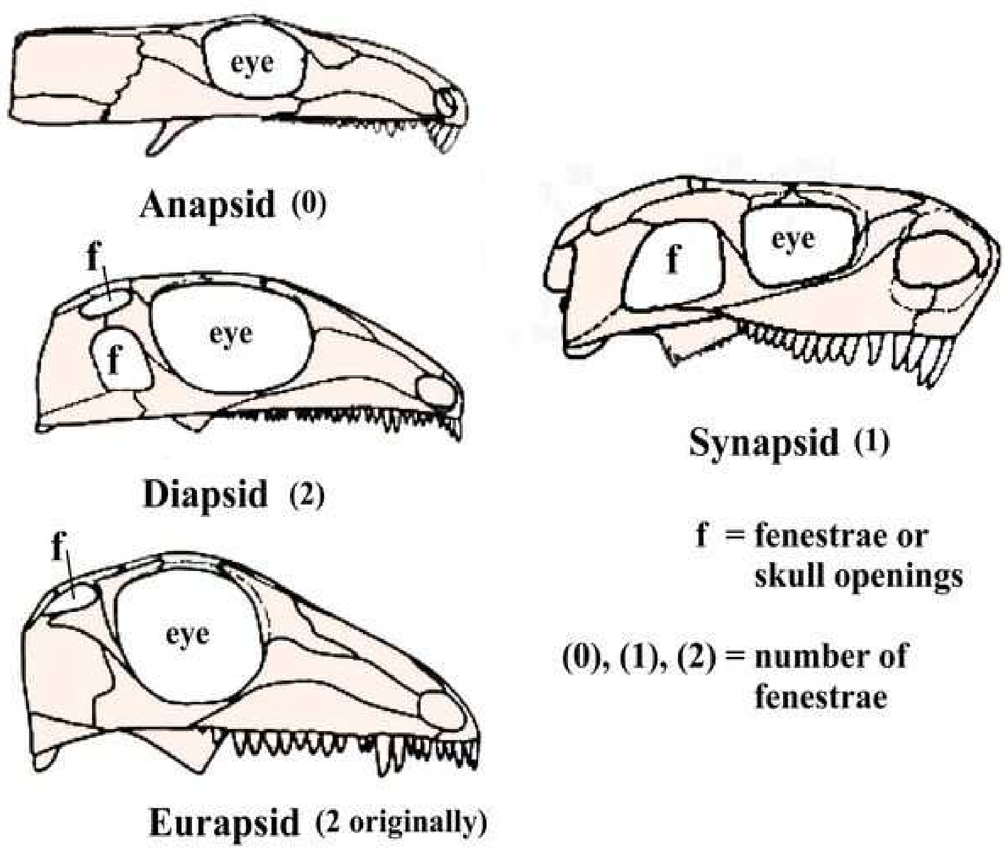

Fig.6.3 Type of Skull

THE ANAPSID SKULL (found in Cotylosauria and Chelonia):

This is the most archaic kind of reptile skull that first appeared in archaic labyrinthodont amphibians, followed by archaic reptiles like Seymoria. The Carboniferous Period saw the emergence of the anapsids as the first reptiles (345 to 280 million years ago). Since the word "anapsid" means "withoutarch," it denotes a lack of fenestrae in the skull. The small, herbivorous Procolophonids and the much bigger, herbivorous Pareiasaurs were the first representatives of the anapsids.

EURYAPSID SKULL (found in Plesiosaurus)

Euryapsid means “widearch“. They have one fenestra high on both sides of the skull. The euryapsids are represented by the marine reptiles such as the icthyosaurs, plesiosaurs, and placodonts, which are all completely extinct groups. The euryapsids arose from the diapsids which had two fenestrae, but sealed one of the openings to strengthen their skulls for life under water. Plesiosaurus was aquatic giant reptile with a long neck, small skull and fish-eating jaws. Its limbs were modified into paddles for swimming and there was no tail fin but a small tail. Skull had a single pair of temporal vacuities bordered by parietal, postorbital and squamosal bones. Maxilla and premaxilla had sharp teeth for fish catching.

PARAPSID SKULL (found in Ichthyosaurus)

This type of skull evolved in Ichthyosaurus, which included dolphin-like aquatic reptiles that preyed upon fishes or other aquatic animals. This skull also had only one pair of temporal vacuities on the upper side, guarded by two additional bones, namely, postfrontal and supratemporal, which push the postorbital and squamosal bones towards the lower side. The vacuities are guarded by parietal bones above. The condition found in ichthyosaurs is distinguished from the euryapsid condition because their temporal fenestrae are only bordered by the parietal, postfrontal, and supratemporal (Pirlot, 1969). This condition has been called parapsid, but it only represents a minor variation from the euryapsid pattern.

DIAPSID SKULL (found in Sphenodon, snakes, lizards, crocodiles and dinosaurs)

This type of skull has two temporal vacuities on either side of the skull. The superior temporal vacuity is surrounded by parietal above and postorbital and squamosal below. The inferior temporal vacuity is guarded by the postorbital and squamosal above and jugal and quadratojugal below. This type of skull is lighter and has more space for the attachment of jaw muscles. It is found in a large number of living reptiles and also in extinct dinosaurs. Dinosaurs and crocodiles also have a pair of preorbital vacuities anterior to the eye orbits.

SYNAPSID SKULL (found in Pelycosauria and Therapsida)

This type of skull was found in Dimetrodon (Pelycosauria) and the mammal-like the rapsid reptiles (Cynognathus), in which there was only one inferior temporal vacuity on each side of the skull but it was guarded by postorbital and squamosal bones above and jugal and quadratojugal below. “Synapsid” means “together arch.” The synapsids were the dominant land vertebrates from the Late Carboniferous Period (280 to 230 million years ago) to the end of Triassic Period (230 to 195 million years ago). Although the syanpsids were reptiles, they later gave rise to mammals.

6.5 VENOM IN OPHIDIANS

Snake venom is **a highly toxic saliva containing zootoxins that facilitates in the immobilization and digestion of prey**. This also provides defense against threats. Snake venom is injected by unique fangs during a bite, whereas some species are also able to spit venom.

The glands that secrete zootoxins are a modification of the parotid salivary glands found in other vertebrates and are usually located on each side of the head, below and behind the eye, and enclosed in a muscular sheath. The venom is stored in large glands called alveoli in which it's stored before being conveyed by a duct to the base of channeled or tubular fangs through which it's ejected.

Venom contains more than 20 different compounds, which are mostly proteins and polypeptides. The complex mixture of proteins, enzymes, and various other substances has toxic and lethal properties. Venom serves to immobilize prey. Enzymes in venom play an important role in the digestion of prey, and various other substances are responsible for important but non-lethal biological effects. Some of the proteins in snake venom have very specific effects on various biological functions, including blood coagulation, blood pressure regulation, and transmission of nerve or muscle impulses. These venoms have been studied and developed for use as pharmacological or diagnostic tools, and even drugs.

Proteins constitute 90-95% of venom's dry weight and are responsible for almost all of its biological effects. The hundreds, even thousands, of proteins found in venom include toxins, neurotoxins in particular, as well as nontoxic proteins (which also have pharmacological properties), and many enzymes, especially hydrolytic ones. Enzymes (molecular weight 13-150 KDa) make up 80-90% of viperid and 25-70% of elapid venoms, including digestive hydrolases, L-amino-acid oxidase, phospholipases, thrombin-like pro-coagulant, and kallikrein-like serine proteases and metalloproteinases (hemorrhagins), which damage vascular endothelium. Polypeptide toxins (molecular weight 5-10 KDa) include cytotoxins, cardiotoxins, and postsynaptic neurotoxins (such as α-bungarotoxin and α-Cobratoxin), which bind to acetylcholine receptors at neuromuscular junctions. Compounds with low molecular weight (up to 1.5 KDa) include metals, peptides, lipids, nucleosides, carbohydrates, amines, and oligopeptides, which inhibit angiotensin-converting enzyme (ACE) and potentiate bradykinin (BPP). Inter- and intra-species variation in venom chemical composition is geographical and ontogenic. Phosphodiesterases interfere with the prey's cardiac system, mainly to lower the blood pressure. Phospholipase A2 causes hemolysis by lysing the phospholipid cell membranes of red blood cells. Amino acid oxidases and proteases are used for digestion. Amino acid oxidase also triggers some other enzymes and is responsible for the yellow colour of the venom of some species. Hyaluronidase increases tissue permeability to accelerate the absorption of other enzymes into tissues. Some snake venoms carry fasciculins, like the mambas (*Dendroaspis*), which inhibit cholinesterase to make the prey lose muscle control.

The beginning of a new neural impulse goes as follows:

1. An exchange of ions (charged atoms) across the nerve cell membrane sends a depolarizing current towards the end of the nerve cell (cell terminus).
2. When the depolarizing current arrives at the nerve cell terminus, the neurotransmitter acetylcholine (ACh), which is held in vesicles, is released into the space between the two nerves (synapse). It moves across the synapse to the postsynaptic receptors.

3. ACh binds to the receptors and transfers the signal to the target cell, and after a short time, it's destroyed by acetylcholinesterase

Dendrotoxins

Dendro toxins inhibit neurotransmissions by blocking the exchange of positive and negative ions across the neuronal membrane lead to no nerve impulse, thereby paralyzing the nerves.

A-Neurotoxins

Alpha-neurotoxins are a large group; over 100 postsynaptic neurotoxins having been identified and sequenced. α-neurotoxins attack the Nicotinic acetylcholine receptors of cholinergic neurons. They mimic the shape of the acetylcholine molecule, and so fit into the receptors, where they block the ACh flow, leading to a feeling of numbness and paralysis.

Snake examples: king cobra (*Ophiophagus hannah*) (known as hannahtoxin containing α-neurotoxins), sea snakes (Hydrophiinae) (known as erabutoxin), many-banded krait (*Bungarus multicinctus*) (known as α-bungarotoxin), and cobras (*Naja* spp.) (Known as cobratoxin).

CYTOTOXINS

PHOSPHOLIPASES

Phospholipids is an enzyme that transforms the phospholipids molecule into a lysophospholipid (soap) → the new molecule attracts and binds fat and ruptures cell membranes. Phospholipase A2 is one specific type of phospholipases found in snake venom.

Snake example: Okinawan habu (*Trimeresurus flavoviridis*)

MYOTOXINS

Myotoxins are small, basic peptides found in rattlesnake and lizard (e.g. Mexican beaded lizard). Venoms involve a non-enzymatic mechanism that leads to severe skeletal muscle necrosis. These peptides act very quickly, causing instantaneous paralysis to prevent prey from escaping and eventually death due to diaphragmatic paralysis.

The first myotoxin to be identified and isolated was crotamine, discovered in the 1950s by Brazilian scientist José Moura Gonçalves from the venom of tropical South American rattlesnake *Crotalus durissus terrificus*. Its biological actions, molecular structure and gene responsible for its synthesis were all elucidated in the last two decades.

6.6 DINOSAURS

The stars amongst the extinct reptiles were undoubtedly the Dinosaurs and the age of reptiles often is called as the age of Dinosaurs. At the end of Triassic, Thecodontia or Pseudosuchia, the early descendants of Archosauria, gave rise to the most fantastic Mesozoic reptiles, the Dinosaurs which means "terrible lizards" (Gr., dinos = terrible + saurus = lizard). They subdivided early into two orders: Saurischia and Ornithischia, depending on the structure of their pelvis. Saurischia had a reptilian triradiate pelvis with pubis entirely separate and anterior to ischium. The early Saurischians were bipedal with short forelimbs, and four or five clawed digits, they progressed on land with hind limbs. Some of the later forms became quadrupedal and herbivorous.

The bipedal carnivorous forms comprise the suborder Theropoda Suborder Theropoda included all flesh-eating and bipedal carnivores. Smaller Cretaceous ostrich-like forms, such as Struthiomimus and Ornithomimus, walked on 3 toes of large hind feet.

Their forelimbs also had 3 fingers, of which one was opposable like a thumb and used for grasping Jurassic Allosaurus, a monster carnivore, was 10 meters' long. But the largest and that ever walked the face of earth was Tyrannosaurus rex from Cretaceous of North America. It was 15 meters' long and stood 6 meters' high. Its head was disproportionately great with large jaws armed with dagger-like teeth 15 cm long.

The 3-toed massive hindlegs were adapted for running, but extremely short forelimbs were almost useless. Suborder Sauropoda included huge herbivorous quadrupedal dinosaurs. Some of them were the largest and heaviest of all terrestrial and amphibious vertebrates that ever lived.Apatosaurus (= Brontosaurus) Diplodocus, and Brachiosaurus were enormous Jurassic reptiles, each more than 25 metres weighing over 50 tons. They probably lived in swamps where their body would be supported partly by the buoyancy of water. They had long necks and tails, small head with exceptionally small brains and weak jaws.

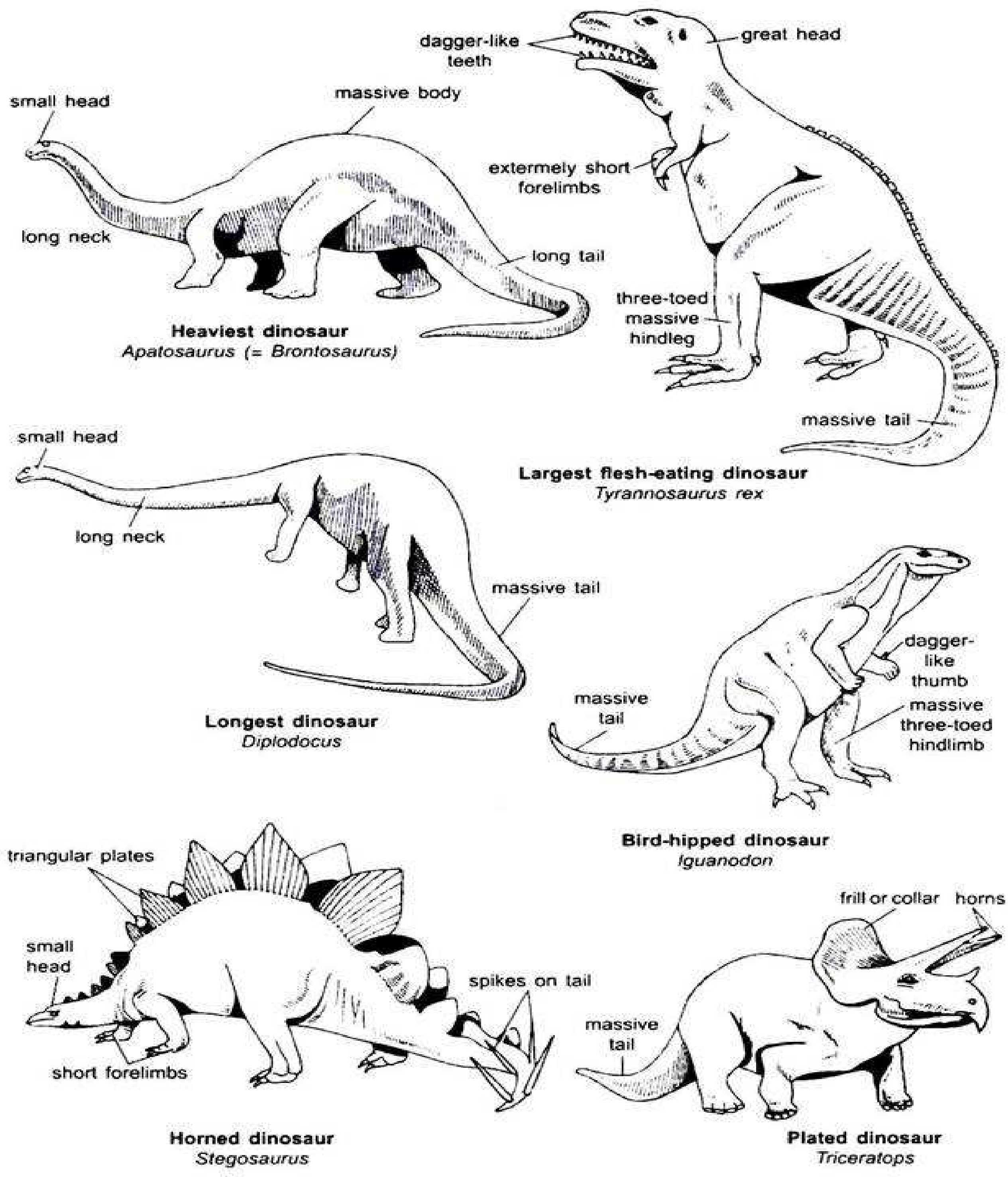

Fig.6.3Various Type of Mesozoic Dinosaurs

CAUSES OF EXTINCTION:

Dinosaurs had a majestic rise and a dramatic fall. After thriving and dominating the earth for 130 million years, the great dinosaurs and their contemporaries became suddenly extinct by the end of Cretaceous period. The extinction of this mighty race which underwent an explosive evolution is still a matter difficult to explain.

Various factors have been suggested for their total extinction such as catastrophism, epidemic, food poisoning, racial senescence, climatic changes, over-specialization, interspecific warfare or competition with ancestral mammals. None of these has been accepted as being completely satisfactory. Probably combinations of several factors are responsible for their extinction.

Now Dr. T. Swain of the New Royal Botanical Gardens in Britain says that dinosaurs were poisoned and murdered in cold blood. According to Dr. Swain it was nature which killed the reptiles by introducing into their diet a new class of plants containing aromatic type of alkaloids". In support of his theory Dr. Swain says there is evidence of increasing physiological trouble in dinosaurs towards the end of their reign.

He further said that there was an increase in the size of their hypothalamus and certain dinosaur fossils have been found in contorted positions suggestive of alkaloid poisoning. Dinosaurs were victims of changes in the ecological relationships between them and plants. Such changes hold the real key to the nature of extinction and to the whole evolutionary process. Dr. Swain goes on to say that demise of dinosaurs is a lesson which all animals including ourselves should heed.

6.7 LIVING REPTILES A BRIEF ACCOUNT OF:

6.7.1 RHYNCHOCEPHALIA

Rhynchocephalia ('beak-heads') is an order of lizard-like reptiles that includes only one living species, the tuatara (*Sphenodon punctatus*) of New Zealand. Despite its current lack of diversity, during the Mesozoic rhynchocephalians were a diverse group including a wide array of morphologically distinct forms. The oldest record of the group is dated to the Middle Triassic around 238 to 240 million years ago, and they had achieved a worldwide distribution by the Early Jurassic. Most rhynchocephalians belong to the group **Sphenodontia** ('wedge-teeth'). Their closest living relatives are lizards and snakes in the order Squamata, with the two orders being grouped together in the super order Lepidosauria.

Many of the niches occupied by lizards today were held by sphenodontians during the Triassic and Jurassic, although lizard diversity began to overtake sphenodontian diversity in the Cretaceous, and they had disappeared almost entirely by the beginning of the Cenozoic. While the modern tuatara is primarily carnivorous, there were also sphenodontians with omnivorous (*Opisthias*), herbivorous (Eilenodontinae), and durophagous (*Oenosaurus*) lifestyles. There were even several successful groups of aquatic sphenodontians, such as pleurosaurs and *Ankylosphenodon*.

Rhynchocephalians were once considered to be a morphologically conservative group with little diversity. However, discoveries in recent decades have disputed this, finding a wide array of diversity within the clade. Early rhynchocephalians possess small ovoid teeth designed for piercing, and were probably insectivores. Amongst the most distinct rhynchocephalians are the pleurosaurs, known from the Jurassic of Europe, which were adapted for marine life, with elongated snake-like bodies with reduced limbs, with the specialized Late Jurassic genus *Pleurosaurus* having an elongated triangular skull highly modified from those of other rhynchocephalians. Several other lineages of rhyncocephalians have been suggested to have had semi-aquatic habits. Eilenodontines are thought to have been herbivorous, with batteries of wide teeth with thick enamel used to process plant material. *Oenosaurus* and *Sapheosaurus* from the

Late Jurassic of Europe possess broad tooth plates unique amongst tetrapods, and are thought to have been durophagous, with the tooth plates being used to crush hard shelled organisms.

6.7.2 CHELONIA

Turtles are an order of reptiles known as **Testudines**, characterized by a shell developed mainly from their ribs. Modern turtles are divided into two major groups, the side-necked turtles and hidden neck turtles, which differ in the way the head retract. There are 360 living and recently extinct species of turtles, including land-dwelling tortoises and freshwater terrapins. They are found on most continents, some islands and, in the case of sea turtles, much of the ocean. Like other reptiles, birds, and mammals, they breathe air and do not lay eggs underwater, although many species live in or around water. Genetic evidence typically places them in close relation to crocodilians and birds.

Turtle shells are made mostly of bone; the upper part is the domed carapace, while the underside is the flatter plastron or belly-plate. Its outer surface is covered in scales made of keratin, the material of hair, horns, and claws. The carapace bones develop from ribs that grow sideways and develop into broad flat plates that join up to cover the body. Turtles are ectotherms or "cold-blooded", meaning that their internal temperature varies with their direct environment. They are generally opportunistic omnivores and mainly feed on plants and animals with limited movements. Many turtles migrate short distances seasonally. Sea turtles are the only reptiles that migrate long distances to lay their eggs on a favored beach.

Turtles have appeared in myths and folktales around the world. Some terrestrial and freshwater species are widely kept as pets. Turtles have been hunted for their meat, for use in traditional medicine, and for their shells. Sea turtles are often killed accidentally as by catch in fishing nets. Turtle habitats around the world are being destroyed. As a result of these pressures, many species are threatened with extinction.

The word *turtle* is derived from the French *tortue* or *tortre* ('turtle, tortoise'). It is a common name and may be used without knowledge of taxonomic distinctions. In North America, it may denote the order as a whole. In Britain, the name is used for sea turtles as opposed to freshwater terrapins and land-dwelling tortoises. In Australia, which lacks true tortoises (family

Testudinidae), non-marine turtles were traditionally called tortoises, but more recently turtle has been used for the entire group.

The name of the order, *Testudines* is based on the Latin word for tortoise, *testudo*; and was coined by German naturalist August Batsch in 1788. The order has also been historically known as *Chelonii* (Latreille 1800) and *Chelonia* (Ross and Macartney 1802), which are based on the Ancient Greek word for tortoise: (*chelone*). Testudines is the official order name due to the principle of priority. The term **chelonian** is used as a formal name for members of the group

Limbs and locomotion

Due to their heavy shells, turtles are slow-moving on land. A desert tortoise moves at only 0.22–0.48 km/h (0.14–0.30 mph). By contrast, sea turtles can swim at 30 km/h (19 mph). The limbs of turtles are adapted for various means of locomotion and habits and most have five toes. Tortoises are specialized for terrestrial environments and have column-like legs with elephant-like feet and short toes. The gopher tortoise has flattened front limbs for digging in the substrate. Freshwater turtles have more flexible legs and longer toes with webbing, giving them thrust in the water. Some of these species, such as snapping turtles and mud turtles, mainly walk along the water bottom, as they would on land. Others, such as terrapins, swim by paddling with all four limbs, switching between the opposing front and hind limbs, which keeps their direction stable.

Sea turtles and the pig-nosed turtle are the most specialized for swimming. Their front limbs have evolved into flippers while the shorter hind limbs are shaped more like rudders. The front limbs provide most of the thrust for swimming, while the hind limbs serve as stabilizers. Sea turtles such as the green sea turtle rotate the front limb flippers like a bird's wings to generate a propulsive force on both the upstroke and on the down stroke. This is in contrast to similar-sized freshwater turtles (measurements having been made on young animals in each case) such as the Caspian turtle, which uses the front limbs like the oars of a rowing boat, creating substantial negative thrust on the recovery stroke in each cycle. In addition, the streamlining of the marine turtles reduces drag. As a result, marine turtles produce a propulsive force twice as large, and swim six times as fast, as freshwater turtles. The swimming efficiency of young marine turtles is similar to that of fast-swimming fish of open water, like mackerel.

6.7.3 CROCODILIA

Crocodilia (or **Crocodylia**, both is an order of mostly large, predatory, semiaquatic reptiles, known as **crocodilians**. They first appeared 95 million years ago in the Late Cretaceous period (Cenomanian stage) and are the closest living relatives of birds, as the two groups are the only known survivors of the Archosauria. Members of the order's total group, the clade Pseudosuchia, appeared about 250 million years ago in the Early Triassic period, and diversified during the Mesozoic era. The order Crocodilia includes the true crocodiles (family Crocodylidae), the alligators and caimans (family Alligatoridae), and the gharial and false gharial (family Gavialidae). Although the term 'crocodiles' is sometimes used to refer to all of these, crocodilians is a less ambiguous vernacular term for members of this group.

Large, solidly built, lizard-like reptiles, crocodilians have long flattened snouts, laterally compressed tails, and eyes, ears, and nostrils at the top of the head. They swim well and can move on land in a "high walk" and a "low walk", while smaller species are even capable of galloping. Their skin is thick and covered in non-overlapping scales. They have conical, peg-like teeth and a powerful bite. They have a four-chambered heart and, somewhat like birds, a unidirectional looping system of airflow within the lungs, but like other living reptiles they are ectotherms.

Crocodilians are found mainly in lowlands in the tropics, but alligators also live in the southeastern United States and the Yangtze River in China. They are largely carnivorous, the various species feeding on animals such as fish, crustaceans, molluscs, birds, and mammals; some species like the Indian gharial are specialised feeders, while others like the saltwater crocodile have generalised diets. Crocodilians are typically solitary and territorial, though cooperative feeding does occur. During breeding, dominant males try to monopolise available females. Females lay eggs in holes or in mounds and, unlike most other reptiles, care for their hatched young.

Some species of crocodilians are known to have attacked humans. The largest number of attacks comes from the Nile crocodile. Humans are the greatest threat to crocodilian populations through activities that include hunting, poaching, and habitat destruction, but farming of crocodilians has greatly reduced unlawful trading in wild skins.

6.7.4 SQUAMATA

Squamata (/skwæˈmeɪtə/, Latin *squamatus* ("scaly, having scales")) is the largest order of reptiles, comprising lizards, snakes, and amphisbaenians (worm lizards), which are collectively known as **squamates** or scaled reptiles. With over 10,900 species,[3] it is also the second-largest order of extant (living) vertebrates, after the perciform fish. Members of the order are distinguished by their skins, which bear horny scales or shields. They also possess movable quadrate bones, making possible movement of the upper jaw relative to the neurocranium. This is particularly visible in snakes, which are able to open their mouths very wide to accommodate comparatively large prey. Squamata is the most variably sized order of reptiles, ranging from the 16 mm (0.63 in) dwarf gecko (*Sphaerodactylus ariasae*) to the 6.5 m (21 ft) Reticulated python (*Malayopython reticulatus*) and the now-extinct mosasaurs, which reached lengths over 14 m (46 ft).

Among other reptiles, squamates are most closely related to the tuatara, the last surviving member of the once diverse Rhynchocephalia, with both groups being placed in the clade Lepidosauria.

Squamates are a monophyletic sister group to the rhynchocephalians, members of the order Rhynchocephalia. The only surviving member of the Rhynchocephalia is the tuatara. Squamata and Rhynchocephalia form the subclass Lepidosauria, which is the sister group to the Archosauria, the clade that contains crocodiles and birds, and their extinct relatives. Fossils of rhynchocephalians first appear in the Early Triassic, meaning that the lineage leading to squamates must have also existed at the time. Scientists believe crown group squamates probably originated in the Early Jurassic based on the fossil record,The first fossils of geckos, skinks, and snakes appear in the Middle Jurassic.and their overall diversity was established during the mid-Jurassic, with further diversity expansions being mostly the result of added species.Other groups like iguanians and varanoids appeared in the Cretaceous. Polyglyphanodontia, an extinct clade of lizards, and mosasaurs, a group of predatory marine lizards that grew to enormous sizes, also appeared in the Cretaceous.Squamates suffered a mass extinction at the Cretaceous–Paleogene (K–PG) boundary, which wiped out polyglyphanodontians, mosasaurs, and many other distinct lineages.

The relationships of squamates are debatable. Although many of the groups originally recognized on the basis of morphology are still accepted, understanding of their relationships to each other has changed radically as a result of studying their genomes. Iguanians were long thought to be the earliest crown group squamates based on morphological data,but genetic data suggest that geckoes are the earliest crown group squamates.Iguanians are now united with snakes and anguimorphs in a clade called Toxicofera. Genetic data also suggest that the various limbless groups - snakes, amphisbaenians, and dibamids - are unrelated, and instead arose independently from lizards.

A study in 2018 found that *Megachirella*, an extinct genus of lepidosaurs that lived about 240 million years ago during the Middle Triassic, was a stem-squamate, making it the oldest known squamate. The phylogenetic analysis was conducted by performing high-resolution microfocus X-ray computed tomography (micro-CT) scans on the fossil specimen of *Megachirella* to gather detailed data about its anatomy. These data were then compared with a phylogenetic dataset combining the morphological and molecular data of 129 extant and extinct reptilian taxa. The comparison revealed *Megachirella* had certain features that are unique to squamates. The study also found that geckos are the earliest crown group squamates, not iguanians.

6.8 SUMMARY

Most small children can tell you that 'reptiles' are the snakes, lizards, crocodiles, and turtles (perhaps with the dinosaurs thrown in) — suggesting that it's easy to tell the difference between reptiles and other animals. Unfortunately, evolutionary biologists struggle with the same task, because phylogenetic analysis tells us loud and clear that these different types of what we loosely call 'reptiles' are not particularly closely related to each other. On the evolutionary tree, some of them (dinosaurs, crocodiles) are much more closely related to birds than to the other animals that we call reptiles. Other reptiles are the descendants of very ancient lineages; for example, turtles separated from the other reptiles, including the now-dominant Squamata (lizards and snakes), at least 200 million years ago. And another 200-million-year-old lineage has left just a single survivor, a lizard-like creature (the tuatara), on a few islands in New Zealand.

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UNIT 7: AVES

7.1 Objectives

7.2 Introduction

7.3 Origin and Evolution of birds

7.4 Origin of flight: Flight adaptations

7.5 Ratitae (Flightless Birds)

7.6 Modifications of Beak, Feet and Palate in Birds

7.7 Birds migration

7.8 Summary

7.9 Terminal Questions and Answers

7.1 OBJECTIVES

We will learn about the Origin and Evolution of birds, Flight adaptations and Ratitae (Flightless Birds).we also learn about the Modifications of Beak, Feet and Palate in Birds, Affinities of birds migration in Birds.

7.2 INTRODUCTION

Birds(Aves)are acollection of endothermic vertebrates, characterized by feathers, toothless beake d jaws,the laying of hard-shelled eggs, a high metabolic rate, a four-chambered heart, and a mild weight however strong skeleton. Birds stay global extensive and variety in length from the 5 cm (2 in) bee humming bird to the 2.75 m (9 ft) Ostrich. They rank as the class of tetra Pods with the maximum residing species, at about ten thousand, with greater than 1/2 of of those being passerines, occasionally referred to as perching birds or, much less accurately, as music birds.

The fossil record indicates that birds are the last surviving group of dinosaurs, True birds first appeared during the Cretaceous period, around 100 million years ago. DNA based evidence finds that birds diversified dramatically around the time of the Cretaceous–Paleogene extinction event that killed off all other dinosaurs. Birds, especially those in the southern continents, survived this event and then migrated to other parts of the world while diversifying during periods of global cooling. Primitive bird-like dinosaurs that lie outside class Aves proper have been found dating back to the mid-Jurassic period. Many of these early "stem-birds", such as Archaeopteryx, were not yet capable of fully powered flight, and many retained primitive characteristics like toothy jaws in place of beaks, and long bony tails.

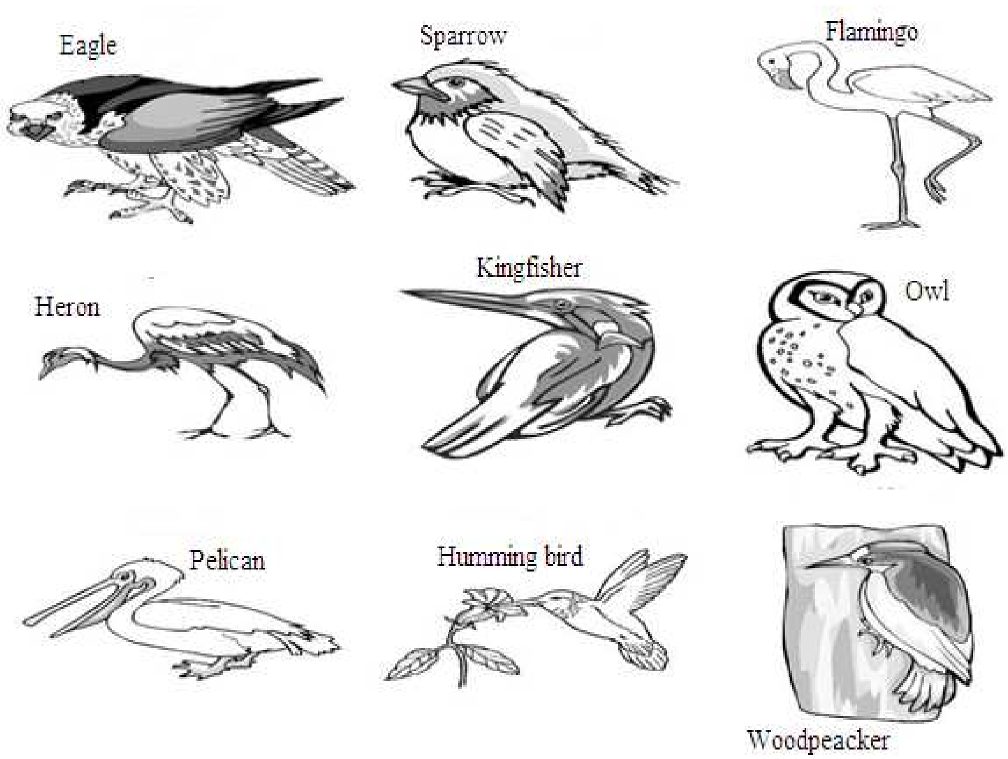

Fig 7.1Different kind of Endothermic vertebrates

Birds have wings which are more or less developed depending on the species; the only known groups without wings are the extinct moss and elephant birds. Wings, which evolved from forelimbs, give most birds the ability to fly, although further speciation has led to some flightless birds, including ratites, penguins, and diverse endemic island species of birds. The digestive and respiratory systems of birds are also uniquely adapted for flight. Some bird species of aquatic environments, particularly the aforementioned flightless penguins, and also members of the duck family, have also evolved for swimming. Birds, specifically Darwin's finches, played an important part in the inception of Darwin's theory of evolution by natural selection.

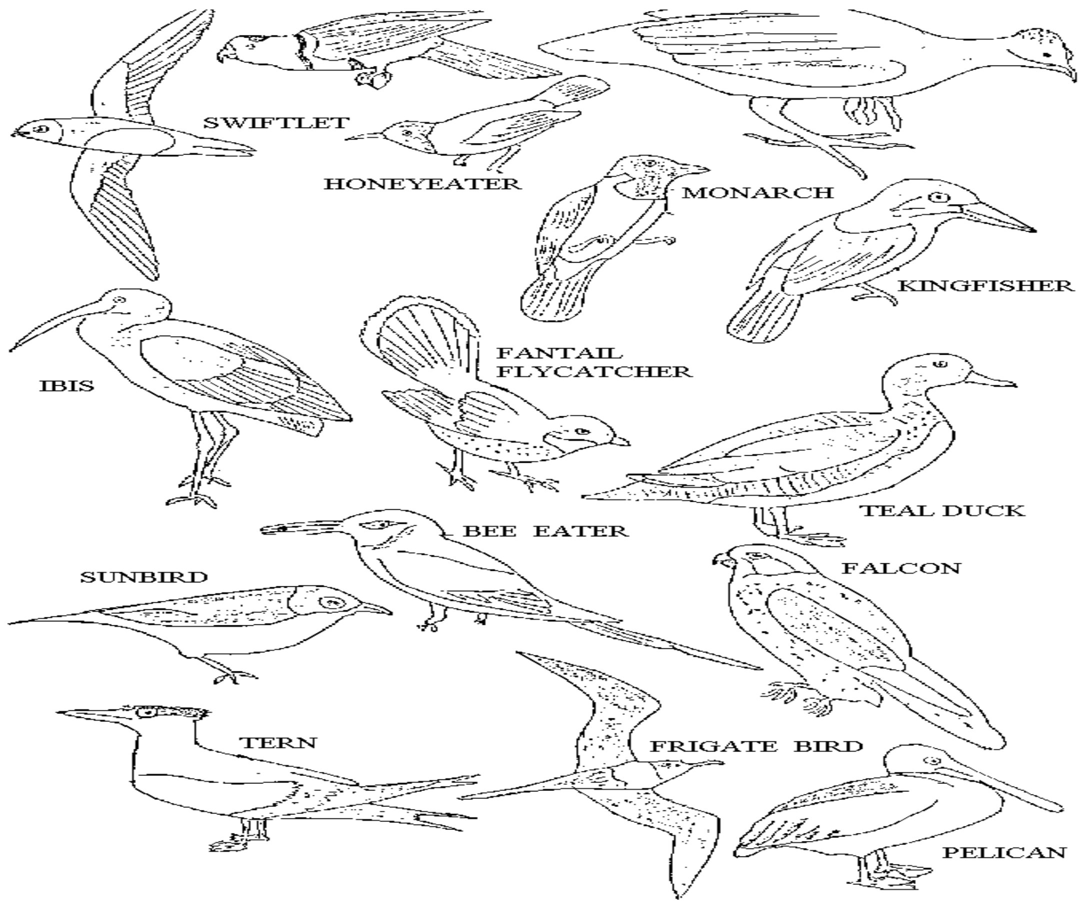

Fig 7.2 Different species of Birds (economically important, domesticated & undomesticated species)

Many species of birds are economically important. Domesticated and undomesticated birds (poultry and game) are important sources of eggs, meat, and feathers. Songbirds, parrots, and other species are popular as pets. Guano (bird excrement) is harvested for use as a fertilizer. Birds prominently figure throughout human culture. About 120–130 species have become extinct due to human activity since the 17th century, and hundreds more before then. Human activity threatens about 1,200 bird species with extinction, though efforts are underway to protect them. Recreational bird watching is an important part of the ecotourism industry.

7.3 ORIGIN AND EVOLUTION OF BIRDS

Evolutionary relationships science has undergone a significant transformation in recent years. In the past, determining an organism's family tree relied on all of its characteristics. For instance, mice, lizards, and fish everyone has backbones; therefore, the characteristic of having a backbone has no bearing on how these animals evolved. However, the trait of having four legs is advantageous because it is an evolutionary novelty shared exclusively by lizards and mice. Inferring from this that neither the lizard nor the mouse is more closely related to the fish than they are to one other. Cladistics, a new method, has been at the heart of the theory that birds descended from dinosaurs.

Thomas Huxley, an English paleontologist, initially proposed the "birds are dinosaurs" hypothesis (1825–1895). Recently discovered fossils from China, South America, and other nations, as well as the examination of ancient museum specimens from new angles and with new techniques, allowed scientists to conclude that birds descended from small carnivorous dinosaurs of the Late Jurassic. When a specimen of Archaeopteryx, the first known bird, was found in the early 1860s, the search for the ancestors of modern birds officially began. It had feathers on its limbs and tail, just like birds, but unlike birds that are alive today, it also had teeth and a long bony tail. Furthermore, many of the bones in Archaeopteryx's hands, shoulder girdles, pelvis, and feet were distinct, not fused and reduced as they are in living birds. Huxley concluded that its forms in both dinosaur and bird skeletons were so similar that they must be closely related.

In the 1970s. Paleontologists discovered remarkable similarities between Archaeopteryx and theropod dinosaurs, small carnivorous dinosaurs, Except for the ornithischian dinosaurs, all of the dinosaur groups on this evogram are theropods. Scientists hypothesized that therapies might have been the ancestors of birds based on the similarities between their traits. Paleontologists became even more certain after creating evolutionary trees to investigate the issue. A twig on the dinosaurs' branch of the tree of life is all that the birds are.

Many of these theropod dinosaurs' traits were altered as birds developed from them. It's crucial to keep in mind that the animals were not in any way "trying" to be birds. In reality, it becomes increasingly clear that the collection of traits that distinguish birds evolved over the course of a complicated series of events and served many purposes.

Consider feathers as an example. The earliest feathers most likely appeared in Compsognathus-related little theropods like Sinosauropteryx. Their bodies, necks, and heads were covered with short, hair-like feathers that served as insulation. It is impossible to determine whether the feathers' various colour patterns were used for exhibition, camouflage, species identification, or some other purpose. We discover various novel feather kinds in theropods that are even more closely linked to birds, such as the oviraptorosaurs. The one in the illustration below is downy and branching.

Others have developed a core stalk from which unstructured branches emerge. Other species, such as the dromaeosaurids and Archaeopteryx, have a vane-like structure with well-placed barbs that are held together by barbules. This is identical to the feather structure of living birds.

The evolution of dinosaurs' digits into those of birds provides another line of support. The first theropod dinosaurs possessed hands with a large second digit, a long second digit, and short fifth and fourth digits. The evogram demonstrates that the fifth finger (as seen in Coelophysoids) and then the fourth (as shown in Allosaurids) were totally lost in the theropod lineage that would ultimately give rise to birds. In order to allow the hand to move sideways against the forearm, the wrist bones that support the first and second fingers consolidated and assumed a semicircular shape. Eventually, this made it possible for the wing joints of birds to move in a way that produces thrust for flight.

It has long been disputed what feathers were used for when they evolved. As we've seen, the earliest, most basic, hair-like feathers undoubtedly served as insulators. Even while the forelimbs themselves are short in later theropods, like some oviraptorosaurs, the feathers on the arms and hands are long. With long feathers on short arms, what did these animals do? One theory is supported by some amazing oviraptorosaur fossils found in the Gobi Desert's Cretaceous strata. The animal's bones are curled up on a nest of eggs, resembling a brooding chicken. The hands are positioned such that they appear to be sheltering the eggs. Therefore, it's possible that these feathers functioned to protect and warm the eggs.

Following Archaeopteryx, birds continued to develop in ways that were similar to those of their theropod forebears. They had far fewer and fused bones, which may have improved the effectiveness of their flight. Similar to how the feathers got longer and their vanes more asymmetrical, the bone walls got even thinner and this probably helped in flight as well. A spray of feathers near the tail subsequently assumed the role of enhancing stability and manoeuvrability after the bony tail was reduced to a stump. The wishbone, which was also present in non-bird dinosaurs, developed into a stronger, more complex structure, and the bones of the shoulder girdle connected to the breastbone over time to secure the forelimb's flight mechanism.

The breastbone itself grew bigger and developed a central keel along its midline that held the flight muscles in place. As the primary mode of locomotion changed from running to flying and teeth were periodically eliminated in different lineages of early birds, the arms evolved to be longer than the legs. The first bird to have ever lived existed somewhere during the Late Cretaceous, and in the 65 million years that have passed since the other dinosaurs went extinct, this ancestral lineage has evolved into the main subgroups of birds that are still alive today.

7.4 ORIGIN OF FLIGHT: FLIGHT ADAPTATIONS

Most kinds of birds that can fly use bird flight as their main form of propulsion. Birds use flight to feed themselves, breed, fend off predators, and migrate. Hovering, lifting off, and landing are all components of the flying action, which includes numerous intricate movements. Through millions of years of evolution, birds have adapted to various demands, surroundings, prey, and predators. Birds' flight adaptations fall into two categories:

A. Morphological Adaptations

B. Anatomical Adaptations

A.Morphological Adaptations

1. BODY SHAPE

The design of the birds' bodies is intended to reduce air resistance during flight. The birds benefit from energy conservation and improved flying prowess as a result.

2. COMPACT BODY

To maintain balance in the air, birds have compact, dorsally powerful, and ventrally heavy bodies. The fact that their wings are attached to their thorax, that their light organs like lungs and sacs are high up, and that their hefty muscles are in the middle of their bodies are all features that aid in flight.

3. BODY COVERED WITH FEATHERS

Smooth, backward-facing, and tightly fitting feathers streamline the body and lessen friction during flight. It reduces the body's weight and shields it from the effects of temperature changes in the surroundings. Additionally, they may strike the air with a lot of surface area.

Feathers raise the buoyancy of the body. It protects the body from heat loss by insulating it. The birds can withstand low temperatures at higher elevations because to this.

4. FORELIMBS MODIFIED INTO WINGS

The only organ of flight is an adaptation of the forelimbs into wings. These are made up of a structure of blood veins, feathers, muscles, and nerves. The surface area of the wings is enormous. Additionally, they help to keep the bird aloft. The leading edge of the wings is thick and strong, and it has a concave lower surface and a convex top surface. This aids in lowering air pressure above and raising air pressure below. As a result, the bird can fly forward and upward while in flight.

5. MOBILE NECK AND HEAD

The birds have a long and flexible neck which helps in the movement of head important for various functions. They possess a horny beak which helps them to pick the grains and insects while feeding.

6. PERCHING

A bird's toes encircle the twig as it rests on a tree limb. Perching is the term for this. The muscles are so strong that the bird can stay in that position while sleeping without tumbling over.

7. SHORT TAIL

The tail bears long feathers that spread like a fan and function as a rudder during flight. They also help in balancing, lifting, and steering while flying and perching.

ANATOMICAL ADAPTATIONS

1. Flight muscles

The flight muscles are controlled by the strong muscles. It is roughly 1/6th the weight of the total bird. The muscles of flying are striated. The wings have a lot of muscle. The above muscles function with the assistance of other muscles.

2. LIGHT AND RIGID ENDOSKELETON

The skeletons of the birds are extremely strong and light. The air sacs in the hollow, human bones. A second plastering is applied to them to make them stiffer. Bone marrow is absent and the bones are joined. The birds are toothless. All save the final thoracic vertebra are united. In the process of wings impacting the air, this is crucial.

3. DIGESTIVE SYSTEM

The metabolism of the birds is extremely rapid. As a result, food digests quickly. Because there is less undigested waste, the rectum is shorter. They are lighter since they don't have a gall bladder.

4. RESPIRATORY SYSTEM

Birds' respiratory systems are built in such a way that food is quickly oxidized and a significant amount of energy is released. The body needs a lot of oxygen molecules since the pace of metabolism is increased. The lungs, which fill the entire area between the internal organs, are supplied for this.

5. CIRCULATORY SYSTEM

Due to birds' quick metabolism, the blood needs a quick supply of oxygen. Therefore, birds need a circulatory system that works well. Birds have a four-chambered heart with two circulatory chambers. Blood with and without oxygen cannot mix as a result. Additionally, the red blood cells of birds have a high concentration of hemoglobin, which aids in the rapid aeration of body tissues.

5. WARM BLOODED

The temperature of the body of a bird remains high and does not change with the change in the environment. This facilitates the birds to fly at very high altitudes.

6. EXCRETORY SYSTEM

The nitrogenous waste is converted to less toxic organic compounds such as uric acid, and urates. They have no urinary bladder. The uriniferous tubules efficiently absorb water.

7. BRAIN AND SENSE ORGANS

Large eyes and large optic lobes are indicative of exceptional visual development. The head is largely taken up by the eyes, which are frequently heavier than the brain when combined. Birds must fast switch from a distant to a close-up view while flying, requiring a well-developed capacity to instantly adapt. The complex and highly developed cerebellum reveals the delicate sense of balance and

The extraordinary ability of birds to coordinate their muscles. The massive growth of the corpus striata in the brain also contributes to the exceptional manoeuvrability needed to achieve flight stability.

8. SINGLE OVARY

Presence of a single functional ovary of the left side in the female bird also leads to reduction of weight which is so essential for flight.

7.5 RATITAE (FLIGHTLESS BIRDS)

Flightless birds are birds that through evolution lost the ability to fly. There are over 60 extant species, including the well known ratites (ostriches, emu, cassowaries, rheas, and kiwi) and penguins. The smallest flightless bird is the Inaccessible Island rail (length 12.5 cm, weight 34.7 g). The largest (both heaviest and tallest) flightless bird, which is also the largest living bird, is the ostrich (2.7 m, 156 kg).

Many domesticated birds, such as the domestic chicken and domestic duck, have lost the ability to fly for extended periods, although their ancestral species, the red jungle fowl and mallard, respectively, are capable of extended flight. A few particularly bred birds, such as the Broad

Breasted White turkey, have become totally flightless as a result of selective breeding; the birds were bred to grow massive breast meat that weighs too much for the bird's wings to support in flight.

Flightlessness has evolved in many different birds independently. There were families of flightless birds, such as the now extinct Phorusrhacidae, that evolved to be powerful terrestrial predators. Taking this to a greater extreme, the terror birds (and their relatives the bathornithids), eogruids, geranoidids, gastornithiforms, and dromornithids (all extinct) all evolved similar body shapes – long legs, long necks and big heads – but none of them were closely related. Furthermore, they also share traits of being giant, flightless birds with vestigial wings, long legs, and long necks with some of the ratites, although they are not related.

Fig 7.3

Fig7.4

Fig.7.3 Ostriches are the largest extant flightless birds as well as the largest extant birds in general.

Fig7.4 Penguins are a well-known example of flightless birds.

Divergences and losses of flight within ratite lineage occurred right after the K-Pg extinction event wiped out all non-avian dinosaurs and large vertebrates 66 million years ago. The immediate evacuation of niches following the mass extinction provided opportunities for Palaeognathes to distribute and occupy novel environments. New ecological influences selectively pressured different taxa to converge on flightless modes of existence by altering them morphologically and behaviorally. The successful acquisition and protection of a claimed territory selected for large size and cursoriality in Tertiary ancestors of ratites. Temperate rainforests dried out throughout the Miocene and transformed into semiarid deserts, causing habitats to be widely spread across the growingly disparate landmasses. Cursoriality was an economic means of traveling long distances to acquire food that was usually low-lying vegetation, more easily accessed by walking. Traces of these events are reflected in ratite distribution throughout semiarid grasslands and deserts today.

Gigantism and flightlessness in birds are almost exclusively correlated due to islands lacking mammalian or reptilian predators and competition. However, ratites occupy environments that are mostly occupied by a diverse number of mammals. It is thought that they first originated through allopatric speciation caused by breakup of the supercontinent Gondwana. However, later evidence suggests this hypothesis first proposed by Joel Cracraft in 1974 is incorrect. Rather ratites arrived in their respective locations via a flighted ancestor and lost the ability to fly multiple times within the lineage.

Gigantism is not a requirement for flightlessness. The kiwi does not exhibit gigantism, along with tinamous, even though they coexisted with the moa and rheas that both exhibit gigantism. This could be the result of different ancestral flighted bird's arrival or because of competitive exclusion. The first flightless bird to arrive in each environment utilized the large flightless herbivore or omnivore niche, forcing the later arrivals to remain smaller. In environments where flightless birds are not present, it is possible that after the K/T Boundary there were no niches for them to fill. They were pushed out by other herbivorous mammals.

New Zealand had more species of flightless birds (including the kiwi, several species of penguins, the takahē, the weka, the moa, and several other extinct species) than any other such location. One reason is that until the arrival of humans roughly a thousand years ago, there were no large land predators in New Zealand; the main predators of flightless birds were larger birds.

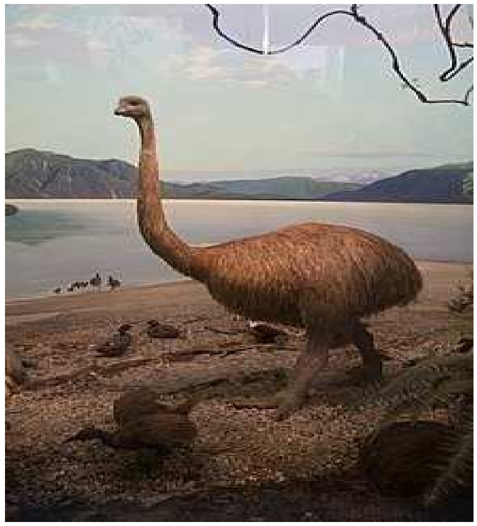

Fig7.5 An extinct moa

Many flightless birds are extinct; this list shows species that are either still extant, or became extinct in the Holocene (no more than 11,000 years ago). Extinct species are indicated with a cross (†). A number of species suspected, but not confirmed to be flightless, are also included here. Longer-extinct groups of flightless birds include the Cretaceous patagopterygiformes, hesperornithids, the Cenozoic phorusrhacids ("terror birds") and related bathornithids, the unrelated eogruids, geranoidids, gastornithiforms, and dromornithids (mihirungs or "demon ducks"), and the plotopterids.

7.6 MODIFICATIONS OF BEAK, FEET AND PALATE IN BIRDS

In most birds, these range from rounded to slightly sharp, but **some species have evolved structural modifications that allow them to handle their typical food sources better**. Granivorous (seed-eating) birds, for example, have ridges in their tomia, which help the bird to slice through a seed's outer hull.

The entire modern world of Aves (birds) is characterized by the absence of teeth. Their absence is compensated by the development of horny sheaths called rhamphotheca for the jaws which constitute the beak. The beak is also referred to as bill. The upper and lower jaws are often described by naturalists as the upper and lower mandibles.

The sheath of each jaw in the majority of birds is entire, but in some it is composed of several pieces. The beak is essentially a structure to obtain food, to preen feathers, to collect nest materials to build the nest and also to act as the organ of defence.

The shape of the beak varies in different birds according to their feeding habits. Because of the functional diversities, the beaks have undergone extensive range of modifications in different birds. Figure 28.6 shows a few varieties of beaks in birds. Some of the most important and common types are described here.

1. Seed-Eating Beak (Seed-Crushing Beak):

(a) The seed-eating beaks are short, stout, and conical and pointed at the tip.

(b) This type of beaks is characteristic of small seed-eating or graminivorous birds such as sparrows, finches and cardinals, etc.

(c) The weaker beaks are used to pierce the small seeds, while powerful beaks crush large, hard-shelled seeds, fruit stones, etc.

2. Cutting and Biting Beak:

(a) The cutting and biting type beaks are long and strong and provided with sharp horny edges,

(b) This type of beaks can be used for various purposes,

(c) These are found in crows (Corvus) and rovens, etc.

3. Fruit-Eating Beak:

(a) The fruit-eating beaks are large, sharp, and powerful and hooked.

(b) The upper beak is movable on the skull and is well adapted for tearing fruits and gnawing hard nuts and seeds,

(c) Such beaks are found in parrots and cockatoos. In hornbills beak is large and heavy having cellular structure in its inner region that act as resonators to produce loud sound.

4. Piercing and Tearing Beak:

(a) The piercing and biting beaks are short, pointed, and sharp-edged and hooked at the tip and are adapted for piercing and tearing the flesh into pieces.

(b) They are operated by well developed mandibular muscles,

(c) These are commonly found in carnivorous birds such as vultures, hawks, eagles, kites and owls.

5. Insectivorous Beak:

(a) The insectivorous beaks are found in swifts, swallows, flycatchers, night jars and hoopoe, etc.

(b) In hoopoe the beak is long, slender and slightly curved, adapted for turning the leaves and probing into soil for insect larvae, pupae and mites, etc.

In swallows, frog-mouth and swifts, the beak is small, wide and delicate to prey upon flying insects. In flycatchers, the beak is small, strong with notched mandibles at the tip end.

The **beak**, **bill**, or **rostrum** is an external anatomical structure found mostly in birds, but also in turtles, non-avian dinosaurs and a few mammals. A beak is used for eating, preening, manipulating objects, killing prey, fighting, probing for food, courtship, and feeding young. The terms *beak* and *rostrum* are also used to refer to a similar mouth part in some ornithischians, pterosaurs, cetaceans, dicynodonts, anuran tadpoles, monotremes (i.e. echid nas and platypuses, which have a beak-like structure), sirens, pufferfish, billfishes and cephalopods. Although beaks vary significantly in size, shape, color and texture, they share a similar underlying structure. Two bony projections –

the upper and lower mandibles – are covered with a thin keratinized layer of epidermis known as the rhamphotheca. In most species, two holes called *nares* lead to the respiratory system.

Although the word "beak" was, in the past, generally restricted to the sharpened bills of birds of prey, in modern ornithology, the terms beak and bill are generally considered to be synonymous. The word, which dates from the 13th century, comes from the Middle English *bec*, which itself comes from the Latin *beccus*.

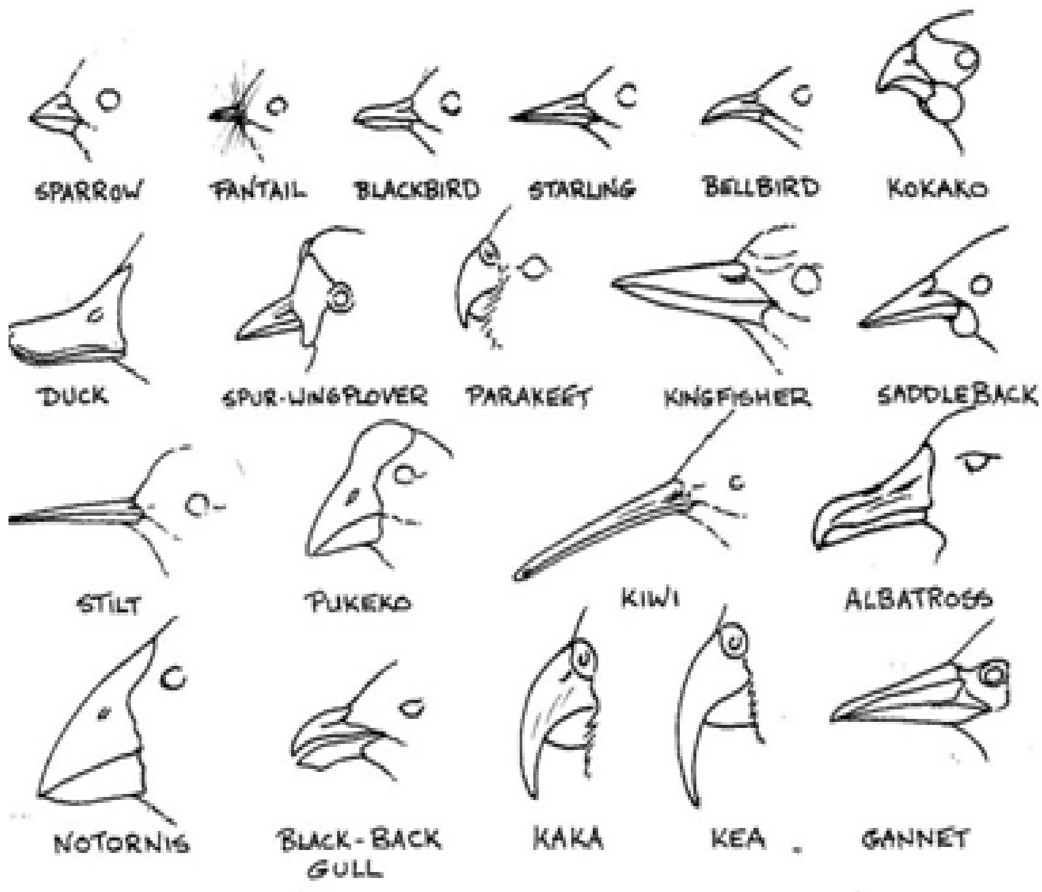

Fig 7.6 Different kind of beaks in Birds

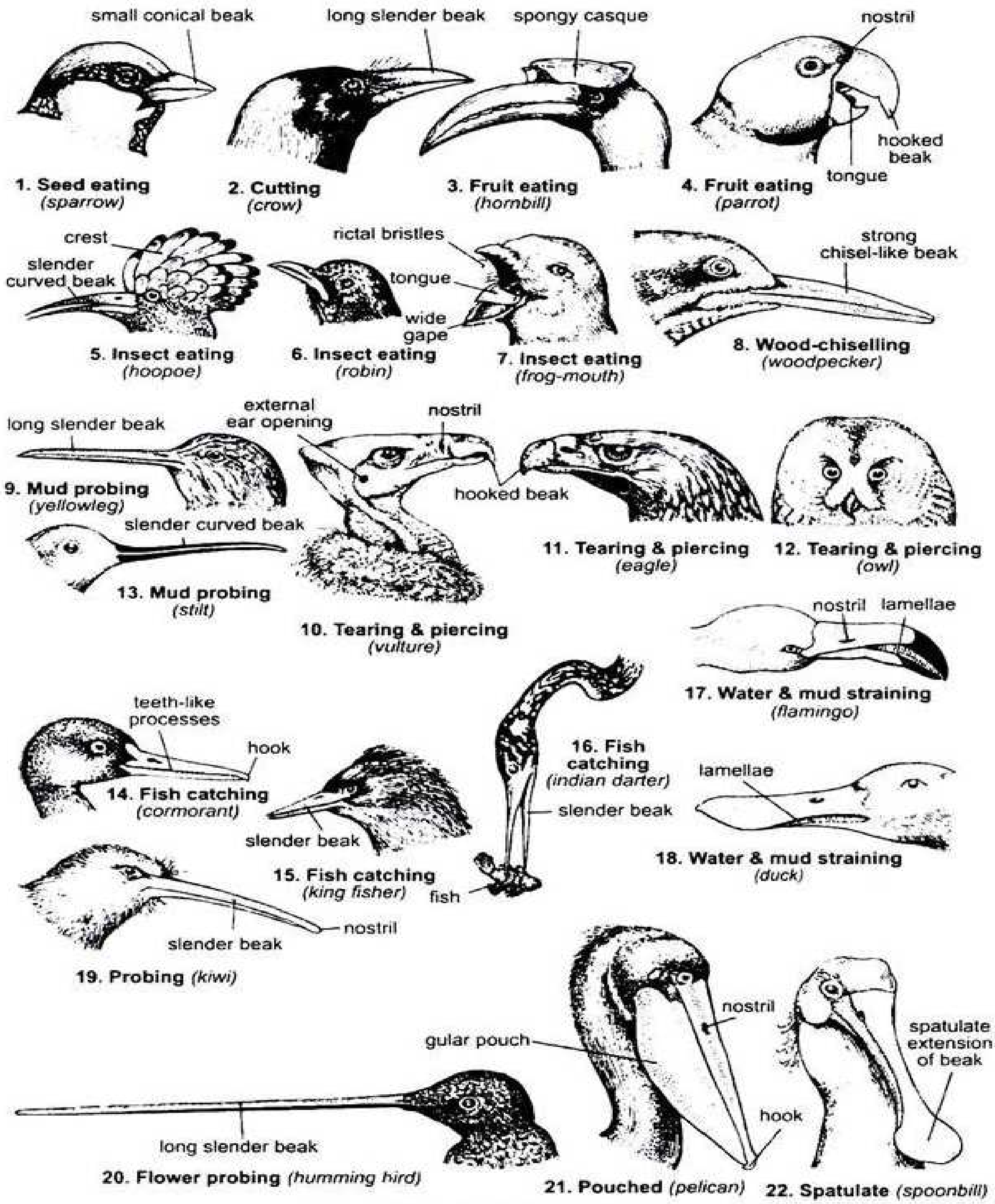

Fig.7.7Type of beaks in birds

All birds have beaks, or bills, made of a bony core surrounded by a thin layer of keratin. Birds do not have true teeth, but many species have tomia -sharp ridges along the edges of their beaks. Birds do not chew food but grind or rip it into pieces small enough to swallow.
The shape of a bird's beak indicates the bird's general diet. Meat-eaters like hawks and owls have sharp, hooked beaks for ripping and tearing. Strong, cone-shaped beaks help seed eaters break through shells. Ducks and geese have broad, flat beaks for straining food out of the water.

The feet of birds are also modified variously in accordance with the character of the environment and the manner of locomotion.

1. Running or Cursorial Feet:
(a) In running birds, the legs are powerful and number of toes is reduced,

(b) The hind toe is elevated, reduced or absent,

(c) Ratites, e.g., Rhea, Emu and Cassowary and coursers, bustards are short-toed birds and having 3 toes directed forward. In ostrich the legs have only two toes, i.e., 3rd or middle toe and 4th or outer toe is smaller and devoid of nail.

2. Perching Feet:
(a) The perching type of feet are found in majority of birds (passer birds), e.g., sparrows, crows, bulbuls, koels, mynas and robins, etc.

(b) In this type of foot there are four movable toes, three toes in front are slender and the hind or hallux is long, strong and sharply clawed,

(c) Because of opposable toes these birds can fasten the foot to a branch of tree.

3. Climbing Feet:
(a) The climbing type of feet are found in parrots, woodpeckers and hoopoes,

(b) The feet are zygodactylous. The second and third toes are directed forwards, while the first and fourth toes are directed backwards,

(c) The foot is modified for grasping and especially adapted for climbing on vertical surfaces of trees and walls.

4. Clinging Feet:

(a) The clinging type of feet are found in martinets, swifts and humming birds,

(b) All the four toes are directed forwards and have long, sharp and curved claws,

(c) The foot is modified for clinging on the trees or any vertical surface while feeding.

5. Scratching Feet:

(a) The scratching type of feet is found in fowls, quails and pheasants.

(b) The feet are stout and provided with strong clawed toes,

(c) The second, third and fourth toes are directed forwards, while the first toe is directed backwards,

(d) The foot is modified for running as well as scratching the earth,

(e) In the male, the foot is usually provided with a pointed bony spur for fighting and for treading the females.

6. Raptorial Feet:

(a) The raptorial type of feet are found in predatory or carnivorous birds such as ospreys, hawks, kites, eagles, owls and vultures, etc.

(b) All the four toes are large and the hallux is strongly developed. The claws are large, strong, sharp and curved. The undersurface of all toes possesses large fleshy bulbs called tylari. These are well developed in hawks,

(c) In osprey and ketupa, tylari are absent but sharp denticulated spines are present which serve to the slippery creatures (fish),

(d) The foot is modified for grasping and holding the prey.

7. Swimming Feet:

In swimming birds the feet are modified in two ways, i.e., swimming and diving type and swimming and paddling type:

(a) Swimming and Diving Feet:

(i) In swimming and diving type of feet, toes are partially or completely webbed. These types of feet are found in coots and grebes. In these birds the web is lobate on the undersurface and the toes are free.

(ii) In grebes each toe is paddle-like bordered on either side by fleshy lobes of integument,

(iii) The nails are flat in a grebe and in coot slightly curved,

(iv) This type of feet is modified for swimming and diving in water.

(b) Swimming and Paddling Feet:

(i) Swimming and paddling type of feet are found in cormorants, pelicans, ducks and teels. Here the toes are webbed,

(ii) In cormorants and pelicans all the four toes are connected with tough web all along their length,

(iii) In ducks and teals the first toe in comparatively small and free, while three anterior toes are completely webbed.

8. Wadding Feet:

(a) The wadding type of feet is found in herons, jacanas, lapwing and snipes, etc.

(b) In this type the legs and toes are very long and slender and the web is absent or feebly developed,

(c) The feet are modified for walking over the aquatic leaves (vegetation) or marshes.

9. Palate in Birds:

In general, the skull in various birds does not show much variation. Amongst some of the universal skull characters of birds are- an early ankylosis of bones except in Ratitae, rounded and spacious cranium, single small rounded occipital condyle formed by basioccipal, the upper beak composed mainly by the two premaxillae united into a large triradiate bone, the slender maxillo-jugal arch, the large parasphenoidal rostrum, the freely articulated quadrate and the reptilian post-frontals. Orbits are large, separated by a thin interorbital septum formed by the mesethmoid which is continued anteriorly with cartilaginous internasal septum.

Importance of Palate in Classification:

There are, however, marked differences in the structure of the palatal region of skull in birds which provides an important character for their classification. The living birds are classified in two suborders- Palaeognathae and Neognathae. In the Palaeognathae or Ratitae are included all the flightless birds.

They have a dromaeognathous type of palate in skull in which the large vomer is extended posterior, so that the two palatines do not meet with one another and with the rostrum.

On the other hand, in Neognathe or Carinatae are included all the modem flying birds. They have a neognathous type of palate with three subtypes (schizognathous, desmognathous and aegithognathous), in which the vomer is small or absent, so that the palatines meet the rostrum.

Kinds of Palate in Birds:

Huxley, in 1877, pointed out the following four types of palate in birds (Fig. 28.8), based on the relations of vomer, palatines, pterygoids and maxillo-palatine processes.

1. Palaeognathous or Dromaeognathous Palate:

This type of palate is characteristic of Ratitae, such as the ostrich, rhea, kiwi and tinamous, etc.

(i) Vomer is large and broad behind connected with the palatines.

(ii) Palatines do not articulate with the parasphenoidal rostrum, because the vomer intervenes between the two.

(iii) Maxillo-palatine processes are small and do not unite with one another or with the vomer.

(iv) Basipterygoid processes of basis phenoid are well developed and they articulate with the hinder part of the pterygoids.

(v) Pterygoids are immovably fixed to vomer and are reptilian in form.

This type of palate is primitive and occurs in the Palaeognathae.

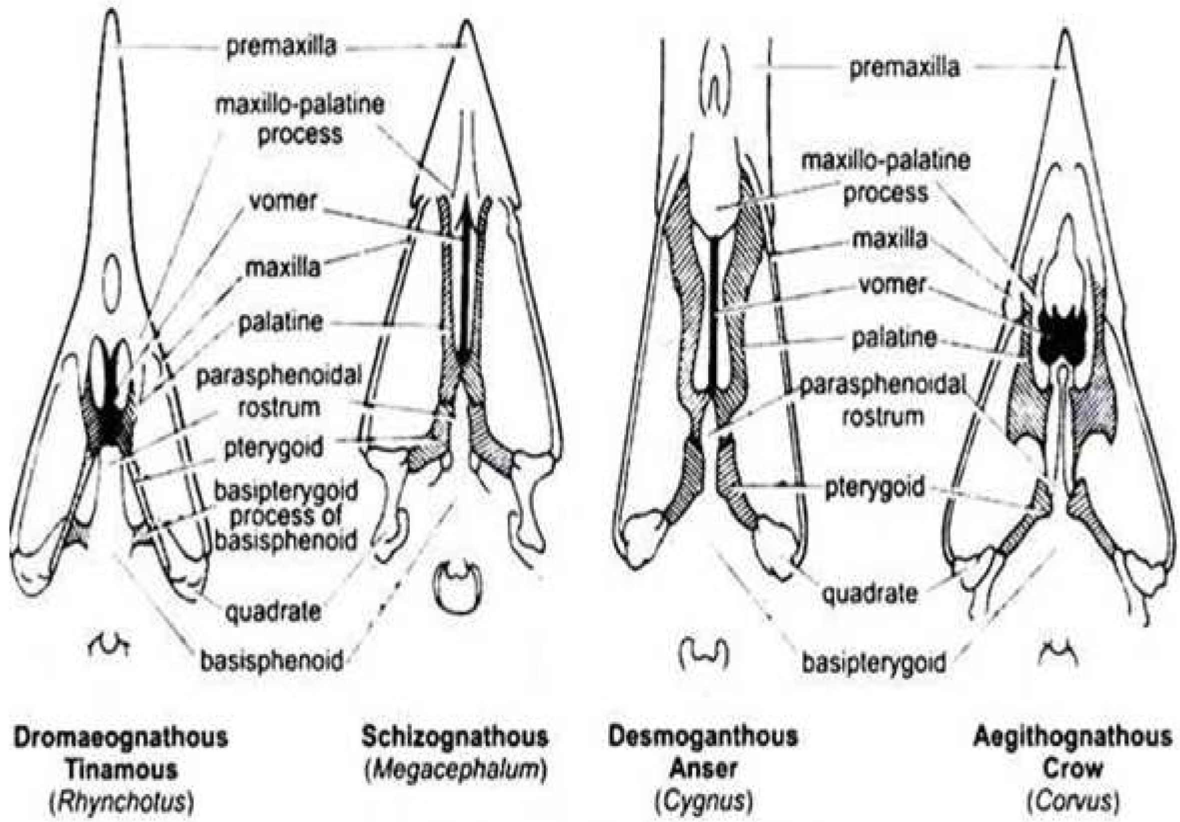

Fig 7.8 Types of skull palate in Birds

2. Schizognathous Palate:

This type of palate is common in a variety of birds, such as pigeons, fowls, gulls, plovers, cranes, woodpeckers, trogons, etc.

(i) Vomer is small and pointed in front, or absent.

(ii) Palatines and pterygoids articulate with the parasphenoidal rostrum at the point where they join one another.

(iii) Maxillo-palatine processes do not unite with one another or with the vomer.

(iv) Basipterygoid processes may be absent or small and arising at the base of the rostrum.

(v) Pterygoids are movably articulated.

3. Desmognathous Palate:

This type of palate is common in most of the wading and swimming birds such as storks, herons, ducks and geese, besides parrots, birds of prey, cuckoos, etc.

(i) Vomer is often abortive or so small that it disappears in the skeleton. When present, it is always narrow, slender and tapers to a point in front.

(ii) Palatines and pterygoids articulate with the rostrum.

(iii) Maxillo-palatines are large and united with one another across the middle line, often forming a flat, spongy palate ventral to the vomer.

(iv) Basipterygoid processes are absent.

(v) In parrots, a special type of desmognathous type of sliding palate occurs so that the depression of the lower jaw automatically raises the upper jaw.

4. Aegithognathous Palate:

This is similar to the schizognathous type of palate. It occurs in passerine birds such as crows, swifts, bulbuls, etc. Vomer is short and broad and truncated instead of being pointed in front. Posteriorly the vomer is deeply cleft embracing the rostrum.

7.8 BIRDS MIGRATION

Bird migration is the regular seasonal movement, often north and south along a flyway, between breeding and wintering grounds. Many species of bird migrate. Migration carries high costs in predation and mortality, including from hunting by humans, and is driven primarily by availability of food. It occurs mainly in the northern hemisphere, where birds are funneled on to specific routes by natural barriers such as the Mediterranean Seaor the Caribbean Sea.

Historically, migration has been recorded as much as 3,000 years ago by Ancient Greek authors including Homer and Aristotle, and in the Book of Job, for species such as storks, turtle doves, and swallows. More recently, Johannes Leche began recording dates of arrivals of spring migrants in Finland in 1749, and scientific studies have used techniques including bird ringing and satellite tracking. Threats to migratory birds have grown with habitat destruction especially of stopover and wintering sites, as well as structures such as power lines and wind farms.

The Arctic tern holds the long-distance migration record for birds, travelling between Arctic breeding grounds and the Antarctic each year. Some species of tubenoses (Procellariiformes) such as albatrosses circle the earth, flying over the southern oceans, while others such as Manx shearwaters migrate 14,000 km (8,700 mi) between their northern breeding grounds and the southern ocean. Shorter migrations are common, including altitudinal migrations on mountains such as the Andes and Himalayas.

The timing of migration seems to be controlled primarily by changes in day length. Migrating birds navigate using celestial cues from the sun and stars, the earth's magnetic field, and probably also mental maps.

Swallow migration versus hibernation:-

Aristotle however suggested that swallows and other birds hibernated. This belief persisted as late as 1878, when Elliott Coues listed the titles of no less than 182 papers dealing with the hibernation of swallows. Even the "highly observant"Gilbert White, in his posthumously published 1789 The Natural History of Selborne, quoted a man's story about swallows being found in a chalk cliff collapse "while he was a schoolboy at Brighthelmstone", though the man denied being an eyewitness. However, he also writes that "as to swallows being found in a torpid state during the winter in the Isle of Wight or any part of this country, I never heard any such account worth attending to", and that if early swallows "happen to find frost and snow they immediately withdraw for a time—a circumstance this much more in favor of hiding than migration", since he doubts they would "return for a week or two to warmer latitudes".

General patterns:-

Migration is the regular seasonal movement, often north and south, undertaken by many species of birds. Bird movements include those made in response to changes in food availability, habitat, or weather. Sometimes, journeys are not termed "true migration" because they are irregular (nomadism, invasions, irruptions) or in only one direction (dispersal, movement of young away from natal area). Migration is marked by its annual seasonality. Non-migratory birds are said to be resident or sedentary. Approximately 1800 of the world's 10,000 bird species are long-distance migrants.

Many bird populations migrate long distances along a flyway. The most common pattern involves flying north in the spring to breed in the temperate or Arctic summer and returning in the autumn to wintering grounds in warmer regions to the south. Of course, in the southern hemisphere the directions are reversed, but there is less land area in the far south to support long-distance migration.

The primary motivation for migration appears to be food; for example, some hummingbirds choose not to migrate if fed through the winter. Also, the longer days of the northern summer provide extended time for breeding birds to feed their young. This helps diurnal birds to produce larger clutches than related non-migratory species that remain in the tropics. As the days shorten in autumn, the birds return to warmer regions where the available food supply varies little with the season.

These advantages offset the high stress, physical exertion costs, and other risks of the migration. Predation can be heightened during migration: Eleonora's falcon Falco eleonorae, which breeds on Mediterranean islands, has a very late breeding season, coordinated with the autumn passage of southbound passerine migrants, which it feeds to its young. A similar strategy is adopted by the greater noctule bat, which preys on nocturnal passerine migrants. The higher concentrations of migrating birds at stopover sites make them prone to parasites and pathogens, which require a heightened immune response.

Within a species not all populations may be migratory; this is known as "partial migration". Partial migration is very common in the southern continents; in Australia, 44% of non-passerine birds and 32% of passerine species are partially migratory.In some species, the population at higher latitudes tends to be migratory and will often winter at lower latitude. The migrating birds bypass the latitudes where other populations may be sedentary, where suitable wintering habitats may already be occupied. This is an example of leap-frog migration.Many fully migratory species show leap-frog migration (birds that nest at higher latitudes spend the winter at lower latitudes), and many show the alternative, chain migration, where populations 'slide' more evenly north and south without reversing order.

Fig.7.9 Shorebirds in North America

Long-Distance Migration:-

The typical image of migration is of northern landbirds, such as swallows (Hirundinidae) and birds of prey, making long flights to the tropics. However, many Holarctic wildfowl and finch (Fringillidae) species winter in the North Temperate Zone, in regions with milder winters than their summer breeding grounds. For example, the pink-footed goose *Anserbrachyrhynchus* migrates from Iceland to Britain and neighbouring countries, while the dark-eyed junco Juncohyemalismigrates from subarctic and arctic climates to the contiguous United States and the American goldfinch from taiga to wintering grounds extending from theAmerican South northwestward to Western Oregon.Migratory routes and wintering grounds are traditional and learned by young during their first migration with their parents. Some ducks, such as the garganey Anasquerquedula, move completely or partially into the tropics. The European pied flycatcher Ficedulahypoleucaalso follows this migratory trend, breeding in Asia and Europe and wintering in Africa.

Often, the migration route of a long-distance migrator bird doesn't follow a straight line between breeding and wintering grounds. Rather, it could follow a hooked or arched line, with detours around geographical barriers. For most land-birds, such barriers could consist in seas, large water bodies or high mountain ranges, because of the lack of stopover or feeding sites, or the lack of thermal columns for broad-winged birds.

In waders

A similar situation occurs with waders (called *shorebirds* in North America). Many species, such as dunlin *Calidrisalpine*and western sandpiper *Calidrismauri*, undertake long movements from their Arctic breeding grounds to warmer locations in the same hemisphere, but others such as semipalmated sandpiper *C. pusilla* travel longer distances to the tropics in the Southern Hemisphere.

For some species of waders, migration success depends on the availability of certain key food resources at stopover points along the migration route. This gives the migrants an opportunity to refuel for the next leg of the voyage. Some examples of important stopover locations are the Bay of Fundy and Delaware Bay.

Some bar-tailed godwits *Limosalapponica* have the longest known non-stop flight of any migrant, flying 11,000 km fromAlaska to their New Zealand non-breeding areas.Prior to migration, 55 percent of their bodyweight is stored as fat to fuel this uninterrupted journey.

Diurnal migration in raptors:-

Some large broad-winged birds rely on thermal columns of rising hot air to enable them to soar. These include many birds of prey such as vultures, eagles, and buzzards, but also storks. These birds migrate in the daytime. Migratory species in these groups have great difficulty crossing large bodies of water, since thermals only form over land, and these birds cannot maintain active flight for long distances. Mediterranean and other seas present a major obstacle to soaring birds, which must cross at the narrowest points. Massive numbers of large raptors and storks pass through areas such as the Strait of Messina, Gibraltar, Falsterbo, and the Bosphorus at migration times. More common species, such as the European honey buzzard *Pernisapivorus*, can be counted in hundreds of thousands in autumn. Other barriers, such as mountain ranges, can also cause funnelling, particularly of large diurnal migrants. This is a notable factor in the Central Americanmigratory bottleneck. Batumi bottleneck in the Caucasus is one of the heaviest migratory funnels on earth. Avoiding flying over the Black Sea surface and across high mountains, hundreds of thousands of soaring birds funnel through an area around the city of Batumi, Georgia. Birds of prey such as honey buzzards which migrate using thermals lose only 10 to 20% of their weight during migration, which may explain why they forage less during migration than do smaller birds of prey with more active flight such as falcons, hawks and harriers.

Nocturnal migration in smaller insectivorous birds:-

Many of the smaller insectivorous birds including the warblers, hummingbirds and flycatchers migrate large distances, usually at night. They land in the morning and may feed for a few days before resuming their migration. The birds are referred to as *passage migrants* in the regions where they occur for short durations between the origin and destination.

Nocturnal migrants minimize predation, avoid overheating, and can feed during the day.One cost of nocturnal migration is the loss of sleep. Migrants may be able to alter their quality of sleep to compensate for the loss.

Fig.7.10 Short distance migration in birds

Short-distance and altitudinal migration:-

Many long-distance migrants appear to be genetically programmed to respond to changing day length. Species that move short distances, however, may not need such a timing mechanism, instead moving in response to local weather conditions. Thus mountain and moorland breeders, such as wallcreeper *Tichodromamuraria* and white-throated dipper *Cincluscinclus*, may move only attitudinally to escape the cold higher ground. Other species such as merlin *Falco* *columbarius* and Eurasian skylark *Alaudaarvensis* move further, to the coast or towards the south. Species like the chaffinch are much less migratory in Britain than those of continental Europe, mostly not moving more than 5 km in their lives.

Short-distance passerine migrants have two evolutionary origins. Those that have long-distance migrants in the same family, such as the common chiffchaff *Phylloscopuscollybita*, are species of southern hemisphere origins that have progressively shortened their return migration to stay in the northern hemisphere.

Species that have no long-distance migratory relatives, such as the waxwings *Bombycilla*, are effectively moving in response to winter weather and the loss of their usual winter food, rather than enhanced breeding opportunities.

In the tropics there is little variation in the length of day throughout the year, and it is always warm enough for a food supply, but altitudinal migration occurs in some tropical birds. There is evidence that this enables the migrants to obtain more of their preferred foods such as fruits.

Altitudinal migration is common on mountains worldwide, such as in the Himalayas and the Andes.

7.9 SUMMARY

Aves are the Latin name for the birds - feathered, winged bipedal, warm-blooded, egg-laying, vertebrate animals with evolutionary origins among the reptiles. The taxon has been historically treated as equal to fish, amphibian, reptiles and mammals, but in order to make classifications reflect evolutionary history, they are now more usually regarded as falling inside the Reptilian. Around 10,000 living species makes them the most species class of tetra pod vertebrates. They inhabit ecosystems across the globe, from the Arctic to the Antarctic. Extant birds range in size from the 5 cm Bee Hummingbird to the 2.75 m Ostrich. The fossil record indicates that birds evolved from there of dinosaurs during the Jurassic period, around 160 million years (Ma) ago. Birds are the only clade of dinosaurs to have survived the Cretaceous "Paleogene extinction event 65.5 Ma ago. Modern birds are characterized by feathers, a beak with no teeth, the laying of hard-shelled eggs, a high metabolic rate, a four-chambered heart, and a lightweight but strong skeleton. All living species of birds have wings. Wings are evolved forelimbs, and most bird species can fly; exceptions include the ostriches, emus and relatives, penguins, and some endemic island species. Birds also have unique digestive and respiratory systems that are well suited to their flying needs. Some birds, especially corvids and parrots, are among the most intelligent animal species; a number of bird species have been observed manufacturing and using tools, and many social species transmit knowledge across generations. Many species undertake long distance annual migrations, and many more perform shorter irregular movements. Many species are social and communicate using visual signals and through calls and songs, and participate in social behaviors', including cooperative breeding and hunting, flocking, and mobbing of predators. The vast majority of bird species are socially monogamous, usually for one breeding season at a time, sometimes for years, and rarely for life. Other species have polygynous (\"many females\") or, rarely, polyandrous (\"many males\") breeding systems. Eggs are usually laid in a nest and incubated by the parents. Most birds have an extended period of parental care after hatching. Many species are of economic importance, mostly as sources of food acquired through hunting or farming. Some species, particularly songbirds and parrots, are popular as pets. Other uses include the harvesting of guano (droppings) for use as a fertilizer. Birds figure prominently in all aspects of human culture from religion to poetry to popular music. About 120â "130 species have become extinct as a result of human activity since the 17th century and hundreds more before then. Currently about 1,200 species of birds are threatened with extinction by human activities, though efforts are underway to protect them.

7.10 TERMINAL QUESTIONS AND ANSWERS

Q1 Explain the different type of migration.

Q2 Give an account of flight mechanism in birds.

Q3 Explain in detail the origin of Birds?

Q4Describe the different kinds of Beaks

Q5 Explain in detail about feet of Birds?

Q6 Give the detail description of Palate in Birds?

7.11 REFERENCES

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UNIT 8: MAMMALIA

8.1 OBJECTIVES

In this topic we will learn about the Origin of Mammals, Distribution and Affinities of Primitive Mammals (Prototheria and Metatheria) .General account on Adaptive Radiations in Mammals Dentition in Mammals Dentition.

8.2 INTRODUCTION

Mammals include the largest animals on the planet, the great whales, as well as some of the most intelligent, such as elephants, primates and cetaceans. The basic body type terrestrial quadruped, but some mammals are adapted for life in sea, in the air, on trees, underground or on two legs. The largest group of mammals, the placental, have a placenta, which enables range in size from the 30–40 mm (1.2–1.6 in) (108 ft) blue whale, With the exception of the five species of monotreme (egg-laying mammals), all modern mammals give birth to live young. Most mammals, including the six most species-rich orders, belong to the placental group. The three largest orders in number of species are Rodentia i.e. mice, rats, porcupines, beavers, capybaras and other gnawing mammals; Chiroptera i.e. bats; and Soricomorpha: shrews, moles and solenodons. The next three biggeorders, depending on the biological classification scheme used, are the Primates including the great apes and monkeys; the Cetartiodactyla including whales and even-toed ungulates; and the Carnivora which includes cats, dogs, weasels, bears and seals The word "mammal" is modern, from the scientific name Mammalian, coined by **Carl Linnaeus in 1758,** derived from the Latin mamma ("teat, pap"). All female mammals nurse their young with milk, which is secreted from special glands, i.e mammary glands. According to Mammalian Species of the World, 5,416 species were known in 2006. These were grouped in 1,229 genera, 153 families and 29 orders. In 2008 the International Union for Conservation of Nature (IUCN) completed a five-year, 1,700-scientist Global Mammal Assessment for its IUCN Red List, which counted 5,488 species. In some classifications, extant mammals are divided into two subclasses: the Prototheria, that is, the order Monotremata; and the Theria, or the infraclasses Metatheria and Eutheria. The marsupials constitute the crown group of the Metatheria, and include all living metatherians as well as many extinct ones; the placentals are the crown group of the Eutheria. While mammal classification at the family level has been relatively stable, several contending classifications regarding the higher levels subclass, infraclass and order.

GENERAL CHARACTERISTICS OF CLASS MAMMALIA ARE GIVEN BELOW:-

- They are Warm blooded.
- Possess hair which is made of keratin. The evolution of mammalian keratin is believed to be independent of reptilian keratin. Hair provides insulation.
- Endothermic. The majority of the heat energy is used to maintain their high body temperature.
- Four chambered heart.
- Mammary glands are used to produce milk to nourish their young. Female glands are the only functional glands.
- Thediaphragm is a muscle that separates the thoracic cavity from the abdominal cavity.
- Seven cervical vertebrae (neck bones) are present in most mammals.
- Most are viviparous though some are oviparous. An extended gestation period uterine development is common in most placental mammals.
- Teeth are imbedded in the jaw bone and come in a variety of forms.
- Well-developed brain.
- Mammals developed from the therapsid ancestors during the Triassic period.
- Mammals are heterodontic, meaning that their teeth are different shapes, except those with no teeth at all.
- Reptiles and fish have teeth that are all basically the same, though they can vary in size throughout the mouth. See image above.
- The Buccal Cavity (the mouth) has a false palate as a roof, meaning that the nostrils do not lead directly into his mouth.
- The body is maintained at a constant temperature they generate heat within their bodies metabolically and also have special cooling mechanisms.
- Highly developed neopallium.

- Tectum reduced to corpora quadrigemina: functions mainly as a relay center for auditory information and to control visual reflexes.
- Corpus callosum in eutherians provides additional communication
- Smell acute except whales and higher apes.
- Eye typical of amniotes.
- Tapetum lucidum well developed in nocturnal mammals.
- Touch- most has vibrissae that are controlled by facial muscles.
- Lateral movement of jaw during mastication.
- Viviparous except monotremes which are egg laying.
- Parental care well developed.

8.3 ORIGIN OF MAMMALS

From approximately 252 million to 201 million years ago, members of the reptile order Therapsida gave rise to mammals during the Triassic Period. Therapsids, members of the Synapsida subclass (also known as the mammal-like reptiles), were typically underwhelming in comparison to other reptiles of their day. One of the earliest known reptile lineages, synapsids lived during the Carboniferous Period (359 million to 299 million years ago). They dominated the reptile world throughout the Permian Period (299 to 252 million years ago), and despite being predominantly predators by nature, they also included herbivorous species in their adaptive radiation. The archosaurs, or "ruling reptiles," were the most significant synapsids throughout the Mesozoic Era (about 252 million to 66 million years ago), while the therapsids were often small active predators. Therapsids tended to develop a specialized heterodont dentition (a set of teeth divided into molars, incisors, and canines) as well as limbs that were closer to the trunk for improved locomotor mechanics. The temporal musculature, the muscle responsible for closing the jaw, enlarged, and a secondary palate formed.

It's likely that the various characteristics that set current reptiles apart from modern mammals evolved at various rates. Mammals have a variety of characteristics that are linked to their high level of activity, including an efficient double circulation, a heart with four chambers entirely, anucleate and biconcave erythrocytes, the diaphragm, and the secondary palate (which separates passages for food and air and allows breathing during mastication or suckling). A correlate of endothermy, or warm-bloodedness, the physiological regulation of personal temperature independent of ambient temperature, is hair for insulation. High amounts of prolonged activity are possible with endothermy. Thus, it would appear that the distinctive traits of mammals originated as a complicated interconnected system.

Because the characteristics that separate reptiles and mammals evolved at different rates and in response to a variety of interrelated conditions, at any point in the period of transition from reptiles to mammals, there were forms that combined various characteristics of both groups. Such a pattern of evolution is termed mosaic and is a common phenomenon in those transitions marking the origin of major new adaptive types. To simplify definitions and to allow the strict delimitation of the Mammalia, some authors have suggested basing the boundary on a single characteristic, the articulation of the jaw between the dentary and squamosal bones and the attendant movement of accessory jawbones to the middle ear as auditory ossicles. The use of a single osteological character allows the placement in a logical classification of numerous fossil species, other mammalian characteristics of which, such as the degree of endothermy and nursing of young and the condition of the internal organs, probably never will be evaluated. It must be recognized, however, that were the advanced therapsids alive today, taxonomists would be hard put to decide which to place in the Reptilia and which in the Mammalia.

8.4 ORGANIZATION, DISTRIBUTION AND AFFINITIES OF PRIMITIVE MAMMALS (PROTOTHERIA AND METATHERIA)

Mammals can organize themselves into **fission-fusion societies, harems, and hierarchies**—but can also be solitary and territorial. Most mammals are polygynous, but some can be monogamous or polyandrous.

In **Ethology**, a **fission–fusion society** is one in which the size and composition of the social group change as time passes and animals move throughout the environment; animals merge into a group (fusion)—e.g. sleeping in one place—or split (fission)—e.g. foraging in small groups during the day. For species that live in fission–fusion societies, group composition is a dynamic property. The change in composition, subgroup size, and dispersion of different groups are 3 main elements of a fission-fusion society. This social organization is found in several primates, elephants, cetaceans, ungulates, social carnivores, some birds and some fish.

In sociology, a **social organization** is a pattern of relationships between and among individuals and social groups. Characteristics of social organization can include qualities such as sexual composition, spatiotemporal cohesion, leadership, structure, division of labor, communication systems, and so on.

And because of these characteristics of social organization, people can monitor their everyday work and involvement in other activities that are controlled forms of human interaction. These interactions include: affiliation, collective resources, substitutability of individuals and recorded control. These interactions come together to constitute common features in basic social units such as family, enterprises, clubs, states, etc. These are social organizations.

MAMMALIAN AFFINITY:

The prototherians are essentially mammals as they possess the following typical mammalian characters:

1. Presence of hair, mammary glands, oil gland and sweat glands.
2. Double occipital condyles.
3. Presence of palate.
4. A typical mammalian diaphragm is present in the body cavity.
5. Skull is dicondylic.
6. Sternum is segmented.
7. Lobes of liver typically mammalian.
8. Heart 4-chambered.
9. Only left aortic arch present.
10. Circulatory system is typically mammalian.
11. Presence of large ear ossicles.
12. Cochlea is slightly coiled.
13. Fertilization is internal.
14. A slender caecum demarcates two intestines.
15. Lobes of liver typically mammalian.

16. R.B.C. small, circular and non-nucleated.

17. Presence of 4 optic lobes (corpora quadrigemina).

18. Presence of milk glands secreting milk, Though monotremes show affinity with non-mammalian groups, the above mentioned characters strongly speak of close and firm affinity with mammals.

AFFINITIES OF METATHERIANS

Metatheria or Marsupials are more advanced than the prototherians. They are all pouched mammals characterized by the presence of an integumentary brood pouch or ***marsupium*** in which the immature young ones are fed with the milk of the mother.

The marsupials occupy an intermediate position between the primitive mammals (monotremes) and the higher mammals (eutherians).

- Marsupium or brood pouch is present in females. The mammary glands are present in the marsupium.
- The marsupium is supported by epipubic (marsupial) bones.
- The teeth are more in number. There are more than 3 incisors and more than 4 molars in each half of the jaw. Teeth are formed only once in life time. Hence, the dentition is called monophyodont dentition.
- Corpus callosum is usually absent in the brain and Placenta is absent.
- Although the anal and urinogenital apertures are separate and distinct, they are surrounded and controlled by a common sphincter muscle.
- Testes are situated in scrotal sacs. The penis is present behind the scrotum and it is bifid.
- The females have 2 oviducts, 2 uteri and 2 vaginae (didelphic condition) which separately open into urinogenital sinus.
- The young ones are born naked and blind, but they posses clawed fore limbs by which they move into the brood pouch.
- Fertilization and a major part of development are internal, but the young ones are born in immature state (mammary foetus).

- Yolk sac placenta is present in marsupialia. True allantoic placenta is absent (except parameles). Yolk sac is large with villi.
- Hind limbs are long in some animals like kangaroo.
- The body temperature ranges from 36° C to 40° C.

8.5 GENERAL ACCOUNT ON ADAPTIVE RADIATIONS IN MAMMALS

Mammals were small, widespread, and few throughout the Mesozoic era, the time of the reptiles (dinosaurs). The dinosaurs had disappeared by the end of the Mesozoic or the beginning of the Cenozoic, and mammals had quickly spread and undergone numerous evolutionary changes. Placental mammals began to diverge from marsupials towards the beginning of the Cretaceous epoch.

Most mammal orders evolved throughout the Eocene and Oligocene, settling in the habitats and ecological niches left vacant by the dead dinosaurs. Divergent evolution or adaptive radiation refers to this process of development from a single ancestral species to a range of forms that occupy various habitats.

The concept of adaptive radiation in evolution was developed by H.F. Osborn in 1898. Examples often given as evidence include Darwin's finches of the Galapagos Islands, varied limb structure of mammals, Australian Marsupials, etc.

A. Radiation in Limb Structure of Mammals:

Pentadactyl limbs are modified into mammalian limbs. It is thought that early, ancestor mammals were short-legged, five-fingered ground dwellers. They did not have any form of locomotion-specific modification to their limbs. These creatures lived on land. The forerunners of contemporary mammals were these terrestrial forebears.

These mammal species with simple limb structures are positioned in the middle of figure 33.10. As a result, adaptive radiation took place in five distinct lines or habitats with altered limb structures.

From these terrestrial mammals the different lines radiated in the following manner:

1. One evolutionary line radiates to form arboreal forms which have adapted limbs for life in trees (e.g., squirrels, sloths, monkeys, etc.).
2. Another line leads to aerial representing mammals adapted for flight (e.g., bats) Only bats occupy the position at the terminus of this line, since they are the only truly flying mammals Somewhere along this line we can place for gliding mammals such as “flying squirrel. ”
The arboreal and aerial forms not arose independently from the terrestrial forms as shown in the diagram It is believed that the ancestral aerial forms were previously lived in trees having gliding type of locomotion which later gave rise to true flight. Hence, perhaps the gliding formed transitional type of locomotion between climbing and true flight.

3. Third line of radiation gave rise to cursorial forms (e.g., horses and antelopes). They have developed limbs suitable to rapid movements over the surface of the ground. Along this line also developed other mammals with less strongly modified limbs, such as wolves, foxes, hyaenas, lions.

4. The burrowing mammals, or fossorial mammals, were created by the fourth line of radiation. Even though some of the fossorial animals, such as moles, have changed their forelimbs for digging, they are not well suited for ground movement. Others, such as pocket gophers and badgers, are skilled diggers but have structures that allow them to travel easily on the ground's surface.

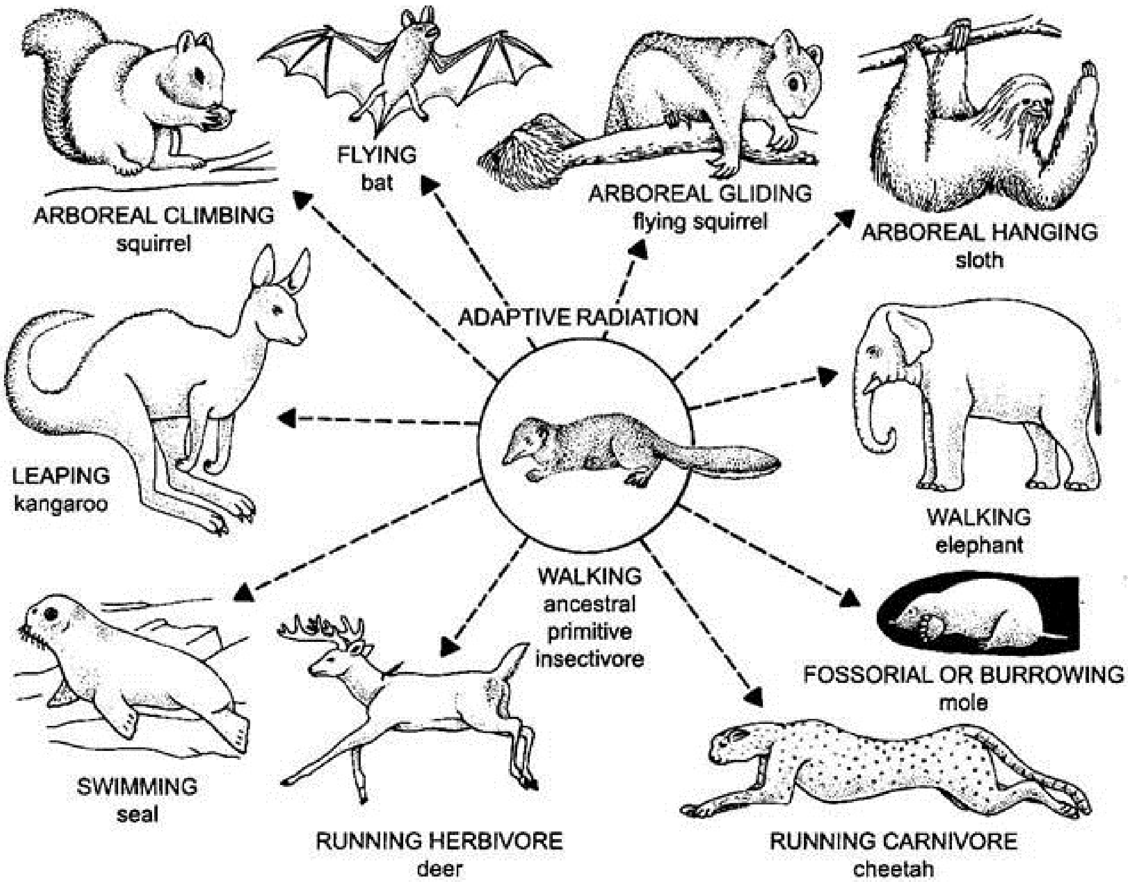

Fig.8.1 a Divergent evolution in Mammals based on locomotion

Thus, all the mammals of different radiating lines have limbs more or less adapted for some particular mode of locomotion. All the lines start from a common centre representing the short, pentadactyl limbs of terrestrial mammals. From the centre, evolutionary lines radiate out in various directions. Hence, adaptive radiation is evolution in several directions starting from a common ancestral type.

8.6 DENTITION IN MAMMALS

With just a few exceptions (Cetacea, ant-eaters, etc.), mammals have heterodont dentition, meaning that, unlike reptiles, their teeth have varied forms and have extremely different purposes. The many tooth kinds include premolars and molars for grinding, incisors for biting, canines for gripping, tearing, or for defence or offence. For various types of food, the premolars and molars exhibit the most structural alteration.

Premolars and molars of the insectivorous type (the stem form in mammals) are low-crowned, simple, and have few cusps. They are typically sharp, pointed, and excellent for crushing weak prey. Premolars and molars in the carnivorous type are high-crowned, trenchant, shearing features (carnassial). The jaws seldom ever move laterally. Dogs have more grinding teeth than cats do, who don't have any. The teeth of Odontoceli (including toothed whales) are essentially identical and lack dental distinction.

In sperm whale, Physeter, no teeth in the upper jaw, but germs of upper teeth are present, while in whalebone whales (Mystaceti) upper teeth are totally absent and their place is taken by curious baleen or whalebone which hangs from the palate.

In herbivorous types, incisors are for seizing and cutting the vegetation. In ruminants, they are absent in the upper jaw, but a horny pad is present there. Canine teeth are of little importance for herbivores, but in musk deer they are used for defence and in swine they are used for uprooting the vegetation.

Grinders (premolar and molars) may be short-crowned and brachydont adapted for succulent leaves and twigs or long-crowned and hypsodont adapted for harsh grasses. In myrmecophagous type teeth have disappeared, jaws reduced and mouth opens at the extreme anterior end of tubular snout with a highly extensible and prehensile adhesive tongue for eating ants.

DEVLOPMENT OF TOOTH:

Teeth develop over the jaw bone where certain malpighian cells start actively multiplying forming a mass of cells called dental lamina or enamel organ. A dental papilla made of group of dermal cells appears below the dental lamina that supplies nourishment to the arrange themselves in a row and get differentiated into **odontoblast cells.** Epidermal cells of the dental lamina that cover the growing dentine are called **ameloblasts**. The tooth gradually grows outwards and eventually gets exposed by penetrating through the skin covering the jaw bone. The dental papilla inside the pulp cavity remains active along with its blood supply and nerve intact. This development of tooth is identical to the development of dermal scales in fishes. Hence shark teeth are also called modified placoid scales.

DENTITION IN MAMMALS:

Mammals as a rule possess heterodont, diphyodont and thecodont dentition. However, some mammals lack teeth as given below in detail.

- Among monotremes, the spiny anteater or echidna *(Tachyglossus* and *Zaglossus)* lacks teeth
- Among the aquatic Cetacea baleen whales have no teeth, such as the blue whale, *Balaenopteramusculus* and, the whalebone whale. Among humans, and astonishingly, males in "Bhudas" tribe of Hyderabad Sindh in Pakistan
- They are genetically so predisposed that they never grow teeth all their lives.

The Mammalian Dental:

Mammals have heterodont dentition having four types of teeth meant for different function in handling food in the oral cavity. Incisors in front are flat teeth designed for cutting food into pieces and the canines next to them are generally long and pointed spike-like used for tearing flesh by carnivore animals. Premolars and molars are located on the posterior side of the jaw, have flat surface with tubercles called cusps and are used for grinding food of plant origin. They are therefore well developed in herbivore animals. Number and arrangement of teeth in mammals is specific in different groups of animals so much so that mammalian orders can be identified by their teeth and dental formula, which is written for one half of the upper and lower jaw as follows.

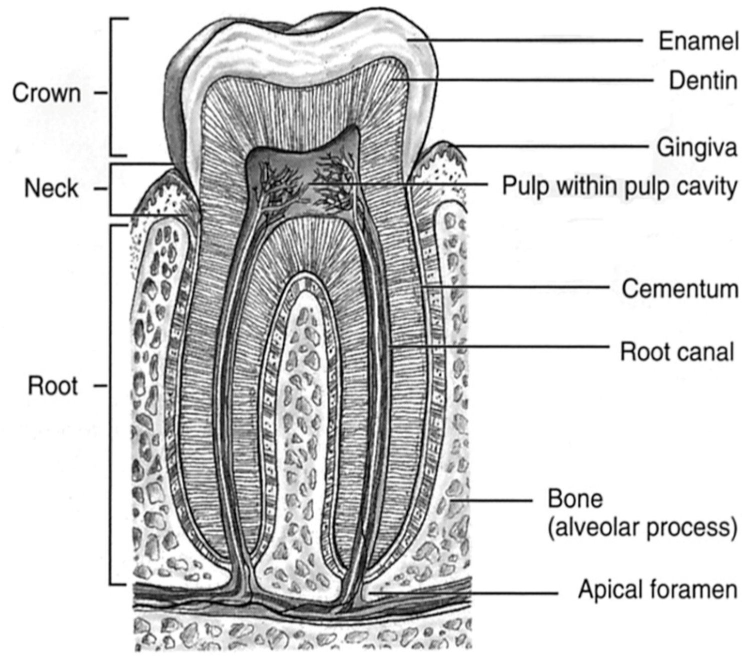

Fig.8.2 Mammalian Dental

TYPES OF TEETH

Polyphyodont dentition involves replacement of teeth from time to time several times in lifetime so that jaws are never left without teeth. Lower vertebrates having loose attachment of teeth lose teeth while feeding and capturing prey and hence teeth must grow again to replace the lost ones.

Diphyodont dentition is a characteristic of mammals in which milk teeth appear in the young ones but as they grow and jaw becomes larger, milk teeth are replaced by larger permanent ones to fit in the larger jaw bone.

Monophyodont teeth appear only once in lifetime and if they fall they are never again replaced by the new ones. Toothless animals have this kind of teeth and marsupials retain their milk teeth.

Based on the type of attachment of teeth on the jaw bone the following three types are found in vertebrates:

Acrodont teeth are attached on the top surface of the jaw bone as in fish and amphibians. This type of attachment is not very strong and teeth are lost easily and are replaced by new ones.

Pleurodont teeth are attached on the inner side and upper side of the jawbone that brings larger surface area of tooth in contact with jawbone and hence attachment is stronger, as in lizards and urodeles. But this attachment is also not as strong as thecodont.

Thecodont dentition is found in mammals in which root of the tooth is firmly fixed in a socket of the jawbone, making the attachment strongest in vertebrates. This is a peg and socket attachment with the help of cementum that surrounds the root portion of the tooth.

Based on the kinds of teeth found there are two types of dentition:

Homodont dentition is found in the majority of vertebrates such as fish, amphibian and reptiles in which all teeth are functionally and anatomically of the same type, although their size may be variable depending on the location. Sometimes functionally some teeth may be specialized as fangs of snakes.

Heterodont dentition occurs in mammals in which there are 4 functionally different types of teeth, namely, flat incisors for cutting, long and pointed canines for tearing flesh and large and broad premolars and molars with flat grinding surface. Molars have no counterparts in the milk teeth.

There are also some other type of teeth as follows:

Secodont teeth have sharp cutting edges that function like scissors to cut flesh as in some primates and in carnivores.

Bunodont teeth are small with smaller cusps or tubercles on the surface for handling soft diet as in man, monkeys, rodents etc.

Brachydont teeth are smaller and low crowned suitable for feeding on soft diet.

Hypsodont teeth possess larger crown that can resist wear and tear of feeding on tough and fibrous diet as in ungulates.

Selenodont teeth are found in horses and other ungulates in which silica deposit around cusps and in the depressions of the grinding surface. This makes the grinding surface of teeth harder to prevent wearing.

Lophodont teeth are found in elephants which feed on the roughest diet that any mammal can feed on. The ridges on the grinding surface are in the shape of rounded lophs and the depressions are filled with silica.

8.7 SUMMARY

Mammals are a well-known class of vertebrates, including many familiar domesticated species and pets, as well as our own species Homo sapiens. All mammals are warm-blooded, and all female mammals possess mammary glands (mammae), which are used to suckle the young with milk. Mammals are further distinguished by the possession of hair or fur, although this is limited to early developmental stages in the Cetacea (whales and dolphins). The vast majority of mammals give birth to live young, the exception being the egg-laying Monotremata (a small group of mammals including the duck-billed platypus and the echidnas or spiny anteaters). Monotremes are found exclusively in Australia and New Guinea. Mammals are found in a wide variety of habitats, including terrestrial, freshwater, and marine systems. They occur from the deserts to the dense forests, from the deep seas to the highest mountains, and from the tropics to the polar ice caps. Only one group of mammals, the Chiroptera (bats) is adapted to flight; other taxa such as flying squirrels or flying possums can glide effectively but are not capable of true flight.

8.8 TERMINAL QUESTIONS AND ANSWERS

Q.1 Give the General Characteristics of Mammals?

Q.2 Give the adaptive Radiation in Mammals?

Q3. Explain in detail the Origin of Mammals?

Q.4 Write a short note on different type of Teeth on Mammals?

Q.5 Write a short note on affinities of metatherians?

8.9 REFERENCES

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- Some figure and tax material are adopted from Biozoom.