AKSUM UNIVERSITY

COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES

DEPARTMENT OF BIOLOGY

VERTEBRATE ZOOLOGY (BIOL. 222) MODULE

CREDIT HOURS: 4

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Course Team

General Introduction

Course Rationale

The vertebrates are at the highest level of evolutionary development in the animal kingdom. As such they play pivotal role in the various ecosystems of the world. Fishes make the aquatic prey base for other species of fishes including the sharks and also to the aquatic carnivorous mammals. The terrestrial antelopes of the savannah plains support the large carnivores at the highest trophic level. Vertebrates are also interlinked with the life of man in various ways. Most wild animals that have esthetic value for tourism are vertebrates; the beautifully colored birds, the fascinating antelopes of the savannah, the graceful mammalian predators including the lions and leopards and many more delightful creatures are vertebrates. The majority of domestic animals which serve man as a source of food, raw materials for manufacturing of clothes, shoes also as pack animals are considered as vertebrates. Also the most diverse and abundant vertebrates, the bony fishes, provide the bulk of the protein requirement of man and livelihoods to a large number of fishermen worldwide. Ethiopia is endowed with diverse and abundant animal resources that fall under the vertebrate group. Studying and knowing them scientifically will benefit the nation.

Course Description

The course deals with the evolutionary development and sequential phylogenetic link that exists between the various groups of vertebrates. Morphological and physiological characteristics and adaptations and geographical locations of each vertebrate class will be covered in adequate detail. The major vertebrate species of Ethiopia will be overviewed with more emphasis on the endemic mammals. The lecture component is reinforced by practical's in which students will study representative live, preserved and/or model specimens of the different vertebrate groups and other relevant audiovisual materials.

Course Objectives

After completing the contents of the course the students will be able to:

- Identify the various vertebrate classes and cite examples of individual species that belong to them
- Describe the evolutionary relationship of vertebrates by integrating knowledge in comparative anatomy and physiology
- Show the geographical distribution of at least the most common vertebrates
- Describe the diversity of Ethiopian vertebrate fauna.

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CHAPTER ONE

CHORDATES

Introduction

In this Unit, we shall be looking at a group of animals called chordates. Chordates belong to the animal phylum Chordata and include the vertebrates, together with several closely related invertebrates, Urochordates and Cephalochordates. Until recently, an invertebrate group the Hemichordata was placed under the phylum Chordata (borne out of interest, we shall also consider it here). The three Chordate subphyla i.e. Urochordata, Cephalochordata and vertebrata are so grouped on account of having primary features namely: a notochord (a dorsal fairly rigid rod of vacuolated cells) or vertebral column, a hollow dorsal nerve cord or spinal cord, pharyngeal slits, and a post-anal tail.

It must be emphasized that although chordates are said to have these four basic features in common, some of these characteristics are not retained throughout the life of an animal but must be present or manifest in an individual at some time during its development.

Unit objectives

At the end of this study, students should be able to:

- *Recognize chordates by their characteristic features and their classifications*
- *Distinguish chordates from other animal groups*
- *Have a mental picture of the body structure of chordates*

1.1. What are Chordates?

Lesson objectives

At the end of this lesson, students will be able to:

- ✓ *List the general of characteristic chordates*
- ✓ *List down the body structures of chordates*
- ✓ *Classify chordates in to different groups*

Chordates are defined as organisms that possess a structure called a notochord (Greek, noton meaning back, chorda, cord), at least during some part of their development. The notochord is a rod that extends most of the length of the body when it is fully developed. Lying dorsal to the gut but ventral to the central nervous system, it stiffens the body and acts as support during locomotion.

The animals belonging to all other phyla of the Animal Kingdom are often termed 'the non chordates' or 'the invertebrates' since they have neither notochord nor backbone in their body. The backboned animals (vertebrates), together with a few closely related animals which do not possess a backbone, are included in this phylum. Most of the living chordates are familiar vertebrate animals. The chordates are of primary interest because human beings are members of this group.

Characteristics of Chordates

All vertebrates are found within the Chordata phylum. All chordates evolved from an ancestor that had a flexible rod (called a notochord) along the dorsal side (back) to provide support for the skeleton and muscles. All chordates share a common internal body plan. There is a dorsal nerve cord; a digestive tract that extends from the mouth to anus; a muscular tail that extends beyond the anus and the heart pumps blood through the body and to the gills (or lungs). Indeed, all tail and gill slits at some stage of development. In the animals we classify as vertebrates, the notochord is replaced by bony vertebrae that surround the nerve cord along the dorsal side (back) of the organism. (Other chordates lack

these bony vertebrae and retain the flexible notochord.) Vertebrates are subdivided into several classes: fishes (which comprise several classes), amphibians, reptiles, birds, and mammals.

A study of vertebrates reveals progressive evolutionary adaptations to life on land and a wider range of ecological niches adaptations that can be found in:

- Improved respiration
- Protective and insulating body coverings
- More efficient reproduction (especially on land)
- Paired, muscular appendages

Vertebrate evolution began around 500 million years ago (mya) during the early Paleozoic era with the evolution of fish, followed by amphibians and then reptiles during middle Paleozoic. Reptiles reached their "peak" (at least in size and ferocity) during the Mesozoic era. Some lizard-like reptiles of the Mesozoic evolved into small hair-covered mammals, birthing their young rather than laying eggs, while awaiting the demise of the dinosaurs before rising to prominence during the Cenozoic. However, before this eventual demise, the dinosaurs gave rise to another group, the birds, which, like the mammals, survive to the present day.

Basic features of chordates

Notochord: During the embryonic development of a chordate there appears a supporting rod called the notochord. It lies dorsal to the alimentary canal and ventral to the nerve cord. In some chordates this structure persists throughout life. In others it is partially or completely replaced by a 'backbone'. It is made up of separate bony elements or vertebrae. Structurally it is composed of large number of specialized vacuolated cells.

It is surrounded by fibrous and elastic sheath. The stiffness of the notochord is due to the turgidity of fluid-filled cells and surrounding connective tissue sheath. It is a stiff but flexible rod (made up of tightly packed vacuolated cells held in position by a firm sheath). The notochord is found lying along the inside of the dorsal side of the body and provides structural support. It can be found in its near original form in some invertebrate chordates. In most modern chordates especially the vertebrates, the notochord exists only during

development but is modified or replaced in the course of development into a bony vertebra known as the spine or backbone. In wholly aquatic species, the notochord (vertebra) helps the animal to swim by flexing its tail.

Dorsal nerve cord: This is a fluid filled tube of nerve tissue that runs the length of the animal, dorsal to the notochord. It is present in chordates throughout embryonic and adult life. In fish and other vertebrates, the nerve cord is represented by the spinal cord, which is the main communications line of the nervous system. The nerve cord lies just above the notochord and remains entirely outside the coelom. It is a tubular structure having a small hollow canal running from one end to the other. The dorsal hollow nerve cord persists throughout the adult life of almost all chordates.

Pharyngeal gill slits: These are paired lateral clefts leading from the pharynx to the exterior. They are present throughout life in fishes and a few tailed amphibians. In amphibians, like frogs and toads it is found only in the larval stages. In higher vertebrates (reptiles, birds and mammals) they are embryonic and non-functional. The pharynx is the part of the throat immediately behind the mouth down toward the stomach in the digestive tract. The pharyngeal gill slits are pairs of openings through the pharynx.

The slits serve as water exit holes through which water, drawn through the pharynx, is passed out without it continuing down into the rest of the gastrointestinal tract. Invertebrate chordates use them to trap food particles in the water the animals live. In fishes, the gill slits have developed into true gills for breathing. In reptiles, birds, and mammals (including humans), the gill slits are vestiges (gone or no longer functional), occurring only in the embryonic stage.

Muscular post anal tail: This is the structure that extends backwards from behind the anus. It is that part of the animal behind the anus, which terminates the digestive tract. The notochord, nerve cord and the myotomes (muscles) extend to the tail. The tail is found at some time during a chordate's development.

Other features of Chordates

Blocks of muscle (metameric masculature): These are muscle blocks on either side of the body that surround the notochord and nerve cord.

Triploblastic coelomates: The body structure is made up of three germ layers (layers of embryonic cells) and a well-developed coelom (body cavity).

Bilateral symmetry: The body of chordate is bilaterally symmetrical i.e. if the body is divided into two halves of left and right, each side is a mirror of the other. Ventral heart, the heart of chordates is ventrally located with dorsal and ventral blood vessels and a closed blood system.

Limbs: Chordates generally have four appendages that are in the forms of legs, arms, wings or fins.

Endoskeleton: Chordates have an inner skeleton with a backbone.

Digestive system: Chordates have a digestive system of stomach and intestines. Food is taken through the mouth which may have a tongue and teeth. Chordates eat plants and animals.

Nervous system: Chordates have brain and nervous system. Chordates have the most developed brains and complex nervous systems of all the animal phyla.

Respiration: Chordates take in oxygen and get rid of carbon dioxide through lungs or gills.

Reproduction: Chordates reproduce sexually.

Excretion: Chordates get rid of wastes through kidneys and intestines.

Ventral heart

The heart is chambered. It is located ventral to the alimentary canal.

Closed blood vascular system

In chordates, the blood passes through a continuous system of tubes namely arteries, capillaries and veins.

Hepatic portal system

In chordates, the food laden blood from the digestive tract passes through the capillary net work in the liver, before reaching the heart. Thus the veins originating from the digestive tract as capillaries and ending in the liver again as capillaries constitute the hepatic portal system.

Body Outline of Chordates

The structure below represents the generalized body outline of chordates:

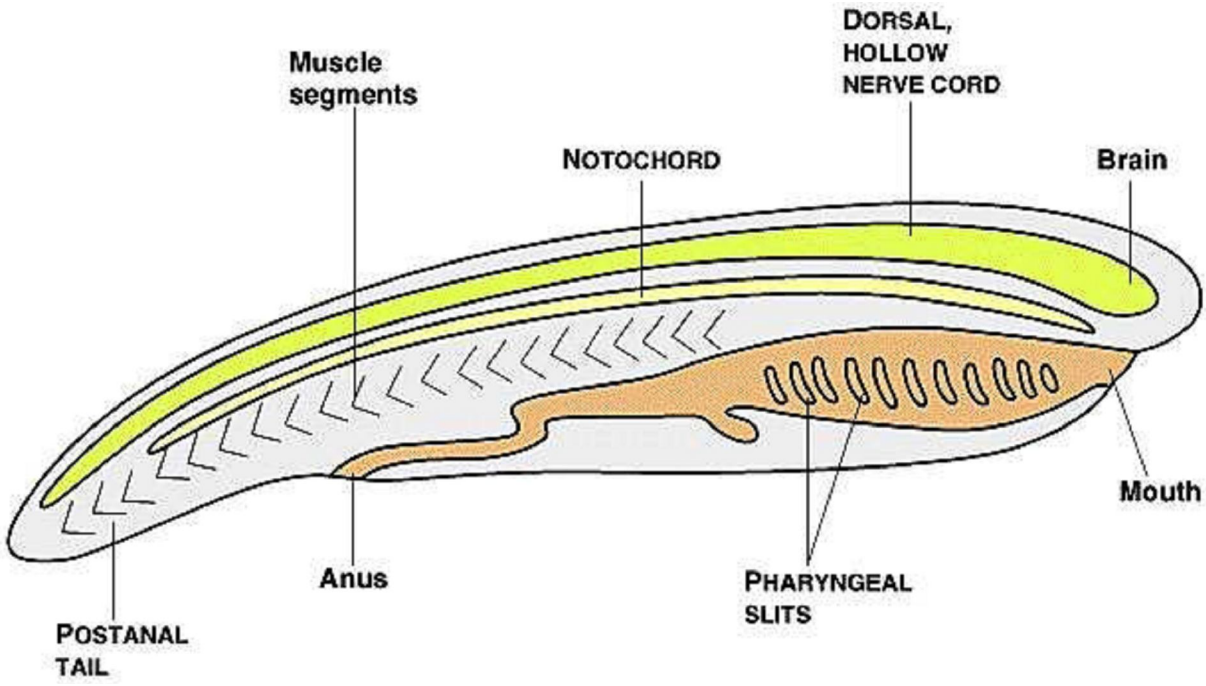


Figure 1 Basic features of chordate

Activities

In the discussion above, we listed 15 features of chordates of which 4 were highlighted as the primary features.

1. *List these primary features of chordates.*
2. *Based on the said primary features only, identify and name any five chordates (2 must be aquatic) you come across in your environment. State the visible features that aided your identification.*

1.2. POSSIBLE INVERTEBRATE ANCESTORS OF CHORDATES

In this part of our study we will be looking for the invertebrate ancestors of all chordate animals. From this part onwards we will be looking the evolutionary aspects of each vertebrate group and in fact we shall be considering the ancestral relationships of all vertebrates in the light of evolution. In this section you will find that annelids, arthropods and echinoderms to be the ancestors of chordates.

1.2.1. Cephalochordates from annelids and arthropods

Annelids & Arthropods share similarities of basic body .design with the chordates

Evidences

- All three groups are segmented
- All exhibit gross brain regionalization with fore brain & hindbrain
- The basic chordate body plan is presented in annelids & arthropods even though upside downs i.e. in annelids and arthropods the nerve cord occupies a ventral position below the gut along with a major blood vessel. If an annelid or an arthropod is flipped over, this brings the nerve cord into a dorsal position along with the major blood vessel which becomes the dorsal aorta. In this reversed position, the inverted annelid or arthropod body becomes the fundamental chordate body.

1.2.2. Cephalochordates from echinoderms

Evidences

1. Both echinoderms and chordates are deuterostomes that share embryonic similarities of cleavage and mesodermal coelomic formation.
2. Echinoderm larvae, like chordates generally .are bilaterally symmetrical.
3. Auricularia larvae of echinoderms are remarkably similar to tornaria larvae of hemichordates.

1.3. BODY MORPHOLOGY, PHYSIOLOGY, HABITAT AND CLASSIFICATION OF LOWER CHORDATES

Now we shall also examine the Subphyla under the Phylum Chordata and the classes and orders under each subphylum. In other words, we shall be looking at the classification of chordates. The phylum Chordata consists of three subphyla: Urochordata, which is represented by tunicates; Cephalochordates, represented by lancelets and Vertebrata represented by the vertebrates. The fourth subphylum Hemichordates presented by the acorn worms is presently treated as a separate phylum by many authors. In this study however, the subphylum Hemichordate will be treated under the Phylum Chordata as was the case previously. This is to widen the scope of our understanding ease our understanding of the group that was earlier considered as a bridge between the ancestral chordate forms and the present day true chordates starting from the subphylum Urochordata.

The hemichordates, Urochordata and cephalochordates therefore form the invertebrate component of the phylum Chordata. Collectively they are referred to as the protochordates in line with the ancestral/primitive position ascribed to them. In the classification arrangement for the protochordate below, we shall limit ourselves to the level of class only since the content of our study programme has its focus on the vertebrate component.

General classification of chordates

The phylum Chordata is comprised of four subphyla and each subphylum is comprised of classes. Each class in turn is comprised of orders. As we have highlighted in the introduction above, we shall classify the proto-chordates to the level of class only and attempt to classify the vertebrates a step further down to the level of order.

- **Subphylum Hemichordata** (half chordates, currently considered by many authorities as a separate phylum).
- **Subphylum Urochodata** (tail chordates)

- **Subphylum Cephalochordata** (head chordates)
- **Subphylum Vertebrata** (backbone chordates).

As indicated above, the hemichordates are considered as half chordates because their chordate features are partial or not well developed. Indeed, they do not have a post anal tail. The urochordates are noted for their tail (uro-) while the cephalochordates show a degree of head (cephalo-) formation. In the vertebrates, the notochord has been replaced by a true backbone (vertebra). We shall now examine the various subgroups (classes) in each subphylum.

- **Subphylum** Hemichordata (half chordates)
  - Class Enteropneusta (acorn worms)
  - Class Planctosphaeroidea (extinct)
  - Class Pterobranchia (Cephalodiscus)
- **Subphylum**: Urochordata (tail chordates)
  - Class Ascidiacea
  - Class Thaliacea
  - Class: Larvacea (Appendicularia)
- **Subphylum** Cephalochordata (head chordates)
  - Class Leptocardii (Leptocardia)

The three invertebrate subphyla (Hemichordata, Urochordata, Cephalochordata) mentioned above are collectively called protochordata because they are considered as the ancestral stock of the chordates. In other words, they represent the primitive form of chordates. We shall now look at the classification of the subphylum Vertebrata and the subgroups under it. In the class mammalia, only the major orders will be highlighted.

- **Subphylum** Vertebrata (craniata)
  - ✓ **Superclass** Agnatha (jawless fish)
    - o **Class** Cyclostomata (lampreys and hagfishes)
      - Order : Petromyzontia (or Hyperoartii)
      - Order : Myxinoidea (or Hyperotreti)
    - o **Class** Ostracodermi (extinct)
  - ✓ Superclass Gnathostomata (jawed vertebrates)
    - o Class Placodermi (armoured fishes, extinct)
    - o Class Chondrichthyes (cartilaginous fish)

    •Subclass Elasmobranchii

    •Subclass Holocephali
    - o Class Osteichthyes (bony fish)
    - o Class Amphibia (amphibians)
      - Order Anura
      - Order Urodela
      - Order Gymnophiona
    - o Class Reptilia (reptiles)
      - Order Crocodilia
      - Order Testudinata

- Order Squamata
- Order Rhynchocephalia

- Class Aves (birds)
  - ◦Subclass Archaeminthes (extinct)
  - ◦Subclass Neornithes
    - ▪Superorder Odontognathae (extinct)
    - ▪ Superorder Palaegnathae
      - Order Struthioniformes
      - Order Tinamiformes

    Superorder Neognathae
      - Order: Anseriformes (waterfowl)
      - Order: Galliformes (fowl)
      - Order: Charadriiformes (gulls, button-quails)
      - Order: Gaviiformes (loons)
      - Order: Podicipediformes (grebes)
      - Order: Procellariiformes (albatrosses)
      - Order: Sphenisciformes (penguins)
      - Order: Pelecaniformes (pelicans)
      - Order: Phaethontiformes (tropicbirds)
      - Order: Ciconiiformes (storks)
      - Order: Cathartiformes (New World vultures)
      - Order: Phoenicopteriformes (flamingos)
      - Order: Falconiformes (falcons, eagles, hawks)

- Order: Gruiformes (cranes)
- Order: Pteroclidiformes (sandgrouse)
- Order: Columbiformes (doves and pigeons)
- Order: Psittaciformes (parrots)
- Order: Cuculiformes (cuckoos and turacos)
- Order: Opisthocomiformes (hoatzin)
- Order: Strigiformes (owls)
- Order: Caprimulgiformes (nightjars)
- Order: Apodiformes (swifts and hummingbirds)
- Order: Coraciiformes (kingfishers)
- Order: Piciformes (woodpeckers)
- Order: Trogoniformes (trogons)
- Order: Coliiformes (mousebirds)
- Order: Passeriformes (passerines)
- Order: Strigiformes (owls)

o Class Mammalia (mammals)

- Subclass Prototheria
- Subclass Theria
  - Infraclass Metatheria
  - Infraclass Eutheria
    - Order: Proboscidea (elephants)
    - Order Sirenia (manatee, dugong)
    - Order: Carnivora (dogs, cats, lions)
    - Order: Edentata (anteaters, sloth
    - Order: Artiodactyla (cows,sheep, pigs)
    - Order: Cetacea (whales, dolphins)
    - Order: Perissodactyla (horses, zebra)

- Order: Chiroptera (bats)
- Order: Insectivora (shrews, moles)
- Order: Rodentia (rats, mice,)
- Order: Lagormorpha (rabbit, hares)
- Order: Primates (monkeys, apes,humans)

The classification of the chordates presented above is the traditional form and is the most common that you would find in text books; it is based on gross anatomical and physiological traits i.e. individual inherited characteristics and not phylogenetics. You must note that the subject of classification generally and of vertebrates in particular is dynamic and often in a state of flux i.e. unstable and continuously changing. As shown above, two super classes namely Agnatha (jawless vertebrates) and Gnathostomata (jawed vertebrates) emerged from the subphylum Vertebrata.

The Gnathostomata are grouped into two based on the diversity of their habits, form and structure. These include the fishes also known as Pisces (Class: Placodermi, Chondricthyes and Osteicthyes) and the tetrapods known as animals with four limbs (class: Amphibia, Reptilia, Aves and Mammalia). The vast majority of chordates have a skull enclosing their brain, eyes, inner ear, etc. and hence the name Craniata. All craniata with the exception of one group i.e. the hagfishes have their notochord modified into a vertebral column or backbone. So while the hagfishes have a skull, they however lack a backbone; that explains why some authors prefer to name the Subphyla, Craniata from which Vertebrata emerges as a superclass.

Based on the classification above, the jawless agnathans are considered as the ancestors of the jawed vertebrates; the cartilaginous fishes (chondricthyes) gave rise to the bony fishes (osteicthyes) which in turn gave rise to the land vertebrates. On land, the amphibians gave rise to the reptiles and the reptiles in turn gave rise to both birds and mammals. The amphibians, reptiles, birds and mammals are referred to as tetrapods on account of having four limbs. The reptiles and mammals are referred to as amniota because they have an amniotic membrane.

1.3.1. The Hemichordates

In our previous studies, we described the hemichordates as half chordates because of the primitive nature of their notochord. This explains why they are excluded from the Phylum Chordata by most authors (taxonomists). However, following the old tradition, we have included the group amongst the protochordates (i.e. the Hemichordates, Urochordata and Cephalochordate). In this unit, we shall be describing the characteristics of the hemichordates. To aid understanding of the study, the description of the characteristics of this group of animals shall follow the classification pattern presented in unit two of this module. In this respect, we shall describe the subphylum Hemichordate and its two extant (living or existing) classes.

Lesson objectives

At the end of this lesson, you will be able to:-

- *Describe the characteristic features of hemichordates.*
- *Distinguish members of the subphylum from other protochordates.*

These are exclusively marine organisms. They are solitary or colonial forms. They mostly remain as tubiculous forms. The body is soft, vermiform, unsegmented, bilaterally symmetrical and triploblastic. The body is divisible into three distinct regions namely proboscis, collar and trunk. The body wall is composed of single layer of epidermal cells. The dermis is absent. They have no endoskeleton. A projection from pharynx, projecting inside the proboscis may be considered as notochord. They have a spacious coelom lined by coelomic epithelium. The alimentary canal is a straight tube running between mouth and anus. They are ciliary feeders. Sexes are separate. Examples: Balanoglossus, Saccoglossus.

General characteristics of Hemichordata

- Body is divided into three sections, a proboscis, a collar and a trunk
- Body is bilaterally symmetrical

- The stomochord (primitive notochord) is restricted to the proboscis only
- Body has more than two cell layers, tissues and organs
- A true coelom (body cavity)
- A straight or U-shaped gut, with an anus
- Nervous system normally diffuse, but variable
- A partially open circulatory system
- Glomerulus as an excretory organ
- Reproduction normally sexual
- Feed on fine particles in the water
- Live in marine environments

As we have described above, the hemichordates are distinguished by a tripartite (three fold) division of the body. At the forward end of the body is a proboscis (pre-oral lobe), behind this is a collar and lastly a trunk. The hemichordates share some (but not all) of the typical chordate characteristics. They have bronchial openings, or "gill slits," that open into the pharynx; there is a rudimentary structure in the collar region called the stomochord, or a diverticulum (blind sac) that is made up of cells that resemble those found in the notochord but which indeed is not a true notochord.

There is a dorsal nerve cord, in addition to a smaller ventral nerve cord. This incompleteness especially on the structure of the notochord accounted for their classification from the true chordates, although they are quite closely related. Indeed, some DNA-based studies of evolution suggest that hemichordates are actually closer to echinoderms than to true chordates. This is supported by the fact that the larvae of at least some hemichordates look very much like those of some echinoderms.

Class Enteropneusta (acorn worms)

The Enteropneusts comprise the majority of the hemichordates with more than 70 species. They are the typical acorn worms and very well fit the description of hemichordates stated above. They have the following characteristics:

- Body is divided into three sections - a proboscis, a collar and a trunk

- Multiple branchial openings, as many as 200 in some species
- Gaseous exchange occurs over the whole body as well as in the pharyngeal slits
- Reproduction is normally sexual involving the two opposite sexes and egg fertilization However, reproduction can occur as a result of fragmentation of the adult body
- They live in burrows in the substrate (mud or fine sand) or under rocks, in both shallow and deeper waters
- Feeding is either substrate eating or filter feeding

Enteropneusta (acorn worms) are 2 cm to 2.5 m long; marine in shallow waters, solitary, live in mud or vegetation; filter-feeders. They have well-developed gill slits and a stomochord. They also have a dorsal strand of nerve cells, believed to be the precursor to the dorsal hollow nerve cord. The enteropneustes are slow burrowers. They use their proboscis to burrow through sediment.

Substrate eaters like Balanoglossus consume large amounts of mud and or sand and digest out the organic matter within it. They deposit their wastes on the surface just like we see earthworm castes. Their burrows may have several openings at one end. They seldom leave their burrows. The filter feeders have mucous secreting glands and numerous cilia on their proboscis. The proboscis is held out of the burrow entrance and organic particles are caught in the mucous and then swept to the mouth by the beating of the cilia. These species can cover their mouth with their collar and thus avoid eating inorganic or any undesirable materials.

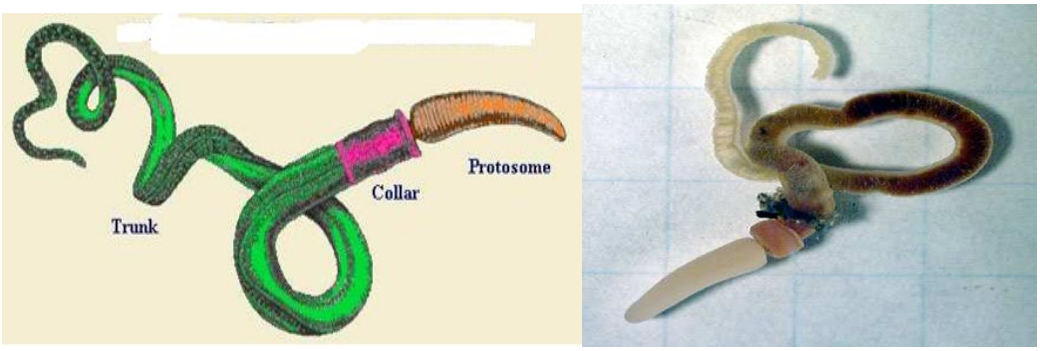


Figure 2 body parts of hemichordates (left and right) showing the basic body features

Classification of Hemichordates

The hemichordates are divided into the following classes comprising about 50 species:

Class Pterobranchia

The class is characterized by the following features:

- Proboscis is modified into a shield
- Collar is modified to produce between 1 and 9 pairs of tentacles or lophophore arms with double row of smaller ciliated tentacles
- Trunk is short and sac-like rather than being long and thin
- Asexual reproduction is by budding and is common and often gives rise to colonies starting from a single individual
- Sexual reproduction is by the normal method of reproduction as in the enteropneusts with external fertilization
- One or no pharyngeal slits
- Protein collagen tube structure houses the organism

Pterobranchia (pterobranchs) are tiny, deep-sea, colonial, moss-like animals. There is no trace of dorsal nerve cord or notochord and only one pair of gill slits in species of the genus Cephalodiscus. The Pterobranchs are an obscure group of animals, which unlike the acorn worms; they form colonies in which the individuals are interconnected by stems, or stolons. The individuals or zooids are generally small often less than 1 millimeter long. The proboscis is not elongated, as it is in acorn worms, but shield-shaped.

The collar bears a pair of branched tentacles that collect small food particles from the water. Most strikingly, almost in all pterobranch species, special glands in the proboscis secrete a collagen material from which a tube casing is made to house the animal. The proboscis is also used as an organ of locomotion (just the way a snail uses its foot), both for movement inside and outside the burrow. The tentacles secrete mucous which is driven, along with the food particles trapped in it, to the mouth by the beating of the cilia. The

mucous and the accompanying food particles are then digested in a U-shaped digestive tract. The animal's anus is on the animal's back approximately opposite the animal's mouth.

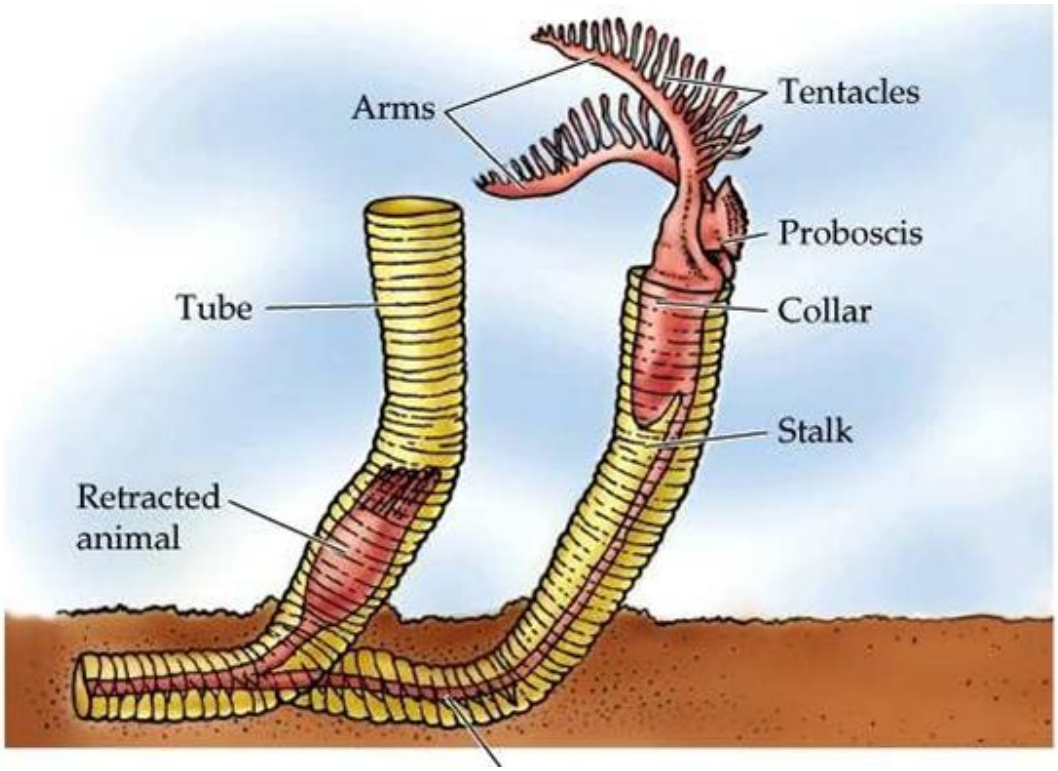


Figure 3 A typical Pterobranch - Rhabdopleura

1.3.2. Urochordata

This portion is all about the Urochordata - the tail chordates. They represent the most primitive of the true chordate. In other words they are the most advanced amongst the protochordates i.e. they are more advanced than the cephalochordates and hemichordates you would recall that we described the hemichordates as half chordates).

Lesson objectives

At the completion of this study, you should be able to:

- Fully describe the characteristics of the Urochordates
- Have a mental picture of what the Urochordates look like

Urochordates constitute a unique group of animals exhibiting diversity in form and habit. In Urochordata the notochord is confined to the tail region of the larva. The adults are mostly degenerate, sessile forms. The body is enveloped by a tunic or test. The free end of the body bears two openings, the mouth and the atriopore. The proximal part of the alimentary canal is greatly enlarged to form a spacious pharynx. They are hermaphroditic animals. The development occurs through free swimming tadpole like larva. Example: Ascidia, Doliolum, Salpa

Characteristics of Urochordata

- Notochord present only at the developmental tadpole stage, absent in the adult stage thus adult has no endoskeleton
- Hollow nerve cord
- Post anal tail
- Body wholly covered by a structure called 'tunic' made of secreted protein and cellulose- like material
- Body has more than two cell layers and includes tissues and organs.
- **U** shaped gut
- Body without coelomic body cavity
- Hermaphroditic with external fertilization
- Nervous system composed of an anterior ganglion from which individual nerves issue
- No excretory organs
- A distinct larval stage that undergoes metamorphosis
- Gill slits are used to trap food particles during filter feeding
- Ventral heart present with incomplete closed circulatory system
- Hemocyanin pigment (no hemoglobin)
- No excretory organs
- Habitat is marine environment

Urochordates are a medium sized group of marine animals commonly referred to as Sea Squirts, Tunicates, Salps or Larvaceans. They are all filter feeders using a basically similar

mechanism of pumping water through a perforated pharynx which collects small particles in a layer of mucous. All the urochordates have an external covering or 'house' called the tunic which is made of secreted proteins and a polysaccharide much like cellulose. In some cases this matrix contains living cells that have migrated from the main body of the animal and even sometimes blood vessels.

The animal lives within its house permanently in most cases. The 'houses' of the larvaceans are less substantial as new ones are secreted every four hours or so. Although the urochordates are close relatives of the chordates and thus of vertebrates such as mammals, they seem to be far less like vertebrates than many of the other invertebrate phyla. They have no limbs, no brain and except in the larvaceans the tail is only evident during larval development.

Classification of Urochordates

The subphylum is divided into three classes namely: Ascidiacea, Thaliacea and Larvacea.

Characteristics of Class Ascidiacea

This class is represented by the Sea Squirts or Tunicates and they make up the bulk of the species found within the Phylum Urochordata.

- Notochord and post-anal tail found in the larval stage only
- Tadpole-like larvae metamorphose into adults
- Sessile (non-moving or staying in one place) adults
- Marine habitat - most species are common coastal animals occurring in rock pools and out into deeper water to about 400 - 5,000 meters in depth
- Solitary or colonial in form - the colonial species may share a common exhalent siphon
- Translucent or whitish body color but some species are much
- More colorful and can be red, brown, yellow and even blue

- Tunic composed mostly of an acellular (not made of cells) matrix of tunicin, a polysaccharide similar to cellulose (there are some living cells of various sorts within this matrix but they are well spaced out)
- Pharynx has numerous small pores or slits in its walls for the passage of water
- Two openings, an inhalant siphon (where water comes in) and an exhalent siphon (where water goes out)
- Hermaphroditic - male and female reproductive organs on each organism.
- Filter feeders

The name tunicates arise from the existence of the tunic (external covering or 'house') while Sea Squirt arise from the fact that when squeezed, water shoots out of the exhalent siphon. The larvae swim towards light towards the surface of the sea at first then after a short while they reverse direction and swim down towards the sea floor, often in less than one day. Tunicate larvae do not feed and are essentially a dispersal form. Soon they find a suitable spot on the sea floor and settle in a head down, tail up position. They attach themselves to the sea floor (substrate) using special adhesive glands in the front of their head and then undergo an amazing metamorphosis during which the post-anal tail and the notochord are lost.

The remainder of the body twists through 180 degrees to form a small tunicate. Tunicates feed by drawing water in through the inhalant siphon. This water passes through the pharynx where small particles are trapped before the water leaves the body through the exhalent siphon. The water current is maintained by beating cilia, though they can force water out of the aerial cavity by muscular contraction of the tunic if frightened.

The small particles, plankton etc, are trapped on a continually moving layer of mucous. This mucous is secreted by special cells and is moved across the surface of the pharynx by the beating of many small cilia, eventually it is passed in the digestive tract where both it and the particles caught up in it are digested.

Characteristics of Class Thaliacea

- Small barrel-shaped animals
- Feed as they swim slowing through warm waters
- Filter feeders
- Inhalant and exhalent siphons at opposite ends of their bodies
- Two-generation cycle - one generation is solitary and the next forms chain-like colonies

The class Thaliacea contains about 70 species. Filter feeding has to do with drawing current of water in through their inhalant siphon and out through the exhalent siphon. Between the two siphons the water passes through the many pore or slats of the enlarged pharynx which occupies most of the body cavity. The water current is driven by beating cilia. Small particles of plankton are collected on a film of mucous which continuously passes across the pharynx. This mucous is secreted by special cells and is kept moving by the beating of numerous small cilia until it is swept into the digestive tract.

Salps belong to the same group as sea squirts (tunicates or urochordates). Although they may not look it, salps are among the most advanced invertebrates in the sea and are closely related to vertebrates (animals with backbones).

Characteristics of Class Larvacea (Apendicularia)

The Larvaceans, sometimes called the Apendicularians, are small animals quite different in form to the rest of the Urochordata which have the following characteristics:

- Planktonic - mass of floating organisms
- Body consists of a basically oval trunk and a relatively long thin tail
- Tail contains the notochord which is retained all through the animal's life, unlike the rest of the Urochordata where it is lost before maturity, or even during embryogenesis
- Larva like that of tunicates - metamorphoses to adult
- Secrete a gelatinous 'house' that encases the trunk or body, but not the tail

- The tail has muscle cells attached to it and is used for swimming

Activities

1. Attempt to make a diagram of a typical larvacean.

2. What distinguishes the larval and adult stages of the larvacean from that of other Urochordates

1.3.3. Cephalochordates

In this section, we shall be looking at a group of marine protochordates the cephalochordates. The cephalochordates are the most advanced protochordates showing clearly the four primary features of chordates (notochord, dorsal nerve cord, pharyngeal gill slits and post anal tail) throughout their life. They are the closest to the vertebrates.

Lesson objectives

After going through this lesson, you will be able to:

- *Describe the features of Cephalochordates.*
- *Distinguish the cephalochordates from other protochordates.*

Cephalochordates are small fish like marine chordates. The persistent notochord extends forward beyond the brain. Hence these are called cephalochordates. The epidermis is single layered. Paired fins are absent. Muscles, nephridia and gonads are segmentally arranged. The pharynx is large with numerous gills. It is a filter feeder. Example: Amphioxus.

General characteristics

- Notochord: well developed and persist throughout life of the animal. It runs the length of the animal from the tail to the tip of the noise on the head (cephalo- meaning head)
- Numerous gill slits over 100 used to trap food particles during filter feeding
- Dorsal nerve cord
- Post anal tail
- Marine and fish-like in appearance (both ends pointed)
- No normal vertebrate endoskeleton
- External fertilization
- Some metamerism (body segmentation) in the musculature
- No heart.
- Use hemocyanin pigment (no hemoglobin)
- Closed circulatory system

The Subphylum Cephalochordates is usually represented by one organism Branchiostoma commonly called Amphioxus (which means "sharp at both ends") or lancelets. Cephalochordates are like vertebrates in having the derived feature of an elongate body as adults, but are still (primitively) filter feeders; that is, they feed while motionless, moving food-laden water by means of cilia on their gill bars. Amphioxus is 2-3 inches in length and whitish to creamy yellow, sometimes with a tint of pink. They live on seashores throughout the temperate zone. Amphioxus shows some Cephalization, in that the primary feeding structures are concentrated at the anterior end, and it has a pigment spot on the anterior end that may be used for orienting toward light.

Amphioxus is fish-like in appearance but without eyes. It has a laterally compressed dorsal fin. They are small 1 to 8 centimeters (0.4 to 3 inches) long There are about 25 species of Cephalochordates inhabiting shallow tropical and temperate oceans; they spend much of their time buried in sand of ocean beds. Lancelets have a notochord - a flexible rod of cells supporting the body. The rest of the skeleton is made up of small, flexible rods between the gill slits and supporting the mouth bristles. A dorsal nerve cord runs along the top of the

notochord. Lancelets have blood vessels but no heart. The pharynx is perforated by over 100 pharyngeal slits or "gill slits", which are used to strain food particles out of the water.

The musculature of the body is divided up into V-shaped blocks or myomeres and there is a post-anal tail. All of these features are shared with vertebrates. On the other hand, Cephalochordates lack features found in most or all true vertebrates: the brain is very small and poorly developed, sense organs are also poorly developed and there are no true vertebrate.

Class: Leptocardii or Leptocardia (small heart)

- No true heart which is represented only by a simple pulsating vessel
- The blood is colorless
- No brain, renal organs, and limbs
- Backbone is represented only by a simple, unsegmented notochord

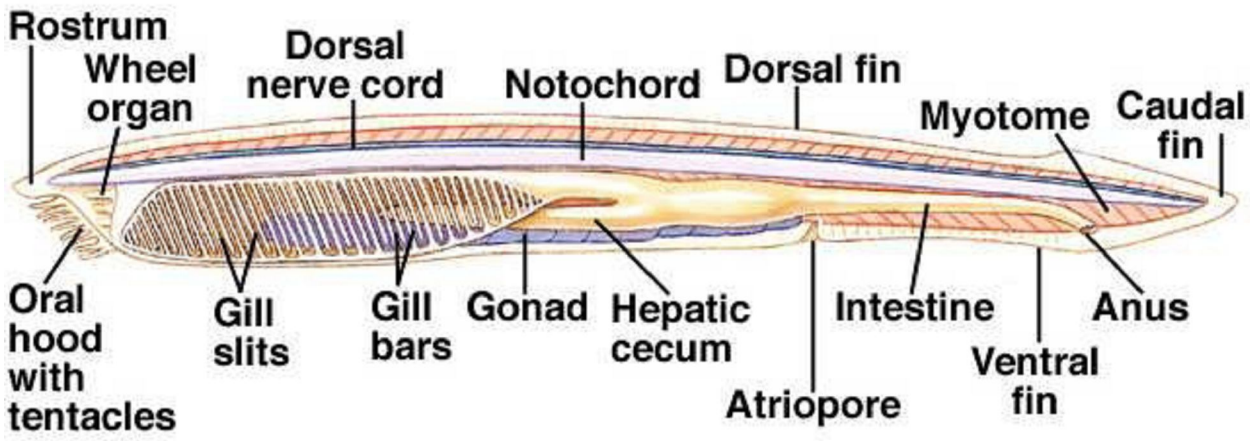


Figure 4 Anatomy of the cephalochordate Amphioxus

Activities

1. *State the characteristic features of cephalochordates.*
2. *Why these animals are called cephalochordates?*

1.4. THE GEOLOGIC TIME TABLE AND ACCOMPANYING EVENTS IN VERTEBRATE EVOLUTION

In this section of our study we will be looking at what the geologic time table is and what are the events that accompany the emergence of vertebrate life on earth. We will also see the time divisions of the geologic scale into different time units like Eons, Eras, Periods, Epochs, and also ages. In addition, we will also explore the associations of these time divisions with the events of life experienced throughout the very long age of the earth. Accordingly you will find that the nominations of the eras to be indications of the life events that had occurred in that specific era. For instance the name Paleozoic Era is to mean ancient animals; Mesozoic means middle animals; and Cenozoic means recent animals.

Lesson objectives

After completing the study in this section student will be able to:

- *Identify the four eras of the geologic time scale.*
- *Indicate the time span of each era.*
- *Classify major events of each era.*
- *Create and recognize the importance of making a geologic time line.*

Paleontology examines the origins and fates of lineages and major groups, evolutionary trends and other changes in anatomy through time, and geographic and temporal variations in diversity throughout the geologic past. It also seeks to understand the physical and biological processes and the unique historical events that have shaped evolution. Paleontological data provide a window on deep time, and thus permit the direct study of problems ranging from the change in the form and distribution of species over millions of years to the evolutionary responses of major groups to both catastrophic and gradual environmental changes. These data also allow calibration of rates for such phenomena as mutations in nucleotide sequences. In this lesson you will deal with how paleontological information is used as evidence for evolutionary studies.

A fossil is defined as any remains, trace or imprint of a plant or animal that has been preserved by natural processes in the Earth‘s crust from some distant geologic time and provides a record of Earth‘s history from that time.

Although it was Darwin, above all others, who first marshaled convincing evidence for biological evolution earlier scholars had recognized that organisms on Earth had changed systematically over long periods of time. For example, in 1799 an engineer named William Smith reported that, in undisrupted layers of rock, fossils occurred in a definite sequential order, with more modern-appearing ones closer to the top. Because bottom layers of rock logically were laid down earlier and thus are older than top layers, the sequence of fossils also could be given a chronology from oldest to youngest.

William Smith‘s findings were confirmed and extended in the 1830s by the paleontologist William Lonsdale, who recognized that fossil remains of organisms from lower strata were more primitive than the ones above. Today, many thousands of ancient rock deposits have been identified that show corresponding successions of fossil organisms. Thus, the general sequence of fossils had already been recognized before Darwin conceived of descent with modification. But the paleontologists and geologists before Darwin used the sequence of fossils in rocks not as proof of biological evolution, but as a basis for working out the original sequence of rock strata that had been structurally disturbed by earthquakes and other forces.

In Darwin's time, paleontology was still a rudimentary science. Large parts of the geological succession of stratified rocks were unknown or inadequately studied. Darwin, therefore, was worried about the rarity of intermediate forms between some major groups of organisms. Today, many of the gaps in the paleontological record have been filled by the research of paleontologists. Hundreds of thousands of fossil organisms, found in well-dated rock sequences, represent successions of forms through time and manifest many evolutionary transitions.

From fossil evidence it was clear that microbial life of the simplest type was already in existence 3.5 Bya. The oldest evidence of more complex organisms (that is, eukaryotic

cells, which are more complex than bacteria) has been discovered in fossils sealed in rocks approximately 2 Billion years ago. Multicellular organisms, which are the familiar fungi, plants and animals, have been found only in younger geological strata.

The fossil record thus provides consistent evidence of systematic change through time--of descent with modification. From this huge body of evidence, it can be predicted that no reversals will be found in future paleontological studies. That is, amphibians will not appear before fishes, or mammals before reptiles, and no complex life will occur in the geological record before the oldest eukaryotic cells. This prediction has been supported by the evidence that has accumulated until now: no reversals have been found.

The geologic time scale provides a system of chronologic measurement relating stratigraphy to time that is used by geologists, paleontologists and other earth scientists to describe the timing and relationships between events that have occurred during the history of the Earth. The geological or deep time of Earth's past has been organized into various units according to events which took place in each period. Different spans of time on the time scale are usually delimited by major geological or paleontological events.

Dividing Earth History into Time Intervals

Geologists have divided Earth's history into a series of time intervals. These time intervals are not equal in length like the hours in a day. Instead the time intervals are variable in length. This is because geologic time is divided using significant events in the history of the Earth. Examples of Boundary "Events"

For example, the boundary between the Permian and Triassic is marked by a global extinction in which a large percentage of Earth's plant and animal species were eliminated. Another example is the boundary between the Precambrian and the Paleozoic which is marked by the first appearance of animals with hard parts. The geologic history of the Earth is broken up into hierarchical chunks of time. From largest to smallest, this hierarchy includes eons, eras, periods, epochs, and ages.

Eons: are the largest intervals of geologic time and are hundreds of millions of years in duration. In the time scale the Phanerozoic Eon is the most recent eon and began more than 500 million years ago. The Phanerozoic Eon represents the time during which the majority of macroscopic organism's algae, fungi, plants and animals such as lived. When first proposed as a division of geologic time, the beginning of the Phanerozoic (542.0 million years ago) was thought to coincide with the beginning of life.

In reality, this eon coincides with the appearance of animals that evolved external skeletons, like shells and the somewhat later animals that formed internal skeletons, such as the bony elements of vertebrates. The time before the Phanerozoic is usually referred to as the Precambrian and is usually divided into the three eons shown.

Eras: Eons are divided into smaller time intervals known as eras. In the time scale that the Phanerozoic is divided into three eras: Cenozoic, Mesozoic and Paleozoic. Very significant events in Earth's history are used to determine the boundaries of the eras. The Phanerozoic is subdivided into three major divisions: the Cenozoic, Mesozoic, and Paleozoic Eras. The "-zoic" suffix comes from the root "zoo," which means animal. This is the same root as in the words zoology and zoological park (or zoo). "Cen-" means recent, "Meso-" means middle, and "Paleo-" means ancient. These divisions reflect major changes in the composition of ancient faunas, each era being recognized by its domination by a particular group of animals.

The Cenozoic has sometimes been called the "Age of Mammals," the Mesozoic the "Age of Dinosaurs," and the Paleozoic the "Age of Fishes." But this is an overly simplified view, which has some value for the newcomer but can be a bit misleading. For instance, other groups of animals lived during the Mesozoic. In addition to the dinosaurs, animals such as mammals, turtles, crocodiles, frogs and countless varieties of insects also lived on land. Additionally, there were many kinds of plants living in the past that no longer live today. Ancient floras went through great changes too and not always at the same times that the animal groups changed.

Periods: Eras are subdivided into periods. The events that bound the periods are widespread in their extent but are not as significant as those which bound the eras. In the time scale, that the Paleozoic is subdivided into the Permian, Pennsylvanian, Mississippian, Devonian, Silurian, and Ordovician and Cambrian periods.

Epochs: Finer subdivisions of time are possible and the periods of the Cenozoic are frequently subdivided into epochs. Subdivision of periods into epochs can be done only for the most recent portion of the geologic time scale. This is because older rocks have been buried deeply, intensely deformed and severely modified by long-term earth processes. As a result, the history contained within these rocks cannot be as clearly interpreted.

Table 1 Geologic time scale

Time	Events
4600	Formation of the approximately homogeneous solid Earth by plan estimate accretion
4300	Melting of the Earth due to radioactive and gravitational heating which leads to its differentiated interior structure as well as out gassing of molecules such as water, methane, ammonia, hydrogen, nitrogen and carbon dioxide
4300	Atmospheric water is photo dissociated by ultraviolet light to give oxygen atoms which are incorporated into an ozone layer and hydrogen molecules which escape into space
4000	Bombardment of the Earth by plant estimate stops
3800	The Earth's crust solidifies--formation of the oldest rocks found on Earth
3800	Condensation of atmospheric water into oceans
3500-2800	Prokaryotic cell organisms develop
3500-2800	Beginning of photosynthesis by blue-green algae which releases oxygen molecules into the atmosphere and steadily works to strengthen the ozone layer and change the Earth's chemically reducing atmosphere into a chemically oxidizing one.
2400	Rise in the concentration of oxygen molecules stops the deposition of unanimities (since they are soluble when combined with oxygen) and starts the deposition of banded iron formations
2000	The oleo natural fission reactor in Gabon goes into operation
1600	The last reserves of reduced iron are used up by the increasing atmospheric oxygen--last banded iron formations
1500	Eukaryotic cell organisms develop

1500 - 1600	Rise of multicellular organisms
580 - 545	Fossils of Ediacaran organisms are made
545	Cambrian explosion of hard-bodied organisms
500 - 450	Rise of the fish--first vertebrates
420	Millipedes have evolved--first land animals
375	Appearance of primitive sharks
350 - 300	Rise of the amphibians
350	Primitive insects have evolved
300 - 200	Rise of the reptiles
200	Primitive crocodiles have evolved
200	Appearance of mammals
145	Archaeopteryx walks the Earth
136	Primitive kangaroos have evolved
100	Primitive cranes have evolved
90	Modern sharks have evolved
65	Extinction of the dinosaurs and beginning of the reign of mammals
60	Rats, mice and squirrels have evolved
60	Herons and storks have evolved
55	Rabbits and hares have evolved
50	Primitive monkeys have evolved
28	Koalas have evolved
20	Parrots and pigeons have evolved
20 -12	The chimpanzee and hominid lines evolved

10 - 4	Ramapithecus exist
4	Development of hominid bipedalism
4 – 1	Australopithecus exist
3.5	The Australopithecus Lucy walks the Earth
1.6 – 0.2	Homo erectus exist
1 – 0.5	Homo erectus tames fire
0.2 – 0.03	Homo sapiens neanderthalensis exist
0.05 - 0	Homo sapiens sapiens exist

1.5. THE FOSSIL RECORD

Fossils provide the dimension of time to the study of life .For at least 300 years; scientists have been gathering the evidence for evolutionary change. Much of this vast database is observational, and the evidence came to light with the study fossils (paleontology) and the rock record (geology). Because bone is resistant to decay, the fossil record of vertebrates is extensive and has been studied for over 200 years. The first known vertebrate fossils, found at the Chengjiang locality in China, date back to the early Cambrian. These early vertebrates, such as *Haikouichthys*, are small, tapered, streamlined animals showing eyes, a brain, pharyngeal arches, a notochord and rudimentary vertebrae.

Vertebrates appear to have radiated in the late Ordovician, about 450 million years ago. However, most Ordovician fossil vertebrates are rare and fragmentary, although available material suggests that ancestors of the sharks and jawed fish were present along with various lineages of armored jawless fish. By the middle Silurian, about 400 million years ago, the picture is clearer: the armored jawless fish were quite diverse, and the first definite jawed fish had appeared the Silurian is sometimes called the "Age of Fishes." By the late Devonian, 360 million years ago, early cartilaginous fish and bony fish were diversifying.

Fossils provide the dimension of time to the study of life .For at least 300 years; scientists have been gathering the evidence for evolutionary change. Much of this vast database is observational, and the evidence came to light with the study fossils (paleontology) and the rock record (geology). The late Devonian also marked the first tetrapods vertebrates with true legs that could walk on land. By about 330 million years ago, in the Mississippian, several groups of land-dwelling amphibians had appeared. The oldest known amniotes -- close to the ancestry of all reptiles, birds, and mammals appeared in the early Pennsylvanian, about 310 million years ago. Land amniotes continued to diversify, and by the middle Pennsylvanian had split into several taxa, two of which would go on to dominate the Mesozoic and Cenozoic: the diapsids and the synapsids.

Documentation of ancestor-descendant relationships among organisms also comes from the fields of biogeography, taxonomy, anatomy, embryology and, most recently, genetics particularly DNA analysis. Fossil record remains first and foremost among the databases that document changes in past life on Earth. Some of the most basic observations about fossils and the rock record were made long before Darwin formulated his theory of "descent with modification." The fossil record clearly shows changes in life through almost any sequence of sedimentary rock layers. Successive rock layers contain different groups or assemblages of fossil species.

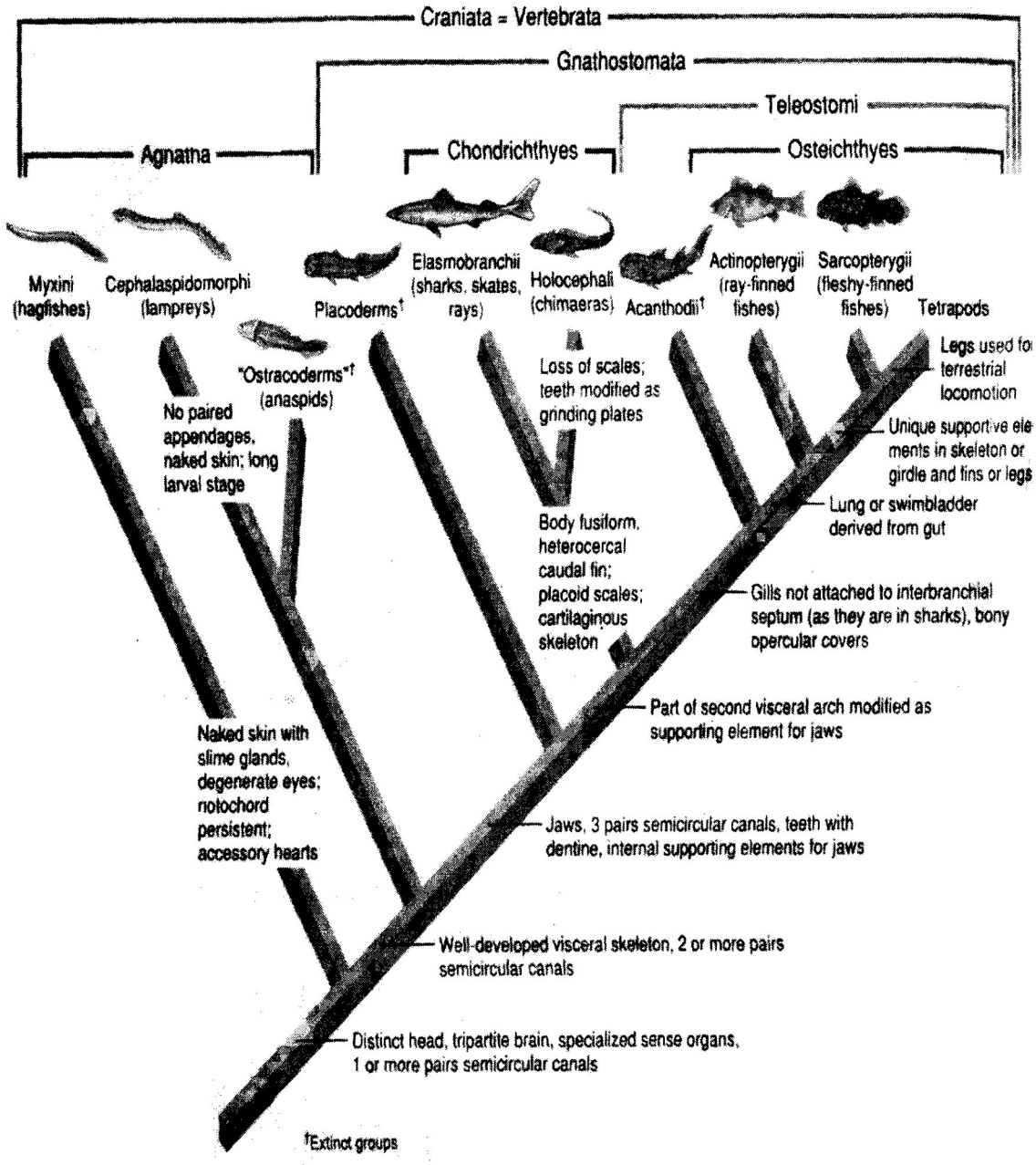


Figure 5 Relationships of major monophyletic fish taxa

Sedimentary rocks are, by far, the most common rocks at Earth's surface. They are formed mostly from particles of older rocks that have been broken apart by water, ice, and wind. The gravel, sand, and mud, which are collectively called sediment, settle in layers at the bottoms of rivers, lakes, and oceans. Particles of Shells and other limy materials may accumulate in the oceans as bury of shells, bones, leaves, pollen, and other bits and pieces of living things. With the passing of time, the layers of sediments accumulate. These sediments are compacted by the weight of overlying sediments and cemented together to become the sedimentary rocks called limestone, shale, sandstone, and conglomerate. The buried plant and animal remains become fossils within the sedimentary layers.

The geological time-period terms: Cambrian, Ordovician, Jurassic, Cretaceous, and on through the Quaternary, define successive changes in species of animals and plants through time on Earth. Thus, Ordovician trilobites differ from Devonian trilobites, Silurian and Devonian fish differ from Jurassic and Cretaceous fish, Mesozoic mammals differ from Cenozoic mammals, and so forth. In addition to changes occurring in many different species found in different geological time intervals.

Whole groups of organisms that were once abundant and diverse, such as trilobites, can become extinct. The boundaries between the great blocks of geologic time called Eras are defined by major changes in the types of fossils found in the rocks deposited in those Eras: Paleozoic means "ancient animals," Mesozoic means "middle animals," and Cenozoic means "recent animals." Trilobites and shelled animals called brachiopods are common and typical Paleozoic fossils. Dinosaurs, certain large marine reptiles, such as ichthyosaurs and masseurs, and the flying reptiles called pterosaurs are found only in Mesozoic rocks. Fossils of mammals, clams, snails, and bony fishes are typical of Cenozoic fossil assemblages. Some species can be found on both sides of a time boundary; however, the overall assemblage of organisms found in the rocks of a given age is recognizably different from the assemblages found in the rocks above and below.

Activities

1. *Give reasons why hemichordates are considered half/primitive chordates?*
2. *Describe the basic body structure of hemichordates and show by way of a diagram?*

Summary

- ✓ *In this first unit of our study, we have learnt of a group of animals called chordates, which comprised the vertebrates, together with several closely related invertebrates. These animals have four primary features that manifest at some stage in their life cycle. These are:*
- ✓ *A notochord: A dorsal fairly rigid rod of vacuolated cells, which provides structural support. In vertebrates, it is represented by the backbone.*
- ✓ *Dorsal nerve cord: A fluid-filled tube of nerve tissue that runs the length of the animal, dorsal to the notochord. In fish and other vertebrates, the nerve cord is represented by the spinal cord, which is the main communications line of the nervous system.*
- ✓ *Pharyngeal gill slits: These are pairs of water-exit openings through the pharynx used in less advanced chordates to trap food particles in the water the animals live or for breathing where gills have developed as in fish.*
- ✓ *In reptiles, birds, and mammals (including humans), the gill slits are vestiges (gone/no longer functional), occurring only in the embryonic stage.*
- ✓ *Muscular post-anal tail: This is that structure that extends backwards from behind the anus. It is that part of the animal behind the anus, which terminates the digestive tract.*

- ✓ *The phylum Chordata is comprised of three subphylum namely, Urochodata, Cephalochordata and Vertebrata. Hemichordata (half chordates) is currently placed as a separate phylum but included to you as an insight of what they constitute.*

- ✓ *The Urochordata (tail chordates) is made of three classes namely, Ascidiacea, Thaliacea and Larvacea (Appendicularia). The subphylum Cephalochordata (head chordates) is quite unique in that it has one class –the Leptocardii.*

- ✓ *The subphylum Vertebrata is comprised of two superclasses namely Agnatha (jawless fish) and Gnathostomata (jawed vertebrates). Agnatha has only one living class - Cyclostomata (lampreys and hagfishes).*

- ✓ *On the other hand, Gnathostomata is comprised of six classes namely Chondrichthyes (cartilaginous fish), Osteichthyes (bony fish), Amphibia, Reptilia, Aves (birds), and Mammalia.*
- ✓ *In this Unit, we have described the hemichordate as a group of primitive chordates on account of stomochord (primitive notochord) that is restricted to the proboscis only.*
- ✓ *Their body structure is divided into three sections viz: proboscis, colar and trunk. Hemichordates are represented by two living Classes i.e. Enteropneusta (acorn worms) and Pterobranchia. The third class Planctosphaeroidea is extinct.*
- ✓ *The Enteropneustes are slow mud burrowers that have welldeveloped gill slits, a stomochord and a dorsal strand of nerve cells, believed to be the precursor to the dorsal hollow nerve cord. The Pterobranchia (pterobranchs) are colonial, moss-like animals showing no trace of dorsal nerve cord or notochord, and only one pair of gill slits in species of the genus Cephalodiscus. Body colonies are interconnected by stems, or stolons.*
- ✓ *The proboscis is not elongated, as it is in acorn worms, but shield-shaped. The collar bears a pair of branched tentacles that collect small food particles from water. In most pterobranch species, special glands in the proboscis secrete a collagen material from which the tube casing housing the animal is made.*

- ✓ *The subphylum Cephalochordata is comprised of small marine organisms that exhibit the basic chordate features throughout their life.*
- ✓ *They have a well defined notochord, numerous gill slits, dorsal nerve cord and post anal tail. They exhibit well defined body segmentation and cephalisation.*

Review Exercise

1. *Carefully write the classification outline of the phylum Chordata as presented above.*
2. *Attempt to classify chordates to the level of subphylum. How many subphyla are there?*
3. *Move further down to classify the phylum to the level of living super class/class/infraclass. Do so repeatedly until you are able to classify chordates to that level without any errors.*
4. *Mention the possible invertebrate ancestors of chordates*
5. *State the evidences that support the origin of cephalochordates from annelids and arthropods*
6. *Provide the evidences that imply cephalochordates might have originated from Echinoderms*

CHAPTER TWO

VERTEBRATE CHORDATES

Introduction

In the previous chapter, we took a journey into the world of the ancestral chordates called the protochordates comprising the Hemichordates, Urochordata and the Cephalochordates. You would recall that the major structural support of this group of animals (protochordates) is the notochord, which manifests at some stage of their life. In this chapter, we shall be looking at the characteristic features of the advanced chordates –the vertebrates. You would also recall that we said that a major departure of the vertebrates from their ancestral stock was the replacement of the notochord with a vertebral column (called the backbone) from which the name is derived.

The vertebral column may be cartilaginous in nature as is the case in some fishes or bony as in most vertebrates. Unlike the proto-chordates, this group of animals (vertebrates) is the one we oftentimes come across more or less on daily basis. Indeed in most homes, some of these animals are part of the family. These include animals such as dogs, cats, horses, chickens, pigeons, etc. It must be emphasized that we humans also belong to the chordate 'family'. In describing the characteristic features of the vertebrates, we shall again follow the pattern we adopted for the protochordates by following the classification outline that was presented earlier. In this chapter, we shall describe the Subphylum Vertebrata in general and go further to consider one of the two super classes (Agnathans) and the two classes (Cyclostomata, Ostracodermi) under the super class.

Unit Objectives

At the end of this portion, you will be able to:-

- *Recognize and describe the basic characteristic features of vertebrates.*
- *Recognize and describe the various groups of vertebrates.*

2.1 Definition:

A vertebrate is an animal that has a backbone and a skeleton. Vertebrate animals include animals having a bony or cartilaginous skeleton with a segmented spinal column and a large brain enclosed in a skull or cranium. When you think about vertebrates, think about bones: this word has to do with animals that have a lot of bones, in the form of a skeleton. It especially refers to animals with a backbone, which protects their spinal cord. Vertebrates have many bones, including a skull which protects their brains, which tend to be large. People, dogs, horses, lizards, dogs, cats and many other animals are in the vertebrate category.

Characteristics of Vertebrates

- Notochord is not present in adult; it is replaced by spine of cartilaginous or bony column the vertebrae (backbone)
- A complex brain encased by a cranium, which protects and supports it
- Well developed head (Cephalization) with advanced nervous and sensory structures
- Most have 2 pairs of appendages: 1 pair of pectoral and 1 pair of pelvic appendages

Other features

- Bony and/or cartilage endoskeleton for structural support and or locomotion
- True body cavity called the coelom
- Male and female are separate and distinct
- Gill slits are few in number, when present
- Variety of feeding strategies: herbivores, carnivores, omnivores, filter feeders, parasites
- Well developed ventral heart with 2-4 chambers
- Closed circulatory system with hemoglobin pigment in the blood
- Variety of habitats including fresh water, salt water, terrestrial
- Specialized epidermal structures in the form of scales, feathers, hair, fur, spines
- True kidneys
- Efficient respiratory system of gills or lungs

- Body is bilaterally symmetrical and of three parts –head (with internal skeleton the cranium), trunk and post-anal tail

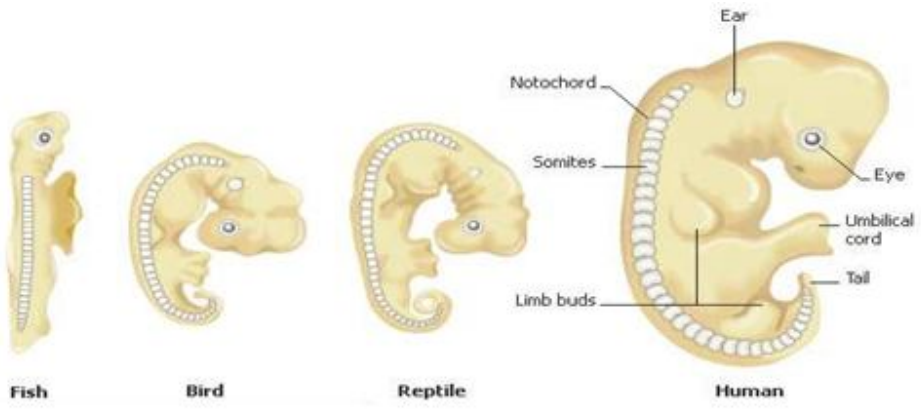


Figure 6 Vertebrate embryos

Vertebrates that evolved from fish pass through similar embryonic stages. A flexible notochord develops in the back and blocks of tissue called somites form along each side of it. These somites will become major structures, such as muscle, vertebrae, connective tissue, and, later, the larger glands of the body. Just above the notochord lies a hollow nerve cord.

2.2. THE FIRST VERTEBRATES (AGNATHANS)

All are jawed fishes, whether extinct or living are collectively grouped in gnathostomes ("jaw mouth") in contrast to the jawless fishes, the agnathans ("without jaw"). Living fishes with jaws mostly fall into two well-marked classes, the cartilaginous fishes (chondrichthyes) such as the sharks and rays and the bony fishes (osteichthyes) including the familiar ray-finned fishes and the lung fishes.

2.2.1. Ostracoderms

They are small, jawless creatures collectively called ostracodrms (ostrakon, -shell: +derm, -skin) which belong to the agnatha division of the vertebrates. These earliest jawless fishes lacked paired fins that later fishes found so important for stability. Ostracoderms were

ancient agnathous fishes possessing an exoskeleton of dermal plates often forming a heavy cephalothoracic shield. This class contains the following group of fishes:

Heterostracans: Is one group of the earliest known ostracoderms. They were mostly a few centimeters long and had a wide anterior region covered by a carapace. Behind the carapace there are a scaly trunk and tail. A heavy exoskeleton is present in many early craniates. The plates and scales are formed by a combination of more superficial denticles and underlying bone. The denticles are like teeth and are composed of the hard tissue, dentine. The lateral line sense organs lay in pits opening by pores between the ridges of dentine. They may lie in canals within the bone.

The bone of heterostraci is called isopedin and this heavy armour of the early forms must have made swimming difficult. The tail was hypocercal with the lower lobe longer. There are no movable paired fins. The mouth was partly surrounded by long plates. It formed a protrusible apparatus, that could be pushed out as a kind of scoop or shovel whereby mud and decaying refuse could be taken off the bottom, for it seems likely that such were the food and habits. In some of the later heterostracans the mouth was a tube at the very front end. These animals mostly had paired eyes and also a median pineal eye. They had paired nasal sacs. There were only two semicircular canals.

General Characteristics

Members of the super class have the following features:

- Lack jaws hence the name agnathans (without jaw)
- Vertebral spine is cartilaginous in nature
- Head with a cranium that encases a brain
- Mouth is generally round/ circular
- No scales or exoskeleton

2.2.2. Cyclostomes (Living agnathans)

Characteristics of Class Cyclostomata (lampreys and hagfishes)

The class cyclostomata derived its name by having a round or circular mouth.

The class is characterized by the following features:

- Eel - like in structure
- Lack jaws but have rows of horny teeth that move in circular motion – hence the name cyclostomata. In the absence of a jaw, the mouth cannot close and hence always open such that water constantly cycles through it
- They are Prey (parasitize on fishes)
- Lack exoskeleton/scales
- Notochord persists in adults
- Marine habitat with size of 10-90cm in length

The Cyclostomes are very unique among vertebrates because of their semi-parasitic nature. The lampreys with the exception of some small fresh-water forms attach themselves to other fishes using their sartorial mouth and then rasp off the flesh by means of the horny teeth carried by the highly-developed tongue.

The hagfishes are capable of boring their way right into the body of their prey, devouring all the soft parts and leaving the skin behind as an ordinary empty shell, held by the bones. In large numbers, lampreys can cause great damage to fisheries especially fishes caught by hooks or nets as they eat up their flesh leaving them as empty shells as described above.
The class Cyclostomata consists of two orders: Petromyzontia (or Hyperoartii) and the Myxinoidea (or Hyperotreti).

Order: Petromyzontia (or Hyperoartii).e.g. lampreys - Petromyzon marinus.

The Petromyzontes are characterized by the following features:

- Soft body without scales
- Pineal (cone-like) eyes

- Endoskeleton made of cartilage and notochord
- Seven gill pouches open directly to exterior
- Circular sucking mouth used in parasitizing other fishes
- Lack paired fins but have fin rays
- Single dorsal nasal opening on top of the head
- Cartilaginous braincase
- Ammocoetes larva which metamorphoses to adult

Figure 7 A cyclostome -sea lamprey

2.3.3 Order: Myxinoidea (or Hyperotreti) e.g. hagfishes- B dellostoma and Myxine species

The hagfishes are characterized by the following features:

- Circular mouth fitted with rasping tongue surrounded by short tentacles (see plate below)
- Gill pouches joined to a common external opening on either side
- Nasal opening at the tip of the snout rather than on top of the head as in the lampreys

- Exclusively marine
- Elongate (eel-like)
- Scale less body
- Many mucous glands present for anti-predator defense
- Unsupported fin rays

Figure 8 cyclostome - hagfish tie self in knot

2.3.4 Characteristics of Class Ostracodermi (extinct)

They are small, jawless creatures collectively called ostracodrms (ostrakon, -shell: +derm, -skin) which belong to the agnatha division of the vertebrates. These earliest jawless fishes lacked paired fins that later fishes found so important for stability. Ostracoderms were ancient agnathous fishes possessing an exoskeleton of dermal plates often forming a heavy cephalothoracic shield. This class contains the following group of fishes:

Heterostracans: are one group of the earliest known ostracoderms. They were mostly a few centimeters long and had a wide anterior region covered by a carapace. Behind the

carapace there are a scaly trunk and tail. A heavy exoskeleton is present in many early craniates. The plates and scales are formed by a combination of more superficial denticles and underlying bone. The denticles are like teeth and are composed of the hard tissue, dentine. The lateral line sense organs lay in pits opening by pores between the ridges of dentine. They may lie in canals within the bone.

The bone of heterostraci is called isopedin and this heavy armour of the early forms must have made swimming difficult. The tail was hypocercal with the lower lobe longer. There are no movable paired fins. The mouth was partly surrounded by long plates. It formed a protrusible apparatus, that could be pushed out as a kind of scoop or shovel whereby mud and decaying refuse could be taken off the bottom, for it seems likely that such were the food and habits. In some of the later heterostracans the mouth was a tube at the very front end. These animals mostly had paired eyes and also a median pineal eye. They had paired nasal sacs. There were only two semicircular canals.

Osteostraci (Cephalaspidiforms): Coexiting with the heterostracans throughout much of the Devonian period were the osteostracans (osteo, bone; ostracon, shell). These are fossil agnathas that show even more similarity to the modern cyclostomes than the heterostracans. The osteostracans improved the efficiency of their benthic life by evolving paired pectoral fins that increased the control of swimming. This ensured well-directed forward movement.

A typical osteostracan, such as cephalaspis (cephale, head; aspis, shield), was a small animal, seldom exceeding 30 cm. in length. It was covered by well developed armour, the head by a solid shield and the body by bony plates. But it had no axial skeleton or vertebrae. The jawless mouth is toothless. Other distinctive features included a sensory lateral line system, paired eyes with complex eye muscle patterns and inner ear with only two semicircular canals. An upturned tail was heterocercal, covered with heavy bony scales.

This class is extinct but had the following characteristics:

- Small fish-like animals (only few centimeters long)
- Bottom dwellers, poor swimmers
- Rudimentary fins and bony armor
- No lower jaw
- No teeth
- Filter feeders or deposit feeders
- Marine

Activities

1. *Write the general characteristics of vertebrate chordates?*
2. *List down the common characteristics of chordates with other vertebrates?*

Summary

We have described vertebrates as advanced chordates with the following characteristics:

- *Well defined backbone (cartilaginous or bony),*
- *Complex brain encased by a cranium*
- *Well developed head with advanced nervous and sensory structures*
- *Two pairs of appendages (1 pair of pectoral and 1 pair of pelvic appendages).*
- *True body cavity – the coelom.*
- *Male and female are separate and distinct.*
- *Gill slits are few in number, when present.*
- *Variety of feeding strategies: herbivores, carnivores, omnivores, filter feeders, parasites*
- *Well developed ventral heart with 2-4 chambers.*
- *Closed circulatory system with hemoglobin pigment in the blood.*
- *Variety of habitats including fresh water, salt water, terrestrial.*
- *Specialized epidermal structures in the form of scales, feathers, hair, fur, spines.*
- *True kidneys.*
- *Efficient respiratory system of gills or lungs.*
- *Body is bilaterally symmetrical and of three parts –head (with internal skeleton the cranium), trunk and post-anal tail.*
- *Similarly, we described the vertebrate superclass - Agnatha as vertebrates with the following features:*
- *Lack jaws hence the name agnatha (without jaw)*
- *Vertebral spine is cartilaginous in nature*
- *Head with a cranium that encases a brain*
- *Mouth is generally round/ circular*
- *No, body scales or exoskeleton*

Review activities

1. *Know that you have learned about vertebrates, take a walk around your home, office, school etc and look out for animals that fit the description of vertebrates.*
2. *Name each and state against it any characteristic features of vertebrates.*
3. *Why are you not likely to see members of the super class Agnathans around you?*

2.3. Gnathostomes (Jawed vertebrates)

Introduction

In part above we described the Super class Agnathans as chordates without jaws. In this and subsequent parts, we shall be introducing you to a diverse group of vertebrates under the super class Gnathostomes, which represents vertebrates with jaws. The fish, dogs, cows, goats, cats and most vertebrates we see most often have jaws and accordingly, we and these animals are gnathostomes. We shall therefore be taking a journey to a complex and yet exiting world of animals that we either consume as food, keep as pets, exploited for services or viewed as wild animals, etc. Our starting point is the fishes which we all know dwell in water.

Objectives

By the end of this study, you should be able to:-

- *Describe the vertebrates with jaws i.e. the super class Gnathostomes and their representative classes.*

2. 3.1. The origin of jaw and paired fins

There is still no certainty about the origin of true, paired fins. However, Anaspids (500 million years ago) have lateral fin folds running all the way down the sides of the body and it is assumed that true fins evolved by the segmental loss of parts of this fold. Agnathans have only two semi-circular canals and lack jaws and proper paired fins. About 450 mya (Silurian) the first true jawed fish appeared. These were the Acanthodians.

Rise in jawed vertebrates:

The jawed vertebrates not only differ from jawless forms based on the presence of jaws but also differ in many other ways. The differences are found in the body musculature, the

structure or even presence of fins, the gills and the sensory apparatus are just a few of the areas.

2.3.1.1. Origin of jaws:

Vertebrate jaws are made from neural crest derived cartilage just at the bronchial arches are. Thus jawed vertebrates converted gill arches into jaws. What was the selection pressure that led to the transition of a gill arch into jaws? How could the transitional states (the proto-jaw) have a selective advantage as well? Fishes developed the appropriate anatomical and physiological adaptations that enabled them to invade every conceivable type of aquatic habitat. The organization of jawless fishes shows that they preserve many characteristics from a very early stage of chordate evolution. Their special interest for us is in giving an insight into the organization passed by the vertebrates before jaws were evolved. The development of cranium and vertebral column in the early fishes provided housing of the central nervous system to separate from the rest of the body. Up to the end of the Silurian period, 395 million years ago, all the known vertebrates were jawless fishes. The origin of jaws was one of the most important events in vertebrate evolution.

The appearance of biting jaws in the jawed fishes enabled them to become more active carnivores. Jaws allowed ancient fishes to become proficient predators, to defend themselves, and to collect food from places and in ways that had not been possible earlier. Fishes were able to bite and chew their food instead of sucking it or filtering it unlike all of the more primitive chordates did. The first jawed fishes to evolve were members of the class chondrichthyes-sharks, skates, rays and chimaeras. Many hundreds of extinct species of the class chondrichthyes are known from the fossil record. The chondrichthyes were the first vertebrates to develop efficient fins. They evolved from agnathans that had bony skeletons, but soon largely replaced agnathans throughout the world. The vast majority of the known species of fishes are bony fishes (class Osteichthyes).

Bony fishes are buoyant and can remain suspended at any depth in the water because they possess a swim bladder (a gas-filled sac) that allows the fishes to regulate their buoyant density. Swim bladder evolved as out pocketing of the pharynx, specialized for respiration,

in fishes of the Devonian period. Bony fishes clearly evolved in fresh water, as can be seen from the places where early fossils of the class are found and the characteristics of the ancient fishes.

Bony fishes apparently entered the sea only after a number of their distinctive evolutionary lines had appeared. Now bony fishes are abundant both in the seas and fresh water. It could be that enlargement of the mandibles arch (the first gill arch) was to increase ventilation of the gills. This would be advantageous for a more active organism and would allow a stronger pumping action for the suction of water into the mouth. The increased suction would lead to increased prey capture ability. Further modification of the mandible arch would increase the ability to restrain a struggling prey item. The earliest fish-like vertebrates branched into two groups; the jawless agnathans and the jawed gnathostomes.

Agnatha means without true jaws and gnathostomes are with true jaws and mouth. The jawless agnathans are the more primitive of the two groups, which include the extinct ostracodrms and the living hagfishes and lampreys. The hagfishes and lampreys have no paired appendages. Although the hagfishes and lampreys superficially look much alike, they are infact so different from each other that they have been assigned to separate classes. All other remaining fishes have true jaws and paired appendages. They are included along with land vertebrates (tetrapods) in the lineage of gnathostomes. By the Devonian period (350-400 million years ago), the age of fishes, several distinct groups of jawed fishes were well represented. One of these jawed fishes, the placoderms became extinct in the carboniferous period (280 –350 million years ago).

The cartilaginous fishes of the class chondrichthyes (sharks, rays, skates, and chimaeras) flourished during the Devonian and carboniferous periods. They adopted cartilage rather than bone for the skeleton. Most chondrichthyes are active predators. Sharks are the successful assemblage of modern chondrichthyes. The other two groups of gnathostome fishes, the acanthodians and the bony fishes, were well represented in the Devonian period. The acanthodians were distinguished by having heavy spines on all the fins except the caudal fin. They became extinct in the lower Permian period (230-280 million years ago).

The bony fishes (class osteichthyes) are the dominant fishes today. You can recognize two distinct lineages of bony fishes.

Ray-finned fishes (subclass Actinopterygii). They are the most diverse and radiated to form the modern bony fishes. Fleshy-finned fishes (subclass Sarcopterygii). They were flourished in the Devonian period, but are declined, and are today represented by few surviving genera of the coelacanth and lungfishes. The tetrapod vertebrates arose from one lineage of the sarcopterygians.

Jaws brought several new abilities

- Ability to grasp prey
- With the development of teeth they gained
- The ability to chew up prey into smaller pieces, thus were able to take larger prey items
- Ability to pick up objects for nest building
- Ability to grasp a mate during courtship
- Ability to grasp young during care of the young
- The jaws allowed the jawed vertebrates to reach much larger sizes and to quickly replace many of the jawless forms in the fossil record of the Devonian period

2.3.1.2. Origin of fins

The head of the lamprey bears a pair of eyes and a conspicuous round sucker. On the dorsal side is a single nasal opening, and behind this there is a pineal eye. There are seven pairs of round gill openings. There is no tract of any paired fins, but the tail bears a median fin, which is expanded in front as a dorsal fin. There are sex differences in the shape of the dorsal fins of mature individuals and the female has a considerable anal fin fold, not supported by fin rays. The lamprey swims with an eel-like motion using its myotomes in the serial manner. Lampreys show great activity in swimming, but their progress is not rapid. The animal often comes to rest, attaching itself with the sucker to stones or to its prey fish.

In a fluid filled environment (water or air) there are three directions of control:

- **Pitch** is head up or down
- **Yaw** is head right or left
- **Roll** is rotation around the longitudinal axis

Fins provide a means of control. By pushing against the water with its fins, a fish can control its motion in these three directions. Fins actually allow very precise control and this gives the fish the ability to orient its jaws relative to a food source or other object to be manipulated by the jaws. Fins allowed fish to greatly increase speed and agility when moving about. The dorsal and anal fins control yaw. The pelvic and pectoral fins control pitch. All of the fins control roll. In addition, fins generate thrust for forward motion. There is no real fossil evidence that sheds any light on the origin of the paired fins (pectoral and pelvic fins). Most evidence comes from embryonic data and innervations patterns. In fact, paired fins probably evolved several different times as there are only a few positions for the fins to function properly.

Early jawed forms may not have had paired fins that were homologous with the paired fins of other taxa (that is, they had different evolutionary origins). However, all modern jawed vertebrates have paired appendages with at least some homologous elements. Several jawless forms possessed a caudal fin of some type (either heterocercal or hypocercal), however, jawed forms support the caudal fin with collagenous fin rays, which greatly strengthens the fin and allows for much greater thrust.

2.3.3. The first Gnathostomes

The first fishes with jaws appeared in the upper Silurian, about 400 million years ago presumably descended from agnathans. They were heavily armored, with a covering of thick rhomboidal scales. The earliest of all were the acanthodians, most or all of which lived in fresh water. In contemporary with the acanthodians were the heavily armoured placoderms, some freshwater and others marine. These first appeared in the fossil record in the early Devonian period. They were armoured fish covered with diamound shaped scales or with large plates of bone. All placoderms became extinct by the end of the Paleozoic era.

Class Placodermi

Class Placodermi includes the earliest gnathostomes except for the acanthodians. They were mostly heavily armoured, as the name implies (placodrmes –plax –plate, +derma – skin). They were mostly bottom living animals, dorsoventrally flattened and somewhat like modern rays. Many lived on invertebrates or by shoveling mud, like their agnathan ancestors. Most lived in the sea, but some in fresh water. The armour consisted of a bony head-shield, movably joined with a trunk shield. The shields are composed of many bones, but their pattern is not like that on the head of later fishes. The body behind the shields was mobile and with a heterocercal tail. It was usually naked but sometimes covered with thick scales. The plates were made of bone arranged in layers; sometimes with dermal tentacles covering the outer layer. Lateral line canals run in grooves in the bone.

The jaws are quite unlike those of later fishes, consisting of bony plates with sharp edges (but usually no teeth) and were often jointed to the head-shield. The spiracle was probably a typical gill-slit. There were paired pectoral and pelvic fins and often large pectoral spines attached to the trunk plate. The males had pelvic claspers and reproduction was presumably like that of sharks. This feature is one of the reasons for considering that the placoderms were related to the ancestors of the chondrichthyes.

General characteristics of members of class Placodermi

- Appear in the Early Silurian and extinct by end of the Devonian, though numerous throughout the Devonian having up to 10 m in length
- Predatory
- The sister taxon to all other jawed vertebrates (Eugnathostomata)
- Unique jaw musculature with the muscles median to the palatoquadrates (the upper jaw elements). This is opposite of all other jawed vertebrates where the muscles are external to the palatoquadrates. This also indicates that jaws may have evolved twice in the evolution of the vertebrates
- Upper jaws were attached tightly to the cranium or head shield, which limited the mobility of the jaws

- No teeth that resemble those of other jawed vertebrates
- Only some individuals within a species had pelvic appendages, which indicate they were male and that the species had internal fertilization
- The head region was covered with thick dermal bone.
- Some forms had a moveable joint between the plates where the neck would be, which allowed the jaws to be opened very wide.

Class Acanthodians

The acanthodians, found in freshwater deposits extending from the Ordovician to the Permian but chiefly in the Devonian, are the oldest known gnathostomes. They were small fishes with a fusiform body, heterocercal tail and one or two dorsal fins. The lateral fins consisted of a series of pairs, often as many as seven in all, down the sides of the body. The fins were all supported by the large spines.

The whole surface of the body was covered with a layer of small rhomboidal scales, composed of layers of material resembling bone. On the hand, these scales were enlarged to make a definite pattern of dermal bones, numerous at first but fewer in the later forms. The pattern of the bones had no close similarity to that of later fishes. The reduced bones of the later acanthodians were related to the lateral line canals, which have an arrangement similar to that in other fishes. The teeth are formed as a series of modified scales. The skull is partly ossified.

General characteristics Acanthodians

- The sister taxon to the Osteichthyes
- Earliest jawed fishes in the fossil record dating from the Early Silurian, but disappeared by the Early Permian.
- Had stout spines anterior to the dorsal, anal, and many paired fins
- 20 cm in length
- Teeth lacked enamel
- Few enlarged scales, though some lacked scales

- Three semicircular canals
- Presence of a tooth whorl as seen in sharks
- Cranium composed of cartilage
- Neural and haemal arches but no vertebral centra are known
- Shared several characteristics that aligns this taxon with the Osteichthyes and places them in the group the Teleostomi (presence of an ossified dermal operculum, mechanism of opening the mouth via the hyoid apparatus transmitting motion to the lower jaw, presence of an interhyal bone, branchiostegal rays)

General characteristics of Gnathostomes

- A vertically biting device called jaws, and which is primitively made up by two endoskeletal elements, the palatoquadrate and Meckelian cartilage, and a number of dermal elements called teeth, sometimes attached to large dermal bones.
- Paired appendages (paired pectoral and pelvic fins) supported by an internal skeleton which supports more efficient locomotion.
- Interventrals and baseventrals in the backbone. These are the elements of the backbone, which lie under the notochord, and match the baiidorsals and interposals respectively.
- Gill arches which support/hold the gills lie internally to the gills and branchial blood vessels, unlike the gill arches of all jawless craniates, which are external to the gills and blood vessels.
- A horizontal semicircular canal in the inner ear.
- Teeth - modified dermal scales
- More proficient predators than the jawless fish.
- Paired nasal sacs.

The gnathostomes differ from all other craniates or vertebrates in having a vertically biting device, the jaws, which consist of an endoskeleton mandible arch and a variety of exoskeleton grasping, crushing, or shearing organs, i.e. the teeth, and jaw bones. The gnathostomes include sharks, rays, chimaeras, ray-finned fishes, lobe-finned fishes and land vertebrates including humans.

2.3.2. Types of caudal fins, scales, jaw suspension, dentition and ventral articulation in different Gnathostomes

Morphology of Fish: the body of fish is composed of head, abdomens, appendages, fins and tail. Although to most people sharks have a fearsome appearance, they are at the same time among the most gracefully streamlined of all fishes. The body of a dogfish shark is fusiform (spindle shaped). In front of the ventral mouth is a pointed rostrum; at the posterior end the vertebral column turns up to end in the longer upper lobe of the tail. This type of tails is called heterocercal with the dorsal lobe larger than the ventral, giving an upward lift. Heterocercal tail allows for steering in the vertical plane and, together with the flattened pectoral fins, compensates for the lack of buoyancy. There are two dorsal fins, which secure stability against rolling, and also assist in making possible the vertical turning movements. The paired pectoral and pelvic fins are supported by appendicle skeletons.

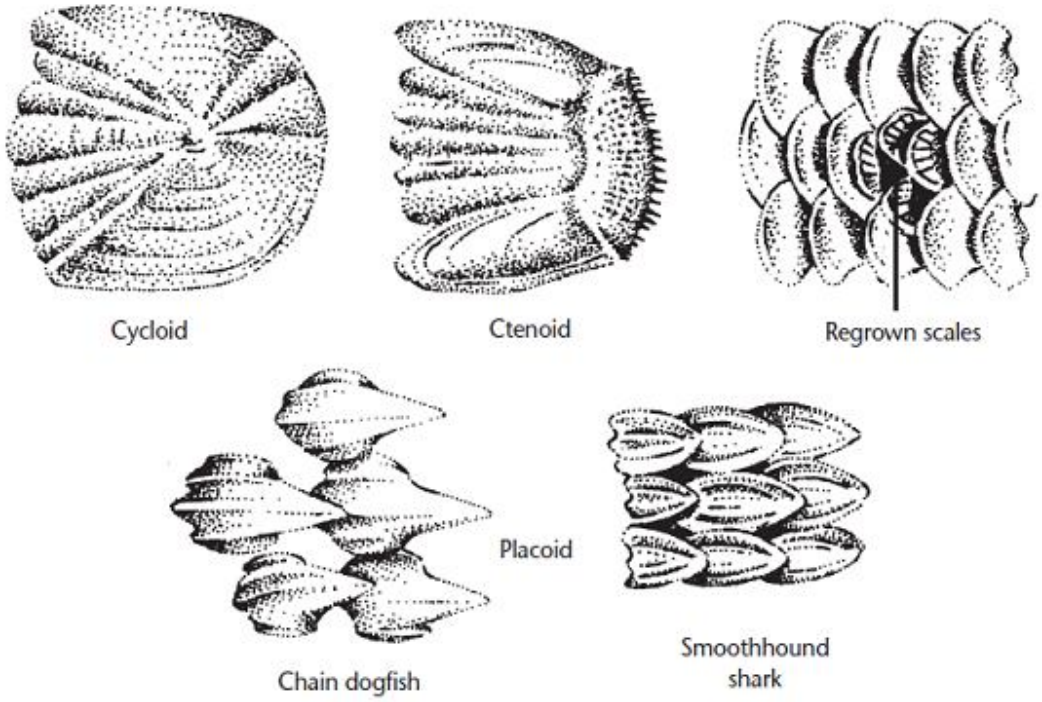
The median fins consist of two dorsal fins, a caudal fin, and a median anal fin. In the male, the medial part of the pelvic fin is modified to form claspers, which is used in copulation. The paired nostrils (blind pouches) are ventral and anterior to the mouth. The lateral eyes are lidless, and behind each eye is a spiracle (remnant of the first gill-slit). Five gill slits are found anterior to each pectoral fin. The tough, leathery skin is covered with tooth like, diagonal rows of minute dermal placoid scales. The scales are arranged to reduce the turbulence of water flowing along the body surface during swimming. Each placoid scale with a backward-pointing spine is covered by enamel and a basal plate of dentine in the dermis. At the mouth region a gradual transition from scales to teeth occurs, suggesting the probable origin of vertebrate teeth.

Scales

A typical fish’s body is covered with thin scales that overlap each other like the shingles of a roof. They are prominent outgrowths of skin, or epidermis, in which numerous glands secrete a protective coating of slime, often referred to as mucus. The slime is a barrier to the entry of parasites, fungi, and disease organisms that might infest the fish, and it seals in the fish’s body fluids so that they are not diluted by the watery surroundings. The slime

reduces friction so that the fish slides through the water with a minimum of resistance; it also makes the fish slippery when predators, including the human variety, try to grab hold. Some fish, such as lampreys and hagfish, give off copious amounts of slime. As a fish grows, its scales increase in size but not in number. Lost scales may be replaced, however. The ridges and the spaces on some types of scales become records of age and growth rate. These can be read or counted like the annual rings in the trunk of a tree to determine a fish's age the fish's growth slowing or stopping during winter when food is scarce and becoming much more rapid during the warm months when food is plentiful.

Experts in reading scales can tell when a fish first spawned and each spawning period thereafter. They can determine times of migration, periods of food scarcity, illness, and similar facts about the fish's life. The number of scales in a row along the lateral line can be used to identify closely related species, particularly the young. Growth rings occur in the vertebrae, in other bones of the body but to study these requires killing the fish. A few scales can be removed without harm to the fish.



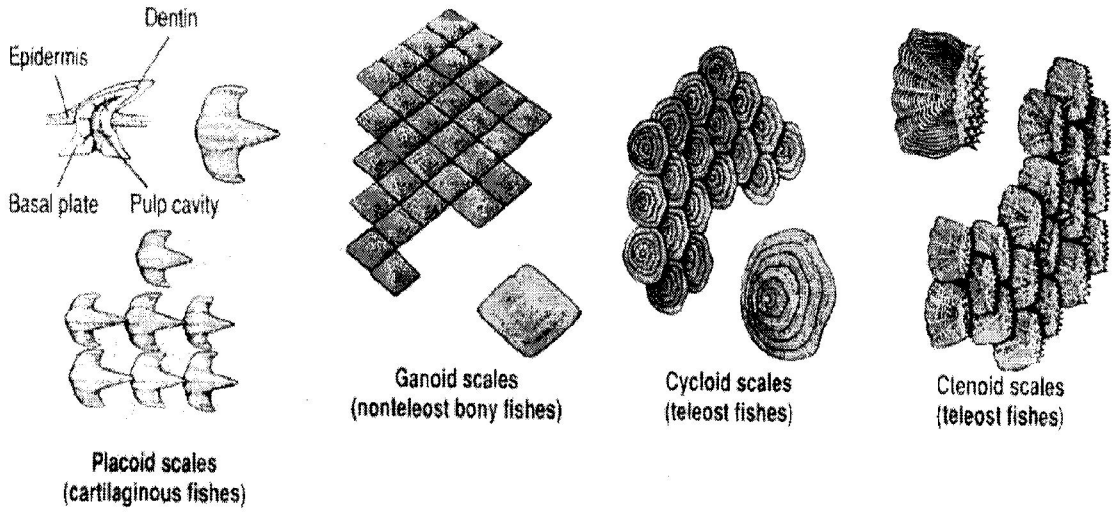


Figure 9 Types of fish scales

Coloration

The beautiful coloration of fish can be appreciated only when observing them alive, for at death the brilliance and the intensity of color begin to fade immediately. Unquestionably, many fish equal or surpass in appearance the most spectacular colored bird or butterfly, and some of the blends and contrasts of body color are impossible to describe with justice. The color in fish is primarily produced by skin pigments. Basic or background color is due to underlying tissues and body fluids. Iridescent colors are present in the body scales, the eyes, and the abdominal linings of some fish. The rain bowlike reflecting hues of certain kinds of fish are caused by skin pigmentation fragmenting through the irregular ridges of transparent or translucent scales.

All fish are not highly colored, however; the range extends widely from fish with bright colors to species that are uniformly drab in brown, gray, and even pitch black. In nearly all species, the shades and the acuteness of color are adapted to the particular environment a fish inhabits.

In oceanic fish, basic color may be separated into three kinds: silvery in the upper-water zone, reddish in the middle depths, and violet or black in the great depths. Those that swim primarily in the upper layers of ocean water are typically dark blue or greenish-blue on the dorsal portions, grading to silvery sides and white bellies. Fish that live on the bottom, especially those living close to rocks, reefs and weed beds may be busily mottled or striped. The degree of color concentration also varies, depending on the character of the fish's surroundings. For example, a striped bass caught from a sandy area will be lighter in general coloration than one captured from deeper water or from around dark rocks.

Most types of fish change color during the spawning season. In some types of fish, the coloration intensifies perceptibly when the fish is excited by prey or by predators. Dolphin, also known as mahimahi, a blue-water angler's delight, appears to be almost completely vivid blue when seen from above in a darting school in calm waters. When a dolphin is brought aboard, the unbelievably brilliant golden yellows, blues, and greens undulate and flow magically along the dolphin's body as it thrashes madly about. These changes in shade and degree of color also take place when the dolphin is in varying stages of excitement in the water.

Fins and Locomotion

Fins are useful for swimming and balancing Fins are supported by rays known as fin rays Fins have both spiny and soft rays. Fins without fin rays are known as adipose fins (*Mystus)* Fins are mainly two types paired and unpaired fins. Paired fins are pectoral and pelvicdor ventral's. Unpaired fins are dorsal, anal and caudal fins. Fins are mostly normal or modified in few fishes. Fish are propelled through the water by fins, body movement, or both. In general, the main moving force is the caudal fin, or tail, and the area immediately adjacent to it, known as the caudal peduncle. In swimming, the fins are put into action by muscles attached to the base of the fin spines and the rays.

Fish with fairly rigid bodies depend mostly on fin action for propulsion. Eels, in contrast, rely on extreme, serpent like body undulations to swim, with fin movement assisting to a minor extent. Sailfish, marlin, and other big game fish fold their fins into grooves (lessening water resistance) and rely mainly on their large, rigid tails to go forward.

Salmon and other species are well adapted for sudden turns and short, fast moves. When water is expelled suddenly over the gills in breathing, it acts like a jet stream and aids in a fast start forward.

A fish can swim even if its fins are removed, though it generally has difficulty with direction and balance. In some kinds, however, the fins are highly important in swimming. For example, the pectoral fins of a ray are broad "wings" with which the fish sweeps through the water almost as gracefully as a swallow does in the air. The sharks, which are close relatives of the rays, swim swiftly in a straight line but have great difficulty in stopping or turning because their fins have restricted movement.

Flying fish glide above the surface of the water with their wing like pectoral fins extended. Sometimes they get additional power surges by dipping their tails into the water and vibrating them vigorously. This may enable flying fish to remain airborne for as long as a quarter of a mile. Needlefish and halfbeaks skitter over the surface for long distances, the front halves of their bodies held stiffly out of the water while their still-submerged tails wag rapidly.

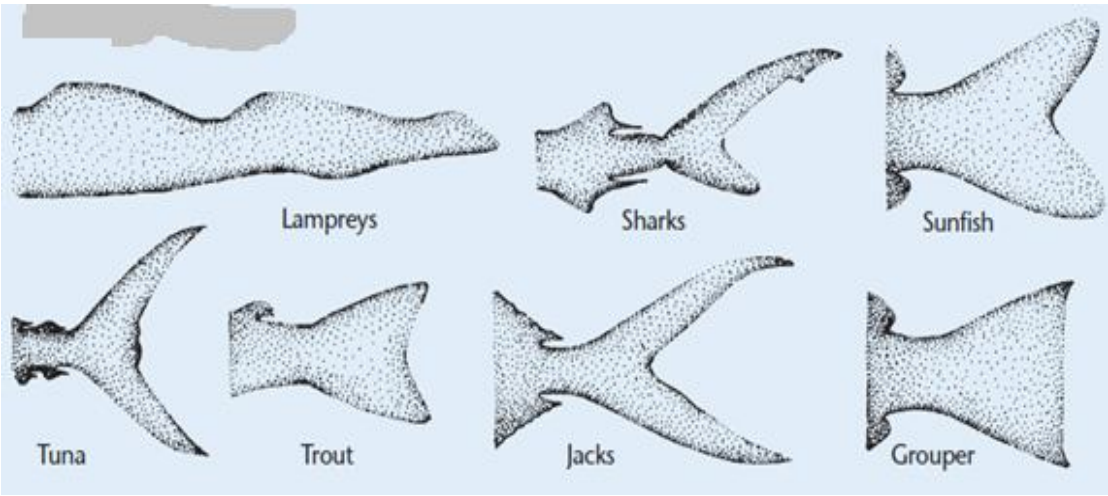


Figure 10 Fin types

Types of fin

Dorsal fins are located on the back. A fish can have up to three of them. The dorsal fins serve as to protect the fish against rolling and assists in sudden turns and stops.

- In anglerfish, the anterior of the dorsal fin is modified into an **illicium** and **esca**, a biological equivalent to a fishing rod and lure.
- The bones that support the dorsal fin are called *Pterygiophore*. There are two to three of them: "proximal", "middle", and "distal". In spinous fins the distal is often fused to the middle, or not present at all.

The **caudal fin** is the tail fin, located at the end of the caudal peduncle and is used for propulsion.

Types of caudal fin:
(A) - Heterocercal, (B) - Protocercal,
(C) - Homocercal, (D) - Diphycercal

The **anal fin** is located on the ventral surface behind the anus. This fin is used to stabilize the fish while swimming.

The paired **pectoral fins** are located on each side, usually just behind the operculum, and are homologous to the forelimbs of tetrapods.

- A peculiar function of pectoral fins, highly developed in some fish, is the creation of the dynamic lifting force that assists some fish, such as sharks, in maintaining depth and also enables the "flight" for flying fish.
- In many fish, the pectoral fins aid in walking, especially in the lobe-like fins of some anglerfish and in the mudskipper.
- Certain rays of the pectoral fins may be adapted into finger-like projections, such as in sea robins and flying gurnards.
    - The "horns" of manta rays and their relatives are called **cephalic fins**; this is actually a modification of the anterior portion of the pectoral fin.

The paired **pelvic** or **ventral fins** are located ventrally below the pectoral fins. They are homologous to the hind limbs of tetrapods. The pelvic fin assists the fish in going up or down through the water, turning sharply, and stopping quickly. In gobies, the pelvic fins are often fused into a single sucker disk. This can be used to attach to objects.

The **adipose fin** is a soft, fleshy fin found on the back behind the dorsal fin and just forward of the caudal fin. It is absent in many fish families, but is found in Salmonidae, characins and catfishes. Its function has remained a mystery, and is frequently clipped off to mark hatchery-raised fish, though data from 2005 showed that trout with their adipose fin removed have an 8% higher tail beat frequency.[4] Additional released in 2011 has suggested that the fin may be vital for the detection of and response to stimuli such as touch, sound and changes in pressure. Canadian researchers identified a neural network in the fin, indicating that it likely has a sensory function, but are still not sure exactly what the consequences of removing it are.

Some types of fast-swimming fish have a horizontal **caudal** keel just forward of the tail fin. This is a lateral ridge on the caudal peduncle, usually composed of scutes, that provides stability and support to the caudal fin. There may be a single paired keel, one on each side, or two pairs above and below.

Fin lets are small fins, generally behind the dorsal and anal fins (in bichirs, there are only fin lets on the dorsal surface and no dorsal fin). In some fish such as tuna or sauries, they are ray less, non-retractable, and found between the last dorsal and/or anal fin and the caudal fin. For every fin, there are a number of fish species in which this particular fin has been lost during evolution.

Unpaired fins or median fins

Due to the differentiation in a continuous embryonic fin fold the median fins of all fishes will develop. During development a continuous embryonic fold tissue is formed dorsally along the back up to the tip of the tail and is then strength and by a series of cartilaginous rods and this condition is seen in lampreys and represents the primitive stage of the median

fin. In higher fishes separate dorsal, caudal, and anal fins are formed by the concentration of the redials in certain areas and degeneration of the fold in the intervening spaces, between the fins. In the present day bony fishes, the fleshy lobe at the base of the dorsal fins are disappeared and the radials are reduced to nodules of bone or cartilage.

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

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

Paired fins

Paired apprises were not present in the ancestral vertebrates and were developed during the course of early evolution. The supporting endoskeleton of the paired fins varies greatly in different groups of fishes. The original primitive condition is known as the ‘archipterygium’ and was provided with an anterior pre-axial and a posterior post-axial series of radials attached to it. The radials were arranged in decreased manner on either side of the median axis. This is called a biserial arrangement of the radials and known as biserial archipterygim, found in ceratodus and present in the Devonian crossopterygian. Various types of paired fin skeleton in the teleosts may be derived from the

archiptenygium by shortening of the median axis and reduction in the number of postaxial radials that finally disappear completely, giving rise to pleuroarchic or uniserial type of skeleton found in teleosts Pectoral fins are present behind the gills and horizontal to the ventral lateral portion. Broad and long pectoral fins acts like the wings of bird in *Exocoetus* and fly in the air. In *Periopthalaus* pectoral fins are useful for walking. In *Trigon, Torpido* they extend laterally from head to tail and modify into leafy structure.

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

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

There are various tail types of fishes are

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

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

C. Heterocercal: the notochord bends upwards at its posterior end, so that the dorsal lobe of the tail is almost lacking or represented by a few spines, while the ventral lobe becomes well developed. The large sized ventral lobe possesses a longer postero-dorsal and a

shorter antero-ventral lobe. Consequently the tail becomes asymmetrical, both externally and internally. Such type of tail is mainly found among the elasmobranches.

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

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

F. Isocercal: is drawn out like structure. The fin fold develops, both, above form of the marginal extensions of the tails and rays. Such tails are found in some deep sea fish's teleosts belonging to Anguilliformes, Notopteridae, Macruridae and Blennidae.

G. Gephyrocercal: is very much like the isocercal, to vestiges. The caudal lobe or eduncle is truncated spinal colunm are not found. Such fin types are Orthagoriscus.

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

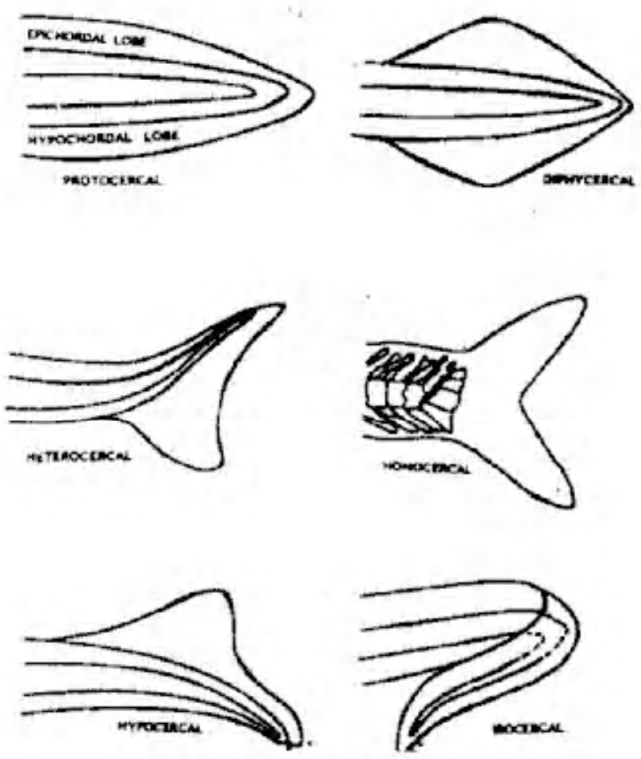


Figure 11 Various kinds of tails in fish

Activities

1. *Describe the different types of fish scales?*
2. *List and explain the different types of fish tails?*

Summary

- ✓ *The jawed vertebrates not only differ from jawless forms based on the presence of jaws but also differ in many other ways.*
- ✓ *Vertebrate jaws are made from neural crest derived cartilage just at the bronchial arches are. Thus jawed vertebrates converted gill arches into jaws.*
- ✓ *The appearance of biting jaws in the jawed fishes enabled them to become more active carnivores.*
- ✓ *Bony fishes are buoyant and can remain suspended at any depth in the water because they possess a swim bladder (a gas-filled sac) that allows the fishes to regulate their buoyant density.*
- ✓ *Agnatha means without true jaws and gnathostomes are with true jaws and mouth. The jawless agnathans are the more primitive of the two groups, which include the extinct ostracodrms and the living hagfishes and lampreys.*
- ✓ *The cartilaginous fishes of the class chondrichthyes (sharks, rays, skates, and chimaeras) flourished during the Devonian and carboniferous periods.*
- ✓ *The head of the lamprey bears a pair of eyes and a conspicuous round sucker. On the dorsal side is a single nasal opening, and behind this there is a pineal eye.*
- ✓ *The first fishes with jaws appeared in the upper Silurian, about 400 million years ago presumably descended from agnathans.*
- ✓ *Class Placodermi includes the earliest gnathostomes except for the acanthodians. They were mostly heavily armoured, as the name implies (placodrmes –plax –plate, +derma –skin).*
- ✓ *The acanthodians, found in freshwater deposits extending from the Ordovician to the Permian but chiefly in the Devonian, are the oldest known gnathostomes.*
- ✓ *A typical fish's body is covered with thin scales that overlap each other like the shingles of a roof.*
- ✓ *The beautiful coloration of fish can be appreciated only when observing them alive, for at death the brilliance and the intensity of color begin to fade immediately.*
- ✓ *All fish are not highly colored, however; the range extends widely from fish with bright colors to species that are uniformly drab in brown, gray, and even pitch black.*

- ✓ *Fins are useful for swimming and balancing Fins are supported by rays known as fin rays Fins have both spiny and soft rays.*
- ✓ *The **anal fin** is located on the ventral surface behind the anus. This fin is used to stabilize the fish while swimming.*
- ✓ *Tail is useful for changing the direction during swimming. Tail consists of fin known as caudal fin tails are of different types diphycercal (Dipnoifishes), hypocercal (extinct fishes), heterocercal (cartilagenious fishes and homocercal (teleost fishes). Caudal fin is either forked or round or confluent with dorsal and anal.*

Review activities

1. *Explain the general characteristics of Gnathostomes?*
2. *Classify the general groups of the Gnathostomes fishes and explain them briefly?*
3. *Compare and contrast the Gnathostomes with the other groups of fishes briefly?*

CHAPTER THREE
ADVANCED FISHES-CHONDRICHTHYES AND OSTEICHTHYES

Introduction

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

Unit objectives

At the end of this unit, students will be able to:

- *Recognize advanced fishes by their characteristic features and their classifications*
- *Have a mental picture of the body structure of those advanced fishes*
- *Understand their basic differences*

What are advanced fishes?

Lesson objectives

At the end of this lesson, students will be able to:

- ✓ *List the general of characteristic chondrichthyes and osteichthyes*
- ✓ *List down the body structures of chondrichthyes and osteichthyes*
- ✓ *Differentiate between chondrichthyes and osteichthyes*

The general characteristics of fishes are:

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

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

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

- ✓ **Body form**: Fish body can be divided into head, abdomen and tail

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

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

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

- ✓ **Respiratory system**: Branchial respiration by gills. Gills are located in branchial chamber. 5-7 gills are found in cartilaginous fishes and 3-5 gill are found in teleosts. Each gill is supported by gill arch, gaseous exchange takes place in gill lamellae, gill rackers are well developed in plankton feeding fishes, where these are useful as sieve. Open type of branchial system is found in cartilaginous fishes, whereas closed branchial system is observed in bony fishes. Operculum is present only in bony fishes.

In cartilaginous fishes more than one pair of external branchial openings are found, where as only one pair of opening are seen in bony fishes. Haemoglobin is respiratory pigment. Accessory respiratory organs are found in few fishes like *Clarias* (respiratory trees), *Channa* (labyrinthin organ), *Heteropneustes* (air sac), dipnoi fishes (lungs), etc, which are useful to live for some time outside water.

- ✓ **Circulatory system**: Closed type of circulatory system is found in fishes. Heart is two chambered, venous, tubular and with either conus or bulbus arteriosus. RBC are biconvex in nature.

- ✓ **Nervous system**: Cerebrum is not much developed Olfactory lobes are well developed, especially in sharks. 10 pairs of cranial nerves are found.

- ✓ **Sensory organs**: Lateral line system is very well developed in fishes. Neuromast cells are found in lateral line system, which are useful to detect water currents. External and middle ears are absent. Internal ear is present in the form of membranous labyrinth. Olfactory organs are well developed with olfactory lamellae. Ampullae of Lorenzini are thermoreceptors found in cartilagerious fishes. Barbles are very well developed in catfishes.

- ✓ **Excretory system**: Mesonephric kidneys are found, ammnotelic animals. Marine fishes retain urea in their blood to maintain isotonic condition with seawater.

- ✓ **Reproductive system**: Monosexuals, sexual dimorphism is found. In Few fishes are Coupulatory organs. Claspers in cartilagenous fishes and gonopodium in poecilidae family fishes are coupulatory organs. Gonads exhibit sesonal variations. Oviparous, except sharks and poecilidae fishes. External fertilisation, except in above fishes Megalecithal eggs. Cleavage is holoblastic, determinate. Direct development except in Anguilla, which consists of elever or

- ✓ leptocephalus larval form. Parental care is found in fishes eg. *Oreochromis* is mouth brooder. Brood pouch is found in *Hippocampus.* Some fishes are nest builders eg *sunfishes.*

- ✓ Electric organs are found in few fishes, which produce current eg. *Tarpedo, Electrphorus*
- ✓ Few fishes exhibit bioluminescence eg, *Blepherodon*
- ✓ Fishes like *Anguilla* and *Salmon* exhibits diadromous migration.
- ✓ The clade pisces of the super class Gnathostomata is divided into three classes
    - o Placodermi
    - o Chondricnthyes
    - o Osteicnthyes

Class Placodermi

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

3.1. Class Chondrihcthyes (Gr. Chondros = Cartilage; icthyos =fish)

General characteristics

- ➢ Internal skeleton is composed of cartilage rather than bone
- ➢ Body scales are placoid (tooth-like) in nature with a bony base
- ➢ Jaws suspended by two gill arches
- ➢ Swim bladder or lung absent; have oil filled liver to provide neutral buoyancy
- ➢ Claspers (modified pelvic fins) present in males for internal fertilization
- ➢ Notochord present in the young and gradually replaced by a backbone of cartilage in adult
- ➢ Ventral mouth
- ➢ Fleshy pectoral and pelvic fins
- ➢ Cold blooded (ectothermic/poikilothermic)
- ➢ Paired nasal openings
- ➢ Two-chambered heart
- ➢ 5 to 7 pairs of gills.

- Gill slits are present and are not covered by operculurn
- In the heart, sinus venosus, auricle, ventricle and conus arteriosus with valves are present
- These are ureotelie animals and store high levels of urea and trimethylamine oxide (TMO) in their blood and body fluids
- Eggs are macrolecithal (high amount of yolk) and cleavage is meroblastic
- Fertilization is internal and many species are viviparous. Development takes place inside the oviduct and in oviparous forms development occurs outside the body

Classification

The cartilaginous fishes are divided into two extant subclasses:
Subclass: Elasmobranchii (sharks, rays and skates)
Subclass: Holocephali (chimaera, sometimes called ghost sharks)
Notes: Members of the chondrichchyes have a backbone that is made of cartilage. Because of their marine nature, they are not the fishes you come across often.

3.1.1 Subclass: Elasmobranchii (sharks, rays and skates)

Sharks

Sharks are some of the oldest creatures on the planet, true examples of an evolutionary masterpiece. These streamlined works of art range in size from the tiny 8 inch gypsy shark to the 45 foot whale shark. In contrast to the bad name sharks have, only a handful of the 350 known species are dangerous to humans. In fact, many sharks will stay far from the surface if there are humans above. Only the Great White Shark has been known to rise to the surface and "look around.

Anatomy

Sharks are covered by a layer of tough skin covered with small tooth-like scales called placoid scales. Unlike fish scales, placoid scales are embedded within the dermis of the shark's skin. The presence of these scales makes the skin tough like sandpaper. Placoid

scales are also a clever modification for swimming. In theory, as a shark swims, a series of whirlpools forms behind each scale. The spinning water reduces water drag and allows the shark to swim fast and efficiently. Placoid scales are also called tentacles because they are thought to be miniature versions of the shark's main teeth.

Shark teeth are some of the most envied teeth in the animal kingdom. Sharks have the amazing ability to replace teeth infinitely during their lifetime. Shark teeth are not set into the jaws, like humans. Instead, teeth are set into the gums. In addition, below each tooth (inside of the gums) are layers of replacement teeth. If a tooth falls out, a brand new tooth rises from the storage layer within a few days. Some species of sharks have been known to shed as many as 30,000 teeth in one lifetime.

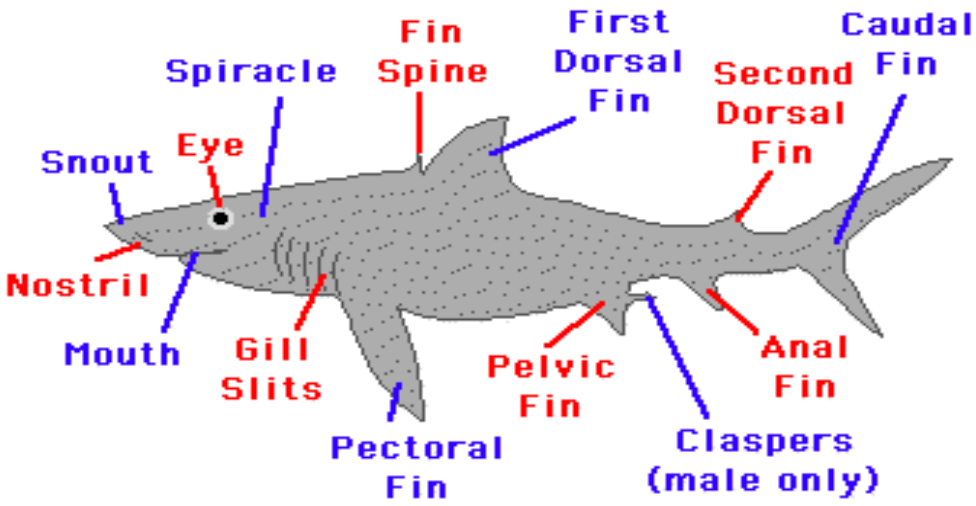


Figure 12 Anatomy of a shark

Feeding

The shark is truly the ultimate predator. It is perfectly adapted in every way to locate, hunt and kill prey. The carnivorous diet of the shark consists of fish, other sharks, young seals and whatever else it feels like eating.

Sensory Features

Sharks are fully-added carnivores that utilize an impressive array of sensing organs. The most obvious is the mouth. The tongue is used for tasting the water, as well as for tasting food. Sharks are quite intelligent too. They often feel and investigate objects by gently biting them. In fact, many shark attacks were provoked (by people) when a shark simply wanted to investigate a person. The next sensory feature is the nose.

Two super-sensitive nostrils lie near the front of the head. They are so powerful they can sense a drop of blood from over a mile away. Shark eyes are also very powerful - they can see 10 times better than humans in darkness. But shark eyes are also very sensitive, and many species have developed a special membrane called a nictitating membrane to cover the eyes when needed. Sharks also have excellent hearing and are especially attracted to low frequency sounds. The less visible sensory structure is the lateral line that runs the length of the shark. It allows the shark to sense vibrations and movement underwater. Finally the most powerful sensory organ sharks have is located on the nose in the form of two little black "dots." This organ has the ability to sense electric impulses produced by an animal. Sharks use this organ to find prey and sense if the animal is dying. To illustrate another human-provoked shark attack, the faster your heart beats, the more a shark thinks you are a dying animal.

Respiration

In the back of every shark's mouth is a set of parallel splits in the skin. These gills are lined with filaments that contain blood vessels. In order to breathe, sharks must keep a constant flow of water through these gills slits. It was once thought that sharks could never stop swimming - even to sleep, but recent studies show that some sharks can lower their metabolism, allowing them to fall into a meditation-like state of sleep.

Mating and Reproduction

Sharks are sexually dimorphic, meaning there are differences between male and female bodies. Mating behavior is very complex. A male shark will select a female and follow her very closely. He may even encircle the female. At a point he will quickly bite the female's pectoral fin to stimulate her. After a while, the female will give in to the male who then positions his ventral surface along the female's ventral surface. The male then inserts his claspers into the female's cloacae. Fertilization occurs internally.

Sharks reproduce in three ways:

Oviparity: The female lays eggs that develop over a period of a few months. Young hatch at sea and are on their own.

Oviviparity: The eggs are hatched in the oviduct of the female. The embryos develop in the uterus until fully grown. Then they are released into the sea.

Viviparity: The embryo is nourished inside of the female by a placenta. The gestation period lasts almost a year before the newborn is released.

Figure 13 Great white shark

Figure 14 Whale shark: the largest living fish

Rays and Skates

Rays and skates make up the second order of Subclass Elasmobranches. Order Batoidei contains about 300 to 350 different species. Rays, like sharks, are found worldwide in every ocean. They are mainly docile animals. Most are slow-moving bottom dwellers that spend most of their time resting on the ocean floor. Most features of rays are true to skates as well. In fact, the two names are almost interchangeable.

Anatomy

The main feature that differentiates a ray from a shark is the flat rough-skinned body, with the gill slits and the mouth both found on the underside of the animal. The pectoral fins of rays have been greatly modified into large wings used for locomotion. The tail has also been greatly modified into a long and slender whip-like tail. Ray tails may have one or a few small spines containing venom.

Table 2 Major differences between sharks and bony fish

Attribute	Sharks	Bony fish
Skeleton	Cartilage only	Bones and cartilage
Swimming	Can only swim forward.	Can swim forwards and backwards
Buoyancy (floating)	Large oily liver	Gas-filled swim bladder
Gills	Gill slits but no gill cover	Covered gill slits
Reproduction	Eggs fertilized in female's body.	Eggs usually fertilized in the water.
Skin	Rough, sandpaper-like placoid scales	Slippery, overlapping scales

Feeding

Rays, like sharks, feed on a variety of seafood. Rays eat mostly fishes and invertebrates with their blunt teeth. Some even consume plankton and small organisms. Between the shark and the ray, the two animals prey on nearly everything that swims.

Special Features

A flat body allows skates and rays to settle in with the sand at the bottom of the ocean floor and wait for prey to pass overhead. Special colorations on the dorsal surface provide some camouflage with the ray's surroundings. Most rays lash out with the poison tail barb to catch unsuspecting animals. And the electric ray uses a pair of special electricity-generating organs to shock and kill prey. The pectoral wings act much like the wings of a bird, gently "flapping" to propel the ray forward. Actually, the wings move by waves of dorsoventrally muscle contractions passing from the anterior end of the wing to the posterior.

Respiration

There are five gill openings on the underside of a ray's body. Most rays breathe by taking in water through large openings on the upper portion of the head. Oxygen is taken in through the gills.

Fertilization and Reproduction

Rays display internal fertilization. Most species will give birth to live young. Skates lay flat, rectangular eggs that are enveloped by a leathery shell. Empty egg cases have been found on beaches and have come to be called mermaid's purses. What are the differences between rays (left) and skates (right).

Figure 15 Rays (left) and Skates (right)

The major difference between rays and skates is in their reproductive strategies. Rays are live bearing (viviparous) while skates are egg laying (oviparous), releasing their eggs in hard rectangular cases sometimes called "mermaid´s purses". Also, skates typically have a prominent dorsal fin while the dorsal fin is absent or greatly reduced in rays. Most rays are kite-shaped with whip-like tails possessing one or two stinging spines while skates have fleshier tails and lack spines. Rays protect themselves with these stinging spines or barbs while skates rely on thorny projections on their backs and tails to for protection from predators. Skates have small teeth while rays have plate-like teeth adapted for crushing prey. Another difference is that rays are generally much larger than skates.

3.1.2. Subclass Holocephali

Chimaera (Fish)

Chimaera (fish), common name for members of any of three families of deep-water cartilaginous fishes related to sharks. Reaching more than 2 m (6 ft) in length, they feed on smaller animals in temperate oceans. The color of their scale less skin ranges from black to brownish gray, sometimes with markings, and the eyes are large. In several species, such as the ratfish's, the tail is long. Rat fish's also bear a poisonous spine directly in front of the dorsal fin. The eggs of chimaeras are laid in capsules of hornlike material. Chimaeras constitute the order Chimaeriformes of the subclass Holocephali. They make up the plownose chimaera family, Callorhynchidae; the longnose chimaera family, Rhinochimaeridae; and the shortnose chimaera family, Chimaeridae, also known as the ratfish family.

Ratfish

The ratfish is a member of a species of deep-water fish related to sharks. The ratfish is characterized by a long tail and a poisonous spine in front of the dorsal fin.

3.2. Class Osteichthyes (bony Fish) (Gr. Osteos = bone; ichthiyes fish)

The most typical fishes are those that have skeletons with bone, are mostly covered by dermal scales, usually have spindle shaped bodies, swim by fins and breathe by gills. Various species inhabit waters that are fresh, brackish or salt, and either warm or cold. Bony fishes reproduce by different mechanisms, may be very complex, involving elaborate nest building and care of the young. Social behavior is shown in shoaling movement, which may be accompanied by interchange of sounds.

The majority of bony fishes are carnivorous but others feed on every type of food, from plankton to seaweeds. They have been a staple protein food of mankind since antiquity, and many species provide pleasant sporting recreation.

The bony fishes originated in the late Silurian, approximately 410 million years ago. Details of head structure of the earliest complete bony fish fossils indicate that they probably descended from an ancestor shared with the acanthodians. By the middle of the Devonian the bony fishes already had radiated extensively, with adaptations that fitted them for every aquatic habitat.

The early bony fishes had an operculum over the gill-slits, composed of bony plates attached to the first gill arch. This feature increased respiratory efficiency because the outward rotation of the operculum created water to be drawn across the gills, as well as pushed across by the mouth pump. These earliest bony fishes also had a pair of lungs that served as accessory breathing structures. Several key adaptations of bony fishes contributed to their radiation. An obvious manifestation of their adaptability is the great diversity of body form among the living bony fishes. Progressive specialization of jaw structure and feeding mechanisms is another key feature in their evolution.

General Characteristics of bony fish

- Bony endoskeleton
- Skin is covered by cycloid, ctenoid or ganoid scales
- Paired pectoral and pelvic fins supported by bony rays.
- Bilaterally symmetrical tail fin.
- Mouth is usually terminal or sub-terminal
- Pairs of gills are present on either side of the pharynx. Their openings are covered by operculum or gill cover.
- Tail is homocercal, diphycercal or heterocercal
- Claspers, cloaca and nasobuccal grooves are absent. Separate Oval and urinogenital apertures are present.
- Heart is two charmbered with an auricle and a ventricle. Conus arteriosus is absent. Lung fishes have an incompletely divided auricle and a ventricle. Pulmonary artery and pulmonary vein are present in lung fishes.
- These are ammonotelic animals
- Air bladder is present in many specie

- No external ear
- Eggs produced
- External fertilization.
- Poikilothermic (cold blooded)
- Bony fishes are usually oviparous. Few are viviparous. (eg. *Gambusia, Labestis*)
- Inhabits both freshwater as well as marine.

Classification

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

Sub class Crossopterygii

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

Sub class crossopterygii is divided into two orders

Order Rhipidistia

- These are marine animals
- Pectoral and pelvic fins are lobed and paddle-like
- Skin is covered by cycloid scales
- Spiral valve intestine is absent
- Includes extinct osteolepids which had internal nostrils and considered to be ancestors of amphibia and the living fossil fish's coelacanths, eg. *Latimeria chalumnae*.

Order Dipnoi (Lung Fishes)

- These are fresh water anima1s
- Body is long and slender
- Jaws are short, teeth form a pair of plates

- Pectoral and pelvic fins are slender
- Skin is covered by cycloid scales
- Spiral valve in Intestine in present
- Internal nostrils and one or two lungs and pulmonary arteries and veins are present

Eg. Protopterus, Lepidosiren, Neoceratodus.

Sub class Actinopterygii

- Internal nostrils are absent
- Paired fins are supported by fin-rays arranged in a palmate fashion Caudal fin is homocercal
- Lungs are absent. An air bladder or swim bladder or gas bladder is present which is hydrostatic in function

Sub class Actinopterygii is divided into the three super orders namely Chondrostei, Holostei andTeleostei

Super order Chondrostei

- These are fresh water fishes
- Weak jaws without teeth
- Endoskeleton is cartilaginous
- Exoskeleton consists of bony plates covering the body.
- Tail is heterocercal
- Spiral valve is present in the intestine
- Air bladder with duct is present

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

Super order Holostei (Gr. Holo- complete; osteo=bone)

- These are known as bow fins
- There are found in fresh water of America
- Endoskeleton is bony
- An air bladder is present above the oesophagus

- Spiral valve is present in the intestine
- Air bladder is present with a duct

  Eg. *Amia, Lepidosteus*

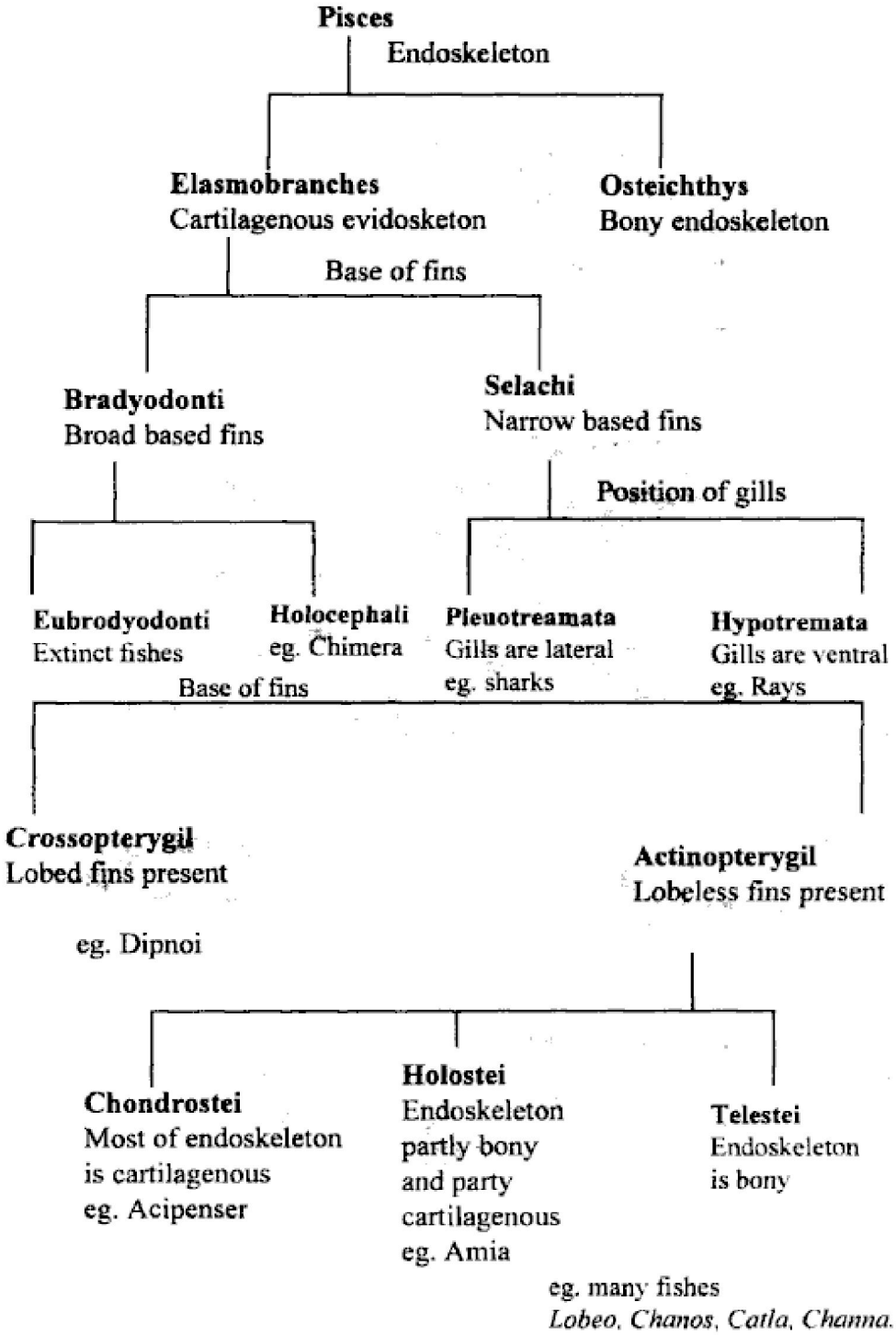
Super order Teleostei (Gr. Teleo = entire, osteo=bone)

- Includes a large number of modern bony fishes. Skeleton is fully ossified
- These are occur in fresh water as well as in sea
- Exhibits great diversity in their structure and shape
- Skin in covered by cycloid or cteniod scales
- Mouth in small. Tail is symmetrical or homocercal
- Four pairs of gill slits are present. Spiracle is absent
- Air bladder is present, having hydrostatic function
- They are ammonotelic animals
- Spiral valve is absent in intestine
- Heart has bulbous arteriosus in place of conus arteriosus

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

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

CLASSIFICATION OF FISHES



The Osteichthyes are characterized by endochondral ("spongy") bone in the endoskeleton, dermal fin rays made up by lepidotrichiae (modified, tile-shaped scales), and three pairs of tooth- bearing dermal bones lining the jaws (dentary, premaxillary and maxillary). The Osteichthyes include two major clades, the Actinopterygii and the Sarcopterygii.

Table 3 Differences between Chondrichthyes and Osteichthyes

Features	Cartilaginous Fish	Bony Fish
Skeleton	Cartilage only	Cartilage and bones
Swimming	Forward only	Forward and backward
Buoyancy	Large, oily liver	Gas-filled swim bladder
Gills	Slits but no gill cover	Covered gill slits
Reproduction	Internal fertilization	Eggs usually fertilized externally
Scales	Rough, sand-paper like placoid scales	Smooth, overlapping scales
Skeleton	Cartilage only	Cartilage and bones

Activities

1. Differentiate briefly between sharks and bony fish?

2. Differentiate briefly between Cartilaginous Fish and bony fish?

Summary

We have described the Gnathostomes as vertebrates characterized by:

- *A vertically biting device called jaws, and which is primitively made up by two endoskeletal elements, the palatoquadrate and Meckelian cartilage, and a number of dermal elements called teeth, sometimes attached to large dermal bones.*
- *Paired appendages (paired pectoral and pelvic fins) supported by an internal skeleton which supports more efficient locomotion.*
- *Interventrals and basiventrals in the backbone. These are the elements of the backbone, which lie under the notochord, and match the basidorsals and interdorsals respectively.*
- *Gill arches which support/hold the gills lie internally to the gills and bronchial blood vessels, unlike the gill arches of all jawless craniates, which are external to the gills and blood vessels*
- *A horizontal semicircular canal in the inner ear*
- *Teeth - modified dermal scales*
- *More proficient predators than the jawless fish*
- *Paired nasal sacs*
- *We also described three classes of fishes namely i) Placodermi (extinct) as gnothostomes with well developed fins and armour plating, which consist of head and thoracic armours, ii) Chondrichyes as having cartilaginous endoskeleton while the iii) Osteichthyes have bony endoskeleton*

Review activities

Know that you have gotten a description of the super class Gnathostomes and three fish classes under it, attempt to:-

1. State three major characteristic features of Gnathostomes.

2. What is the distinguishing feature of each of the three fish classes?

3. Obtain fish from the market and attempt to classify as either cartilaginous or bony fish.

4. Describe features that aided your identification/categorization.

CHAPTER FOUR

LAND VERTEBRATES-TETRAPODS

Introduction

Tetrapods (Greek *tetrpodedona*, "on all fours"); (Greek *tetrpodesa*, correspondent to Latin *quadruped*, "four-footed") are vertebrate animals having four limbs. Amphibians, sauropsids and mammals are tetrapods. The ancestors of snakes, glass lizards and other limbless amphibians and sauropsids are tetrapods. The earliest tetrapods evolved from the lobe-finned fishes in the Devonian. They are now a dominant part of the terrestrial fauna, representing all known larger land animals. Some groups have even returned to an aquatic existence, including the largest animal known, the blue whale.

Unit objectives

At the end of this study unit, you should be able to:-

- *Describe the characteristic features and classifications of the tetrapods*
- *Recognize their basic difference among those tetrapods*

Recognize the origin of Tetrapods and their Fish ancestors

Lesson objectives

At the end of this study unit, you should be able to:-

- *Describe the characteristic features and classifications of Amphibians, Reptiles, Birds and Mammals*
- *List down their basic difference among Amphibians, Reptiles, Birds and Mammals*

4.1. Class Amphibians

In the previous two chapters, we examined the characteristics of fishes, which are aquatic throughout their life. In this unit, we shall be looking at animals that exhibit dual habitation of being able to live in both water and on land. These are the amphibians (amphi - meaning both). They represent an attempt by animals to colonize land from water. Accordingly, you will find that respiration by gills is being supported by moist skin and not too efficient lung system.

Amphibian, animal with moist, hairless skin through which water can pass in and out. Nearly all amphibians live the first part of their lives in water and the second part on land—a double life reflected in the name *amphibian*, which comes from the Greek words *amphi*, meaning "both," and *bios*, meaning "life." Amphibians were the first animals with backbones to adapt to life on land. They are the ancestors of reptiles, which in turn gave rise to mammals and birds.

Scientists recognize more than 5,000 species of amphibians, all of which are members of one of three main groups: frogs and toads, salamanders, or caecilians. Frogs and toads are the most abundant of all amphibians, numbering more than 4,000 species. Frogs have smooth skin and long limbs. Toads, in contrast, have warty skin and short limbs.

There are about 400 known species in the salamander group, which also includes newts and mud puppies. Members of this group have long, slender bodies ending in tails. Some salamanders live entirely on land, whereas others never leave the water, and still others spend some time in the water and some on land. Caecilians, with about 160 species, are the rarest of amphibians. They have no limbs and look much like earthworms. Most live underground and spend their time burrowing in the soil, but a few are aquatic.

4.1.1. Brief evolutionary history

The living representatives of this class include frogs, toads, newts, salamanders and limbless caecilians. The transition from aquatic to terrestrial living is clearly indicated in the class Amphibians. These were the first vertebrates to live on land. Amphibians are not

completely land adapted. They hover between aquatic and land environments. This double life is expressed in their name, amphibian. It is because of, these reasons 'the amphibians are considered, a defeated group 'smooth and slimy. The slimy nature is due to the presence of mucous secreting glands. Scales are practically absent.

The mouth is usually large with small teeth in upper or both jaws. The external nostrils communicate into the anterior part of the mouth cavity. Respiration is effected by gills, lungs, skin and pharyngeal region. The heart is three chambered with two auricles and a single ventricle. The skeleton is mostly bony, with varying number of vertebrae; exoskeleton is absent. Sexes are separate. Fertilization is either external or internal. The tadpole Metamorphoses into adult.

Examples: Frog, Toad, Salamander, Caecilian

The body forms vary greatly from an elongated trunk with distinct head, neck and tail to a compact, depressed body with fused head and trunk and no intervening neck. The forelimbs of frogs and toads are smaller than hind limbs. In frogs, hind limbs have webbed feet. Over the past 350 million years, amphibian descendents of lobe-finned fishes have radiated into most habitats on Earth. In doing so, they have acquired spectacular and sometimes bizarre physiological, morphological, behavioral, and ecological attributes that mold their innovative life histories. Amphibians have highly permeable skin, which makes them both vulnerable to losing water and able to absorb water. Their eggs, covered with jelly capsules rather than hard shells, lose water rapidly. For these reasons, amphibians require relatively moist environments. Amphibians are important components of species assemblages of many terrestrial ecosystems, often having a diverse number of species occupying a range of niches.

Amphibians are often considered to be good habitat indicators, given their usually relatively narrow environmental tolerance. The limited tolerance of amphibians means that populations can rapidly change in response to ecosystem change. Many sampling techniques have been developed in North America or Europe where most amphibians exhibit the complex life cycle of aquatic eggs, aquatic larvae, and metamorphosis into terrestrial adults that return to water to breed. Not all amphibians fit this stereotype. The

spectacular diversity of amphibian life histories provides a focus for studying their natural history, as well as presents a challenge since researchers must ensure Amphibians play a key role in energy flow and nutrient cycling because they serve as both predator and prey. By eating huge quantities of algae, tadpoles reduce the rate of natural eutrophication, the over-enrichment of water with nutrients, which leads to excessive algal growth and oxygen depletion. Most adult amphibians eat insects and other arthropods. As ectotherms, amphibians are efficient at converting food into growth and reproduction. Unlike endothermic birds and mammals that generate heat metabolically, amphibians expend relatively little energy to maintain themselves.

Paleontologists (scientists who study fossils) agree that amphibians must have evolved from the lobe-finned fishes, although for some years there has been considerable disagreement about whether the direct ancestors were coelacanths, lungfish, or the extinct rhipidistian fishes. Good arguments can be made for each. Many details of amphibian internal anatomy resemble those of the coelacanth. Lungfish and rhipidistians have openings in the tops of their mouths similar to the internal nostrils of amphib- ians. In addition, lungfish have paired lungs, like those of amphibians.

Recent DNA analysis indicates lungfish are infact far more closely related to amphibians than are coelacanths. Most paleontologists consider that amphibians evolved from rhipidistian fishes, rather than lungfish, because the pattern of bones in the early amphibian skull and limbs bears a remarkable resemblance to the rhipidistians. They also share a particular tooth structure.

The successful invasion of land by vertebrates involved a number of major adaptations:

- Legs were necessary to support the body's weight as well as to allow movement from place to place
- Lungs were necessary to extract oxygen from air. Even though there is far more oxygen available to gills in air than in water, the delicate structure of fish gills requires the buoyancy of water to support them and they will not function in air.

- The heart had to be redesigned to make full use of new respiratory systems and to deliver the greater amounts of oxygen required by walking muscles.
- Reproduction had to be carried out in water until methods evolved to prevent eggs from drying out.
- Most importantly, a system had to be developed to prevent the body itself from drying out.

General Characteristics of Class Amphibians

- Moist, glandular skin that lacks the keratinized scales of reptiles.
- Complex life cycles (adults, eggs, and larvae that metamorphose into juveniles).
- Non-amniotic eggs (they lack the amniotic membrane that surrounds the embryo).
- Amphibian eggs do not have a shell instead they are surrounded by several gelatinous layers.
- Gills at the larval stage and lungs at the adult stage. In many amphibians, the skin is also important in gas exchange.
- Amphibians are cold-blooded animals, meaning they do not have a constant body temperature but instead take on the temperature of their environment.

The moist, scale-less skin of amphibians absorbs water and oxygen from the surrounding atmosphere, but that also makes them vulnerable to dehydration (loss of bodily fluids). Without moist conditions, their skin dries out and they die. That explains why amphibians are most often found near ponds, marshlands, swamps, and other areas where freshwater is available. Some amphibians become inactive when conditions are unfavorable for survival. This period of inactivity is called aestivation when it occurs during hot, dry weather and hibernation when it occurs in response to cold temperatures. Activity resumes when favorable conditions return. The thin skin of amphibians contains many glands, among them poison glands that protect certain species against predators.

The poison from the glands of the brightly colored poison-dart frog is particularly toxic and is used by South American Indians to coat the tips of their arrows. Some amphibians

protect themselves from enemies by changing color to blend in with their surroundings i.e. they camouflage.

The life cycle of most amphibians begins in water when the female lays eggs that are fertilized outside of her body. The eggs then hatch into larvae (known as tadpoles), that breathe through external gills. The larvae grow flat tails and feed on vegetation. During a process called metamorphosis, physical changes occur and external gills give way to lungs. The tadpoles also change from plant-eating animals to meat eaters. Amphibians usually reach full adulthood at three to four years.

Classification of class amphibian

The class Amphibia is comprised of three orders which include the Gymnophiona (caecilians), Urodela (newts and salamanders) and Anura (frogs and toads).

Order: Anura (amphibians without tail)

The anurans are the largest group of living amphibians, comprising about 3,000 species. This order is made of the most common amphibians we come across in our environment. These include the frogs and toads.

Members of this order have the following characteristics:-

- Lack true tails in the adult form.
- Hind legs are longer than front limbs; and by this they are well adapted for hopping, jumping and swimming.
- Live in aquatic environment, although some are well adapted to drier habitats.
- Larval forms are called tadpoles lacking true teeth, are usually herbivorous, and develop hind limbs before front limbs (which is the opposite of Urodela larvae).
- Larvae also lack external gills, having opercular chambers that allow water to flow over internal gills, before exiting through a spiracle.

Frogs and toads differ; toads have drier skin that is warty (which enables adaption to drier habitats) in comparison to the smooth skin of frogs. Frogs also have longer and well pronounced webbed feet (that facilitate movement in water) than toads and are often in or near water. Frogs range in size, the smallest measuring about 1 inch (2.5 centimeters) and the largest (the West African Goliath frog) measuring more than 1 foot (about 30 centimeters). To a large extent, toads are the ones we see hopping around our surroundings especially during the rains. They are more tolerant to dry conditions than frogs, which are often in water or not too far from a water source. Frogs and toads live mainly on a diet of insects and other invertebrates. The largest frogs and toads also eat small mammals, birds, fish, and other amphibians.

Figure 16 Representative frogs

Order: Urodela (visible tail)

Members of this order (Urodela) are amphibians that have visible tail and they include the newts and salamanders.

The order is characterized by the following features:-

- A long true tail hence the name "Urodela" meaning "visible tail."

- The adults are shaped like eels
- Lack a tympanum (external ear drum)
- They have small and underdeveloped legs adapted to walking rather than jumping or hopping
- They breathe through external gills as well as lungs

Urodelas are usually found in or near water and often reside in moist soil under rocks or logs. The adults usually spend most of their time on land and have a diet consisting of insects and worms and burrow in mud at the bottom of marshes. They range in size from approximately 10 centimeters to the largest of all amphibians that is the giant salamander of Japan, which grows to more than 1.5 meters.

Figure 17 Mud puppies (unusual type of salamander)

Like most adult amphibians, mud puppies have lungs. But unlike most mature amphibians, they also have gills to breathe under water. The red spotted new lives in ponds and streams found in the eastern and central United States. In its larval stage, shown here, its skin is a bright reddish-orange. After reaching adulthood, its skin turns olive with red spots. Note that this amphibian can easily be mistaken for a reptile.

Order Gymnophiona (Caecilians)

Members of the order have the following characteristics:

- Lack legs (dig by ramming its bony head through the soft dirt).

- Worm-like in shape.
- Mistaken for a reptile.

The untrained eye may mistake this amphibian for a snake (reptile) or earthworm. Members of this order are blind and legless amphibians that are shaped like worms. They burrow in moist soil in tropical habitats of Africa and South America, feeding on soil invertebrates such as worms and insects. Some caecilians live in moist soil that is rich in decayed plant matter. They also live in leaf litter and sometimes even in the lower parts of plants. Other caecilians live in water all or most of the time. The burrowing movements of land-dwelling caecilians turn soil and thus keep it in good condition.

4.2.3. The life of Amphibians

Some fish evolved adaptations minimally adequate for life on dry land while retaining a need to reproduce in water. The class amphibia includes animals that partly live on land and partly in fresh water. The name amphibia was given to the group by Linnaeus and comes from two Greek words amphi meaning dual plus *bios* meaning life, indicating their dual life both in water and on land. They are the only living vertebrates that have a transition from water to land in both their ontogeny and phylogeny. Many amphibians reproduce in water, emerging from eggs as aquatic larvae, and later maturing into terrestrial, aquatic, or semi-aquatic adults.

Legs: some ancestral fish undoubtedly lived in shallow freshwater marshes and lagoons where they could find more food and deposit eggs “out of reach” of larger aquatic predators. For a fish even partially out of water, buoyancy would be diminished and more muscular and leg like fins would have been an enormous advantage.

Cutaneous respiration and lungs: extended visits to land would have been problematic for fish that extract oxygen from water moving through gill slits, and this selected for fish that could absorb more oxygen directly through their skin. Gulping air into pouches in the gut was another solution and these pouches eventually evolved into lungs.

Improved vascular system: larger muscles require more oxygen, and the heart and circulatory system allowed greater oxygen transport between the respiratory tissue and the body.

Characteristics of amphibians

Skeleton: in amphibians, as in other vertebrates, the well developed endoskeleton of bone and cartilage provides a framework for muscles in movement and protection for the viscera and nervous systems. The number of vertebrae in amphibians varies from ten in the salientia to approximately two hundred in gymnophiona.

Amphibians are the first vertebrates in which a sternum appears. Ribs present in some (in salamanders, caecilians and some toads) absent or fused to vertebrae in others. Ribs, however, are poorly developed and not attached to sternum. Amphibians have broad, flat skull, in contrast to that of most fishes. The frog skull is also vastly altered as compared with its vertebrate ancestors; i.e. it is much lighter in weight and more flattened in profile and has fewer bones and less ossification.

The front part of the skull, wherein are located the nose, eyes and brain, is better developed, where as the back of the skull, which contained the gill apparatus in fishes, is much reduced. Although in ancient amphibians there were numerous bones in the lower jaw, the number has been markedly reduced in living species. Most amphibians have fine teeth on the upper jaw and roof of the mouth; some salamanders have teeth on both jaw, but toads are toothless. Nearly all modern amphibians have teeth in which the crown and base (pedice) are composed of dentine and are separated by a narrow bone of uncalcified dentine of fibrous connective tissue. A few amphibians lack pedicellate teeth, including salamanders of the genus *Siren* and frogs of the genera *phyllobat*e and *cereatophrys*.

Body forms: It varies greatly from an elongated trunk, with distinct head, neck, and tail to a compact, depressed body with fused head and neck distinct, the trunk long and either cylindrical or depressed dorsoventrally, and a long tail, rounded to oval in land dwellers but fin-like in aquatic species. Toads and frogs have the head and trunk joined in a broad,

depressed body with no neck or tail. Caecilians are limbless and worm-like, with annulated bodies and their skin contains small internal scales.

The anuran body forms a more salamander-like starting point. Both jumping and swimming have been suggested as the mode of locomotion that made the change advantageous. Salamanders and caecilians swim as fishes do by passing a sine wave down the body. Anurans have inflexible bodies and swim with simultaneous thrusts of the hind legs. Some paleontologists have proposed that the anuran body form evolved because of the advantages of that mode of swimming. Another hypothesis traces the anuran body to the advantage gained by an animal that could rest near the edge of a body of water and escape aquatic or terrestrial predators with a rapid leap followed by locomotion on either land or water.

Amphibians possess two pair or four (tetrapod) pentadactyl (five-toed) limbs. However, there is considerable diversity to be found in modern forms as a result of their adaptation to terrestrial, aquatic, arboreal, and subterranean life. The caecilians which are confined to tropical parts of the world today are entirely limbless. Their bodies are superficially worm –like and modified for burrowing in humus and rotten wood.

Most modern caudate amphibian possesses four relatively weak limbs. Generally the front feet possess four digits and the hind feet five digits. Some species however show marked limb reduction. For example members of the genus *Siren* possess only pectoral limbs. Another genus *pseudobranchus* lack hind limbs and has the front toes reduced from four to three. Lack of hind and/or forelimb is a degenerate rather than a primitive condition. Although most salamanders are terrestrial or aquatic, some species are arboreal to some extent. In species that can climb trees, the toes are broadly expanded and truncate to enable them to cling the trunks, and the tail is somewhat prehensile. The limbs of frogs and toads in general are much more specialized than those of salamanders; the usual number of toes on the front limbs is four.

The hind toes and additional digits known as the prehallux on the inner side of the foot. In some prehallux forms the bony base of the sharp-edged tubercle used for digging. Many of the arboreal types of frogs have the tips of the toes enlarged and adhesive disk present on

the undersurface. Claws are generally lacking. However, these may be horny, epidermal growth on the tip of toes (protuberances). There is considerable variation concerning webbing on the hind feet of anurans. In some species the webbing is complete and extends to the tips of the toes, whereas in others it may be present in varying degree or even entirely absent.

The skin of amphibians is usually smooth: In some of the aberrant caecilians, however, there are small scales embedded beneath the surface, but in all others, scales are absent. The skin is kept soft and moist by the presence of numerous mucous glands. Even in aquatic species the mucus serves to lubricate the body. There are some amphibians that develop glands on the snout and back before hatching, and the secretion serves to break down the egg capsules at the time of hatching.

Most amphibians possess granular glands (poison glands) in addition to mucous glands. Although the two are quite similar in many respects, the granular glands produce the poisonous secretions, which protect these animals from enemies. Both the mucous and poison glands are classified as alveolar glands. In addition, however, some amphibians possess tubular glands. These are often formed on the thumbs of some frogs and toads and occasionally on the chest, and produce a sticky secretion, which assists the male in holding on tightly to the female during amplexus. In amphibians, and in fishes, pigment is located in pigment cells or chromatophores in the skin, and these pigment cells are usually named according to the type of pigment that they contain.

Melanophores contain various black and brown pigments and lipophores contain red, yellow, and orange pigments. They also possess cells called guanophores that contain crystals of guanine (one of the nitrogenous bases of nucleic acid) that may produce either iridescence or a white effect. Generally the lipophores are closest to the surface of the skin, beneath these are the guanophores; the melanophores are deepest. Coloration of amphibians is protective.

Respiration: Amphibians have more means for respiration than any other animals. This reflects their transitional place between aquatic and land habitats. During the larval or tadpole stage, most amphibians respire by means of gills. Three pairs of external gills

occur in the embryo or larvae of all amphibians and persist in the adults of some strictly aquatic salamanders. Most amphibians respire to some extent through the skin and some salamanders, which lack both lungs and gills as adults, obtain oxygen entirely through the skin and the oral epithelium (buccopharyngeal). This means that the skin must be kept moist. In terrestrial amphibians this is accomplished by the numerous mucous glands distributed over the surface of the body.

Amphibians are the lowest vertebrates with lungs. The lungs are usually simple sacs with a few shallow internal partitions that contain blood vessels. Reduction of lungs has occurred in some salamanders that inhabit swift mountain streams, and lungs are absent in the American land salamanders (*Plethodentidae*). Frogs and toads show a much great dependence on lung breathing than do salamanders. However, the skin continues to serve as an important supplementary site for gas exchange in anurans, especially during hibernation in winter.

Circulation: As in fish, circulation in amphibians is a closed system of arteries and veins serving a vast peripheral network of capillaries through which blood is forced by the action of a single pressure pump, the heart. In fish that respire entirely by means of gills, only deoxygenated blood is received by the heart, which pumps it forward to the gill region and the oxygenated blood goes to the different parts of the body and returns to the heart after giving off oxygen. In amphibians (and other vertebrates) the principal change in circulatory involves the shift from gill to lung breathing. With the elimination of gills, a major obstacle to blood flow was removed from the arterial circuit. But two new problems arose. The first was to provide a blood circuit to the lungs. This problem was solved by converting the sixth aortic arch into pulmonary arteries to serve the lungs and developing new pulmonary veins for returning oxygenated blood to the heart.

The second and evidently more difficult evolutionary problem was to separate the pulmonary circulation from the rest of the body's circulation. Oxygenated blood from the lungs would be selectively sent to the body and oxygenated venous blood that return from the body would be selectively sent to the lungs.

Tetrapods solved the problem by evolving a partition (inter atrial septum) down the center of the heart, creating a double pump, one for each circuit (pulmonary and systemic). Amphibians and reptiles have made the heart separation to varying degree. Amphibians possess three-chambered heart, the auricle completely divided to form two atrial and a single undivided ventricle.

Temperature regulation: Amphibians are ectotherms. Their body temperature is determined by and varies with the environment, i.e., they depend on their environment as a source of heat. During intense cold (cold season) amphibians go to deep steep, the phenomenon called hibernation or winter sleep. For example during cold season frogs bury themselves deep into the ground and take rest.

Excretory system: The most important organs of excretion in amphibians are kidneys. Adult amphibians have paired mesonephric kidneys. Pronephric kindney develops in the larva of amphibians. This degenerates at or before metamorphosis and is replaced by the tubule of mesonephros. Therefore, the mesonephric kidney or Wolffian body is the second excretory organ to arise.

In tailed amphibians, the kidneys are rather elongated structures, but in anurans there is a tendency for these structures to be short and compact. Since many amphibians live partly or entirely in fresh water, we find that they have developed large renal (kidney) corpuscles to assist in the elimination of water and thus prevent excessive dilution of the body fluids.

Nervous system: The nervous system of amphibians is basically like that of fishes. The spinal cord, the peripheral nerves and the autonomic nervous systems are essentially similar. However, the three fundamental parts of the brain, i.e., forebrain (telencephalon) concerned with the sense of smell; midbrain (mesencephalon), concerned with vision; and hind brain (rhombencephalon) concerned with hearing and balance; have undergone dramatic developmental trend as the vertebrates move onto land and improved their environmental awareness.

The center of brain activity remains in the dorsal part of the midbrain, where the gray cells are concentrated in what is called the tectum. The forebrain is largely olfactory (sense of

smell) in nature, but for the first time in vertebrates, we find nerve cells invading the pallium. Although these cells are internal in location, the result is a definite enlargement of the cerebral hemispheres.

Bothe parietal and pineal bodies are present although, in living amphibians, neither penetrates the cranial roof. Since members of this vertebrate class (living amphibians) are notably slow and sluggish in their movement, the cerebellum is very small. Except in the caecilians, flexures are lacking in the amphibian brain. In general there is only ten pair of cranial (spinal) nerves in amphibians.

Reproductive system: The reproductive system of amphibians has the function of producing the sex cells and transporting them outside the body. Amphibians have separate sexes (either male or female). The primary sex organs, ovaries in females and spermaries or testes in males perform the function of producing the sex cells. While the ovaries and testes are homologous organs, the sexual products are carried to the outside in the two sexes by very different method. The amphibian ovaries are paired and contain a cavity within them that is filled with lymph. Although the oviducts are also paired, in some forms the lower end of each oviduct is enlarged into a uterus-like structure or ovisac.

The ovisac serves as a temporary storage space for ova before they are shed or, in a few species that are ovoviviparous, for the development of the young. Glands that secrete a jelly-like covering for the eggs are usually situated along the oviduct. Oviparous amphibians lay **mesolectral** (moderately yolky) eggs with jelly-like membrane coverings. The testes, like ovaries, are paired and are connected either directly or by way of mesonephric tubules to the archinephric ducts which in turn open into cloaca. No special copulatory organs are present. In some toads there is a structure called Bidder's organ located anterior to each testis.

Under certain circumstances this may develop in to an ovary. Unusual fact is that old females sometimes may produce sperm. In the ancestral life history of amphibians, eggs are aquatic and hatch to produce an aquatic larvae form that use gills for breathing. A metamorphosis follows in which gills are lost and lungs, which are present throughout

larval life, are then activated for respiration. Many amphibians retain this general pattern but there are some exceptions. Some salamanders lack a complete metamorphosis and retain a permanently aquatic, larval morphology throughout life. Others live entirely on land and lack the aquatic larval phase completely. Both of these are evolutionarily derived conditions. Some frogs also have acquired a strictly terrestrial existence by eliminating the aquatic larval stage.

The most dramatic example of metamorphosis in amphibians is found among anurans, where almost every tadpole structure is altered. Anuran larval development is generally divided into three periods:

I. **During premetamorphosis period:** tadpole's increase in size with little change in form;
II. **Prometamorphosis:** the hind legs appear and growth of the body continues at a slower rate; and;
III. **Metamorphosis period:** the forelegs emerge and the tail regresses. These changes are stimulated by the action of thyroxin, and production and release of thyroxin is controlled by a product of the pituitary gland, thyroid-stimulating hormone.

Sensory structure: All amphibians have a special sensory area, the **papilla amphibiorum,** in the wall of the sacculus of the inner ear. The papilla amphibiorum is sensitive to frequencies below 1000 hertz (cycles per second), and a second sensory area **papilla basilaris,** detects sound frequencies above 1000 hertz.

Salmenders and frogs have a distinct type of retinal cell, the **green rod**. Caecilians apparently lack green rods, but the eyes of caecilians are extremely reduced and these cells may have been lost. Most amphibians have two bones that are involved in transmitting sound to the inner ear. The columella (plectrum) is derived from the hyoid arch and is present in Salamanders and caecilians and in most frogs. The operculum develops in association with the fenestral ovalis of the inner ear. The columella and operculum are fused and form operculumplectrum complex in anurans and caecilians and in some salamanders.

Structure of the bulbi muscle: This muscle is a thin sheet in the floor of the orbit that is innervated by the fifth cranial nerve. It causes the eyes to bulge outward, thereby enlarging the buccal cavity. This muscle is present in salamanders and anurans and in modified form in caecilians.

Activities

1. Define and characterize Amphibians?
2. Explain and classify Amphibians?

Summary

- *In this study unit, we have described amphibians as vertebrates and gnathostomes with the following features:-*
- *Moist, glandular skin that lacks the keratinized scales of reptiles.*
- *Complex life cycles (adults, eggs, and larvae that metamorphose into juveniles).*
- *Non-amniotic eggs (eggs lack the amniotic membrane that surrounds the embryo).*
- *Eggs without a shell but instead surrounded by several gelatinous layers.*
- *Gills at the larval stage and lungs at the adult stage for respiration. In many amphibians, the skin is also important in gas exchange.*
- *Cold-blooded animals, meaning that they do not have a constant body temperature but instead take on the temperature of their environment.*
- *We also described three orders in the class Amphibia i.e.: i) Anura - as amphibians without tails in the adult stage ii) Urodela - as amphibians with tails, and iii) Gymnophiona - worm-like and without legs.*

Review activities

1. Look around your environment for animals you consider as amphibians. Give reasons for listing each as an amphibian?

2. Attempt to place each amphibian identified in your environment to its appropriate class.

3. Attempt to locate a toad or frog. Describe its habitat and body features.

4. Looking at the physical appearance of members of Urodela and the Gymnophiona, you will mistake them for reptiles? Why are they not so regarded as reptiles but instead amphibians?

CHAPTER FIVE

AMNIOTES

Introduction

The tetrapods like reptiles, birds and mammals are referred to as amniotes. The amniotes have certain membranes associated with embryos inside the egg. It is an adaptation in terrestrial forms during development.

These membranes are the amnion; chorion and allantois.Amniotes are a group of tetrapod vertebrates that lay eggs that are specially adapted to survive in a terrestrial environment. These eggs are referred to as amniotic eggs. Amniotes include all present day reptiles, birds, and mammals. Amniotes evolved about 340 million years ago during the Carboniferous Period. They arose from a group of lizard-like amphibians called the amphibian reptiliomorphs. In this section of our study, we shall be looking at a group of vertebrate gnathostomes called reptiles that, unlike the amphibians, have successfully found habitation on land. This is supported by the dry skin which prevents loss of water from the body of the animal.

Some reptiles live in water but return to land to lay eggs which, unlike the eggs of amphibians that is laid in water, have a shell covering that also protects against desiccation. Furthermore, unlike the situation in amphibians, the embryo in the eggs of reptiles is protected by a thin membrane called the amniotic membrane. (If you break the chicken egg, especially the boil egg, you will find a thin membrane just beneath the shell that is the amniotic membrane in birds).

So we can rightly say that the amniotic membrane finds its genesis in reptiles. The ability of reptiles to colonize land is also supported by efficient lungs at the adult stage, which enhance respiration as against the use of gills and moist skin in many amphibians. Reptiles are animals we see quite often the most common being the lizards. Others include geckos, crocodiles, snakes and tortoises.

Unit objectives

At the end of this chapter, you will be able to:-

- Define what amniotes are?
- Explain the concept of amniotic egg and its survival advantage
- Describe the characteristic features of reptiles.
- Recognize reptiles when you see them.

5.1. ORIGIN OF THE AMNIOTIC EGG AND ITS STRUCTURE

Amniotes are a monophyletic group that appeared and diversified in the late Paleozoic. Most zoologists agree that amniotes are most closely related to anthracosaurs, a group of an amniotes (vertebrates lacking an amnion) of the early Carboniferous period. Anthracosaurs were better adapted for terrestrial life than most other an amniotes, and sometimes initially mistaken for early reptiles.

Their diet probably consisted mostly of insects, which had radiated into diverse forms by the Carboniferous. *Diadectes* is the most likely sister taxon of amniotes, and interestingly enough, may be the only completely herbivorous an amniotic tetrapod, past or present. The first amniotes were small and lizard like, but quickly underwent an adaptive radiation by the early Permian period into forms diverse in morphology, feeding biology, and use of habitats.

Early diversification of amniotes produced three patterns of holes (fenestrate) in the temporal region of the skull. Anapsid (Gr. *an,* without, *apsis,* arch) skulls have no openings in the temporal area of the skull behind the orbit (opening in the skull for the eye); thus, the temporal region of the skull is completely roofed by dermal bones. This skull morphology was present in the earliest amniotes, and in one living group, the turtles, although the anapsid condition in turtles likely evolved secondarily, from ancestors having temporal

fenestra. Two other amniotes clades, Diapsida and Synapsida, represent separate evolutionary derivations from the ancestral anapsid condition. The diapsid (Gr. *di*, double, *apsis*, arch) skull has two temporal openings: one pair located low over the cheeks, and a second pair positioned above the lower pair, in the roof of the skull, and separated from the first by a bony arch.

Diapsid skulls are present in birds and all amniotes traditionally considered "reptiles," except turtles. In many living diapsids (lizards, snakes, and birds) one or both of the bony arches and openings have been lost, perhaps to facilitate skull kinesis. The earliest diapsids gave rise to five morphologically distinct clades. The lepidosaurs include most of the living reptiles, including lizards, snakes, and tuataras. The archosaurs include dinosaurs, pterosaurs, and living crocodilians and birds. A third, smaller clade, the sauropterygians, includes several extinct aquatic groups, the most conspicuous of which are the large, long-necked plesiosaurs. Ichthyosaurs, represented by extinct, aquatic dolphinlike forms, form a fourth clade of diapsids. Placement of the last clade, the turtles, in the diapsid clade is controversial, although we treat turtles as highly modified members of the clade Diapsida here.

Turtle morphology is a mix of ancestral and derived characters that has scarcely changed since they first appeared in the fossil record in the Triassic some 200 million years ago. Turtle skulls lack temporal fenestra and are often considered tobe the only living descendants of parareptiles, an early anapsid group. However, other morphological and genetic evidence published over the past 15 years places turtles within the diapsid clade, suggesting that the two pairs of temporal fenestra characteristic of diapsids were lost early in turtle evolution. The relationship of turtles to other diapsids is unclear; morphology of the appendicular skeleton suggests affinities with lepidosaurs, but genetic evidence suggests affinities with archosaurs.

The third skull fenestration condition is synapsid (Gr. *syn*, together, _ *apsis*, arch), characterized by a single pair of temporal openings located low on the cheeks and bordered by a bony arch. The synapsid condition occurs in a clade that includes mammals and their extinct relatives, the therapsids and pelycosaurs. Synapsids were the first amniote group to

undergo extensive adaptive radiation and were the dominant large amniotes of the late Paleozoic.

What was the functional significance of the temporal openings in early amniotes? In living forms these openings are occupied by large muscles that elevate (adduct) the lower jaw. Changes in jaw musculature might reflect a shift from suction feeding in aquatic vertebrates to a terrestrial feeding type that required larger muscles to produce more static pressure, for doing activities such as nipping plant material with the anterior teeth, or for grinding food with the posterior teeth. Amniotes exhibit considerably more variation in feeding biology than an amniotes, and herbivory is common in many amniotes lineages.

Although the functional significance of the evolution of temporal openings in amniotes is not fully understood, it is clear that expansion of the jaw musculature of amniotes must have been important. Even in fenestra-lacking turtle skulls, imaginations (notches) in the temporal area of the skull provide room for large jaw muscles.

LAYERS:

Egg shell: outermost layer with pores for aeration

Albumin: Provides embryo with protection, water, protein

Yolk sac:

- Yolk is energy supply for the embryo.
- Embryo starts as a few cells on the yolk. As embryo grows, endodermal and mesodermal tissues surround the yolk and make the yolk sac.

Chorion

- Surrounds entire contents of egg

Amnion

- Inner membrane surrounds only the embryo

Allantois

- Grows out from hindgut posterior to yolk sac and is inside chorion.
- Storage of nitrogenous waste
- Urinary bladder grows out from base of allantois.

- Allantois serves in respiration because it is vascularized and transports oxygen from egg surface to embryo and carbon dioxide from embryo to egg surface.

Why amniotic eggs?

- Extra-embryonic membranes and shell improve respiration for the embryo and shell provides mechanical support. This allows much larger eggs and larger hatchlings.
- Amniotic egg internal structures

Figure 18 External View of an amniotic egg

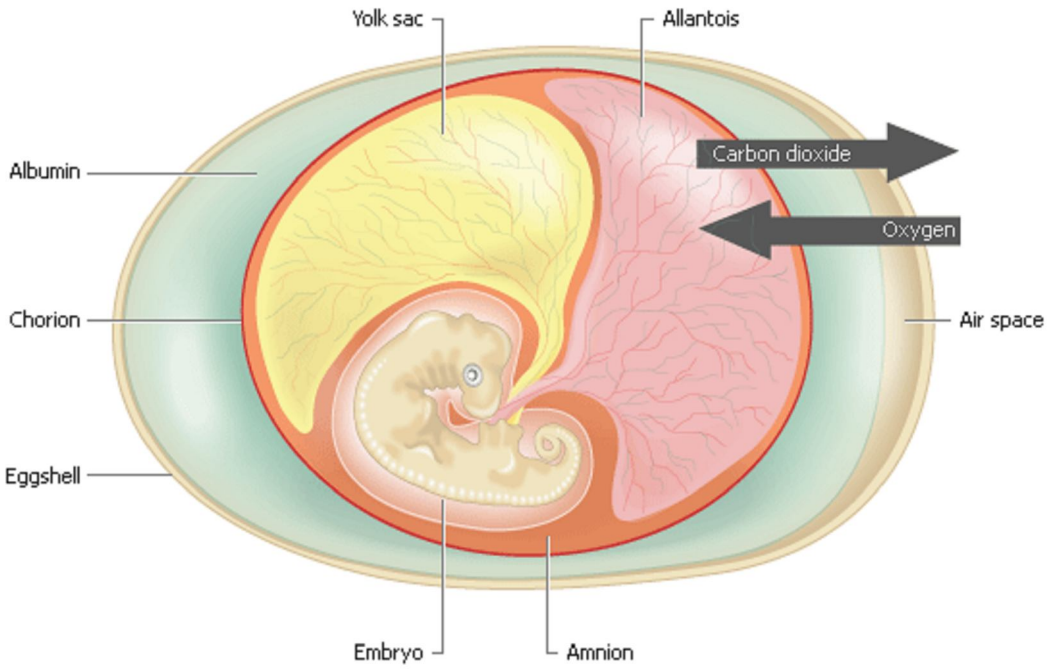


Figure 19 Structure of the egg

Evolutionary perspectives

Today, amniotes are represented by mammals, turtles, lizards, snakes, *Sphenodon*, crocodiles and birds. All these animals lay an amniotic egg or did so primitively. The embryos of viviparous amniotes (therian mammals and some snakes) retain the extraembryonic membranes found in the amniotic egg (the allantois, chorion and amnion; the allantois is a bladder storing metabolic wastes. It absorbs water from the environment because of the high osmotic pressure of its fluids and helps gas exchange.

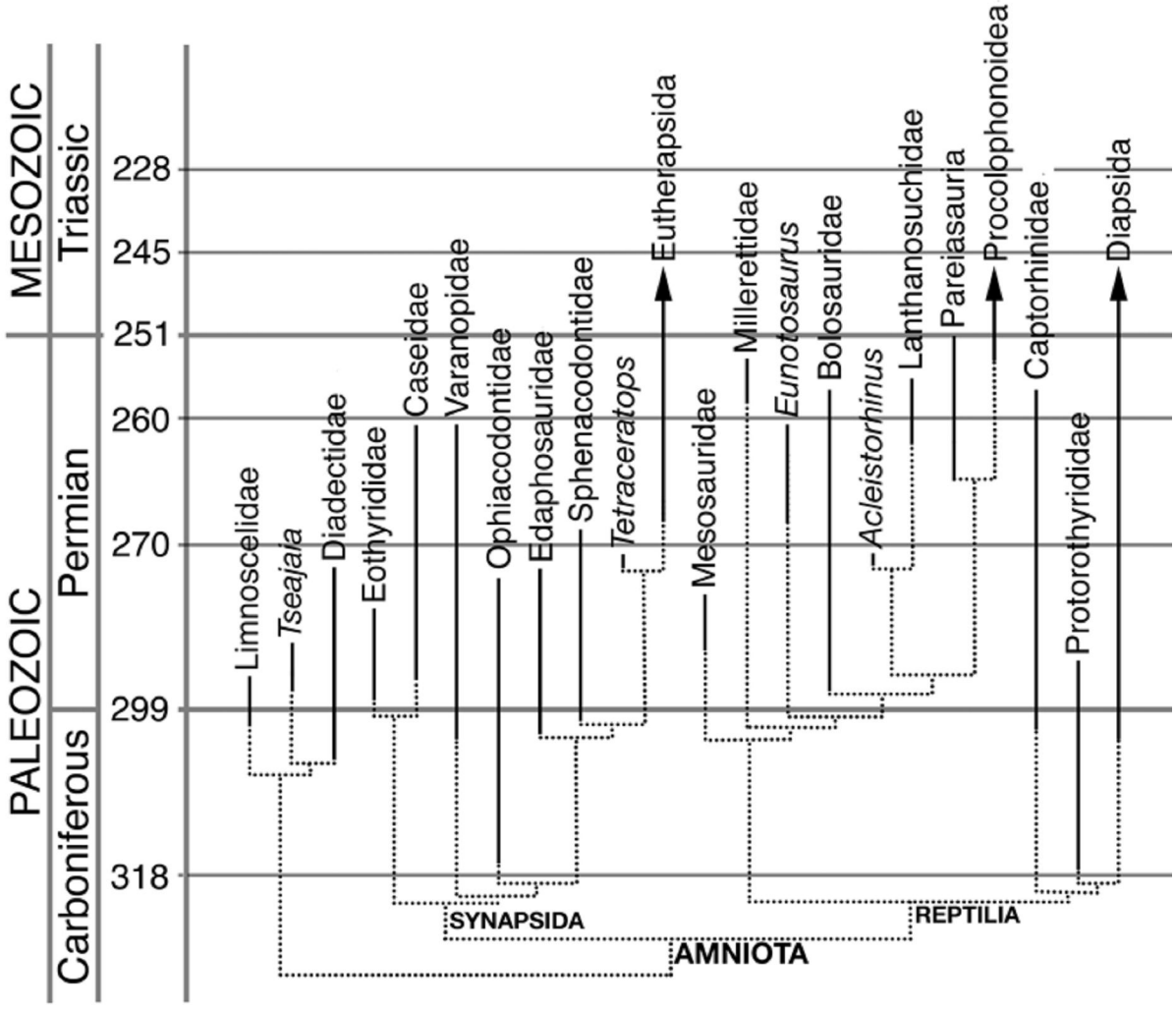
The chorion provides a surface for gas exchange with the outside, while the amnion stores food reserves). Amniotes are the only tetrapods able to reproduce effectively away from the water. We have no direct evidence of amniotic egg before the Mesozoic, but Paleozoic amniotes must have laid similar eggs because all their descendants do. Paleozoic amniotes share several osteological synapomorphies with later amniotes. These include:

Postparietal, tabular and supratemporal are no longer part of the skull table but are integrated to the occiput. There is a row of large teeth on the posterior edge of the transverse flange of the pterygoid.

The teeth are not infolded (not labyrinthodont). There is a well developed neck between the head and the shoulder girdle. There is an astragalus and a calcaneum in the tarsus. There are no more than two centralia in the foot.

Amniotes can be divided into two large groups: synapsids and reptiles.

Synapsids include mammals and all fossil amniotes more closely related to mammals than to reptiles. We will study synapsids later. Reptiles include testudines, diapsids (including birds), and all the fossil amniotes more closely related to them than to mammals.



Thus, Reptilia include mesosaurids and reptiles (in our taxonomy, birds are reptiles because their ancestors were reptiles). Reptiles share the following derived characters: Presence of a single coronoid bone. There are two coronoids in the lower jaw of synapsids, and most early non-amniote tetrapods had three coronoids. Presence of a single pedal centrale. There are two centralia in the foot of synapsids and diadectomorphs.

Mesosaurs are the first fully aquatic amniotes. They are known from the Permian of southern Africa and eastern South America. Their presence on both sides of the Atlantic has been used to support the theory of continental drift. Their snout was very long and long teeth extended anteriorly (near the tip of the snout), laterally (on the anterior half of the

sides of the snout) and ventrolaterally (on the posterior half of the sides of the snout) from the upper jaw. The dentition seems to have formed a basket for filtering water and capturing small invertebrates. The neck is long, an adaptation of several aquatic amniotes, and there are 10 cervical vertebrae. The tail was long and laterally compressed. It was probably used for swimming. The trunk ribs are pachyostotic; they were very thick and heavy. They served as ballasts. The scapular blade was very short, as in several other aquatic amniotes. All other reptiles are either related to turtles or to diapsids (including birds). We will call Reptilia the clade including the last common ancestor of turtles and diapsids, and all its descendants. The Reptilia is diagnosed by the following derived characters:

A reduction in size of the tabular. The appearance of a suborbital foramen between the pterygoid, palatine and ectopterygoid (when present) or jugal. The Reptilia can be divided in two major groups, the Parareptilia and the Eureptilia. The Parareptilia includes turtles and their close relatives, while the Eureptilia includes diapsids and their close fossil relatives.

We will study parareptiles first. They include four main groups; millerettids, pareiasaurs, procolophonids, and turtles. They are united by the following synapomorphy:

A dorsally enlarged quadratojugal bordering the quadrate emargination. The quadratojugal is a low, triangular element in other early amniotes.

Millerettids appear at the beginning of the Upper Permian. They were small, insectivorous animals superficially similar to lizards. Several millerettids have either a lower temporal fenestra or a deep cheek emargination. They have a quadrate emargination supporting a tympanum. Millerettids were the first amniotes to acquire a tympanum. This tympanum is homologous to the tympanum of turtles but it is not homologous to the tympanum found in diapsids, in mammals or in frogs and temnospondyls.

Pareiasaurs were large, herbivorous amniotes. They lived in the Upper Permian in Africa, Western Europe, Russia and China. They were among the largest Paleozoic amniotes; they reached a length of 3 m. They were covered by an extensive armor of osteoderms (dermal

bony scales). Their skull was massive, broad and had strange bony processes in the cheek and lower jaw. They probably had a parasagittal posture. Their scapular blade was very high. They had a reduced phalangeal formula in the foot, a character advantageous for an animal having a parasagittal posture.

They share with turtles and procolophonids a reduction in width of the **supraoccipital** (it is reduced to a vertical pillar). A high **prearticular** and dorsally opened adductor fossa. The prearticular is narrow and the adductor fossa faces medially in most other amniotes. Only four **distal tarsals** (instead of five).

Procolophonids were small and primitively insectivorous, as millerettids were, but late procolophonids have transversely broad teeth that may indicate a herbivorous diet. Procolophonids appear in the fossil record at the very end of the Upper Permian and became extinct at the end of the Triassic. The orbit is expanded posteriorly, especially in late procolophonids. Reisz and Laurin (1991) showed that procolophonids share thefollowing derived characters with turtles:

The **stapes** is a light rod without a foramen or a dorsal process. A broad contact between the prefrontal and palatine. A high coronoid process composed of coronoid only.

A splenial excluded from the symphysis. The last procolophonids had strange bony processes and their orbit was much longer posteriorly than the orbit of early procolophonids. The Upper Triassic procolophonid *Hypsognathus* is a good example of a late procolophonid.

Testudines are the only surviving parareptiles. They appear in the fossil record in the Upper Triassic, but they must have been present since the Upper Permian, because this is when their sister-group, the Procolophonidae, appears in the fossil record.

- ✓ The oldest known turtle is ***Proganochelys***, from the Upper Triassic of Germany.
- ✓ *Proganochelys* shares several **derived** characters with later turtles:
- ✓ No marginal teeth.

- ✓ No postparietal.

An expanded posttemporal fenestra allowing the jaw muscles to become longer and stronger (they take their origin on the occiput).

A **carapace** and plastron incorporating the interclavicle (entoplastron) and clavicles

(epiplastron). Posterior to the clavicle and interclavicle, there are dermal plastral elements. Dorsally, the carapace is composed of neural plates above the vertebrae, costal plates above the ribs, and marginal plates at the edges of the carapace. Horny, epidermal scutes overlap these dermal bones to strengthen the carapace and plastron.

- ➢ Only 10 trunk vertebrae (not including cervicals)
- ➢ Ribs external to the girdles
- ➢ No cleithrum A gracile scapulocoracoid and pelvic girdle
- ➢ *Proganochelys* retains **primitive** characters lost in most other turtles
- ➢ Lacrimal
- ➢ Supratemporal
- ➢ Denticles on vomer, palatine and pterygoid
- ➢ A paired vomer
- ➢ Mobile basicranial articulation
- ➢ Paroccipital process only loosely attached to squamosal
- ➢ Interpterygoid vacuity

Later turtles belong to one of the two main groups of turtles, the Cryptodira and Pleurodira. These names refer to the way in which these turtles retract their neck into their carapace. Cryptodires bend their neck vertically whereas pleurodires bend it laterally. The adaptations of the cervical vertebrae allowing the neck to be retracted were present by the Late Cretaceous, but these two groups are probably older than that because there are shells

with fused pelves (indicating that they belonged to a pleurodire) in the Upper Triassic and Upper Jurassic.

Captorhinids were one of the most successful group of early amniotes. They appear in the fossil record in the Lower Permian and became extinct in the Upper Permian. They were a cosmopolitan group. Early captorhinids had a single row of marginal teeth, but soon after the appearance of the group, several captorhinds had several marginal tooth rows in the upper and lower jaws. Some had up to 12 rows. The rows resulted by medial additions of teeth while the lateral teeth were not resorbed or lost.

Captorhinids were once believed to be closely related to turtles, because they have no ectopterygoid and no tabular and because there is a medial alary process on the jugal. Even though these characters are also found in turtles, other early amniotes share more derived characters with turtles than captorhinids, so captorhinids are no longer believed to be closely related to turtles. However, captorhinids are related to diapsids.

Protorothyridids are a group of small (100 mm snout-vent length), lizard-like reptiles. We are not certain that they are a monophyletic group. They are probably closely related to diapsids because both groups have long and slender hands and feet (they are broad and robust in other amniotes). They are some of the oldest known amniotes; the oldest protorothyridid is *Hylonomus* from the Middle Pennsylvanian of Joggins, Nova Scotia. The best known protorothyridid is *Paleothyris*. They resembled a bit early captorhinids, but they had more slender limbs (fig. 10-8) and narrow neural arches (fig. 10-6c, d). Carroll believes that they are ancestral to most other amniotes or that they represent the primitive morphotype of amniotes, but this is not supported by the latest phylogenetic analyses of amniotes or by simple out-group comparisons with diadectomorphs. Therefore, very few people agree with Carroll on this.

Derived Characters of Amniotes

Amniotic egg: All amniotes have eggs with four extra embryonic membranes, the amnion, allantois, chorion, and yolk sac. The amnion encloses the embryo in fluid, cushioning the

embryo and providing an aqueous medium for growth. Metabolic wastes are stored in a sac formed by the allantois. The chorion surrounds the entire contents of the egg, and like the allantois, is highly vascularized. Thus, the chorion and allantois form an efficient respiratory organ for removing carbon dioxide and acquiring oxygen.

Most amniotic eggs are surrounded by a mineralized but often flexible shell, although many lizards and snakes and most mammals lack shelled eggs. The shell forms an important mechanical support, and especially for birds, a semipermeable barrier, which allows passage of gases but limits water loss. Like eggs of anamniotes, amniotic eggs have a yolk sac for nutrient storage, although the yolk sac tends to be larger in amniotes. In marsupial and placental mammals, the yolk sac does not store yolk, but it may form a temporary or persistent yolk-sac placenta to transfer nutrients, gases, and wastes between the embryo and mother.

How did the amniotic egg evolve? It is tempting to think of the amniotic egg as *the* land egg. However, many amphibians lay eggs on land and many amniotic eggs, such as those of turtles, must be buried in wet soil or deposited in areas of high humidity. Still, amniotic eggs can be laid in places too dry for any amphibian; clearly the evolution of amniotic eggs was a major factor in the success of tetrapods on land.

Perhaps a more important selective advantage of the amniotic egg was that it permitted development of a larger, fastergrowing embryo. An amniotes eggs are supported mainly by a thick jellylike layer. This jelly layer is inadequate to support large eggs and limits movement of oxygen into the eggs. One hypothesis suggests that a first step in the evolution of the amniotic egg was replacement of the jelly layer with a shell, which provided better support and movement of oxygen. Furthermore, calcium deposited in the shell can be dissolved and absorbed by the growing embryo, to provide one of the raw materials needed for skeleton construction. This hypothesis is supported by physiological studies, which show that embryos of species with the smallest amniotic eggs have a metabolic rate about three times that of embryos of an amniotes with eggs of the same size. All amniotes lack gilled larvae and have internal fertilization.

These characteristics, along with the amniotic egg, eliminated the need for aquatic environments during reproduction. Shelled amniotic eggs require internal fertilization because sperm cannot penetrate the shell. Internal fertilization in amniotes is accomplished with a copulatory organ, except for tuataras and most birds, which transfer sperm by pressing their cloacae together. The most common copulatory organ in amniotes, a penis derived from the cloacal wall, appears to be another amniotes innovation.

Rib ventilation of the lungs: Amphibians, like air-breathing fishes, fill their lungs by *pushing* air from the oral and pharyngeal cavities into the lungs. In contrast, amniotes *draw* air into their lungs (aspiration) by expanding the thoracic cavity using costal (rib) muscles or pulling the liver (with other muscles) posterior. This shift from positive to negative ventilation probably influenced the evolution of amniotes limbs. Early tetrapods used their rib muscles to make lateral undulations, causing a wriggling motion not unlike that of elongate fishes. Enlargement and mechanical rearrangement of the limbs enabled more efficient locomotion of amniotes, particularly for those with large bodies, while allowing rib muscles to serve a primary function in lung ventilation. However, we note that limbs are not required for terrestrial locomotion as some amniotes, such as snakes and amphisbaenas, are very successful with no limbs at all.

Thicker and more waterproof skin: Although the skin varies widely in structure among living amniotes and anamniote tetrapods, amniote skin tends to be more keratinized and less permeable to water. A wide variety of structures composed of keratin, such as scales, hair, feathers, and claws, project from amniote skin, and the epidermis itself is more heavily keratinized. Keratin gives the skin protection from physical trauma, and lipids in the skin limit water loss through the skin. Reptiles uniquely have a form of keratin called beta keratin. This especially hard form of keratin is in reptile scales and scutes, bird feathers, and other reptile epidermal structures.

Keratin and lipids limit the skin's ability to exchange respiratory gases so, unlike most amphibians; few amniotes use their skin as a primary respiratory organ. Amniotes gas exchange takes place primarily in the lungs, which have considerably more surface area than antimonite lungs.

5.2 Class Reptilia: The first amniotes

Lesson objectives

At the end of this lesson, you will be able to:-

- *Describe the characteristic features of reptiles*
- *Recognize reptiles when you see them*

Reptiles are cold-blooded vertebrates, which breathe by lungs throughout their existence and poses dry skin covered by scales. They are the first animals to fully escape a dependence upon the availability of an open body of water**.** The following adaptations are the points performed in their transition to reptiles:

Amniotic eggs: Is one of the most important evolutionary innovations. In reptilian eggs, the embryo develops within an internal watery compartment, the amnion chamber, provided with a large nutritional supply (in the yolk sac), and surrounded by a tough outer shell.

Internal fertilization: A shelled egg layed on dry land can no longer be fertilized by sperm swimming freely in water. Internal fertilization allows sperm to swim to the eggs in the moist interior of the female's body, and for fertilization to occur before the hard shell is added around the egg.

Breathing: Muscles of the rib cage expand and contract to pump larger quantities of air into larger, more advanced lungs.

5.2.1. Brief evolutionary origin

Reptiles are emerged from amphibian-like creatures. In the age of reptiles (lasted for greater than 165 million years) a great radiation of reptilian lineages with various terrestrial and aquatic appeared from. Among these some are extinct (e.g. dinosaurs) at the end of Mesozoic era. Among the few reptilian lineages to emerge from the extinction are today's (living) reptiles. The evolutionary origin of amniotes occurred by the evolution of an

amniotic egg that made reproduction on land possible, although this egg may well have developed before the earliest amniotes had ventured for on land.

The amniotes that includes the reptiles, birds, and mammals, are a monophyletic group that evolved in the late Paleozoic. Most paleontologists agree that the amniotes (reptiles, birds and mammals) arose from a group of amphibian-like tetrapods, the anthracosaurs, during the early Carboniferous period of the Paleozoic. The extinct progenitors of reptiles are cotylosaurs; which have been referred to as the "stem-reptiles". The first traces of these are found in the carboniferous, in the deposits formed in the great coal swamp when the amphibians were at the peak of their development. According to the most accepted view *Seymouria* of pre-carboniferous is the ideal stem-reptile. It forms a good structural link between labyrinthodont amphibians and primitive reptiles. It possesses characters both of amphibians and reptiles. Some authors consider it to be a reptile-like amphibian while there are others who call it amphibian-like reptile. That means the *Seymouria* was an amphibian, which was almost a reptile, or it was a reptile, which has just ceased to be amphibian. This controversy emphasized that this animal connects the two groups, amphibians and reptiles. The above-mentioned fact is an induction that reptiles were emerged from labyrinthodont amphibians.

Characteristics of Class Reptilia (lizards, crocodiles, snakes, tortoises)

- Dry skin with keratinized epidermal scales
- Bony endoskeleton
- Two pairs of pentadactyle (five digits) limbs with true claws (if limbs are present)
- No external ear
- Fertilization is internal and fertilized eggs laid on land or eggs retained internally until hatching
- Amniotic leathery skin shell eggs (if they lay eggs; some give live birth)
- Cold blooded (poikilothermic/exothermic)
- Gut and the ducts of the urinary and sexual organs empty into a posterior chamber called the cloaca.

There are about 6,550 living species of reptiles worldwide. Reptiles live in a wide range of habitats, including forests, swamps, grasslands, deserts, oceans, and mountains. The name "reptile" is generally applied to any of a group of ectodermic (cold-blooded i.e. need an "outside" source of heat to generate adequate body heat) vertebrates in the Class Reptilian. Reptiles must regulate their body temperature by behavior, either by basking in the sun to keep warm or by hiding under cover to keep cool. Some reptiles (such as lizards) look superficially similar to some amphibians (such as salamanders). However, reptiles have dry and not slimy skin. They are covered in scales or a shell. If they have legs, they have claws on their toes. Reptiles can be far from water sources because their skins retain water better than that of amphibians. Reptiles lay amniotic eggs that have a leathery shell preventing rapid water loss.

The Class Reptilian is composed of four orders namely Order Crocodilia (crocodilians), Order Testudines (turtles), Order Squamata (lizards and snakes) and Order Rhynchocephalia which has only two living species - the tuataras, found only in New Zealand.

5.2.2. Classification of class Reptilia

Composed of four Orders:

1. Order Crocodilia (Crocodiles & Alligators)
2. Order Testudinata (Tortoises & Turtles)
3. Order Squamata (lizards and snakes)
4. Order Rhynchocephalia (Tautarans)

Order:Crocodilia (crocodiles and aligators)

Have the following features:

- Have a long snout.
- Four well-developed limbs.
- A muscular tail used to propel them through the water.
- Lay eggs in large mounded nests or in cavities dug in the soil.

- Carnivorous on fish, amphibians, reptiles, birds, and mammals.

Figure 20 Crocodiles (A, left) and Alligators (B, right)

A crocodile has a very long, narrow, V-shaped snout, while the alligator's snout is wider and U-shaped. A crocodile's upper and lower jaws are nearly the same width, so the teeth are exposed all along the jaw line in an interlocking pattern, such that even when the mouth is closed the bottom teeth are visible (**A**). An alligator's teeth don't show when its mouth is closed (**B**).

Order Testudinata (Tortoises & Turtles)

Characteristics of Order Testudinata (Turtles and tortoises)

- Shell or carapace formed from the fusion of vertebrae and ribs with dermal bones.
- No teeth but have a sharp-edged beak, called a tomia, used as cutting edges to bite off chunks of food.
- Oviparous and fertilization internal and accomplished by a penis which is an outgrowth of the cloacal wall. Turtle eggs are buried in a nest and left to incubate and hatch.
- Lack of holes in the temporal region of the skull, a condition known as anapsis. This feature is unique among living reptiles.

- The shell of testudinata is covered with scutes that cover the bony shell.
- No other vertebrate has the hard shell that surrounds and protects the organs of turtles/tortoise.
- The shell of turtle/tortoise consists of two basic parts, the top shell which is referred to as a carapace, and a bottom shell that is known as a plastron.
- The two parts of the shell are connected on each side by a portion of the shell known as the bridge.
- The ribs and vertebrae of turtle/tortoise, with the exception of the neck and tail, are fused to form the carapace.
- Because of the fusion, you cannot see a clearly defined vertebrae/ backbone as is the case in other vertebrates we have studied so far.
- The shell is not an exoskeleton, as some people mistakenly assert but a modified ribcage and part of the vertebral column. It cannot be "taken off".
- Because of the shell, the pectoral and pelvic girdles are uniquely located within the ribcage. The limb bones are also modified to accommodate the shell.
- Turtles/tortoises are long-lived animals. Some live from 20 to over 100 years, depending on species.
- Some species only eat animal matter while others eat both plants and animals.
- The Latin word-root "test" is synonymous for shell, and the order name "Testudines" is Latin for turtle.
- Tortoises are considered as turtles that inhabit land and have unwebed feet unlike the water turtle that live most of the lives in water and have webbed feet.
- Both lay eggs on land. The Americans make no such distinctions as the word turtle refers to both whether on land or water. The two are distinguished by their habitat i.e. land turtle or water turtle.

Order: Squamata (lizards and snakes)

General characteristics:

- Transverse vent or cloacae opening
- Skull that is more moveable (or kinetic) than other reptile orders
- Paired copulatory organs called hemipenes
- Body covered in scales
- Periodically shed their skin (a process known as ecdysis)
- Carnivorous or omnivorous
- Variety of habitats (aquatic, terrestrial, or arboreal)
- Lay eggs; others bear live young

The Order squamata (meaning scaled reptiles) is the largest order of reptiles with over 6,000 living species. It is the most diverse of the reptile orders, containing 96% of the reptile species. In other words, these are the reptiles you come across often times. They are represented by the Lacertilia (lizards) and the Serpentes (snakes).

Chameleons (family Chamaeleonidae) are a distinctive and highly specialized group of lizards. They have a parrot-like zygodactylous feet, mobile and stereoscopic eyes, very long, highly modified, and rapidly extrudable tongues, their swaying gait, prehensile tail, crests or horns on heads, and the ability of some to change color.

Order Rhynchocephalia (Tuatara)

Members of this order are characterized by the following features:

- A scaly loose skin which may be soft for touch.
- A spiny back.
- A third primitive, light-sensitive eye above the brain.
- Live in burrows and are nocturnal, hunting at night just outside their burrow entrance.
- They feed on worms, lizards, millipedes and small seabirds.

5.2.3. General physiology and morphology of the various reptilian subclasses

Subclass Anapsida: As described earlier the term anapsid refers to the absence of opening in the bones and roof over the temporal region of the skull, a feature that distinguishes this subclass from others. The subclass consists of two orders.

Subclass Diapsida: As described earlier, the term diapsida refers to the presence of an upper and lower fenestra in the temporal openings. They are classified into three super orders. Super orders Lepidosauria (the lepidosauromorphs) include the tuatara (Sphenodontidae) and squamates plus their extinct relatives. In addition, four groups of specialized marine tetrapods (the placadonts, plesiosaurs, ichthyosaurs, and Hupehsuchus) are tentatively considered to belepidosauromorphs. The two superorders with living representatives are the super order Lepidosauria, containing the lizards, snakes, wormlizard, and Sphenodon; and the superorder Archosauria, containing the crocodilians. The other, superorder Sauropterygia contains extinct reptiles.

Subclass Synapsida: Synapsids are extinct mammal-like reptiles lived from Carboniferous to early Jurassic. They are characterized by possessing a skull with one pair of lateral temporal opening. The skull fairly large and not flattened: a parietal foramen genrally absent. It consists of two orders.

5.2.4. Extinction of dinosaurs

During the 250 million years that reptiles were the dominant large terrestrial vertebrates, four major forms of reptiles took turns as the dominant type: pelycosaurs, therapsids, thecodonts, and dinosaurs.

Pelycosaurs: Becoming a Better Predator

Early reptiles like *pelycosaurs* were better adapted to life on dry land than amphibians because they evolved watertight eggs. They had powerful jaws because of an innovation in skull design and muscle arrangement. Pelycosaurs were **synapsids,** meaning that their skulls had a pair of temporal holes behind the openings for the eyes. An important feature

of reptile classification is the presence and number of openings behind the eyes. Their jaw muscles were anchored to these holes, which allowed them to bite more powerfully. An individual pelycosaur weighed about 200 kilograms. With long, sharp, "steak knife" teeth, pelycosaurs were the first land vertebrates to kill beasts their own size. Dominant for 50 million years, pelycosaurs once made up 70% of all land vertebrates. They died out about 250 million years ago, replaced by their direct descendants the therapsids.

A pelycosaur. *Dimetrodon*, a carnivorous pelycosaur, had a dorsal sail that is thought to have been used to dissipate body heat or gain it by basking.

Therapsids: Speeding Up Metabolism

Therapsids ate ten times more frequently than their pelycosaur ancestors (figure 48.24). There is evidence that they may have been endotherms, able to regulate their own body temperature. The extra food consumption would have been necessary to produce body heat. This would have permitted therapsids to be far more active than other vertebrates of that time, when winters were cold and long. For 20 million years, therapsids (also called "mammal like reptiles") were the dominant land vertebrate, until largely replaced 230 million years ago by a cold-blooded, or ectothermic, reptile line the thecodonts. Therapsids became extinct 170 million years ago, but not before giving rise to their descendants the mammals.

A therapsid is a small weaslelike cynodont therapsid, *Megazostrodon,* may have had fur. From the late Triassic, it is so similar to modern mammals that some paleontologists consider it the first mammal.

Thecodonts: Wasting Less Energy

Thecodonts were **diapsids,** their skulls having two pairs of temporal holes, and like amphibians and early reptiles, they were ectotherms (figure 48.25). Thecodonts largely replaced therapsids when the world's climate warmed 230 million years ago. In the warm climate, the therapsid's endothermy no longer offered a competitive advantage, and ectothermic thecodonts needed only a tenth as much food. Thecodonts were the first land

vertebrates to be bipedal to stand and walk on two feet. They were dominant through the Triassic and survived for 15 million years, until replaced by their direct descendants—the dinosaurs.

A thecodont. *Euparkeria,* a thecodont, had rows of bony plates along the sides of the backbone, as seen in modern crocodiles and alligators.

Dinosaurs: Learning to Run Upright

Dinosaurs evolved from thecodonts about 220 million years ago. Unlike the thecodonts, their legs were positioned directly underneath their bodies, a significant improvement in body design. This design placed the weight of the body directly over the legs, which allowed dinosaurs to run with great speed and agility. A dinosaur fossil can be distinguished from a thecodont fossil by the presence of a hole in the side of the hip socket. Because the dinosaur leg is positioned underneath the socket, the force is directed upward, not inward, so there was no need for bone on the side of the socket. Dinosaurs went on to become the most successful of all land vertebrates, dominating for 150 million years. All dinosaurs became extinct rather abruptly 65 million years ago, apparently as a result of an asteroid's impact. The following figures summarize the evolutionary relationships among the extinct and living reptiles.

5.3 Class Aves

This unit deals about birds (Aves), which are very familiar vertebrates we come across virtually every day. Birds represent a major departure from the reptiles as the body scales have been replaced by feathers, which is a major characteristic feature of the class. Indeed, any animal you see with feathers is undoubtedly a bird. They include the doves and pigeons on your roof and trees around your homes, to the chickens and turkeys you eat as delicacies, to the big ostriches that cannot fly. Birds are better equipped to live on land than the reptiles. Unlike the reptiles, they are warm blooded animals, have more efficient lungs with pouches for gaseous exchange coupled with a heart of four chambers. Most birds fly but a few such as penguins and ostriches have lost their ability to fly (though their

ancestors did fly). Birds also have a large egg yolk encased in a hard-calcareous shell that can withstand desiccation.

Lesson objectives

After going through this study Unit, you will be able to:

- *Describe birds by their characteristic features.*
- *Describe the subclass Archaeomithes and Neornithes*

5.3.1. Origin of Feather and Flight

As little as 50 years ago, the idea that birds descended from dinosaurs seemed completely ridiculous after all, birds are small, light, fluttery creatures, while dinosaurs were huge, plodding, and distinctly unaerodynamics. But as the evidence--small dinosaurs possessing feathers, beaks, and other birdlike characteristics--began to mount, the connection between dinosaurs and birds became apparent to scientists and the general public. Today, it's the rare paleontologist who disputes the descent of birds from dinosaurs, though there are some who try.

This doesn’t mean, though, that all the technical aspects of the dinosaur/bird transition have been settled once and for all. Researchers still disagree about which dinosaurs were most closely related to modern birds, whether terrestrial dinosaurs sported aerodynamic or strictly ornamental feathers, and--perhaps most contentiously of all--how these reptilian proto-birds managed to achieve the huge evolutionary leap into powered flight.

The Origin of Feathered Dinosaurs

Why, and how, did the small theropod dinosaurs of the Jurassic and Cretaceous periods evolve feathers? It's a common mistake among people unversed in evolutionary theory to assume that feathers evolved specifically for the purpose of flight. Evolution, however, is a blind process--it doesn’t "know" where it's going until it gets there. For this reason, the accepted explanation is that dinosaurs evolved feathers as a means of insulation in cold

climates (and, possibly, as a way to puff themselves up in the eyes of the opposite sex). If this sounds unlikely, bear in mind that even birds that have been flightless for millions of years still have feathers. If the purpose of feathers were solely to power flight, there would be no reason, from an evolutionary perspective, for penguins to keep their feathers: in fact, they might be better off with thick coats of fur.

The first dinosaurs known to have sported feathers such as Archaeopteryx and Epidendrosaurus appeared on the scene during the late Jurassic period, about 150 million years ago. As the eons ground on, the primitive (that is, short and hair like) feathers of these early dino-birds gradually evolved into the broad, flat kind we're familiar with today, which are better suited to trapping air (and thus insulating the skin beneath). At this point the question asks itself: how did these feathered dinosaurs make the transition to flight?

Theory 1: Feathered Dinosaurs Took a Running Leap

Extrapolating backward from the behavior of modern birds, like ostriches, it's reasonable to infer that the small- to medium-sized, two-legged theropod of the Cretaceous period (notably the ornithomimids, or "bird mimics," but other feathered theropod as well, including raptors and possibly even small tyrannosaurs) could attain top running speeds of 30 or 40 miles per hour. As these theropod ran (either chasing down prey or trying to outrun bigger carnivores), their coat of insulating feathers gave them a slight aerodynamic "bounce," helping them land their next meal or live another day. Since well-fed dinosaurs, or those that avoided being eaten, produced more offspring, the evolutionary trend would be toward larger feathers, which provided more "lift."

From there, the theory goes; it would only have been a short step to taking actual flight for brief periods of time. At this point, though, it's important to realize what the phrase "short time" means in an evolutionary context. There wasn't a single defining moment when a small, feathered theropod accidentally ran off the side of a cliff and took flight like a modern bird. Rather, you have to picture this process happening gradually over the course of millions of years and with multiple theropods, not any specific genus.

In the excellent Nova episode The Four-Winged Dinosaur (about the specimen of Microraptor that had recently been discovered in China), a scientist is quoted to the effect that the hatchlings of modern birds recapitulate their evolutionary heritage. That is, though they're still unable to fly, they can jump farther, and scuttle up inclined surfaces, with the aerodynamic lift provided by their feathers--the same advantages that may have been enjoyed by Cretaceous theropod.

Theory 2: Feathered Dinosaurs Fell Out of Trees

Behavior can be extrapolated back to extinct dinosaurs. Flying squirrels glide across forests by leaping off the tall branches of trees and spreading the flaps of skin attached to their arms and legs. They're not capable of powered flight, of course, but they can glide for impressive distances, up to two-thirds of the length of a football field for some species.

Conceivably, some species of feathered theropod might have lived high up in trees (this would entail their having a relatively small size and the ability to climb). These feathered dinosaurs might then have followed the same evolutionary path as flying squirrels, gliding for longer and longer distances as their feathers slowly evolved to the optimum shape and configuration. At some point, the evolutionary innovation of flappable wings would have allowed them to take to the air for indefinite periods of time.

The main problem with this "arboreal" theory of flight, as it's called is that it's easier to imagine powered flight evolving in the ground-up alternative (picture a terrified dinosaur desperately flapping its vestigial wings to try to escape a larger carnivore) than as a result of tree-to-tree gliding. Also, despite millions of years of evolution, no flying squirrel (with the exception of Bullwinkle's pal Rocky) has managed to achieve powered flight although, to be fair, bats certainly have.

Current Thinking about Feathered Dinosaurs and Birds

One of the problems with small, feathered dinosaurs is that new genera are constantly being discovered, many of them in China's Liaoning fossil beds. Since these specimens

date back to different geologic periods, separated by tens of millions of years, it can be difficult for paleontologists to reconstruct the exact evolutionary line that led from dinosaurs to birds.

The above-mentioned Microraptor is a good example. This weird, four-winged dinosaur has provoked intense disagreement among paleontologists, some of whom see it as an evolutionary dead end, others as an "intermediate" form between dinosaurs and birds, and yet others as not technically a dinosaur at all, but an offshoot from a branch of the archosaur evolutionary tree long before dinosaurs arrived on the scene.

Today, most working paleontologists subscribe to the theory that a) birds are descended from feathered theropod dinosaurs, and b) flight developed from the ground up, rather than from the trees down. But as with all things prehistoric, these views may change with the next spectacular fossil find.

General Characteristics of Class Aves (Birds)

- Body covered with feathers composed mainly of keratin (the only animals that have feathers)
- Strong bony endoskeleton (bones have air spaces)
- Forelimbs modified as wings for flight (some have lost ability to fly)
- Bipedal- two legs for locomotion (upper part of legs has scales)
- Toothless horny beak; use gizzard to grind food
- Warm blooded animals (body temperature is internally regulated; endothermic (homeothermic)
- Efficient lungs with pouches for gaseous exchange
- Heart of four chambers
- Internal fertilization
- Hard-calcareous shelled eggs with yolk

It is interesting to note that birds are the only vertebrates with feathers. So any animal you see with feathers is undoubtedly a bird. Birds are said to have come from a common

ancestor (monophyletic lineage) and are thus related through that common origin. Modern birds have traits related to hot metabolism, ability to fly, a beak with no teeth, lying of hard-shelled amniotic eggs, a four-chambered heart, a lightweight but strong skeleton and forelimbs modified as wings. Birds also have unique digestive and respiratory systems. Some birds, especially parrots, are among the most intelligent animal species that one could find; a number of bird species have manufacturing skills and ability to use tools, and many social species exhibit cultural transmission of knowledge across generations.

Adaptation to flight in birds is facilitated by light body weight (caused by absence of teeth, reduction or absence organs and having ultra-light bones and air sacs), high body temperature, improved blood circulation, high metabolism, and acute vision (that enables avoidance of danger such as tree-branch at high speed).

Classification of birds

The class Aves is comprised of two subclasses namely Archaeomithes (extinct ancient birds) and Neornithes (recent birds). So it is right to say that all living birds belong to the subclass Neornithes, which is further divided into three super orders namely Odontognathae (extinct), Paleognathae and Neognathae.

Subclass Archaeornithes

Members of this subclass are extinct ancient birds. They were characterized by having clawed wings, a reptilian style ribcage without a large carina and the presence of a long bony tail. The long, known members of the group are Archaeopteryx and Archaeornis.

Subclass Neornithes

Let us now look at the neornithes, which represent all the living birds we see today. In this subclass, there are three super orders namely Odontognathae (extinct), Paleognathae and Neognathae. We shall now look at the Super orders under the subclass and attempt to bring to you pictorial representations.

Super order Odontognathae

Members of this super order though considered as modern birds on account of their anatomy are however extinct. As the name implies, they had teeth-like structures. Unlike the Archaeornithes described above, the Odontognathae had short tails with a well developed carina for flight muscle and the wings are generally without claws (though some modern birds such as the kiwis have claws). The brain of the Odontognathae appears to be somewhat simpler than those of modern birds.

Super oder: Palaeognathae

The super order Palaeognathae derived its name from 'paleognath', the ancient Greek word for "old jaws" in reference to the skeletal anatomy of the palate of the bird, which is described as more primitive and reptilian than of other birds. In other words, the super order represents birds with primitive jaws, which are more like reptilian jaws. In this super order we have ratites which have lost ability to fly and the tinamous that can fly. We shall now take a close look at the orders under this super order by way of brief description and pictorial presentation.

Order: Struthioniformes (Ostriches, Emus, Kiwis)

The order Struthioniformes comprised of birds called ratites, which are large flightless birds; these are birds that have lost their ability to fly and have a flat breastbone. The Ratites have a simplified wing bone structure, strong legs, and no feather vanes, making it unnecessary to oil the feathers. Consequently, they have no preened gland that contains preening oil. This group is composed of ostriches, rhea, cassowaries, emus and kiwis.

Kiwi (Apteryx) is flightless birds endemic to New Zealand. As we will see in our study of Zoogeography, Kiwi is a national symbol of New Zealand. Just about the size of a domestic chicken, kiwi are by far the smallest living ratites and lay the largest egg in relation to their body size of any species of bird in the world. The Ostrich (Struthio) is one or two species of large flightless birds native to Africa, the only living member(s) of the genus Struthio The bird is distinctive in its appearance, with a long neck and legs and the

ability to run at maximum speeds of about 70 kilometres per hour, the top land speed of any bird. The Ostrich is the largest living species of bird and lays the largest egg of any living bird.

The Emu is the largest bird native to Australia and the only extant member of the genus Dromaius. It is the second-largest extant bird in the world by height, after its ratite relative, the ostrich. The soft-feathered, brown, flightless birds reach up to 2 meters (6.6 ft) in height. They have long thin necks and legs. Emus can travel great distances at a fast, economical trot and, if necessary, can sprint at 50 km/h (31 mph) for some distance at a time. Cassowaries are not well known birds as they usually shy birds of the deep forest of Australian and New Guinea. They are quick to disappear long before they are seen. Females are bigger and more brightly colored.

Adult Southern Cassowaries are 1.5 to 1.8 meters tall, although some females may reach 2 meters and weigh 58.5 kilograms. A cassowary's three-toed feet have sharp claws and the bird is fearsome since cassowaries sometimes kick humans and animals with their enormously powerful legs. Indeed, according to the Guinness Book of Records, 'the Cassowaries are the world's most dangerous birds', capable of dealing fatal blows. They are very unpredictable, aggressive creatures, especially if wounded or cornered. Cassowaries can run up to 50 km/h through the dense forest. They can jump up to 1.5 meters and they are good swimmers, crossing wide rivers and swimming in the sea as well. They are certainly a delight to watch.

Order: Tinamiformes (Tinamous)

The Tinamous are a family found in Central and South America. One of the most ancient living groups of bird, they are related to the ratites. Generally ground dwelling, they are found in a range of habitats and can fly and have keeled breastbone (shaped like a wishbone) although they look similar to other ground-dwelling birds like quail and grouse.

Super order Neognathae

We continue with our study of birds by looking at the biggest super order i.e. Neognathae. In view of the large number of orders in this super order, we shall give a description and pictorial presentation of some selected few, especially of those we have in our environment or those that are common elsewhere.

Characteristics of avian super order Neognathae

The super order Neognathae comprises 27 orders which have a total of nearly ten thousand species. The Neognathae have undergone adaptive radiation to produce the staggering diversity of form (especially of the bill and feet), function, and behavior that we see today. Most of the birds you see often are indeed members of Neognathae. Let us now take a brief description together with pictorial presentation of some of the selected orders.

Order: Strigiformes (owls)

Owls are easy to recognize. They have an almost human appearance, with upright posture, large rounded heads, and large eyes that face forward (most birds have eyes on the sides of their heads). All owls are carnivores, or meat-eaters, and several adaptations make them effective hunters, including a hooked beak for tearing flesh and strong feet tipped with sharp talons, or claws. The toes can be used in a two-forward, two backward arrangements for a good grip on prey (most birds have three toes pointing forward and one pointing backward). Feathers are unusually soft, allowing for silent flight, so owls can hear their prey and approach it without warning.

Most owls are nocturnal, active at night and asleep by day. Adaptations for night hunting include eyes that can see in low-light conditions and very sensitive hearing. The eyes are enclosed in a ring of bone and cannot move freely, so owls must turn the entire head to look sideways. The Eurasian scopes owl ranges from southern Europe through East Asia. It is a small medium-sized, “eared” and nocturnal owl that feeds mostly on insects.

Order: Galliformes (fowl)

Galliform are medium to large in size, with a stocky body, small head, and short wings. Members of the order are quite familiar to us as it comprised birds we keep and also eat as meat virtually on daily basis. These include chickens and turkeys and quails. Quails are the smallest species, weighing less than 20 grams and measuring just 12 to 15 cm. The wild turkey weighs 8 to 10 kilograms, and the domesticated turkey bred for eating can weigh up to 20 kilograms. Galliformes have short bills that usually curve downward to assist in pecking plant material from the ground. Their feet are big and strong - so strong that they can move heavy branches or stone. Some galliform tails are one-third the size of their total body length. Both sexes are often brown or black, but the males of a few species are incredibly colorful.

Fowl is a word for birds in general but usually refers to birds belonging to one of two biological orders, namely the game fowl or land fowl (Galliform) and the waterfowl (Anseriformes). Indeed, they are close relatives. Many birds that are eaten by humans are fowl, including poultry such as chickens or turkeys, game birds such as pheasants or partridges, other wildfowl like guinea fowl or peafowl, and waterfowl such as ducks or geese.

Quail is a collective name for several genera of mid-sized birds generally considered in the order Galliform. Many of the common larger species are farm raised for table food or egg consumption as is the case in Nigeria, whereby the quail meat and eggs are sought after as delicacies especially by health conscience class.

Order: Falconiformes (Falcon)

Falconiformes have a sharply hooked beak with a cere (soft mass) on the proximodorsal surface, housing the nostrils. Their wings are long and fairly broad, suitable for soaring flight, with the outer 4–6 primaries emarginated. Falconiformes have strong legs and feet with raptorial claws and an opposable hind claw. Almost all Falconiformes are

carnivorous, hunting by sight during the day or at twilight. They are exceptionally long-lived, and most have low reproductive rates.

Order: Columbiformes (doves and pigeons)

This is a very familiar order with members such as the pigeons and doves. These birds are compact with broad, rounded, powerful wings; short bills; short legs; and short necks. Males tend to be slightly larger than females in size. In most species, males and females are similarly colored, although there are a few tropical species where males are much more colorful than females. Many pigeon and dove species are gray, brown, or cream in color. However, some tropical species may be green, red, purple, pink, blue, or orange.

Order: Psittaciformes (parrots and allies)

Parrots are very familiar birds on account of their brightly colored plumage (feathers), intelligence, and the ability of some species to imitate human voices, which enhances their popularity as pets. Most have green feathers, and many parrots are blue, red, and yellow. Parrots have large heads, short necks, and curved beaks. They use their hooked beaks to crack nuts and grab branches. Birds use their beaks and feet to pick up food and carry it their mouths. Parrots have zygodactyl feet - two toes on each foot face forward and two face backward.

Order: Sphenisciformes (penguins)

Penguins are a group of aquatic, flightless birds living almost exclusively in the southern hemisphere, especially in Antarctica. Highly adapted for life in the water, penguins have counter shaded dark and white plumage, and their wings have become flippers. Most penguins feed on krill, fish, squid, and other forms of sea life caught while swimming underwater. They spend about half of their life on land and half in the oceans. Although all penguin species are native to the southern hemisphere, they are not found only in cold climates, such as Antarctica. In fact, only a few species of penguin live so far south.

Several species are found in the temperate zone, and one species, the Galápagos Penguin, lives near the equator.

Penguins always return to their ancestral nesting sites to lay their eggs and rear their young. The emperor penguin, the largest of the penguins, lays its single egg during the coldest time of the Antarctic year, when temperatures drop as low as -62°C (-80 degrees F). The egg is incubated on top of the parent's feet, protected by abdominal folds of skin. Young chicks remain under these abdominal folds until they are able to regulate their own body temperature.

Order: Coraciiformes (kingfishers and allies)

Coraciiformes are a fairly large order characterized by syndactyl feet (three forward pointing toes) and long, pointed bills. Birds in the order are usually colorful, have one mate partner (monogamous) and nest in cavities. Their young are helpless and depend on the parent for food (altricial) and retain waxy sheaths on their feathers until just before fledging. Most birds of this order are carnivorous.

Kingfishers are a group of small to medium sized brightly coloured birds in the order Coraciiformes. They have a cosmopolitan distribution, with most species being found in the Old World and Australia. There are roughly 90 species of kingfisher. All have large heads, long, sharp, pointed bills, short legs, and stubby tails. Most species have bright plumage with little differences between the sexes. Most species are tropical in distribution, while majority are found only in forests. They consume a wide range of prey including fish from where they derive their name on account of their ability to catch fish by a swift dive. It is a delight to watch the kingfisher swooping down to catch fish. Like other members of their order they nest in cavities, usually tunnels dug into the natural or artificial banks in the ground.

Order: Piciformes (woodpeckers and allies)

The piciforms are small to medium-sized, hole-nesting land birds. The bill is short to mediumlong, straight, and strong, and the wings are of medium length and rounded. The

legs are short and strong, with the strong toes arranged in a zygodactylous (yoke) pattern, with two toes forward and two toes back. The tail may have stiffened feathers. The plumage is frequently brightly colored and boldly patterned. Piciforms are good fliers and can easily perch and climb, but are poor at walking. Most species feed on insects. The eggs are incubated by both sexes, and both parents care for the unfeathered young, which remain in the nests. Except for a few species of woodpeckers, the piciforms are no migratory.

Members of this order have strong bills for drilling and drumming on trees and long sticky tongues for extracting food. Woodpecker bills are typically long, sharp and strong with chisel-like tip; the chisel-like tip is kept sharp by the pecking/hammering action in birds on wood. The long sticky tongues armed with bristles, aid these birds in grabbing and extracting insects deep within a hole of a tree.

Order: Anseriformes (waterfowl)

Members of this order are strong swimmers with medium to large bodies. They are an important food source, and continue to be hunted as game, or raised as poultry for meat and eggs. A well known member of this order is the domestic duck, which is sometimes kept as a pet. Some definitions of the term 'waterfowl' include the saltwater shorebirds or waders, gulls, pelicans, and herons, as well as seabirds such as the albatross, but 'fowl' especially refers to birds used by humans for game.

All species in the order are highly adapted for an aquatic existence at the water surface. They have a web-foot well suited for efficient swimming (although some have subsequently become mainly terrestrial). Ducks are mostly aquatic birds, mostly smaller than the swans and geese, and may be found in both fresh water and sea water.

Order: Phoenicopteriformes (Flamingos)

Flamingos or flamingoes are a type of wading bird found in the Americas and in the old World. Flamingos are 3-5 feet tall and have long legs, long necks, and long, bent bills. Most species are pink, white, or red and are found in tropical fresh and salt water lagoons

and lakes. Flamingos often stand on one leg while they are resting! Flamingos are filter feeders and are uniquely adapted to feed on algae and small shellfish. Flamingos have two rows of lamellae or comb-like bristles that line the inside of their bills. They also have bristles on their tongues that help filter food out of the water. Flamingos live in large flocks that can include thousands of birds. The following table shows the general classification of birds in to the listed orders of birds:

Table 4 Classification of birds

SNo	Order	Description	Example
1.	Struthioniforms	✓ Contains one species which is the largest of living birds (ostrich) ✓ 2.4m tall and weighing 135kg. ✓ The feet are provided with only two toes of un-equal size covered with pads, which enables them to travel rapidly through sand.	Ostrich
2.	Rheiformes	✓ Contains two species of flightless birds restricted to South America often called the American ostriches.	Rheas
3.	Casuariformes	✓ Four species of flightless birds found in Australia, New Guinea and a few other islands.	Cassowaries, Emus
4.	Apterygiformes	✓ Three species of kiwis, flightless birds about the size of domestic fowl, found only in New Zealand. ✓ The egg is extremely large for the size of the bird.	Kiwis
5.	Tinamiformes	✓ Ground-dwelling, grouse like birds of central and South America. This order has about 60 species.	Tinamous
6.	Sphenisicformes	✓ Web-footed marine swimmers of the southern seas from Antarctica to the Galapagos Islands. ✓ Although penguins are carinate birds, they use their wings as paddles for swimming rather than for flight.	Penguins

		✓ About 17 species.	
7.	Gaviiformes	✓ The four species of loons are remarkable swimmers and divers with short legs and heavy bodies. ✓ They exclusively live on fish and small aquatic forms.	Loons
8.	Podicipediformes	✓ These are short legged divers with lob ate webbed toes. ✓ Grebes are most common in old ponds where they build their rafttike floating nests. ✓ 18 species with worldwide distribution.	Grebes
9.	Procellaricformes	✓ All are marine birds with hooked beak and tubular nostrils. ✓ Albatrosses are the largest of flying birds. ✓ About 100 species with worldwide distribution.	albatrosses, petrels, fulmars shearwaters
10.	Peleconiforms	✓ These are colonial fish-eaters with throat pouch and all four toes of each foot included within the web. ✓ About 55 species, distribution worldwide, especially in the tropics.	Pelicans, cormorants, gannets, boobies
11.	Ciconiiforms	✓ These are long-necked, long-legged, mostly colonial waders. ✓ About 90 species with would wide distribution	Herons, bitterns, storks ibises Spoon bills, Flamingos
12.		✓ The members of this order have broad bills with filtering ridges at their	Swans, geese, ducks

	Anseriforms	margins, a foot web restricted to the front toes, and a long breastbone with a low keel. ✓ About 150 species with cosmopolitan distribution.	
13.	Falconiformes	✓ These are diurnal birds of prey. ✓ All are strong fliers with keen vision. ✓ About 270 species with worldwide distribution.	eagles, hawks, vultures, falcons
14.	Galliformes:	✓ Chicken like ground-nesting herbivores with strong beaks and heavy feet. ✓ About 250 species with worldwide distribution.	quail, grouse, pheasant's turkeys, and domestic fowl:
15.	Gruiformes:	✓ Prairie and marsh breeders. ✓ About 215 species with worldwide distribution	e.g. cranes, rails, coots, gallinules:
16.	Charadriiformes	✓ All are shore birds. They are strong fliers and are usually colonial. ✓ About 330 species, worldwide distribution. ✓ Includes turnstones, Lapwings Snipe, avocets, phalaropes, Skimmers, auks puffins	Gulls, oystercatchers, plovers, Sand pipers, woodcocks,
17.	Columbiformes	✓ All have short necks, short legs and a short slender bill. ✓ About 290 species with worldwide distribution	Pigeons, doves
18.		✓ Birds with hinged and movable upper	Parrots, Parakeets

	Psittaciformes	beak, fleshy tongue. ✓ About 320 species, pan tropical in distribution.	
19.	Cuculiforms	✓ The common European cuckoo lays its eggs in the nests of smaller birds, with rear young cuckoos. ✓ About 150 species, with worldwide distribution	Cuckoos, roadrunners
20.	Strigiformes	✓ Nocturnal predators with large eyes, powerful beaks and feet, and silent flight. ✓ About 135 species worldwide distribution.	Owls
21.	Apodiformes	✓ These are small birds with short legs and rapid wing beat. ✓ The familiar chimney swift fastens its nest in chimneys by means of saliva. ✓ A swift found in china builds a nest of saliva that is used by the chinees for soup making. ✓ Most special of humming birds are found in the tropics. ✓ About 400 species, worldwide distribution.	Swifts, humming birds
22.	Coliiformes	✓ Small birds of uncertain relationship. ✓ Six species restricted to southern Africa.	Mouse birds
23.	Trogoniformes	✓ Richly colored, long tailed birds. ✓ About 35 species, pan tropical distribution	Trogons

24.	Coraciiformes	✓ Birds with strong prominent bills that nest in cavities. ✓ About 200 species, worldwide distribution.	Kingfishers, hornbills
25.	Piciformes	✓ Birds with highly specialized bills and having two toes extending forward and two backwards. ✓ All nest in cavities.	Wood peckers, toucans, and puff birds, honey guides
26.	Passeriforms	✓ This is the largest order of birds, containing 60% of all birds. ✓ Most have a highly developed Syrnix. ✓ Their feet are adapted for perching on thin stems and twinges. To this order belong many birds with beautiful songs and hosts of others. ✓ More than 5000 species, with worldwide distribution.	Perching songbirds
27.	Caprimulgiformes	✓ Night and twilight feeders with small, weak legs and wide mouths fringed with bristles. ✓ About 95 species, worldwide distribution.	Goatsuckers, nighthawks whip poor wills

5.4. CLASS MAMMALIA- MAMMALS

We shall in this part of our study be considering a highly diverse but yet interesting group of vertebrates, called mammals. This is where we humans find a place under the vertebrates. Mammals, as we shall be considering shortly, are so termed on account of having mammary glands (modified sweat glands) in females that produce milk for the newborn. It is from these glands that the whole group takes its name, 'Mammals'. As we journey into the world of mammals, we shall see that indeed mammals are part of the beauty and diversity of life that make this world so good to live in.

Lesson objectives

By the end of this lesson, you will be able to:-

- *Describe the characteristic features of mammals*
- *Distinguish mammals from other vertebrates*

5.4.1. Evolutionary history of mammals

The first mammals arose from therapsids ("mammallike reptiles") in the mid-Triassic about 220 million years ago .Tiny, shrew like creatures that lived in trees eating insects, mammals were only a minor element in a land that quickly came to be dominated by dinosaurs. Fossils reveal that these early mammals had large eye sockets, evidence that they may have been active at night (Nocturnal).

The most primitive mammals, direct descendents of therapsids, were members of the subclass Prototheria. Most prototherians were small and resembled modern shrews. All prototherians laid eggs, as did their therapsid ancestors. The only prototherians surviving today are the monotremes the duckbill platypus and the echidnas, or spiny anteaters.

General Characteristics of mammals

Main mammalian features

- Mammary glands in females for milk production for the newborn. This milk is produced by modified sweat glands called 'mammary' glands. It is from these glands that the whole group takes its name, 'Mammals'.
- Hairy skin of keratin (for insulation) with sebaceous and sweat glands. All mammals have some hair at least at the beginning of their lives - baby whales and dolphins are born with a moustache.
- A single jaw bone on either side. In all other vertebrates, there is more than one bone on each side of the jaw.
- Four chambered heart with the main artery leaving the heart curves to the left becoming the aortic arch. (In birds it curves to the right and in all other vertebrates there is more than one main artery leaving the heart).
- Muscular diaphragm separates the thoracic cavity from the abdominal cavity.

Other mammalian features

- Bony endoskeleton.
- Two pairs of pentadactyl limbs.
- External ear plus middle and inner ears - three middle ear bones (the stapes or stirrup, incus or anvil and the malleus or hammer) used in hearing.
- Warm blooded (endothermic/homeothermic -heat energy generated from within to maintain a constant high body temperature).
- Seven cervical vertebrae (neck bones) are present in most mammals.
- Viviparous though some are oviparous.
- Teeth (where present) are imbedded in jaw and in a variety of forms for different functions (heterodentic).
- Internal fertilization.
- Well developed brain in a skull.

Mammals are divided into three main categories depending how they are born. These categories are monotremes, marsupials, and placentals. Except for the five species of monotremes (which lay eggs), all mammal species give birth to live young. Most mammals also possess specialized teeth, and the largest group of mammals i.e. the placentals, use a placenta during gestation. The mammalian brain regulates endothermic and circulatory systems, including a four-chambered heart.

Mammals have a buccal cavity (the mouth) with a false palate as a roof, which means that the nostrils do not lead directly into the mouth. Effectively, this means that if your mouth is full of food you can still breathe, but a reptile has to breathe around its food. The body temperature of mammals is maintained at a constant level, meaning that mammals are endothermic i.e. they generate heat within their bodies metabolically and also have special cooling mechanisms. This does not however imply that all mammals maintain the same body temperature. There are approximately 5,400 species of mammals, distributed in about 1,200 genera, 153 families, and 29 orders (though this varies by classification scheme). Mammals range in size from the 30-40-millimetres (1.2-1.6 inches) bumblebee bat to the 33 meters (110 feet) blue whale.

Classification of Class mammalia

Mammals are divided into two subclasses:-

Subclass Prototheria: (monotremata: platypuses and echidnas)

Members of this subclass are extinct except the Order Monotremata, which is represented by the duckbilled platypus (flat footed) and the echidnas - spiny anteaters. This group of mammals can be described as have transited from the reptiles as they exhibiting some reptilian features as we shall see below.

The monotremes have the following characteristics:-

- Shelled eggs like reptiles.
- Single opening – the cloaca (like reptiles) for both urine/faeces discharge and copulation,
- Testes are not in scrotum but retained in body cavity.
- Penis lies within the cloaca and although homeothermic, their body temperature is low between 30-33°C so also is the basal metabolic rate
- Mammary glands (though not truly mammary glands), that produce a fatty sweat (milk) from glands in the skin. The milk collects and drips down tufts of hair into the offspring's mouth.

The monotremes are found in Australia and New Guinea. The duck-billed platypus is semi-aquatic, lives in and around rivers and lakes in Tasmania and other parts of eastern Australia. The female platypus lays eggs in dug holes (burrows) by the bank of rivers. The animal keeps the eggs and the emerged young warm by curling around them. After hatching from eggs, platypus babies feed on milk from the mother. The spiny anteater lives on land and lays a single egg in a temporary pouch formed on the female's belly.

The egg has a leathery shell. The egg hatches in 10 days and the baby echidna is born blind and hairless. It gets milk from a gland within the mother's pouch. In a few weeks, the baby (called a puggle) develops sharp spines, and must leave the pouch. The body of the spiny anteaters, with the exception of the underside, face and legs, is covered with cream colored spines as seen in the plate below. These spines, which reach 50 mm in length, are in fact modified hairs. Like the hedgehog, the animal roll into ball form when disturbed.

Subclass Theria: (Live-bearing mammals)

Members of this subclass, unlike the monotremes described above, do not lay eggs but give birth to live babies. This means that there is a period of development for the embryo in the mother before birth. So we can look at the therians as more advanced mammals than

the prototherians. The therians are further divided into two infraclasses namely Metatheria and Eutheria.

Infraclass Metatheria (Marsupiala) marsupials - kankaroo, opossum, koala

The metatherians i.e. the marsupials have the following features:-
A pouch (marsupium) i.e. a built in baby carrier, where the embryo completes its development. The young of metatherians is called Joey and is born during the early stage of development (just after a month) akin to premature birth. Under this condition the Joey cannot survive on their own and so must be kept in a pouch (marsupium - from which the group derives its name) situated on the mother's belly. When delivered, the newly born Joey crawls up to the mother's pouch and clings on to a nipple from where it feeds until it fully develops. Members include the kangaroos, Opossums, and koalas.

A newborn kangaroo stays in its mother's pouch for about six months, where it feeds on her milk; this is the stage we often see on TV or photographs as shown below. Koala babies are born with eyes closed and have no ears or fur (body hair) so they stay inside a pouch on the mother's abdomen for about seven months while they grow fur and their eyes and ears develop. We can therefore say that the attempt by the metatherians to have their embryos develop within the mother before birth was only partial as the young are born in the early stage of development. The nutritive link between the mother and developing embryo is weak and cannot provide the needed support for long. Kangaroos are found in Australia and New Guinea. Opossums are marsupials found in North and South America. Koalas are found in Australia.

Opossums (Didelphimorphia) make up the largest order of marsupials in the Western Hemisphere. The word opossum means "white dog" or "white beast/ animal". The koala has large, sharp claws used in climbing tree trunks. The Virginia opossum is North America's only marsupial. A marsupial is an animal with a pouch, like a kangaroo or a koala. The opossum has been around for at least 70 million years and is one of Earth's oldest surviving mammals. The opossum is about the size of a large house cat. It has a triangular head and a long pointed nose. It has grayish fur everywhere but on its ears, feet

and tail. Its tail is prehensile. A prehensile tail is adapted for grasping and wrapping around things like tree limbs. The opossum can hang from its tail for a short time. Some people think opossums hang from their tails and sleep. They don't. Their tails aren't strong enough to hold them for that the koala's five fingers include two opposable thumbs, providing better gripping ability. The first two fingers are positioned in apposition on the front paws, and the first three fingers for the hind paws. The koala is one of the few mammals (other than primates) that have fingerprints very similar to human fingerprints.

Infraclass Eutheria: (placentals)

This group of mammals, also known as the placental is characterized by having:- A placenta - a reproductive structure, which is housed in the uterus of the female by which the developing embryo connects to the mother to get nutritive support.

The offspring of eutherians receives all its nutritional needs through the placenta that links it to the mother to develop into a fully developed organism before birth. The period of development (gestation period) varies with the species of mammal but undoubtedly longer than that in the metatherians that we have just described above. For example the gestation period in the whales is 2 years, in mouse 21 days, and in humans the period is 9 months. These mammals are the most abundant and diverse of the class representing 94% of the species of mammals.

They include the animals we come across or are with us in and around our homes. Indeed, humans are eutherians. To Conclude that Mammals are vertebrates that have mammary glands for feeding their young ones, which may come from shelled eggs as monotremes, or borne live but prematurely as in metatherians or fully developed through placental support as in eutherians.

Eutherians: Proboscidea, Sirenia, Carnivora

General Characteristics of Order Proboscidea (e.g. elephant)

Most members of this order are extinct. The last living proboscideans are the elephants, the only extant members of the family Elephantidae. They include the Elephas (Asian elephants) and the Loxodonta (African elephants). Members of this mammalian order are well known for having: Trunks, tusks and loose skin. The savanna elephant (Loxodonta Africana) is the largest of the three species of elephants. It lives in grasslands and drier woodlands throughout Kenya, Tanzania, Botswana, Zimbabwe, Namibia, Nigeria, and South Africa.

A well known member of this group is the elephant, an animal we all familiar with in Zoos, and wild life parks. Elephants are huge mammals characterized by a long muscular snout and two long, curved tusks. They are highly intelligent and strong. Elephants are the largest land animals and are among the longest lived, with life spans of 60 years or more. The female elephant carries her young in her worm for 22 months (gestation period). Generally healthy, full- grown elephants have no natural enemies other than humans. African elephants live in grassy regions south of the Sahara Desert. They are dark gray in color with the bull (male) elephant standing about 3.4 m (11 ft) tall and weighing about 5.4 metric tons, while the cow (female) elephant stands 2.8 m (9 ft) tall and weighs about 3.6 metric tons. They have no sweat glands and that explain why they like to cool off by rolling in ponds and streams. The mud that dries on their skin provides protection from the sun.

General Characteristics of Order Sirenia (e.g. manatees, dugongs)

The euherians in this order are characterized by the following features:-

- Aquatic habitat
- Finlike forelimbs
- Vestigial hind limbs
- Tails elongated to caudal fins

Manatees (Trichechus) aquatic eutherians that feed on aquatic plants look like whales but are actually relatives of elephants. Manatees are found in shallow coastal waters and rivers in the southeast United States, the Caribbean, northeast South America and West Africa. The Dugongs are found in Indian and western Pacific oceans. West Indian manatee and Indian dugong are commonly called the sea cows. These aquatic eutherians are not within our waters and thus are on the list of animals we are familiar with. Members of order Carnivora (e.g. dogs, cats, lions, bears, raccoons, seals) are characterized by having by having sharp canine and molar teeth for ripping flesh. The diverse order Carnivora (flesh devourer) includes over 260 species of placental mammals.Members of this order are formally referred to as carnivorans, while the word "carnivore" (often popularly applied to members of this group) can also refer to any meat-eating animal.

Carnivorans are the most diverse in size of any mammalian order, ranging from the least weasel (Mustela nivalis), as little as 25 g to the polar bear (Ursus maritimus), which can weigh up to 1,000 kg, to the southern elephant seal (Mirounga leonina), whose adult males weigh up to 5,000 kg. Apparently one may not figure out the similarities that put them together. Think of it, the aquatic seal does not have any noticeable resemblance with the land animals such as dogs, cats or the lion, but are described as carnivorans on account of their flesh eating habit, which is supported by the nature of their dentition dominated by sharp canines and molars for tearing flesh.

There is need to point out that the carnivorous nature of some of these animals has changed over time from being exclusively obligate carnivores as in lions and polar bears, to being omnivores as in domestic cats and dogs. Some, such as the giant pandas, are almost exclusively herbivores but will take fish, eggs and insects when available. Carnivorans have teeth, claws, and binocular vision adapted for catching and eating other animals.

Eutherians: Edentata , Artiodactyla, Cetacea

General Characteristics of Order Edentata (sloths, armadillos)

- Have reduced or no teeth
- Lack enamel (the hard thin calcium-containing covering of the crown of a tooth)

- Have heavily clawed forelimbs for burrowing

All Armadillos are hard bone plated animals. The hard armor-plated carapace which covers their bodies may be just one solid armor while in others the armor is constructed of hinged bands, allowing the creature to roll into a ball. Most are about the size of a cat but the giant armadillo reaches 0.9 m (3 ft) in length and can weigh 59kg (130 lbs). Armadillos are found in the southern part of the United States and in Central and South America. The sloths are generally known as lazy animals on account of their sluggish movement. Indeed, they are the slowest mammals.

A sloth spends most of its days alone, hanging upside down from tree branches, feasting on leaves. On account of its sedentary habit, algae grow in its fur and this helps the animal to camouflage from its predators such as birds. The pale-throated three-toed sloth, Bradypus variegates, with its black face and white band across the forehead, are found Honduras and Argentina.

Order Artiodactyla (e.g. sheep, pigs, cattle, deer, antelopes, giraffes, and hippopotamus)

The majority live in relatively open habitats, such as plains and savannahs, but others dwell in forests, and one group is semi-aquatic. Within this order you will find some of the fastest-running mammals such as the antelopes and deer, and the relatively slow and cumbersome species such as pigs and hippopotamus. Artiodactyls are paraxonic (i.e. the plane of symmetry i.e. the line that divides the foot into two equal representatives passes between the third and fourth digits). In all species the number of digits is reduced at least by the loss of the first digit, and the second and fifth digits are small in many. The third and fourth digits, however, remain large and bear weight in all artiodactyls. This pattern has earned them their name Artiodactyla, which means "even-toed.

General characteristics of order Cetacea (e.g. whales, dolphins)

- They are aquatic
- Have blowholes on their heads
- Have flipper-like forelimbs
- Hind limbs are vestigial
- Tails are elongated to flukes (like a caudal fin)

Cetaceans are relatively large, generally characterized by streamlined bodies that glide easily through the marine environment. The Cetacea are one of the most distinctive and highly specialized orders of mammals. They include the largest animal that has ever lived, the blue whale; the highly intelligent and communicative dolphins; the tusked narwhals and blind river dolphins and singing humpback whales -nearly eighty living species in all. Although hunting and other human activities have endangered most cetacean species, the outlook for many is improving. Whales are highly specialized for life in the water. Most species are marine but dolphin species are found in the Yangtze, Amazon, Paraná, Indus and Ganges Rivers. Whales have stream-like bodies with highly compressed neck vertebrae, dorsal fins, and a tail with two finlike flukes arranged horizontally. Modern whales have greatly elongated anterior skull bones, and the nostrils are located on the top of the head, forming the blowhole. The forelimbs are specialized to form flippers, and the hind limbs and pelvis are extremely small and do not normally extend out of the body wall of the animal.

Eutherians:Perissodactyla, Chiroptera, Insectivora

General characteristics order Perissodactyla (e.g. horses, zebras, rhinoceroses)

Hooves with odd number of toes and members of this order have odd number of toes. Odd-toed ungulates comprise the order Perissodactyla (uneven finger/toe). The middle toe on each hoof is usually larger than its neighbours. In all species, the third digit is the most prominent on all feet; the plane of symmetry (the dividing line) of the foot passes through this digit and on the basis of which the perissodactyls are said to have a mesaxonic foot. The first digit (equivalent the thumb or big toe of humans) is lost in all species.

Perissodactyls are truly unguligrade, with the heel, sole, and digits of the foot never touching the ground.

Order Chiroptera (e.g. bats)

This order is well represented by bats, which are known as mammals:
Capable of flight; have wings derived from skin-folds which extend from fingers to body and legs.
Bats are the only flying mammal. A bat's wings are supported by bones like those in your hand. Each wing has a clawed thumb that the bat uses for clinging to trees, cave walls, or buildings.

Order Insectivora (e.g. hedgehogs, moles, shrews)

A notable feature of these eutherian mammals is that they feed on insects. The name insectivore (insect eater) refers to the food habits of the group as a whole. Although shrews and moles are not all strictly insectivorous, insects and other small animal life constitute the chief dietary items of most members of the group. Hedgehogs are mammals with long, pointed spines and soft, furry bellies. When threatened, they roll into a ball such that their spines point in all directions. Moles are small mammals with large claws that spend most of their time underground. Moles have polydactyl hands; each hand has an extra thumb (also known as a prepollex) next to the regular thumb.

Moles are nearly blind; they use their sense of touch to navigate their dark burrows. Moles are found in Australia and South Africa.

Shrews are active day and night, but mostly after dark. They are active most of the time, resting for only a few minutes between burst of activity. Shrews are common in our environment and give a sharp sound when confronted by man, dogs, cats etc. They not liked by cats because they give a pungent smell.

Eutherians of Rodenta, Lagormorpha, Primata

Order Rodentia (e.g. mice, rats, squirrels, marmots, capybara, beavers, porcupines, hamsters, Guinea pigs)

Rodentia is an order of mammals characterised by:

Two continuously growing - chisel-like incisors in the upper and lower jaws which must be kept short by gnawing. Forty percent of mammal species are rodents, and they are found in vast numbers on all continents other than Antarctica. Common rodents include mice, rats, squirrels, porcupines, beavers, guinea pigs, and hamsters. Rodents have sharp incisors that they use to gnaw wood, break into food, and bite predators. Most rodents eat seeds or plants, though some have more varied diets. Some species have historically been pests, eating seeds stored by people and spreading disease.

The capybara (Hydrochoerus hydrochaeris) is the largest extant rodent in the world (weighing up to 91 kg). Its closest relatives include the guinea pigs. The rodent is native to South America where the animal inhabits savannas and dense forests and lives near bodies of water. It is a highly social species and can be found in groups as large as 100 individuals but usually live in groups of 10–20 individuals. The capybara is not a threatened species though it is hunted for its meat and skin. The beaver (genus Castor) is a primarily nocturnal, large, semi-aquatic rodent. Beavers have flat and broad tails and sharp front teeth. They use their teeth to cut down trees for wood to build lodges and dams. They build dams to provide still, deep water to protect against predators, and to float food and building material.

The North American beaver population was once more than 60 million, but as of 1988 was 6-12 million. This population decline is due to extensive hunting for fur, for glands used as medicine and perfume, and because their harvesting of trees and flooding of waterways may interfere with other land uses. They are the second-largest rodent in the world (after the capybara).

Porcupines (spined pigs) are rodents with a coat of sharp spines, or quills, which the animal uses for defense or camouflage from predators. They are indigenous to the Americas, southern Asia, and Africa. Porcupines are the third largest of the rodents 63-91 cm long; 5.4-16 kg), behind the capybara and the beaver. They are rounded, large and slow and may brown, grey, and the unusual white. The common porcupine is a herbivore. It eats leaves, herbs, twigs and green plants like cabbage, clover or the bark of trees. In Nigeria, the meat of porcupines is eaten as a delicacy (bush meat).

Mice are small rodents found all over the world. The common house mouse, shown here, can be destructive causing damage and eating up crops, and spreading diseases through their feces. Squirrels are generally small animals with slender bodies, bushy tails and large eyes. Their fur is generally soft and silky, although much thicker in some species than others. Squirrels live in almost every habitat from tropical rainforest to semiarid desert, avoiding only the high Polar Regions and the driest of deserts. They are predominantly herbivorous, subsisting on seeds and nuts, but many will eat insects and even small vertebrates.

Order Lagomorpha (e.g. rabbits, hares, pikas)

Members of this order include the rabbits, hares that we, to some extent, are familiar with. They have in common:

- Chisel-like incisors for gnawing and strong hind legs for running and jumping.

Hares have longer ears than rabbits and usually larger than rabbits. Hares are born with fur on the body and with opened eyes, and the adults merely construct a simple nest and rarely live in colonies. Rabbits give birth to naked offspring's and with closed eyes, and tend to live in colonies in underground burrows. These animals are found in Nigeria and are very much loved for their meat.

New Zealand rabbits have well-rounded bodies; slender and muscular faces with round cheeks; large, long back feet; and small, short front pectoral muscles, long perforated ears that stand straight up, bright eyes, and thick, snowy fur on their bodies. Generally used for

scientific research and the meat eaten as a delicacy in Nigeria. Pikas are small mammals found in America and parts of Europe. They have short limbs and rounded ears. Like rabbits, they are herbivores.

Order Primata (e.g. monkeys, apes, humans)

We come to an interest order of the eutherians which includes monkeys, apes and humans. This is where we belong together with, so to say, our close relatives – the monkeys and apes. So what do we have in common with monkeys and apes that warrant our being put together in the same order? As primates, we share the following characteristics:

- Highly developed cerebral cortex.
- Have thumbs that are opposable to varying degrees.
- Forward facing eyes
- Omnivorous

Apes (chimpanzees, gorillas, and gibbons) are larger than monkeys, do not have tails and their arms are also usually longer than their legs.

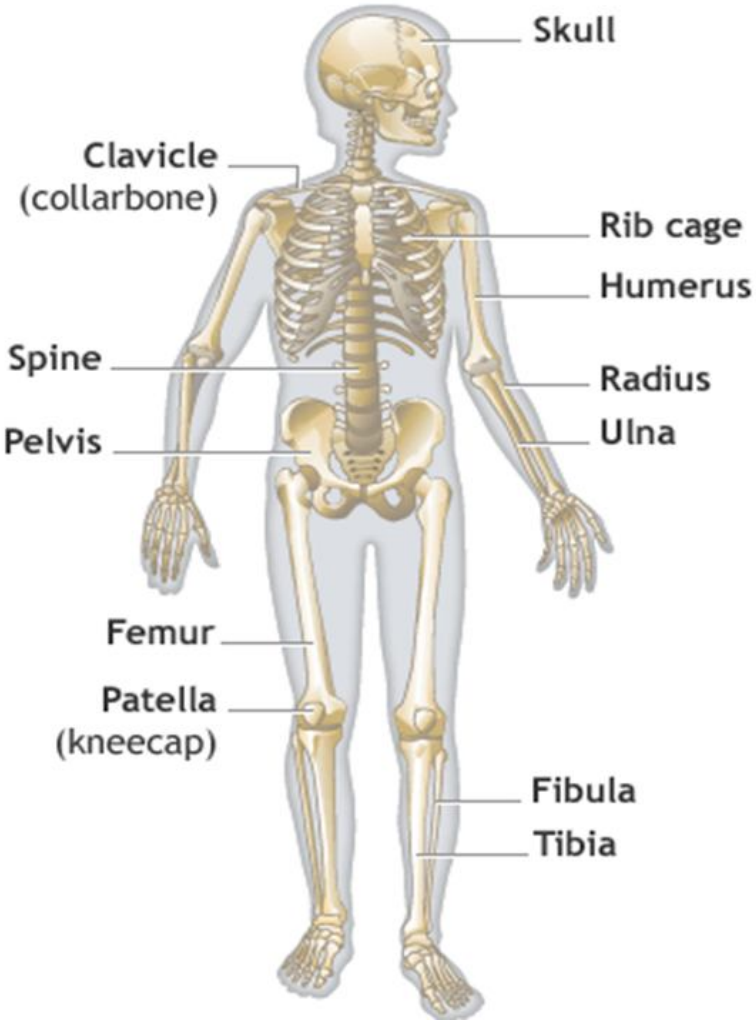


Figure 21 Representative skeletal system

Activities

Write the general characteristics of the following group of tetrapods:

- *Amniotes*
- *Reptiles*
- *Mammals*
- *Birds*

Summary

- ✓ *The tetrapods like reptiles, birds and mammals are referred to as amniotes. The amniotes have certain membranes associated with embryos inside the egg.*
- ✓ *Amniotes are a monophyletic group that appeared and diversified in the late Paleozoic.*
- ✓ *Allantois serves in respiration because it is vascularized and transports oxygen from egg surface to embryo and carbon dioxide from embryo to egg surface.*
- ✓ *Amniotes can be divided into two large groups called synapsids and diapsyds.*
- ✓ *Reptiles are cold-blooded vertebrates, which breathe by lungs throughout their existence and poses dry skin covered by scales.*
- ✓ *Reptiles are emerged from amphibian-like creatures. In the age of reptiles (lasted for greater than 165 million years) a great radiation of reptilian lineages with various terrestrial and aquatic appeared from.*
- ✓ *The Class Reptilian is composed of four orders namely Order Crocodilia (crocodilians), Order Testudines (turtles), Order Squamata (lizards and snakes) and Order Rhynchocephalia.*
- ✓ *The body of birds is covered with feathers composed mainly of keratin (the only animals that have feathers).*
- ✓ *They have strong bony endoskeleton (bones have air spaces).*
- ✓ *Their forelimbs modified as wings for flight (some have lost ability to fly).*
- ✓ *Their bipedal- two legs for locomotion (upper part of legs has scales).*
- ✓ *They have toothless horny beak; use gizzard to grind food.*
- ✓ *They are warm blooded animals (body temperature is internally regulated; endothermic/ homeothermic).*
- ✓ *They have efficient lungs with pouches for gaseous exchange.*
- ✓ *Their heart of four chambers.*
- ✓ *They have internal fertilization*
- ✓ *They have hard-calcareous shelled eggs with yolk.*

Review activities

Write the general classification of the following group of tetrapods and explain each:

- ✓ *Amniotes*
- ✓ *Reptiles*
- ✓ *Mammals*
- ✓ *Birds*

CHAPTER SIX

VERTEBRATES OF ETHIOPIA

Introduction

Manifold as the landscape is the Ethiopian wildlife. Ethiopia is one of the world's rich biodiversity countries and it deserves attention regionally and globally. It has a very diverse set of ecosystems ranging from humid forest and extensive wetlands to the desert. Ethiopia has a total land area of 1.22 million hectares, with a varied topography from 116 m below sea level at the Afar triangle to 4533 m above sea level at mount Ras-Dashen. Alpine and mountainous vegetation vary with coniferous and broadleaved forests, vast savannah, steppes and desserts are interrupted by lakes and intersected by permanent and seasonal rivers accompanied by galley forests.

The variations in climate, topography and vegetation have contributed to the presence of a large number of endemic species. Ethiopia's high faunal biodiversity reflects the existence of a large number of species of mammals and other higher vertebrates. This in turn reflects a diversity of habitats, created by differing combination of elevation rainfall, geology, soil surface and ground water. Ethiopia is among the world leaders in terms of richness and endemism of mammalian species. Ethiopia and Tanzania are among the top 25 endemic-rich countries of the world in terms of higher vertebrate species where as Ethiopia, Kenya, Uganda and Tanzania are individually, among the world leaders in terms of species richness and endemism of mammal species.

However, wildlife population in Ethiopia has diminished over the past century both in amount and distribution through loss of habitat, hunting and land clearance for farming; land degradation due to overgrazing is also intense. The forest cover of Ethiopia declined from 47% to only 3%. Even more important to conservationists, many endemic wild species occur within the country some of which inhabit only very small areas. In Ethiopia, 40 protected areas (National Parks, Animal Sanctuaries and Area Enclosure). Cover roughly 16.4% of the country's land area (186,000km2). These areas face many challenges due to growing populations, border conflicts and recurring drought. A chronic and growing

issue for Ethiopia's largely pastoral people is local access to grazing lands Given the recurring nature of conflict between conservation and local communities, it is critical that conservationists better understand local views with respect to wildlife and protected areas.

ENDEMIC LARGE MAMMALS OF ETHIOPIA AND THEIR STATUS

Mountain Nyala (*Tragelaphus buxtoni*)

The Mountain Nyala was the last of the great African antelopes to become known to science and still today very little is known about its habits or the full extent of its range. It was first collected by Major Ivor Buxton in 1908 and at that time seemed to be fairly widespread throughout the Arsi and Bale regions. Large numbers of them lived at very high altitudes, between ten and thirteen thousand feet, in the mountain forests where it was cold and wet much of the time, until the pressure of the human population destroyed vast tracts of their forest habitat.

In Arsi the population is now reduced to a remnant. Fortunately in Bale, despite a certain amount of burning of the heath, great tracts of mountain giant heath forest and hagenia were left unspoiled and the Nyala were never seriously threatened with extinction. They were so much hunted that they became even more wary and shy than is their nature and one rarely caught more than a glimpse of them as they melted away into the bush. The creation of the Bale Mountains National Park has considerably altered this picture. Here, where they are fully protected, they are beginning to be much more confident, and one can see them readily, especially in the mornings and evenings when they come down in to the hagenia forest on the lower slopes to graze. They are breeding prolifically and comparatively large groups of females and young can be seen.

Nyala are a magnificent sight, particularly the old bulls with their fine spiralled horns. Females do not carry horns and they have rather long necks and large ears, which are very conspicuous. The body colour of an old male is dark grey, with a line of long hair along the back forming a straggly mane which continues' along the spine as a brown and white

crest. Young calves are bright refocus and can be mistaken for bushbuck if the mother is not seen. Females are redder than the males, although they tend to become greyer with age. They move in parties or small herds of about five to ten females, and although the really old bulls are solitary and not often seen, young adult males carrying quite impressive spreads of horns, can sometimes be seen with or near the herds of females and young, and males are sometimes seen in small groups of two or three individuals. There are white markings on the legs and two white spots on the face, a white chevron between the eyes.

Nyala are similar to Greater Kudu but can be distinguished by the single spiral horns and the absence of clear white stripes on the body. Those of the Nyala are only faintly visible, and with a few faint spots on the flanks. It can however, be thought of as a high altitude race of the kudu. lt stands 135 cms. (53 inches) at the shoulder and weighs some 200-250 kgs (440-550 1bs). An old bull reaches 300 kgs. (660 Ibs). It has two white patches on the underside of the neck; the upper very wide and the lower one crescent-shaped. The back and upper flanks have about four white ill-defined stripes and a few white spots on the thighs. The tail does not reach to the hocks; it is bushy with a white underside and black tip.

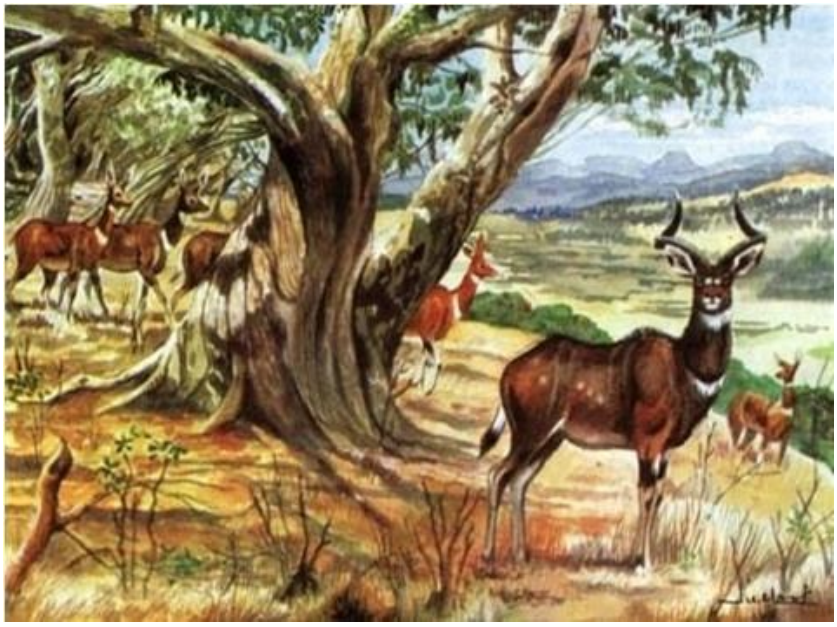


Figure 22 Mountain Nyala (Dega Agazain)

During the hottest part of the day, Mountain Nyala lie up in some shady place generally in the giant heath zone. They often choose a place where anyone approaching gives them warning by stepping on dried bracken or twigs and they then disappear in an almost miraculous way - not to be seen again. The best way to observe them is to select an inconspicuous spot and sit quietly until about four in the afternoon when they

Leave the giant heath and come down among the wider-spaced kosso trees. The Nyala is not an endangered species - there is a population of four to five thousand animals in the Bale region and they are breeding strongly. In fact, it may well be necessary to cull some of them by controlled hunting in order to prevent them destroying their own habitat by over browsing and breaking tracks through the undergrowth of the forest cover.

Licensed hunting also brings in revenue to the Wildlife Conservation Organization. Old bulls with trophy head (horns over 88 cms (35 inches) are fairly rare) are a true sporting challenge to the hunter. The Bale Park protects and preserves a representative section of forest and mountain unique in Africa and of spectacular beauty, as well as Ethiopia's finest antelope.

Harte beest (*Alceluphus buselaphus swaynei*)

The common African hartebeest has fifteen races of which two are already extinct and Swayne's is seriously endangered. In 1891-2, Brigadier-General Swayne, who discovered the animals, was the first European to visit the area well south of the Golis range of Somaliland and about 200 kms, (125 miles) from the coast. The plains were described as "covered with hartebeest, 300-400 to a herd and a dozen or so herds in sight at any time"- Herds of a thousand individuals were observed.

Within fifteen years the tens of thousands in Haud and Ogo that Swayne had seen had dwindled to such an extent that he estimated only about 880 remained. This rapid decline was due to the rinderpest, which swept Africa during the last century. The Somalis "went out daily and pulled down the sick animals with their bare hands in order to take the hides". Military campaigns followed in which the armed forces were permitted to kill as much game as they wanted. Arms flowed in and in the unsettled conditions which

prevailed hunters very efficiently, and in a very short time, had almost succeeded in wiping out the remnants of the Oryx and Hartebeest herds in the area.

Hartebeest are almost grotesquely long-faced and have high withers and sloping hindquarters. The horns, carried by both sexes, are doubly curved and mounted on a pedicle. Some authors still consider that according to the shape of the horns, which is supposed to be the most important diagnostic character, each race of hartebeest should enjoy full specific rank. However, the presence of hybrid forms has led zoologists to regard them as a sub-species, and it is now generally accepted to classify them as geographic representatives of the same species.

Figure 23 Hartebeest (Korkay)

Three types of horns can be distinguished in the buselaphus group: U-shaped as in the now-extinct North African buba hartebeest, and in the western hartebeest from Gambela, Nigeria and Cameroon; V-shaped as in the Lelwel Hartebeest (*A. buselaphus lelwel*), Jackson's Hartebeest (*A. buselaphus jacksoni*), and the South African cape hartebeest (*A.*

buselaphus caama), (all of which have very long heads and a uniform red-brown colour). The third type of horn is shaped like inverted brackets as in Coke's Hartebeest (*A. buselaphus cokii*), in the pale tawny *A. buselaphus tora* from Sudan and Ethiopia, and Swayne's Hartebeest, previously found in both Somalia and Ethiopia, but now restricted only to Ethiopia. Swayne's is the eastern race of *tora* to whom it is closely related, both species being smaller than the uthers, but is distinguished from it by its considerably darker body colour. It is a deep red chocolate brown or chestnut with a fawn or cinnamon colored rump, tail and lower half of legs.

The tail tuft is black. Its face and upper parts of its body have dark blackish markings: a black stripe from the shoulder to the knee, a black smudge on the flanks, and black markings on the outside of the hind limbs are typical, but on the darkest individuals these black markings do not show clearly in the field. Adult specimens sometimes have a silvery appearance as the hairs are tipped with white.

The horns are fully expanded and shaped like those of the *tora*; and curve out- wards and slightly downwards from the top of the head and then sweep upwards at the tips, and are usually, but not always, hooked backwards and they may or may not turn inwards. Swayne's Hartebeest lives in open country, light bush, sometimes in tall savanna woodland. These are social animals and are normally seen in herds of 4-15, up to thirty. Each herd is under the leader- ship of the master bull which leads the females with their young. The territory is defended by the male.

You may often see them grazing peacefully, with the bull on slightly higher ground acting as sentinel for his herd. The small surviving population is now restricted to the grass and thorn scrub plains of southern Danakil and the Rift Valley lakes region, on the Alledeghi plains east of Awash and from Awash valley to the southern lakes. The Nechisar National Park has been established for their protection. Located on the shores of lakes Abaya and Chamo, the park is accessible from Arba Minch. The best known herd is about 100 head which inhabits an area of 400 sq. kms near the shore of lake Chamo. However, the largest known population is on the heavily settled plain of Senkela in the Shashemane area. Here there are probably about 500 now in excellent condition but less likely to survive because of pressure on habitat. This hartebeest is listed by the IUCN among the species in the

world in "imminent danger of extinction" and is completely protected by law in Ethiopia (1972 Wildlife Conservation). Pressure on its habitat by human beings was the main cause of its decline, and it is to hope that with the creation of the national park and rigorous enforcement of the protection law, this beautifully colored antelope will start to recover its numbers.

Walia Ibex (*Capra W'alie*)

The habitat of the Walia Ibex is the High Semen, Ethiopia's dramatic high mountain terrain. In the earth's long history of violent geographical change, the most recent volcanic upheavals took place in eastern Africa, followed by torrential rains which created the thousand gushing waterfalls which in turn eroded away the newly formed mountain massif, creating the great gorges and gulleys which are so typical of the region. South west of Axum the land descends gradually southwards toward the Tekeze River. At the lip of the gorge at about 1,400 meters (4,600 ft.) one can look across the chasm to a similar plateau beyond. On top of this plateau, adorned with steep turrets and bastions rising in three distinct steps, is perched the north wall of the Semen.

Figure 24 Walia Ibex (Walia)

The mountain massif is a broad plateau, cut off on the north and west by this enormous single crag over 60 kms. (40 miles) long and 1,000-1,500 meters (3000- 5000 ft.) high. To

the south the table]and slopes gently down to 2,200 meters (7,000 ft.) divided by deep gorges 1,000 meters deep and taking two days to cross. Time has not yet been sufficient to soften the contours of the crags and buttresses of hardened basalt. As far as the eye can see looking north from the escarpment, the fused volcanic cores stand starkly defying the elements.

Overhead stretches the vast dome of a sky of the deepest blue, which spreads downwards as clear as sapphire to the mauve of the horizon. In this scenic splendour, live the Walia Ibex; here and nowhere else in the world. Forced by Man to retreat, and to retreat again, it has been driven in its extremity to inhabit the most inaccessible (except to a bird or a Walia), cliffs of the Semyen escarpment. The Walia once existed in significant numbers probably several thousands in the highland massif, feeding on the cliff faces and coming up to roam the plateau at rutting time.

Large herds wandered unmolested on these chilly heights. Even up to 50 years ago there were well over a thousand. With the Italian aggression in Ethiopia, the species started its dramatic decline to the brink of extinction. Guerrillas fighting the Italians and living off the country found the Walia a convenient source of meat. Later, the local people again took i up arms against the Walia, killing perhaps five in order to reclaim the meat from one. Most of them, whose wounded bodies spin and crash from the narrow ledges where they feed, into the abysses a thousand feet or more below, are never recovered.

Rarely, a rope descent will bring to the surface the meat and parts of the skin, but the trophy, the splendid horns desired by locals to make drinking mugs, and by sportsmen to decorate their sitting rooms, are usually lost forever. First recorded in 1835 by Ruppell, and first properly observed by Powell Cotton at the beginning of the century (l900), the Walia at that time was a mythical beast and little was known of its numbers and status. The inaccessibility of its habitat combined with various historical events such as the Italian occupation and World War II, which made visits to the region out of the question for longish periods, has prevented the keeping of a continuous record since then. So until Leslie Brown made his preliminary study in the early sixties, little was known of its

behavior or habits. A remnant of the early incursion of Palearctic fauna into the tropics, the nearest relative of the Walia is the Nubian Ibex. There is a gap of several hundred miles of lowlands between the southern- most limit of the Nubian and the highland habitat of the Walia.

The Walia differs in being 1arger and more massive, with dark brown as opposed to pale brown fur. The horns of the males are more massive but not quite so long, and have the knobs or ridges on the anterior surface reduced. The Walia has a bony process on the forehead. The anatomical differences together with the differences in habitat have lent weight to the argument that the Walia is a distinct species. The terrain which the Walia inhabits is from 2,300- 4,000 meters (7,500-13,500 ft.) but chiefly above 2,500 and below 3,000 (8,000-9,500ft.).

The tiny remnant population which remains is now con- fined to a range of about twenty miles of the highest and steepest bays and but tresscs of the northern escarpment. They are already extinct in all other parts of their range which once stretched from Byeda along the escarpment to Geech and Adis Gey. The narrow vertical range which they tend to occupy today would seem to be the result of persistent hunting. They have become extremely wary and shy and chosen to be not gettable from top or bottom. With protection maybe they will once again emerge on to the plateau.

Mountain sheep and goats have feet that are specially adapted for living in mountainous terrain. Their hooves have sharp edges and the undersides are concave, enabling them to adhere somewhat like suction cups. To watch even the youngest and smallest of the Walia kids gamboling about on slanted rocky ledges in a cliff face of terrifying steepness, a 500 meter drop only inches away, makes one catch one's breathe with anxiety. They never fall. The males and the females both have horns, but the males' are more massive. Curving back in a graceful arc to the withers they sometimes attain a length of over 110 cms. The females are smaller in body and lighter in color with shorter thinner horns. They live in small parties of two to half a dozen and the big old males often live solitary except during

the mating season. Because of the rarity of the animal, it is not often possible to observe a large male and one feels privileged to do so.

The magnificent horns and striking coloration make it an unforgettable sight. They are sturdily built animals standing about a meter high at the shoulder and weighing up to 120 kgs. Their beautiful chocolate to chestnut brown coats shade to grayish brown round the muzzle, paler grey around the eyes, lower flanks, legs and rump, and pale grey or white on the belly and inside of the legs. There is a black stripe down the outside of the legs and a white garter on each fetlock broken in the hind legs by a black streak into the cleft of the hoof. Mature males sport an elegant black beard.

The tail is short with a brush like tuft of black hairs. You can usually observe them when come out on to the rocky ledges to sun themselves in the morning and evening. Little herds of females and young are not uncommon or even single females with a kid at foot. Sometimes you will see a yearling group of young males which can be distinguished by their paler greyer color and the thickness of their small short horns. They eat grass and herbs, but prefer to to browse rather than graze, standing up on their hind legs like domestic goats to reach the tender shoots of giant heath. There is no shortage of food, as inside the forest of heath there is abundant forage of herbs and sweet soft grasses.

They tend not to drink although water is plentiful; it is assumed that they get sufficient moisture from the green stuff on which they feed. They usually lie up in caves or thickets during the day, although this is not an in- fallible rule and I have observed them at lunchtime - a group of youngsters playing in the sun. The Walia's story is not yet ended. In 1963 it was classified by the IUCN as in danger of extinction. In that year the total number remaining alive was estimated at less than 200, probably 150. Indiscriminate hunting and destruction of habitat by local people had combined to drive the few remaining animals on to the vertical cliff sides for survival- (Only four adult males have been taken since 1956 by legitimate shooting). Fortunately before the end came the Ethiopian Government recognized the danger and, in 1965, drew up plans to establish a national park to protect both the habitat and its fauna, and the park was gazetted the same year. It was found that

numbers had remained steady for two years, indicating that with protection they might increase fairly rapidly. Guards were appointed from Geech to Mietgogo to curb local poaching and illegal cultivation and burning of habitat. In the past fifteen years, numbers have increased steadily, as the females are still ready and willing to breed in the caves in the cliff face. At the present time, not less than 10% of the cliff surface is composed of broad] edges or green gullies in which Walia can feed. Brown estimates that this amount of land space can support a population of two or three thousand. The Walia has no natural enemies apart possibly from the occasional bird of prey, and thus with complete protection from Man they could be expected to recover their numbers and to double the present population in ten years.

At present it is still difficult to properly enforce the protection laws, and the local people cannot be expected to know that this animal exists only here. Nor could they realize that it could be anticipated to generate a far larger income if allowed to live and breed, than its dead parts will ever earn. It can only be hoped that the precipitous terrain in which the last survivors live will enable a nucleus herd to survive until such time as visitors from all over the world will be able to come and observe this rare creature in the magnificence of its mountain habitat.

Gelada Baboon (*Theropithecus gelada*)

The Semen highland massif is considered to be the finest scenery in all Africa and it is for this reason, and the fact that the area is the home of the Walia Ibex, the Semen Fox and the Gelada Baboon that it has now been gazetted as a national park.

Figure 25 Gelada Baboon

The Gelada is not in fact peculiar to the Semen as is the exclusive Walia Ibex, but they are more numerous here than in their other habitats Some live at Debre Sina not far from Addis Ababa and others at Debre Libanos on the way to the Blue Nile; there are also small populations in the Mulu and Bole Valley gorges. But in the Semen there may be as many as 20,000, and troops of 400 together may be seen. They do not molest humans and, more surprisingly, the local people do not molest them. Thus they are very tame and will allow humans to approach quite close to the troop before moving nearer to the cliff edge.

The Gelada was discovered in 1835 by the explorer Ruppell, who named it by the local name used by the inhabitants of Gondar region where he first observed it. They are not difficult to study as they are very tame; however, little interest was shown in them until recently, when Patsy and Robin Dunbar made an exhaustive study of their social behavior. The social behavior of the apes and monkeys is evidence of a very high degree of intelligence and studies of their rudimentary social structures are proving of considerable value in analyzing the origins of human social behavior.

Geladas live along the edges and steep slopes of precipices. They never move far from the rim and thus their distribution is linear along the escarpment. At night they climb down the steep cliff faces to caves where they roost on ledges, often huddled close together for

warmth as Semen nights are frosty and bitterly cold. Babies cling tight to their mothers even in sleep. In the morning in the warm sun they climb up again to the top of the cliff and spread out to feed. Geladas are mainly vegetarian, living on herbs, grasses and roots, but they also eat insects and locusts. They never eat meat, or hunt or kill even small birds or mammals.

As a result of this restricted diet they are obliged to spend a very high percentage of their lives foraging and browsing in order to obtain sufficient nutrients to survive. This may explain why they are so extremely peaceable by nature, with very little squabbling even amongst themselves. They have no natural enemies (except of course, Man, who takes a fair toll with his rifle. The great mane of the adult male is used for traditional headdresses by highland warriors). Apart from feeding, "grooming" is their other main pastime.

This entails simply picking through each other's fur. This is not only a friendly and peaceful occupation, but it serves also to establish bonds between various members of a 'harem' and to cement the accepted relationships in the hierarchy, between male and female, older and younger members. The long narrow plateaus of the Semen slope upwards from the south until they end in the dizzying precipices of the northern escarpment. This is the haunt of the Walia, and the Gelada do not frequent these vertical cliffs, but the rims of the stupendous gorges and ravines which bisect the plateau. The troops tend to graze the higher moorlands, amongst everlastings, giant lobelias and alchemilla-tussock grass.

Never far from the rim, which is their refuge when danger threatens, have they disappeared over the edge on to the grassy slopes and ledges of the gorge sides. Their grazing ranks are so arranged that the males are always farthest from the edge and thus it is "women and children first" when they have occasion to flee to safety. They are comparatively large and impressive, the males being about 75 cms (30 inches) tall without tail and twice the size of the females. Their sad up- turned faces are marked with large ridges running from below the outer side of the eyes to the nose.

The face is dark grey with wrinkles and very long whiskers, forming falciform tufts of light colored hairs projecting upwards and backwards on the sides of the head. Their nickname, "bleeding heart baboon" stems from the bare red skin areas on the chest, which

are actual]y two triangles, and another crescent-shaped on the throat. Both sexes have these bare places. In the female the fleshy "beads" which surround the bare patch swell up and turn from whitish to bright red to indicate estrous condition. In the males the patches are always red and do not changes color.

The old males have a cape of very long hair which hangs down (to the ground when they are sitting) and tufted tails which have earned them another name - lion monkey. The female's mane is much less impressive than the male's. Both sexes are a light to dark brown, the fur cape shading from one color to another as it moves in the mountain breezes.

They are found at more than 4,500 meters (14,600 ft.) and have even been seen at the top of Ras Dashan at 4,620 meters (15,160 ft.) where there is nothing fox them to eat, so they must just go up to look at the view. Their handsome appearance and the beauty of their habitat is one thing, but perhaps the most fascinating aspect of these creatures is their social structure which is the most complex in the animal kingdom after that of man. You see them grouped into herds of up to 400 or so individuals, each of which is made up in turn of "harems", which are groups of from two to eight females and young ones with one dominant male and often one hanger-on called a "follower", who ingratiates himself with the juvenile females, with a view to enticing them away in due course and forming his own harem. Harem owning males do not attempt to steal each others' wives.

Young males get together in groups from the age when they finally leave their mothers until they are mature enough to become a follower. These various social groups all move and feed together, only occasionally leaving the herd if food supplies demand it. They travel about three miles a day while feeding, and sleep on ledges on the cliff face wherever they happen to be when night falls. The harem is a very close family unit. Ninety-five percent of the social interactions of adults are with other members of the same harem.

Only juveniles and babies cross the invisible boundaries to play with others of their own age. Unlike the Hamadryas baboon, where the harem is kept together by male aggression, the Gelada harem is run more or less by solidarity between the females. It is they who decide in which direction they will feed, it is they who instantly rally together if their male

should threaten any one of them because she strayed too near another male! Only one of the females has a strong relation- ship with the male at any given time. But they all groom each other as well as him and thus establish a jealousy-free harmonious relationship with each other.

For a young male to acquire a harem of his own is quite a long and difficult process. He starts off when he is about two leaving his mother's harem in favors of play groups of other juveniles. By the age of three he starts playing around with the younger members of the all-male groups, and at four he things of nothing else but joining one (which is not always easy as the groups are very tight and do not readily welcome new members).

Having succeeded he settles down to life as a bachelor sub-adult in his group. When he is about five or six, he begins to show an interest in the harems again. He doesn't want to anger the adult male of any harem so he confines his activities to following along, occasionally grooming with the male but mainly amusing himself with the young females the ones too young to cause jealous feelings in the old male. Should the old male die or become weak, the young one will take his place, but it is more common for the youngster just too gradually withdraw taking with him several of the young females. This is not a sudden break the one group just spends progressively more time on its own. The male then sets about getting a few more females from other harems - young females belonging to a harem with no follower may join him before their father takes an interest in them.

Over the years each male has a succession of followers who take away his daughters to form the nucleus of their own harems; a system which prevents in- breeding. Sometimes a younger male may persist in paying court to the wives of an older, and generally harass him. The few fights which occur are usually the outcome of such behavior. The old one finally, after trying to retain his females' loyalty and affection, may give up the struggle. If so, he does not retire from the harem - he just adopts the follower role and spends his retirement grooming and playing with the juveniles.

The relationships of the Geladas are very delicately balanced. To communicate their intentions they have need of a fairly subtle range of signals. They have therefore acquired a

great diversity of social behavior patterns and vocalizations. Greater in fact than any other non-human primate. For example, where the olive baboon has fifteen contact calls, and the colobus six, the gelada makes twenty-seven distinct noises. To hear him speak is as it were to listen to a foreign language being spoken. The expressions on the face are in fact signals with a distinct meaning: the raising of the eyebrows reveals two red triangles above the eyes a warning signal; the rolling back of the upper lip in a ghastly smile, a flash of red gums and white teeth, signifies (as perhaps does the human smile) appeasement, and thus avoids possible conflict.

So far, the gelada is not on the endangered species list, and now that he lives protected in at least one of his habitats, one can hope that he never will be. However, the occasional random slaughter "for fun" of these beautiful, gentle and intelligent creatures should be curbed for obvious reasons.

Menelik's Bushbuck (*Tragelaphus seriptus meneliki*)

Belonging to the same family as the Mountain Nyala, the Kudu, the Bongo and the Eland, the bushbuck shares with them the family characteristic of shy and elusive behavior. Over forty races of bushbuck have been identified, which vary considerably both from the point of view of coloration and from the type of habitat they frequent. Most of them are forest-living animals inhabiting dense bush, usually near water, though this is not an essential, as some of them have been known to go without drinking for long periods when necessary.

Of the two Ethiopian races, meneliki and powelli, the latter is the more common and somewhat smaller. But Menelik's is also fairly widespread and can be seen in much of Ethiopia's highland forest up to the treeline at 4,000 meters (13,000 ft.) They are common, for example, in the cedar forests of Menagesha and parts of the Entoto range, even if, eucalyptus groves as long as there is still some ground cover. No accurate estimate has been made of their total population because of their nocturnal and furtive habits.

Like the Mountain Nyala, they are easier to observe in the Bale Mountains National Park where they are fully protected and therefore a little less shy. Powelli inhabits the lower

lying country, so between them they cover almost all types of habitat, from highland forest to savanna woodland - with the exception of open country.

In Bale, as you climb up through the hagenia forest with its flowering trees, and enter the zone of Giant Heath and St. John's Wort, sunlight dapples the ground beneath your feet, lichens hang softly from every twig and bright dark green mosses clothe the branches. Suddenly a glimpse of bright chestnut draws your attention to the female bushbuck, and usually not far away is the shining dark, almost black, male.

Bushbucks are often solitary, but in Bale anyway, Menelik's is almost always seen in pairs or small family parties of female and young. They are extremely beautiful little animals, with a coat longer than that of other bushbucks, perhaps because of living in the lower temperatures of high altitudes. The horns, which are carried only by the male, have a spiral twist and a well-defined longitudinal ridge or keel on the front or back surfaces, and transverse rings. The record horn length is 34.93 cms. They stand 80-90 cms (35 inches) at the shoulder and slightly higher at the rump, running along in a hunched up manner between the bushes and shrubs. They have large broad ears and when they stop to regard an intruder the ears with their tufts of white are conspicuous.

A spinal crest of longish white or black hairs runs down the centre of the back. A white spot on the cheek, and on the female sometimes a blackish collar on the lower neck, faint white spots on the haunches, and limbs with a contrasting dark and light pattern. The tail is bushy and long, reaching to just above the hocks, white underneath and black- tipped.

Figure 26 Menelik's Bushbuck (Dukula)

Most bushbucks tend to spend the heat of the day lying up in dense bush where there is no hope of spotting them. The highland forest where Menelik's bushbuck lives, is relatively cool and you can see them (if you are in luck) at any time of day. It is more usual however, to spot them from about four o'clock onwards, or in the early morning.

They have a loud barking alarm call, sometimes repeated, which can be heard from some distance away, and also a series of grunts. Very few Menelik's have been collected by sportsmen. The multiplication of numbers in the park could lead to its greater accessibility to authorized huntsmen, and produce an income for conservation

5.1. Wildlife in National Parks and Natural reserves

Awash National Park is one of the National Parks of Ethiopia. Located at the southern tip of the Afar Region, this park is 225 kilometers east of Addis Ababa (and a few kilometers west of Awash), with its southern boundary along the Awash River, and covers at least 756 square kilometers of acacia woodland and grassland. The Addis Ababa - Dire Dawa highway passes through this park, separating the Illala Saha Plains to the south from the Kudu Valley to the north.

Abijatta-Shalla National Park is one of the National Parks of Ethiopia. Located in the Oromia Region 200 kilometers south of Addis Ababa to the east of the Ziway - Shashamane highway, it contains 887 square kilometers including the Rift Valley lakes of Abijatta and Shalla. The two lakes are separated by three kilometers of hilly land. The altitude of the park ranges from 1540 to 2075 meters, the highest peak being Mount Fike, which is situated between the two lakes.

Besides the two lakes, the primary attraction of this national park are a number of hot springs on the northeast corner of Lake Abijatta, and large numbers of flamingos on the lake. Care must be exercised in driving vehicles out to the edge of this lake, as the thin crust of dried mud on the surface can give way without warning.

The Bale Mountains National Park is a national park in the Oromia Region of southeast Ethiopia. Created in 1970, this park covers about 2,200 square kilometers of the Bale Mountains to the west and southwest of Goba in the Bale Zone. Within its boundaries are some of the highest points in Ethiopia, which include Mount Batu. Bale Mountains contains three distinct ecoregions: the northern plains, bush and woods; the central Sanetti Plateau with an average elevation of over 4000 meters; and the southern Harenna Forest, known for its mammals, amphibians and birds including many endemic species. The central Sanetti Plateau is home to the largest population of the rare and endangered Ethiopian wolves.

Gambela National Park is a proposed National Park, but the steps needed to fully protect it have not been completed as of 2002. Located in the Gambela Region, its 5061 square

kilometers of territory is encroached upon by cotton plantations and refugee camps. The Gambela Park was established primarily to protect two species of endangered wetland antelopes: the White-eared Kob and the Nile Lechwe. Other wildlife reported as living here include populations of elephant, African Buffalo, lion, roan antelope, tiang, Lelwel Hartebeest, olive baboon, and guereza monkey. Several birds only found in this area include the shoebill stork, the Long-tailed Paradise Whydah and the Red-throated and Green Bee-eaters.

Mago National Park is one of the National Parks of Ethiopia. Located in the Southern Nations, Nationalities, and Peoples Region about 782 kilometers south of Addis Ababa, the 2162 square kilometers of this park are divided by the Mago River, a tributary of the Omo River, into two parts. The park office is 115 kilometers north of Omorate and 26 kilometers southwest of Jinka. All roads to and from the park are unpaved.

Nechisar National Park (also spelled as Nech Sar) is one of the National Parks of Ethiopia. Located in the Southern Nations, Nationalities, and Peoples Region (SNNPR) immediately to the east of Arba Minch, its 514 square kilometers of territory include the "Bridge of God" (an isthmus between Lakes Abaya and Chamo), and the Nechisar (English: white grass) plains east of the lakes. Park elevations range between 1108 and 1650 meters above sea level. Nechisar National Park was established in 1974. Under the management of African Parks since 2005, it is reportedly scheduled to hand over management to the Ethiopian government in June 2008.

Omo National Park is one of the National Parks of Ethiopia. Located in the Southern Nations, Nationalities, and Peoples Region on the west bank of the Omo River, the park covers approximately 4,068 square kilometers, about 870 kilometers southwest of Addis Ababa; across the Omo is the Mago National Park. Although an airstrip was recently built near the park headquarters on the Mui River, this park is not easily reachable; the Lonely Planet guide Ethiopia and Eritrea describes Omo National Park as "Ethiopia's most remote park."

The lower reaches of the Omo River were declared a UNESCO World Heritage Site in 1980, after the discovery of the earliest known fossil fragments of *Homo sapiens* that have been dated circa 195,000 years old.

Semen Mountains National Park is one of the National Parks of Ethiopia; located in the Semen (North) Gondar Zone of the Amhara Region, its territory covers the Semien Mountains and includes Ras-Dashan, the highest point in Ethiopia. It is home to a number of extremely rare species, including the Ethiopian wolf, Gelada Baboon, and the Walia Ibex, a wild goat found nowhere else in the world. More than 50 species of birds inhabit the park, including the impressive Bearded Vulture, or Lammergeyer, with its 10-foot (3m) wingspan.

Yangudi Rassa National Park is one of the National Parks of Ethiopia. Located in the Afar Region, its 4,730 square kilometers of territory include Mount Yangudi and the surrounding Rassa Plains, with altitudes from 400 to 1459 meters above sea level.

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Self test exercise

Part I. Choose the best answer from the given options under each question.

1. *Which one of the following is classified as the inner layer of the animal tissue?*

A. *Ectoderm*

B. *Endoderm*

C. *Mesoderm*

2. *Animals have no general body plan or axis of symmetry that divides the body into mirror-image halves is:*

A. *Asymmetrical*

B. *Radial*

C. *Bilateral*

D. *All*

3. *One of the following is the change in the evolutionary history of the animals?*

A. Development of radial symmetry

B. Development of Cephalization and segmentation

C. Development of invertebrates from sac-like body animals

D. All are correct

4. *One of the following is not the organization of the animal cell?*

A. Cell wall B. Cytoplasm C. Nucleus D. Cell membrane

5. Which organ of the body is responsible for protection against environmental factors?

A. Respiratory organs B. Integumentary organs C. Digestive organs D. Internal organs

6. One of the following is the classification system of animals to understand their diversity?

A. Kingdom B. Phylum C. Species D. Class E. All are correct

7. All of the following criterias are used to classify animals in to groups except:

A. Body plan B. Body symmetry C. Segmentation D. Body appendages E. Species list

Part II. Answer the following questions accordingly

1. *Describe the general characters of fishes.*
2. *Explain four fish tail types briefly?*
3. *Write short and concise notes on the evolution of amphibians?*
4. *List down four general characteristics of reptiles?*

5. *Write three points that birds and reptiles made similar?*
6. *Write short notes about the different groups of mammals?*