CHAPTER 9

DIVERSITY AMONG ANIMALS

Major Concepts:

Number of allotted teaching periods: 18

The name animalia is derived from Latin word *anima* meaning breath or soul. All the animals of the world are included in the kingdom animalia. Now the question arises, what is an animal? How can we define an animal? We can define animal very generally that animals are eukaryotic, multicellular heterotrophs that lack cell walls. We will have a glance at the characteristics of animals.

9.1 CHARACTERISTICS OF ANIMALS

Animals may be free living and motile, sessile or a parasite. Animals are found almost in all types of habitat. They range in **size** from worms only seen with a microscope to blue whales, which weigh up to 150 tons. Animals are multicellular eukaryotes.

Most animals have cells specialized to form tissue and organs. Body may be soft or hard, radial symmetry or bilateral symmetry, diploblastic or triploblastic segmented. Body may be covered by shell, chitin, scales, furs. Animals may be acoelomate, pseudcoelomatc and coelomate. All animals are **heterotroph** and usually acquire food by ingestion followed by digestion. Animals may have no **definite digestive** system e.g. sponges, it is a saclike

gastrovascular cavity e.g., *Hydra*, or it may be rudimentary e.g. tapeworm. **Digestive system** may have one opening e.g. planaria. Tube like digestive system have two openings e.g. nematodes to mammals. **Excretory system** may be absent in sponges, cnidarians. It is like branching tubes in flatworms. Excretory system is present in nematodes to mammals. There is no definite **nervous system** in sponges, and cnidarians. Nervous system is present in nematodes to chordates. Most animals have sense organs. All animals respire but a **respiratory system** is absent in sponges, cnidarians, flatworms, nematodes (roundworms) and annelids. Respiratory system is present in arthropods to chordates.

Skeleton is present is all animals. Spicules are present in sponges. Hydroskeleton is present in worms and annelids. Skeleton may be exoskeleton in arthropods, molluscs (mollusks), and chordates or it may be endoskeleton in mollusks (sepia), echinoderms, chordates and highly developed in vertebrates. Most animals are capable of locomotion at sometime during their life cycle.

Circulatory System is absent in sponges, cnidarians, roundworms and flatworm. It is present in annelids to chordates. Reproductive cells; organs or **reproductive system** is present in all the animals. Asexual reproduction is seen in sponges, cnidarians, sexual reproduction takes place in all other groups of animals and produce an embryo that undergoes specific stages of development. Animals have a **life cycle** in which the adult is always diploid. The life cycle may have larval stages e.g. sponges, annelids, arthropods, molluscs, echinoderms and amphibians. **Regeneration** is exhibited by sponges, some cnidarians, annelids and echinoderms.

Thus we have a number of characteristics that answer the question, what is an animal? What characteristics animals have common?

First, being **eukaryotic**, unites animals with protists, fungi and plants and separates them from all prokaryotes. Secondly being **multicellular** separates animals from fungi, plants and most **protists**, which are unicellular. Third being **heterotrophic** separates animals and fungi from plants and plantlike protists (the algae), which are photosynthetic. Finally **lacking cell walls** distinguishes animals from plants, algae and fungi, so we have four features that taken together distinguish animals from other organisms.

9.2 CRITERIA FOR ANIMAL CLASSIFICATION

Classification of animals is based on presence or absence of tissues, number of tissue layers, type of symmetry and type of coelom.

Animals can be Classified According to Presence or Absence of Tissues

The animal kingdom has been divided into two subkingdoms on the basis of presence or absence of tissues: subkingdom – **Parazoa** and subkingdom – **Eumatozoa**. Parazoa includes the simplest metazoans or multicellular animals that show the cellular grade of organization in which cells demonstrate division of labour but are not strongly associated to perform a specific collective function. They are asymmetrical. It includes all the sponges.

In **Eumatozoa** – similar cells are grouped together and perform their common functions as a highly coordinated unit called **tissue**. The tissues are assembled into larger functional unit called **organs**. Most metazoa have an additional level of complexity in which different organs operate together as organ system. Eleven different kinds of organ systems are observed in Eumetazoa: skeletal, muscular, integumentary, digestive, respiratory, circulatory, excretory, nervous, endocrine, immune and reproductive.

Animals can be Classified According to Number of Tissue Layers

Animals may be classified as diploblastic and triploblastic animals.

Diploblastic Organization

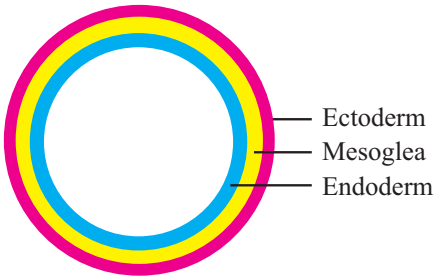


Fig: 9.1 Diploblastic Organization

One of the main events during the development of the animals is the establishment of **germ layers** from which all other structure is derived. The body of **diploblastic animals** consists of two germ layers of cells, the **ectoderm** and **endoderm**. Such animals have tissue level of organisation. There is a jelly like **mesoglea**, which in most cases is non-cellular between the two germ layers. There are no specialized organs, no special transport system and no central nervous system in diploblastic animals. A neuron net is present. There is only one cavity called **gastrovascular cavity** (9.9) with only one opening. This is known as sac like digestive system. These animals are radial symmetry. The examples of diploblastic organization are animals of phylum Cnidaria.

Triploblastic Organization

The body of the **triploblastic animals** consists of three germ layers i.e. ectoderm, mesoderm and endoderm (9.3a). After embryonic development these layers in most triploblastic animals are not distinct as separate layers of cells, but are represented by the structures formed from them. Animals with three germ layers have an organ level of organization. The animals have specialized cells, organs and organ systems. The **ectoderm** gives rise to integumentary and nervous system. **Mesoderm** gives rise to muscular, skeletal, blood vascular and reproductive systems. **Endoderm** forms the lining of digestive tract and the glands of digestive system. The digestive system is of a tube type having two openings the mouth and the anus. The body of the animals has bilateral symmetry. Triploblastic animals may be acoelomate, pseudocoelomate or coelomate.

Animals can be Classified According to Body Symmetry

The subkingdoms Eumatozoa are divided into: grade Radiata and grade Bilateria.

Grade Radiata

It includes all the animals with radial symmetry having a top and bottom and similar body parts are arranged as spokes or radiate from a central body axis. e.g. Jelly fish, sea anemone belong to phylum Cnidaria. The body of a sea anemone can be cut in two equal halves vertically in any plane. All the animals included in grade radiata are also diploblastic. Radial symmetry is considered an adaptation for a sessile life.

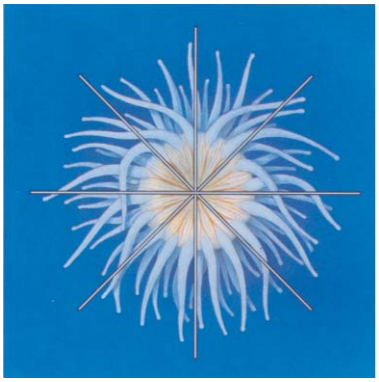


Fig: 9.2a Radial Symmetry

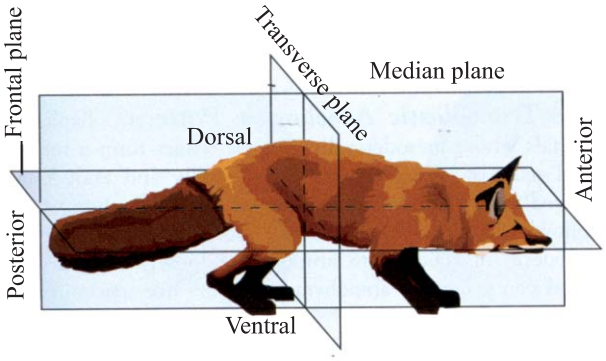


Fig: 9.2b Bilateral Symmetry

Grade Bilateria

In bilateral symmetry, a plane through the midline of the body divides it into roughly equivalent right and left halves that are mirror image. The front or anterior end of the animal generally has a head. The posterior or rear end of the animal may be equipped with a tail. There are well defined dorsal and ventral surfaces. The animals belonging to phyla Platyhelminthes, Aschelminthes, Annelida, Mollusca, Arthropoda, Echinodermata, Hemichordata and Chordata are included in this grade. In Echinoderms the larval stages show bilateral symmetry and the adult secondarily develops radial symmetry. All the animals included in grade Bilateria are triploblastic. These may be acoelomate, pseudocoelomate or coelomate. Bilateral symmetry is considered an adaptation to motility.

Animals can be Grouped According to Type of Body Cavity

A widely held system for grouping animal phyla is based on the presence and type of body cavity or **coelom**, a fluid filled space between the other body wall and the digestive tube.

Acoelomate

In platyhelminthes the body is essentially a double walled sac surrounding a digestive cavity with a single opening to the outside, the mouth. There is no body cavity so these animals are called **acoelomate**. There are cellular tissues called **mesenchyma** which fills the spaces between ectoderm and mesoderm. It forms a packing around the internal organs of the animals to support and protect them.

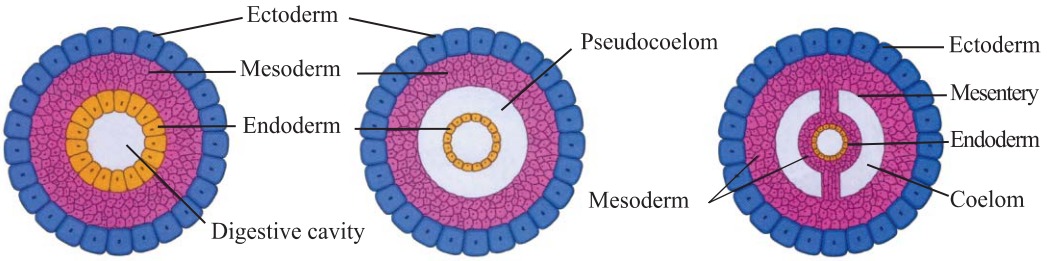


Fig: 9.3 Acoelomate, Pseudocoelomate, and Coelomate Comparison

Pseudocoelomates

Complex animals usually have a tube within a tube plan. The inner tube, the digestive tract, is lined with tissue derived from the endoderm and open at each end. Between the two tubes is a second cavity the body cavity. If the body cavity develops between the mesoderm and endoderm it is called pseudocoelom (false cavity). Animals with this type of body cavity are called **pseudocoelomates** e.g. Aschelminthes (Nematodes).

Coelomate

If the body cavity forms within the mesoderm and is completely lined by mesoderm the body cavity is a **true coelom**. It is filled with coelomic fluid. Animals with a true coelom are called **coelomate**. In coelomates gut is more complex and neurosensory, excretory, circulatory respiratory and reproductive systems are well developed. Animals from annelids to chordates are coelomate.

Coelomate Can be Classified as Protostomes or Deuterostomes

Animals with a true coelom can be divided into two groups: **protostomes** and **deuterostomes**. These groups reflect two main line of evolution based on their pattern of early development. Early during development, the embryo consists of a little ball of cells known as **blastula**. A group of cells move inward to form and opening called the **blastopore**. In most of the mollusks, annelids and arthropods, this opening develops into the mouth. These animals are **protostomes** (from Greek words meaning "first, the mouth").

In echinoderms (for example, sea stars and sea urchins) and chordates (the phylum that includes the vertebrates), the blastopore does not give rise to the mouth. Instead it generally develops into the anus. The opening that develops into the mouth forms later in development. These animals are the **deuterostomes** ("second, the mouth").

Another difference in the development of protostomes and deuterostomes is the pattern of **cleavage**, the first several cell divisions of the embryo. In many protostomes, the early cell divisions are diagonal to the polar axis (the long axis of the egg), resulting in a somewhat spiral arrangement of cells; any one cell is located between the two cells above or below it (fig 9.4). This pattern of division is known as **spiral cleavage**. In **radial cleavage**, characteristics of the deuterostomes, the early divisions are either parallel or at right angles to the polar axis; the cells are located directly above or below one another.

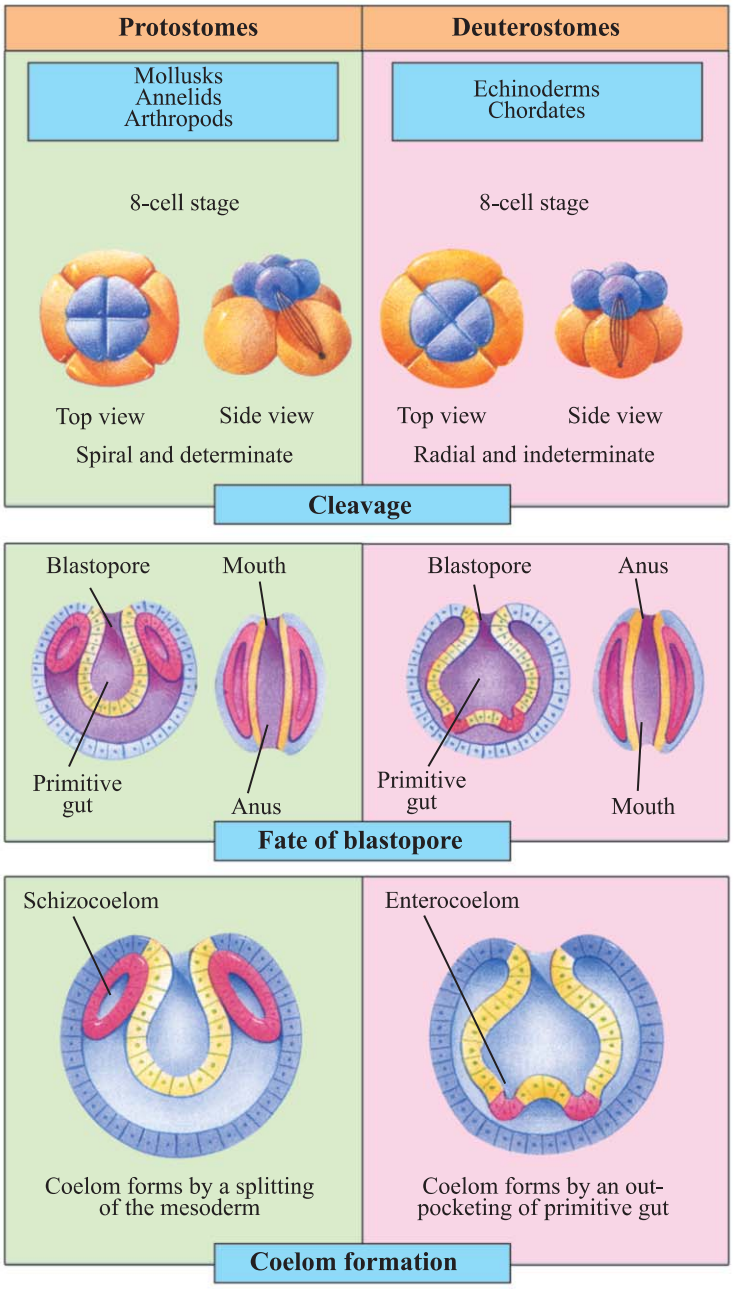


Fig: 9.4 Protostomes versus Deuterostomes

In the protostomes, the fate of each embryonic cell is often fixed very early. For example, if the first four cells of an annelid embryo are separated, each cell develops into only a fixed quarter of the larva; this is known as

determinate cleavage. In deuterostomes, cleavage is usually **indeterminate**. If the first four cells of a sea star embryo, for instance, are separated, each cell is capable of forming a complete, though small, larva.

Still another difference between protostome and deuterostome development is the manner in which the coelom is formed. In protostomes, the mesoderm splits and the split widens into a cavity that becomes the coelom. This method of coelom formation is known as **schizocoely** and for this reason the protostomes are sometimes called **schizocoelomates**. In many deuterostomes, the mesoderm forms as "outpocketings" of the developing gut. These outpocketings eventually separate and form pouches; the cavity within the pouches becomes the coelom. This type of coelom formation is called **enterocoely** and these animals are sometimes referred to a **enterocoelomates**.

Table 9.1 Comparison of Protostomes and Deutrostomes

PROTOSTOMES	DEUTEROSTOMES
Cleavage mostly spiral	Cleavage mostly radial
Endomesoderm usually from a particular blastomere.	Endomesoderm from enterocoeluos pouching (except chordates)
In coelomate protostomes the coelom forms as a split in mesodermal bands (schizocoelous)	All coelomate, coelom from fusion of enterocoelous pouches (except chordates, which are shizocoelous)
Mouth form, at or near blastopore; anus a new formation.	Anus form, at or near blastopore; anus a new formation
Embryology mostly determinate (mosaic)	Embryology usually intermediate (regulative)
Blastopore develops into mouth	Blastopore develops into anus
Includes phyla Platyhelminthes, Aschelminthes, Annelida, Mollusca, minor phyla.	Includes phyla Echinodermata, Hemichordata, Chordata

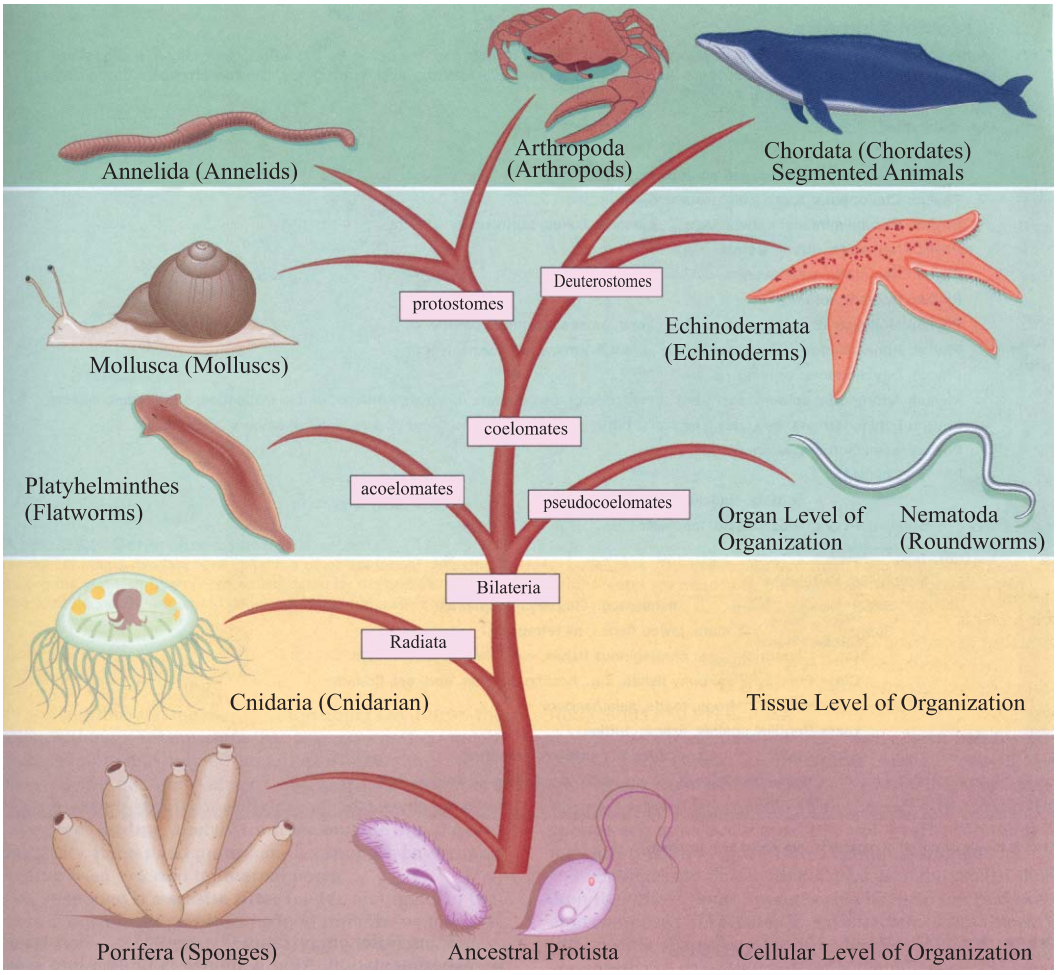


Fig: 9.5 Phylogenetic Tree of the Animal Kingdom

Science, Technology and Society Connections

Trace the position in the phylogeny of major groups of animals.

Skills: Interpreting and Communication

- Draw the evolutionary tree of sponges, butterfly and monkey.

1. Ancestral Protista – Choanoflagelates – Sponges (Porifera),
2. Ancestral Protista – Bilateria – Coelomets – Prostotomes, Butterfly (Arthropods) –
3. Ancestral Protista – Bilateria – Coelomets – Deuterostomes – Monkey (Chordates)

9.3 DIVERSITY IN ANIMALS

Animals are incredibly diverse in structure. Despite the vast differences in structural complexity of organisms ranging form the simplest sponges to humans, all share an intrinsic material design and fundamental functional design.

9.3.1 INVERTEBRATES

When we think of animals we tend to imagine birds, dogs, fishes, and squirrel etc. However most animal species are those that lack a backbone and are commonly known as invertebrates. The invertebrates have been divided into eight major phyla: porifera, cnidaria, platyhelminthes, aschelminthes, mollusca, annelida, arthropoda, echinodermata. The chordates may be grouped as invertebrate chordates (Phylum Hemichordata, sub phylum Urochordata and subphylum cephalochordata) and vertebrates (subphylum vertebrata).

1. PHYLUM PORIFERA

The General Characteristics of phylum porifera (Latin *porus*, pore, *ferra*, to bear) are: Sponges are sessile, attached to the rocks at the bottom of water. Larvae are motile. Sponges are all aquatic, mostly marine, some found

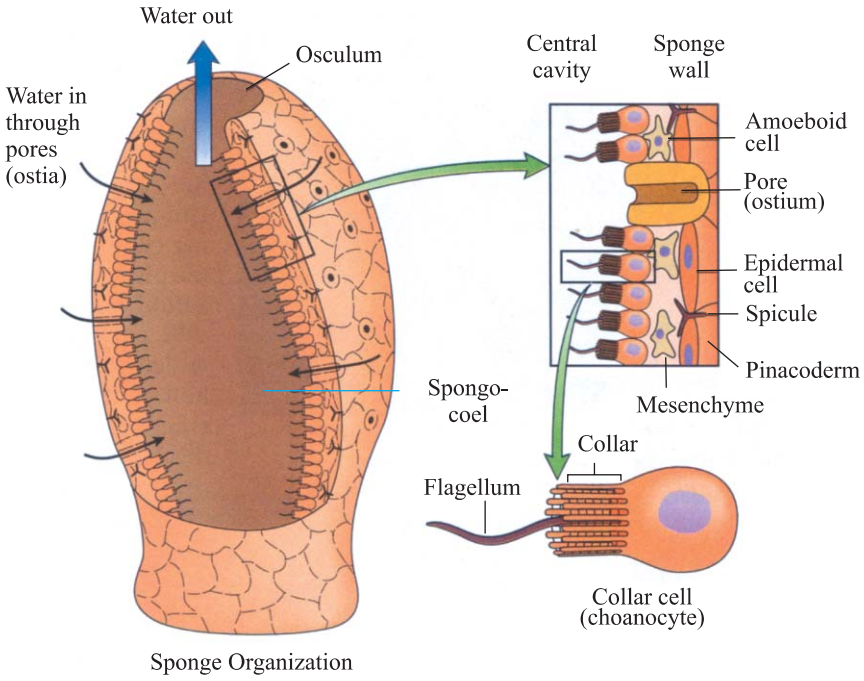


Fig: 9.6 Generalized Sponge Anatomy

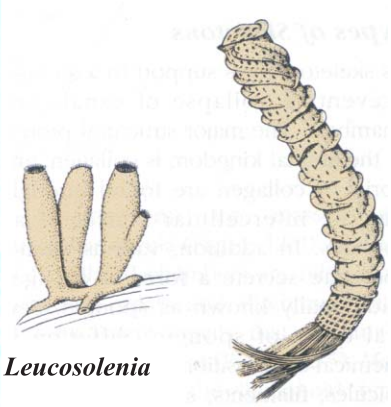
in fresh water. They range in size from a few millimetre wide to more than a metre long. Body is multicellular and not organized as tissue or organs. Body lacks symmetry. The sponges consist of outer dermal layer called **pinacoderm**, and inner layer **choanoderm** made of flagellated cells called choanocytes. The middle region is called **mesenchyme**.

Body is perforated by many pores called **ostia**. There is a single cavity inside the body called **spongocoel**. Water enters through ostia travels through the canal and goes out by a large main opening called **osculum**. Sponges depend on food coming along with water currents. There is no definite nervous system. Various shapes of spicules form the skeleton. These are needle like and may be calcarious or siliceous. The bath sponge has spongin fibre.

Asexual reproduction takes place by budding or **gemmules**. Buds develop into new sponges. Sexual reproduction takes place by egg and sperm. Sexes may be separate or hermaphrodite. The embryo development includes free swimming ciliated larval stages.

Sponges have remarkable ability of **regeneration** from a small fragment. Sponges have evolved from the protists called choanoflagelates. The examples of Sponges are: *Sycon, Leucosolenia, Euplectella, Spongilla*.

Yellow sponges



Leucosolenia

Euplectella

Fig: 9.7 Examples of Sponges

Q. Justify the classification of sponges as animals.

Evolutionary Adaptations in Sponges

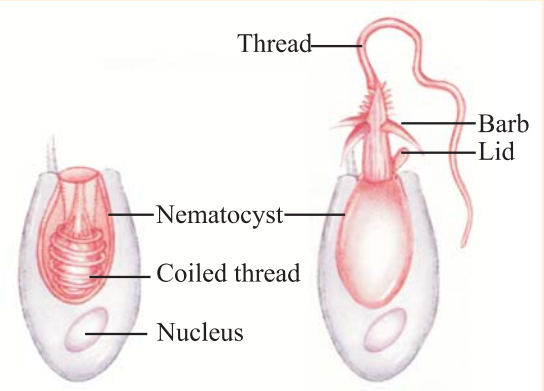
Digestion is completely intracellular and occurs in food vacuoles within choanocytes. **Respiration** is aerobic. All the cells of the dermal and gastral layers are in contact with water. There are no special organelles for respiration. Transportation takes place through water current and diffusion. The water current system has greatly enlarged area for the feeding and gaseous exchange. **Excretion** takes place through diffusion and outgoing water-current. The individual cells react as independent effectors. A sponge lacks nervous system. Sensory cells probably seem to coordinate the flow of water. Sponges are the only animals with **collar cells** (choanocytes). In the sense that they apparently did not give rise to any other animal group, sponges seem to represent a dead end in evolution.

Economic Importance of Sponges

Skeleton of sponges are used for washing and bathing. Sponges have great capacity to absorb water. They are used in surgical operations for absorbing fluid and blood. Sponges are used for sound absorption in buildings.

2. PHYLUM CNIDARIA

The name Cnidaria as this group of animals have special cells called cnidocytes. These cells give rise to nematocyst the stinging cells characteristics of this group.



The General characteristics of phylum Cnidaria (Greek, *Knide*, nettle, + L. *aria*, connected with) are: Most of the species are sessile, e.g. *Hydra*, free living and motile e.g. Jelly fish, colonial e.g. *Obelia*. Cnidarians are entirely aquatic, mainly marine, few found in fresh water, e.g. *Hydra*.

They range in size from microscopic (*Hydra*) to two metres in length (**hydrozoan polyp**). Body is radial symmetry. Cnidarians are diploblastic animals having ectoderm, endoderm and **mesoglea** in between the two. They have a sac like internal **gastrovascular cavity**, which has only one opening the mouth. The mouth is often surrounded by **tentacles**. Tentacles and body is provided with stinging cell organelles called **nematocysts**. Nervous system consists of nerve net and some sense

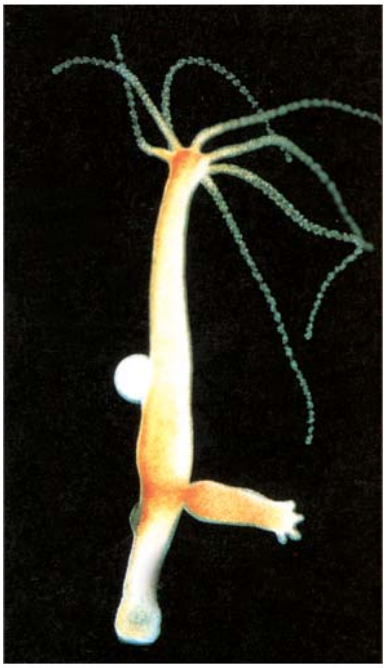


Fig: 9.8 *Hydra*

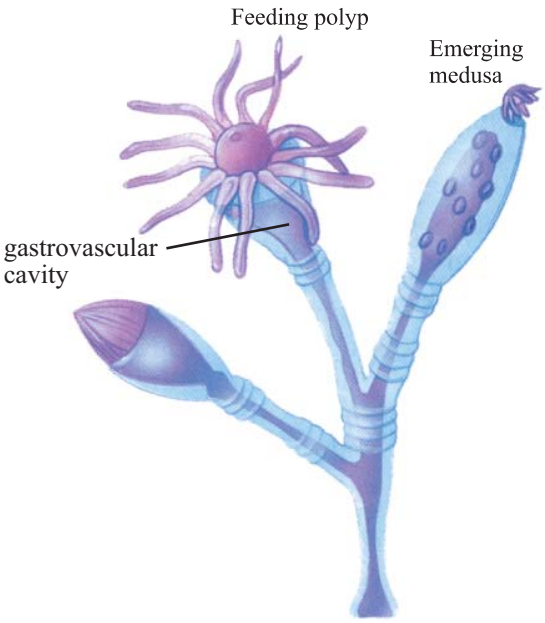
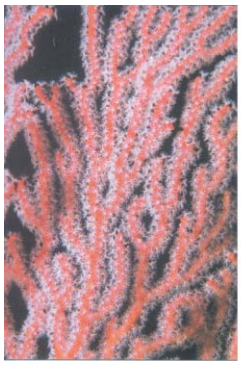


Fig: 9.9 *Obelia*

Science Titbits

Alternation of Generation: Polyp reproduces asexually by budding to form medusae. In turn medusae reproduce sexually to form polyp. It is called alternation of generation. Both the generations are diploid, often the two generations consist of one free living and one attached stage. e.g. *Obelia*. Some do not show any alternation of generation e.g. *Hydra*.



Red gorgonian

Sea fan

Red whip coral

Jelly fish

Fig 9.10 Cnidarians

organs. Asexual reproduction takes place by budding and sexual reproduction by gametes. Cnidarians also occur in the form of colonies. The units of the colonies are called **zooids**, There are two main types of zooids. **Hydroids** or **polyps** which are feeding zooids and **Medusae** are reproductive zooids, for sexual reproduction.

Evolutionary Adaptations in Cnidarians

In cnidaria, both the polyp and medusa are constructed on the same scheme. The colonial form of life shows alternation of generation and polymorphism. Occurrence of different types of zooids in the same organism is called polymorphism. Some colonies grow to a great size e.g. corals. Gastro vascular cavity is often branched or divided with septa with a single opening. Nerve net is present. Transportation and excretion take place through diffusion. There is no respiratory and excretory system.

Economic Importance of Cnidarians

Coral reefs protect shores from erosion by tidal waves. Corals are used in jewellery and others are used in aquaria, rock gardens etc. Some cnidarians have poisonous stings. Large jelly fish and sea anemone are even more dangerous. Jellyfish is common at seashore in Karachi and stings many persons every year.

Coral Reefs: Corals are cnidarians. It is made of $CaCO_3$. The ectodermal cells of the corals take lime from the sea water and form their exoskeleton. These exoskeleton form coral reefs and even island. Coral reefs are found in the coastal water of Florida, West Indies, East coast of Africa, Australia and Island of Coral Sea.

3. PHYLUM PLATYHELMINTHES

The general characteristics of phylum platyhelminthes (flatworms) are: The flat worms are free living e.g. *Planaria*, or parasite e.g. Tapeworm. They are found in fresh water, marine, animal gut, liver. Body is soft and flattened dorsiventrally. Platyhelminthes are triploblastic and exhibits a bilateral symmetry. Coelom is absent, and the spaces are filled with mesenchyme tissue. Digestive system is incomplete and is of gastrovascular type and it is absent in some flatworms.

Excretory system consists of two lateral canals with branches bearing **flame cells** (protonephridia). Nervous system consists of a pair of anterior ganglia to which longitudinal nerve cords are connected by transverse nerves

and are located in the mesenchyme. Cells, organs are simple and eyespots are present in some flatworms. Free living forms are motile. They move by cilia present on the underside of the animals e.g. *Planaria*. In parasitic forms movement is restricted.

Reproduction takes places both by asexual and sexual means. Asexual reproduction is by fission. Most forms are monoecious. The reproductive system is complex, usually with well-developed gonads, ducts and accessory organs. The fertilization is internal.

Development is direct in free-swimming forms and with those with a single host in the life cycle. Indirect development takes place in internal parasites in which there may be a complicated life cycle involving several hosts. The examples of flatworms are: *Dugesia* (planaria), *Fasciola* (liver fluke), *Taenia* (tapeworm).

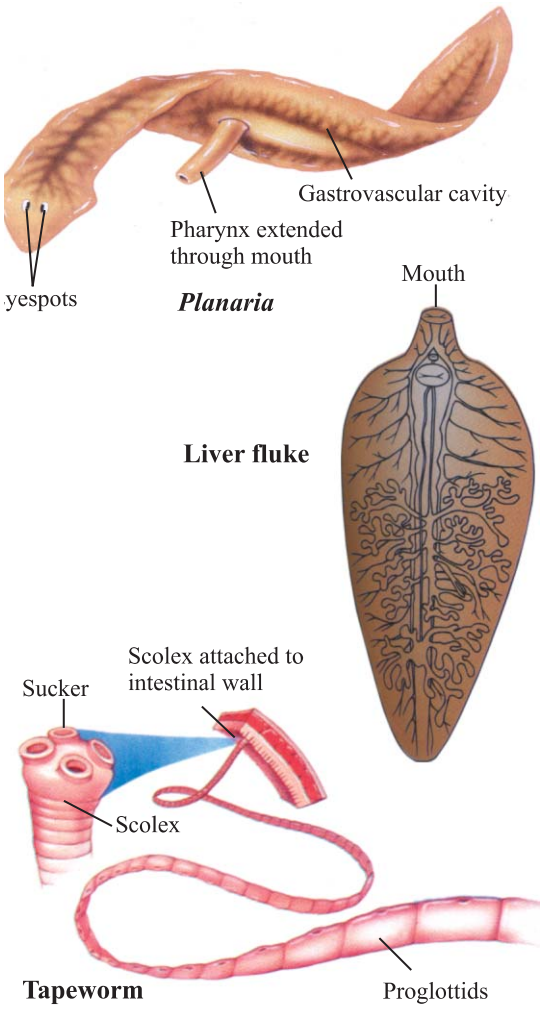


Fig: 9.11 Flatworms

Evolutionary Adaptations in Platyhelminthes

Digestive system is incomplete i.e. gastrovascular type, having only one opening to the exterior, the mouth. Respiratory and transport systems are absent, exchange of gases take place through diffusion. Excretory system of two lateral canals with branches bearing flame cells (protonephridia). Nervous system consisting of a pair of anterior ganglia with longitudinal nerve cord.

Economic Importance of Platyhelminthes

The parasitic forms of flukes and tapeworms are very harmful for man e.g. Tapeworm, liver fluke, the blood fluke of cattle etc.

4. PHYLUM ASCHELMINTHES

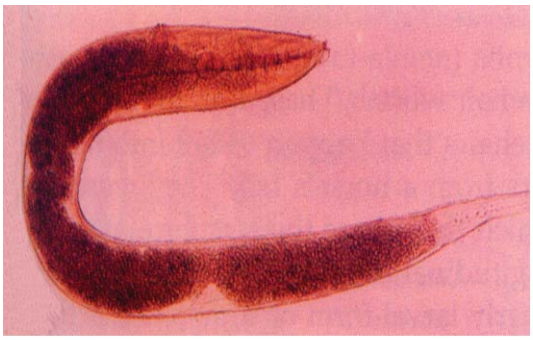
The phylum is also known as Nematoda (Gr, *nematos*, thread). The general characteristics of Phylum Aschelminthes (roundworms) are: The roundworms are free living or parasites, and live in soil, roots, human and animal intestine and muscles. Most roundworms are less than five cm long and many are microscopic but some parasitic roundworms are more than one metre in length.

The worms are symmetry bilateral, having three germ layers. Body is cylindrical, tapering at both ends. **Digestive** tract is complete. It is a straight tube with mouth and anus at opposite ends of the body. Muscular layer is not continuous. It is divided into four longitudinal quadrants: two - dorsolateral, two - ventrolateral.

The body cavity is pseudocoelom. The excretory system consists of a pair of longitudinal excretory canals and excretory pore. Nervous System consists of a nerve ring around oesophagus (pharynx), from which nerve cord and fibres extend in various directions. Most nematodes are dioecious. Fertilization is internal. Most animals are unisexual. The circulatory and respiratory organs are absent.

Evolutionary Adaptations in Aschelminthes

Aschelminthes have been able to adapt to almost every habitat available to animal life. Their basic pseudocoelomate body plans with the



Pinworms *Enterobius vermicularis* (Female)

Ascaris

Fig: 9.12 Nematodes

cuticle hydrostatic skeleton and longitudinal muscles have proved generalized and plastic enough to adapt to an enormous variety of physical conditions and virtually all potential host have been exploited. All types of life cycle occur from the simple and direct to the complex with intermediate hosts from normal dioecious reproduction to parthenogenesis, hermaphroditism and alternation of free living and parasitic generation. Aschelminthes have extraordinary capacity to survive conditions suboptimal for viability.

Digestive System is complete with mouth and anus. Pharynx is muscular well-developed tube within a tube arrangement. Circulatory and respiratory organs are absent. Excretory system consists of canals and protonephridea. Nervous system consists of a ring of nerve tissue and ganglia around the pharynx with longitudinal nerve cords connected by transverse nerve.

Economics Importance - Parasitic Diseases

Aschelminthes is important from the point of view of its parasites which has a great variety causing some very serious diseases in man and plants. *Ascaris lumbericoides* is an intestinal parasite of man. The genus *Rhabditis* contains numerous species normally found in soil, organic matter, water and faeces of man and animals. *Enterobius vermicularis* commonly known as pinworm is cosmopolitan but more common in Europe and America. Pinworms are parasites in the human caecum, colon and appendix. Their movement causes intense itching of anus, inflammation of mucous membrane of colon and appendix resulting in insomnia and loss of appetite.

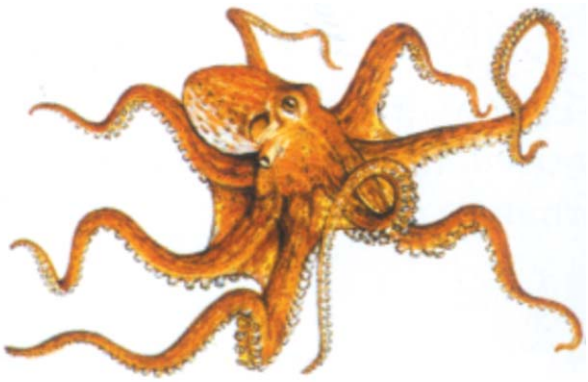
5. PHYLUM MOLLUSCA

The general characteristics of Phylum Mollusca (Latin; *Moallis*, soft) are: They are free living or sessile, and live in fresh water, marine and land (in moist places). The molluscs are bilateral symmetry, triploblastic, coelomate, soft and unsegmented animals. Body is divided into; head ventral muscular foot dorsal visceral region containing most of the internal organs. The whole animal is covered in an envelope of glandular epithelial tissue called **mantle**. It secretes the shell. The shell may be external (snail), internal (cuttle fish) or even absent (octopus). Mouth Cavity may have a tongue like structure called **radula**, provided with horny teeth e.g. Cuttle fish, snail. Respiration takes place by gills, lungs mantle or by body surface, which is richly provided with blood vessels. Circulatory System is of open type except for the Cephalopods e.g. Squids. Coelom is divided into **haemocoelic channels** or sinuses. The excretory system consists of one or two metanephridia. Nervous System consists of three pairs of interconnected ganglia in the head, foot and visceral

mass. There is a collection of ganglia in the head region forming a ganglionic mass. e.g. Squids. Sexes may be separate e.g. *Unio* or united e.g. *Helix*. The development takes place through **trochophore larvae**.

The molluscs are classified into six classes. The three major classes are: (1) Gastropoda e.g. *Helix aspera* (gardan snail), *Limax* (slug) (2) Bivalvia (Pelecypoda) e.g. *Mytillus* (marine mussel) , *Ostrea* (Oyster), *Anodonta* (fresh water mussel) (3) Cephalopoda e.g. *Loligo* (squid), *Sepia* (cuttlefish), Octopus.

Nautilus



Octopus

Snail

Fresh Water Mussel

Fig: 9.13 Molluscs

Evolutionary Adaptation in Molluscs

Most of the diversity among molluscs is related to their adaptation to different habitats and modes of life and to a wide variety of feeding method ranging from sedentary filter feeding to active predation. Digestive system is complex having rasping organ radula and anus usually emptying into mantle cavity. Gaseous exchange by gills, lungs mantle or body surface. Open

circulatory system consists of heart and blood vessels. In cephalopods mostly closed circulatory system is present. There are one or two metanephridia, which open into the pericardial cavity. The nervous system consists of paired cerebral, pleural, pedal and visceral ganglia with nerve cords.

Economic Importance in Molluscs

Beneficial molluscs: Shell of fresh water mussels are used in button industry. Shells of oyster are mixed with tar for making roads in America. Shells in certain parts of the world are also used for making ornaments. Some oysters make valuable pearls e.g. pearl oyster. Calms, oyster, mussels are source of food in Far East, Europe, and America.

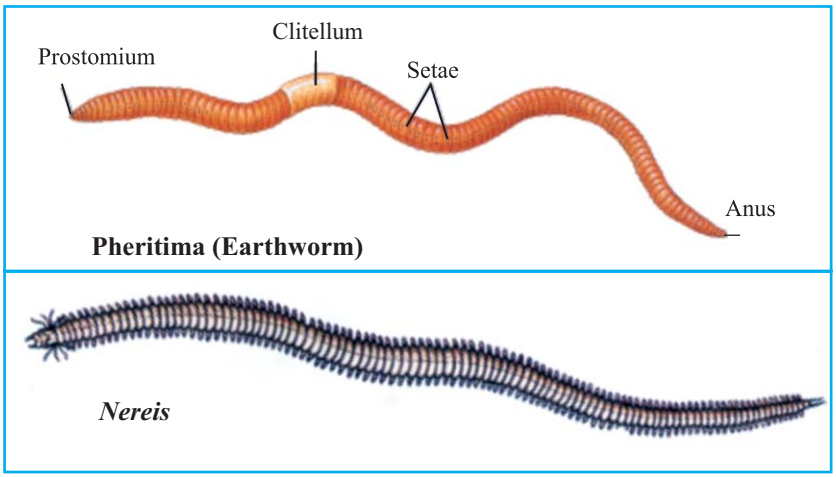
Harmful molluscs: Slugs are injurious in garden and cultivation. Toredo a shipworm damages wooden parts in ships.

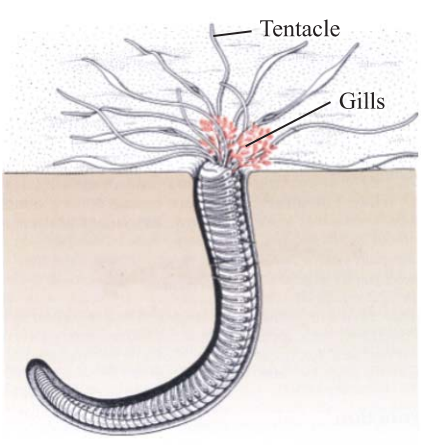
6. PHYLUM ANNELIDA

The annelids are called segmented worms. The general characteristics of Phylum Annelida (Latin - *Annelus* = little ring) are: They are free living (Earthworm) or ectoparasite e.g. (*Stylaria*, *Hirudo*). They are found in soil, freshwater and marine (*Nereis*). Body is metamerically segmented i.e. the body is divided into segments both internally and externally by transverse septa. Circulatory, nervous and digestive system extend throughout the body. Coelom is a true coelom. It is separated into compartments. Due to spaces around alimentary canal, the adjacent coelomic chambers communicate with each other. Thus coelomic fluid of the adjacent chamber is mixed. The coelomic fluid serves as a hydrostatic skeleton also. Digestive system is in the form of a alimentary canal. It is divided into distinct parts each performing a specific function. It has two openings the mouth and anus. The mouth is surrounded by a lobed structure the prostomium. The digestive system is poorly developed in parasitic species. Annelids are the first group in the animal kingdom having definite **closed blood vascular system**. Excretion takes place by **nephridia**. These are ciliated organs present in each segment of the body. Central nervous system is present. It consists of a pair of dorsal ganglia and a solid double, longitudinal ventral nerve cord. Nerves arise in each segment from the nerve cord. Respiratory system is absent and respiration takes place through the moist skin. The body wall contains circular and longitudinal muscles which help in locomotion. The locomotion takes place by the interaction of muscles and hydrostatic skeleton. The organs of locomotion in the annelids are chitinous **chaetae** or **setae**. It is embedded in sacs in earthworm. **Parapodia** is present in the body wall of *Nereis*. The

chaetae are absent in leech. The common mode of reproduction is sexual. Most of the annelids are hermaphrodite e.g. earthworm, leech. Sexes are separate in some annelids e.g. *Nereis*. Fertilization is external. Development is direct or indirect through **trochopore larvae**. Regeneration is common in annelids.

Phylum Annelida consists of three classes: 1. Class Polychaeta e.g. *Nereis*, 2. Class Oligochaeta e.g. *Pheritima posthuma* (Earthworm). 3. Class Hirudinea e.g *Hirudo* (Leech).





Amphitrite *Leech*

Fig: 9.14 Annelids

Evolutionary Adaptations in Annelids

A basic adaptive feature in evolution of annelids is their septal arrangement resulting in fluid filled coelomic compartments. Fluid pressure in those compartments is used as a **hydrostatic skeleton** for movement.

Powerful circular and longitudinal muscles have been adapted for flexing shortening and lengthening of the body. There is a wide variation in feeding adaptations from the sucking pharynx of the oligochaetes and the chitinous jaws of carnivorous polychaetes to the specialized tentacles and cirri of the ciliary feeders. In Polychaetes the parapodia have been adapted in many ways and for many functions, chiefly locomotion and respiration.

Economic Importance of Annelids

Polychaetes form an important food item for many edible fish. Polychaetes that build calcarious tubes greatly contribute to reef formation. Earthworms help in soil improvement. Leech is an ectoparsite to man and cattle.

7. PHYLUM ARTHROPODA

The arthropods are called joint footed animals. The general characteristics of Phylum Arthropoda (*Arthros*, joined *pods*, feet) are: They are free living or parasites and are found in all types of habitat. The body is segmented. The segments are attached to each other by a modified portion of the cuticle which is thin and flexible. Arthropods vary in structure. Some are worm like and others are flying insects. Segments are modified, specialized and fused. Symmetry is bilateral; head, thorax and abdomen variously distinct or fused. Body is covered by **chitin**. It is flexible at many places to allow articulation.

There are several pairs of appendages. Each pair of appendages with many joints is used for movement in various directions, often modified for specialized functions. Coelom is not present as the main body cavity. It is reduced and is called **haemocoel**, because it is connected with the blood vascular system.

Arthropods have complex digestive system. Alimentary canal has two openings, the mouth and anus. Each part is modified for specific function. Mouthparts are modified from appendages and are adapted for different methods of feeding. Arthropods feed on small plants, plant juices, animals etc. Nervous System is highly developed. There is a brain and a ventral double nerve cord. There is a ganglion in each segment from which nerves

arise. A pair of compound eyes and antennae form the sensory organ. Excretion takes place through paired excretory glands called coxal, antennal or maxillary glands. In insects the excretory organs are called **Malpighian tubules**, and the nitrogenous wastes are excreted in the form of solid uric acid. Respiratory system consists of extensive tracheal system formed by the air tubes called **trachea**. Spiracles are the openings of the main tubes to the exterior. In aquatic arthropods respiration takes place through **gills**.

Circulatory system consists of dorsal contractile heart and haemocoel (blood sinuses). Skeleton is exoskeleton, formed chiefly of chitin. Muscles are attached to exoskeleton for locomotion. Arthropods have active and swift movements. They may swim, crawl or fly as per habitat. The organs of locomotion are paired appendages. Insects have paired wings.

Sexes are separate in arthropodes. The male and female arthropods are often unlike. The reproductive organs and ducts are paired. The testes produce sperms and ovaries produce eggs. Fertilization is mostly internal.

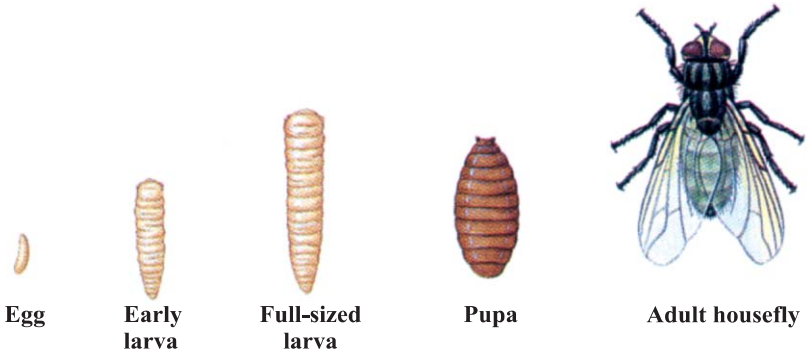


Fig: 9.15 Complete Metamorphosis

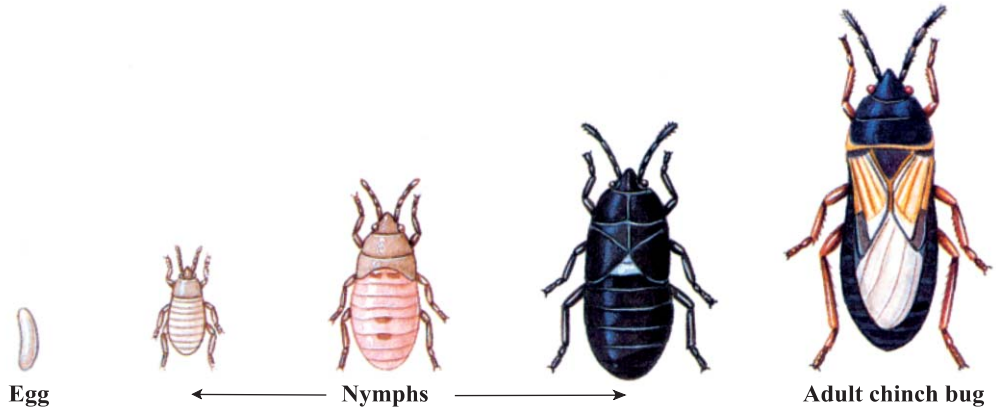


Fig: 9.16 Incomplete Metamorphosis

Development takes place through **metamorphosis**. It is of two types. In **incomplete metamorphosis** only larval stage is present which resembles the adult called nymph e.g. cockroach, chinch bug. In **complete metamorphosis** the life cycle consists of egg, larva, pupa and adult e.g. butterfly, housefly. In the larvae e.g. insects, the chitinous exoskeleton is shed from time to time to allow growth of the larvae. This process of shedding of exoskeleton is called **moulting** or **ecdysis**.

Science Titbits

What are the secrets of insect success? The body plan is modified and specialized in so many ways that insects have been able to adapt to a number of life styles. They have ability to fly. Protective mechanisms include: body is covered by cutin, mimicry, protective colouration and aggressive behaviour. The larvae and pupae do not have to compete with adults for food or habitats.

Classification of Arthropods

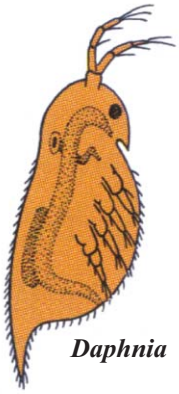
Phylum Arthropoda is a large group. It shows a great diversity. It has been divided into four major classes. (1) Crustacea e.g *Daphnia*, *Cyclops*, Crab, Lobsters, Prawn and Wood louse. (2) Insecta e.g. Dragon fly, mosquitoes, butterflies, moths, wasp and beetles etc. (3) Arachnida e.g. Scorpions, Spiders, Mites and Tick. (4) Myriopoda e.g. Centipede (Scolopendra), Millipedes (Julus).

Evolutionary Adaptations in Arthropods

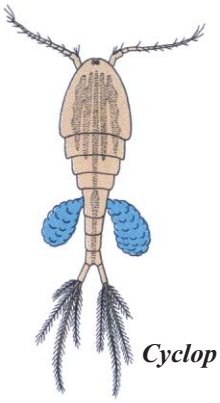
In arthropods there is the strong but flexible exoskeleton composed primarily of chitin. It is hard and nonexpandable so arthropods molt the exosekeleton as they grow larger. Before molting, the body secretes a new larger exoskeleton. Arthropods are segmented but some segments are fused into regions, such as head, thorax and abdomen. In modern arthropods apppendages are specialised for walking, swimming, reproducing, eating and sensory reception. Several arthropod groups, such as insects, arachnids, centipedes, and millipedes, contain species that are adapted to terrestrial life. The head bears various types of sense organs including compound and simple eyes. Arthropods have a variety of respiratory

Science Titbits

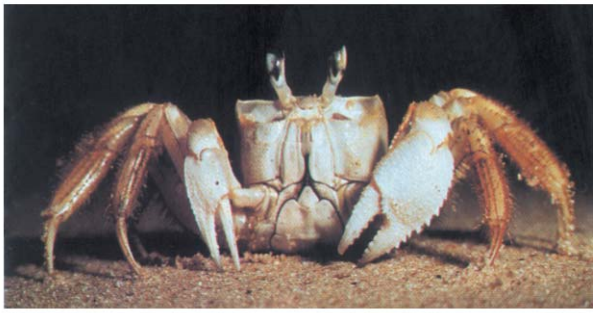
Origin of Arthropods: It is believed that the arthropods and annelids have a common origin, as both have appendages, a segmented body and cuticle.



Daphnia

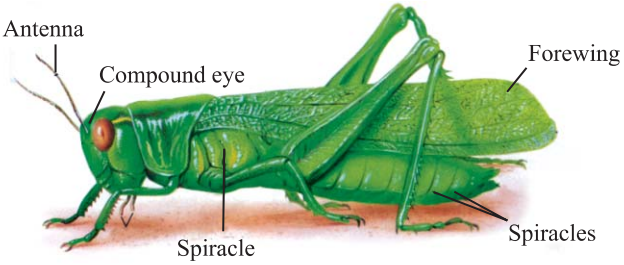


Cyclop



Crab

Fig: 9.17 Crustaceans



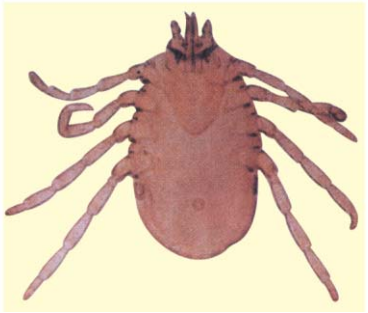
Grasshopper

Butterfly

Wasp

Fig: 9.18 Insects

Spider



Tick

Mite

Fig: 9.19 Arachnids

Scolopendra Julus

Fig: 9.20 Myriapods

organs. Marine forms have gills. Terrestrial forms have book lungs (e.g., spiders) or air tubes called tracheae (L. *trachia*, windpipe).

Digestive system is complete, mouthparts modified from appendages and adapted for different methods of feeding. Open circulatory system with dorsal contractile heart arteries and blood sinuses (homocoel) is present. Paired excretory glands called coxal, antenna or maxillary glands present some with other excretory organs called **Malpighian tubules**. Nervous system with dorsal brain connected by a ring around the gullet to a double nerve chain of ventral ganglia, well developed sensory organs.

Economic Importance of Arthropods

Many arthropods are of great importance, as some are useful and others are harmful to mankind.

Crustacea: Many crustaceans provide human food, directly or indirectly. Lobsters, cray fish and prawns are eaten. Some crustaceans act as intermediate hosts for human parasites, e.g Cyclops carry larvae of a nematode, the Guinea worm.

Insecta: The insects are of very great economic importance. They are beneficial as well as harmful.

Beneficial Insects: They give us many substances of commercial importance, e.g. Honey and bee's wax are produced by the honeybee, silk by silk worms and shellac from a wax is secreted by lac insects. Insects aid in the production of fruits, seeds and vegetables by pollinating the flowers e.g. bees, wasps, ants and butterflies. Insects like grasshoppers, locusts, crickets, and many more are eaten by human beings in certain parts of the world. Insects form food

Fig: 9.21 Lady Bird Beetle

for animals useful to man. Insects act as scavengers. Insects destroy other injurious insects. Dragonflies feed on mosquitoes, ladybird beetles eat up plant lice. Insects destroy weeds by feeding on them. Insects are employed in scientific studies. Fruit fly (*Drosophila*), cockroach, grasshopper are abundantly used as laboratory animals for scientific learning and research.

Harmful Insects: They destroy field crops, fruit trees and timber plants. The more destructive insects are locusts, grasshoppers, beetles, caterpillars, aphids, leafhoppers, scale insects, bugs and weevils. They damage stored grains, e.g. grain weevils and ants. They spoil useful articles in the houses, e.g. Silverfish damages books and white ants destroy furniture. They spread diseases among human beings. The more important disease carriers are housefly, mosquitoes, lice, sand fly, tsetse fly and bugs. They irritate man in various ways. Bees and wasps sting, mosquitoes, lice and fleas bite and suck blood; small insects fall into the eyes.

Arachnida: The arachnids are mainly harmful to man. Scorpions and a few spiders are poisonous and sting. Certain mites damage crops. Spiders and scorpions are beneficial to a certain degree as they feed largely on injurious insects.

Science, Technology and Society Connections

Explain the role of invertebrates in the field of research and daily life.

8. PHYLUM ECHINODERMATA

The echinodermata are called **spiny skinned animals**. The general characteristics of phylum echinodermata (GK. *echinos*, spiny and *derma* skin) are: They are free living, some are attached to the substratum. The echinoderms are exclusively marine. Most are found at the bottom along the shorelines in shallow seas.

Body is covered by delicate epidermis. The echinoderms are triploblastic coelomates and exhibit radial symmetry in adult. Echinoderms have an endoskeleton consisting of a spine bearing calcium rich plates. The spines, which stick out through the delicate skin, account for their name. The mouth is on the oral side and anus is on the aboral side. There is a central disc from which arms radiate.

The body may be flattened like biscuit, (cake urchin), star-shaped with short arm (starfish) globular (sea urchin), star-shaped with long arms (brittle star) or elongated (sea cucumber).

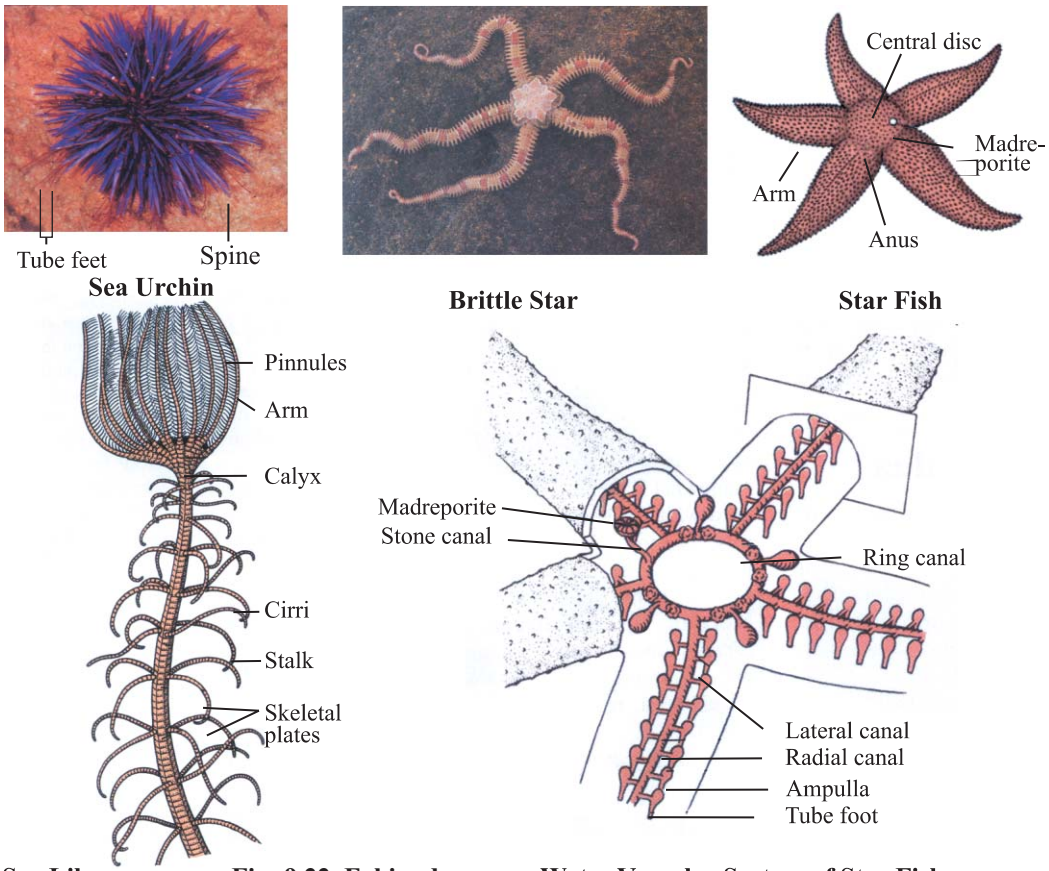


Fig: 9.22 Echinoderms

Coelom consists of canals and spaces. One of which forms water vascular system. It is a complex system of tubes. It consists of stone canal, ring canal, lateral canal, radial canal, ampulla and tube feet. Water circulates through these channels. Water enters through a sieve like plate called madreporite present on the aboral surface. Organs of locomotion are the tube feet. Each foot is a soft structure. These are present along the edges of grooves present in the arms.

There are specialized organs for digestion and reproduction. There are no specialized organs for respiration or excretion. The nervous system is poorly developed. There is no brain, only a nerve ring is present around the pharyngeal region. The circulatory system is poorly organized. The sexes are separate. The fertilization is external. The larvae such as **bipinnaria** and **brachiolaria** are complex and exhibit bilateral symmetry. Autotomy and regeneration are common among starfish, sea cucumber, sea lily, brittle star and sea urchin.

Science Titbits

Echinoderms show close resemblance with chordates. Both: (1) have mesodermal skeleton. (2) are deuterostomous, (3) have similar early development. That is why echinoderms have been placed closest to phylum chordata.

Evolutionary Adaptations in Echinoderms

The most evolutionary characteristic are: Radial symmetry, the water vascular system and their dermal endoskeleton. If their ancestors had a brain and specialized sense organs these were lost in the adoption of radial symmetry. There are large numbers of echinoderm, which are creeping benthic forms with filter feeding, deposit feeding scavengers and herbivores, comparatively few predators and very large pelagic forms. Digestive system usually complete axial or coiled anus absent in ophiuroids. Respiration by dermal branchiae, tube feet, respiratory tree e.g. see cucumber and bursae e.g spiny brittle star. Blood vascular system is much reduced. Excretory organs are absent. Nervous system includes a circumoral nerve ring and radial nerve-cords. There is no brain.

Economic Importance of Echinoderms

Many echinoderms are used as food e.g. Sea cucumber is used in making soup in China. Gonads of sea urchin are eaten in South America. Eggs of starfish, sea urchin are eaten in West Indies etc. Dried skeleton of echinoderms are used as fertilizer because of their high percentage of calcium and nitrogen. Starfishes act as scavengers and thus clean seawater. The echinoderms are also harmful. They cause damage to oyster beds. The stinging sea urchins are poisonous.

9.3.2 CHORDATES

Both invertebrate and vertebrate chordates have been divided into two phyla, phylum Hemichordata and phylum chordata.

1. PHYLUM HEMICHORDATA

They show characteristics of both echinoderms and chordates and both phyla belong to the group deuterostome branch of animal kingdom. Hemichordates are also called **prochordates** because of their close relationship to chordates. Examples: *Balanoglossus*, *Saccoglossus*.

The hemichordates are called **acorn worms**. The general characteristics of Phylum Hemichordata (Gr. *Hemi*, half, *Chorda*, string cord) are: All hemichordates are marine. Some are solitary, naked and slow moving, others are sedentary. Body is soft and unsegmented and has a worm like form. Body has three distinct regions: proboscis, collar and trunk.

The body wall consists of a single layered epidermis with mucous secreting cells and nerve net. Symmetry is bilateral and hemichordates are **triploblastic**. Body cavity is a **true coelom** with three parts corresponding to the three body divisions. Respiration occurs by one pair to numerous pairs of gill slits forming a dorsal row behind collar.

Circulatory system includes a dorsal heart and two longitudinal vessels, a dorsal and a ventral, interconnected by small lateral vessels. Blood is colourless and without corpuscles. Excretory system comprises of a proboscis gland or glomerulus situated in the proboscis and connected with blood vessels. There are no nephridia. Nervous system is diffused, consisting of an epidermal plexus of nerve cells and nerve fibres. Sexes may be separate or united. Fertilization is external. Developmen may include free swimming larval stage.

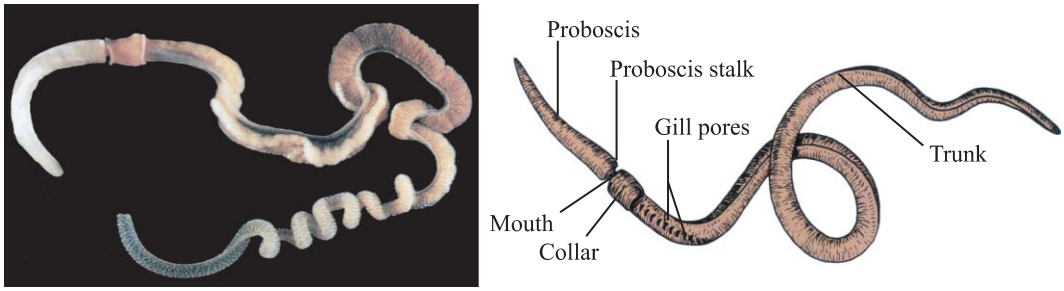


Fig: 9.23 ***Saccoglossus***

Evolutionary Adaptations in Hemichords

(a) The body is long slender having tapering proboscis

(b) Hemichordates live in burrows, foul smell provide safety from the predators

(c) Filter feeding habit suits the sluggish life in burrow

(d) Gonads are multiple

(e) There is a great power of regeneration

(f) Free swimming larva causes dispersal so essential for a sluggish creature.

2. PHYLUM CHORDATA

The representatives of the phylum chordata called the chordates, are the most familiar, adaptable, successful and the most widely distributed animals, showing diversity of form, habitat and habits to an amazing degree. The chordates include the tunicates, lancelets, lampreys, fishes, salamanders, frogs, lizards, snakes, tortoises, turtles, crocodiles, birds and mammals along with man.

Characteristics of Chordates

Notochord: The notochord is a solid unjointed rod located in the mid-dorsal line between the gut and the central nervous system outside the coelom. The notochord serves as an axial endoskeleton, giving support to the body and providing space for muscle attachment. In some lower chordates the notochord persists throughout life, but in higher chordates it is partly or wholly replaced in the adult stage by a jointed backbone or vertebral column.

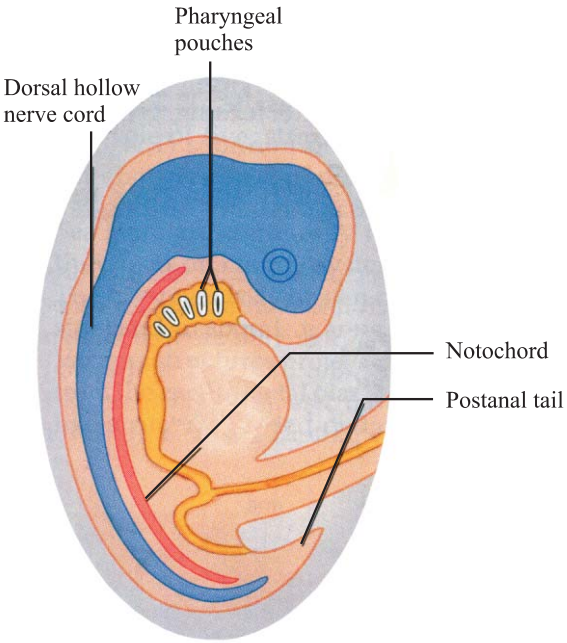


Fig: 9.24 Main Features of the Chordates, as Shown in a Generalized Embryo

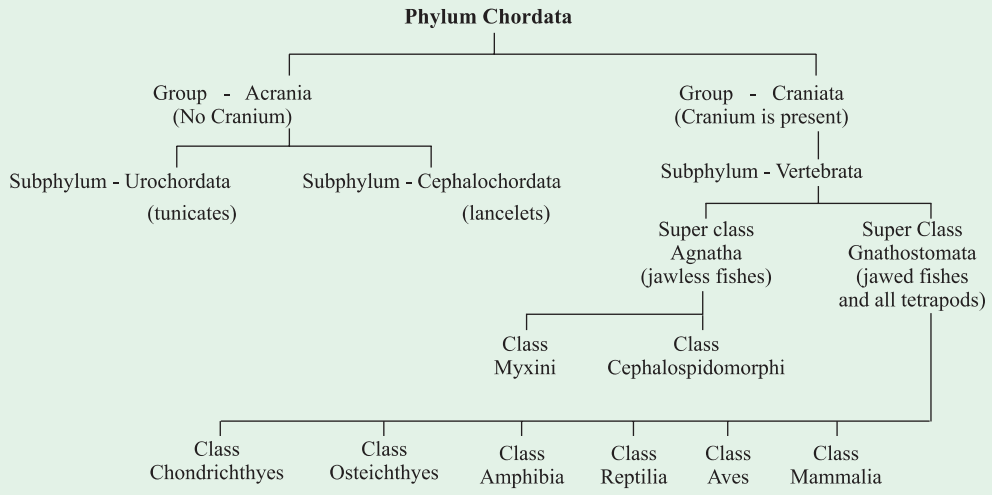
Nervous System: The central nervous system of all the chordates consists of a single, tubular fluid filled, nongangliated nerve cord, situated along the mid dorsal line above the notochord and outside the coelom.

Gill Slits: The gill slits are paired perforations on the lateral sides of the anterior part of the body, leading from the pharynx to exterior.

Classification of Chordates

The phylum chordata has been subdivided into two groups: **Protochordata (Acrania)** in which brain is not enclosed in bony case and **Craniata** in which brain is enclosed in a bony case and notochord has been replaced by vertebral column. Protochordata has been divided into two sub-phyla: (1) Subphylum urochorda, (2) Subphylum cephalochordata.

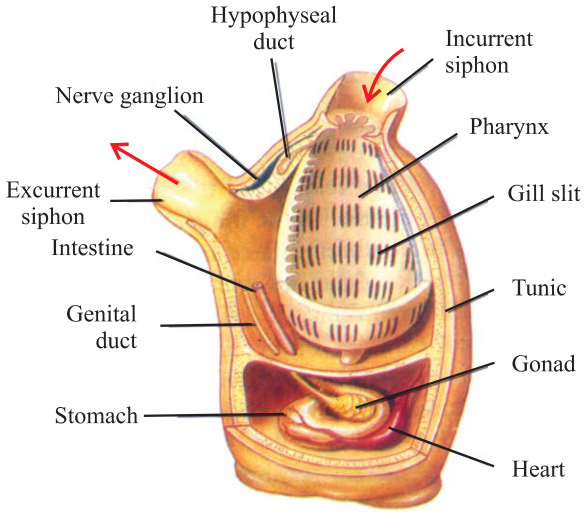
Table 9.1 CLASSIFICATION OF PHYLUM CHORDATA



i. Subphylum Urochordata

The general characteristics of subphylum urochordata are: Body varies considerably in size, form and colour. The body is covered by a covering called **tunic** so they are called **tunicates**. Lining the tunic is an inner membrane, the mantle. On the outside are two projections: the incurrent siphon which corresponds to the anterior end of the body and excurrent siphon that marks the dorsal side. Larva has a mid-dorsal supporting rod, the **notochord**, in the tail. The notochord usually disappears during metamorphosis, so that adult has no

Halosymthia



Ascidia

Fig: 9.25 Urochordates

skeleton. Digestive tract is complete. There are two to many gill or pharyngeal slits in the pharyngeal wall. Circulatory system is of open type. Nervous system is represented in the adult by a single **ganglion**. Excretion is carried on by nephrocytes.

Urochordates are hermaphroditic, usually with a single testis and a single ovary in the same animal. Germ cells are carried by the **genital duct** to the arterial cavity and then to surrounding water where fertilization takes place. Asexual reproduction takes place by budding. Larvae are free swimming and have a dorsal hollow nerve cord extending the greater length of the body and a notochord confined to the tail so the group has been named urochordata. The examples of urochordates are *Ascidia*, *Halosymthia*, etc.

Evolutionary Adaptations in Subphylum Urochordata

Adaptation for feeding: Inability to move about in search of food has been overcome by developing ciliary feeding in which food particles are drawn towards the mouth.

Adaptation for survival: Thick leathery test and calcarious spiny spicules keep the predators away. Free-swimming larva brings about dispersal.

ii. Subphylum Cephalochordata

The general characteristics of subphylum cephalochordata are: Body is fish like. It has no head but tail is present. Notochord extends the entire length of the body. Digestive tract is complete. There is no organ for respiration. It takes place through general body surface. Circulatory system is of closed type. Excretory system consists of paired **protonephridia**. Sexes are separate and fertilization is external. Development takes place through a ciliated free-swimming larva. The example of cephalochordata is *Branchiostoma* (*Amphioxus*) (lancelet).

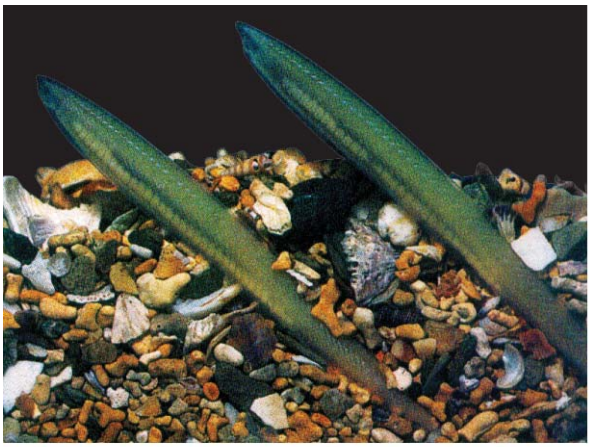
Evolutionary Adaptations in Subphylum – Cephalochordata

Adaptation for Swimming: Streamlined form, expanded caudal fin increases the forward thrust of the body

Adaptation for Burrowing: Stream lined body helps burrowing in sand, mucus acts as lubricant and front end acts as efficient drill during burrowing.

Adaptation for Feeding: Ciliary feeding by the lancelet best suits its nearly sedentary life inside burrows.

Adaptation for Survival: Translucence of the body renders it almost invisible in water. Habit of leaving the burrows at night, free-swimming larvae and high degree of sensitivity also contributes to survival of the animal.



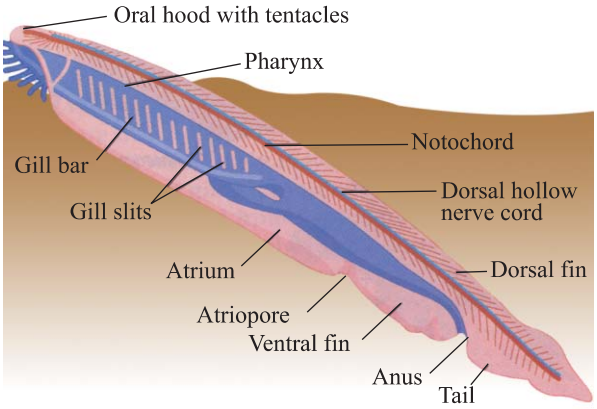


Fig: 9.26 ***Branchiostoma lanceolatum***

iii. Subphylum Vertebrata (Craniata)

The third subphylum of the chordate is the largest and imminently diverse vertebrata. The characteristics that give the member of this group the names "vertebrata" and "craniata" are spinal column of vertebrae, which forms the chief skeletal axis of the body, and a brain case or cranium. The classification of the subphylum vertebrata is given in the table No. 9.1

Vertebrates may be divided into nonamniotes or those without foetal membrane, include cyclostomata, chondrichthyes, osteichthyes, amphibia and amniota or those with foetal membranes includes reptiles, aves and mammals.

a. SUPER CLASS AGNATHA

The living members of agnatha are divided into two classes; **Mixini** (hagfishes) and **Cephalospidomorphi** (lampreys) members of both groups lack jaws, internal ossification, scales and paired fins and both group share pore like gill openings and an eel-like body form. In other aspects however, the two groups are morphologically very different.

Science Titbits

Vertebrates are distinguished, in particular by, having endoskeleton, closed circulatory system, paired appendages, efficient respiration and excretion, high degree of cephalisation.

The general characteristic of super class Agnatha are: Body slender, eel-like, rounded with naked skin. There are no paired appendages and no dorsal fin in class Myxini. There are one or two median fins and no paired appendages in class Cephalospidomorphi. The caudal fin extends anteriorly along the dorsal surface. Skeleton is fibrous and cartilaginous and the notochord is persistent. Biting mouth with two rows of eversible teeth in Class Myxini and the oral disk is sucker like and tongue with well-developed teeth in class Cephalospidomorphi. There are five to sixteen gills for respiration in class Myxini and seven pairs of gills each with external gill opening in class Cephalospidomorphi. Digestive system is without stomach. Dorsal nerve cord with differentiated brain. Sexes are separate. Fertilization is external and there is no larval stage. The examples of agnatha are Hagfish, and Lamprey.

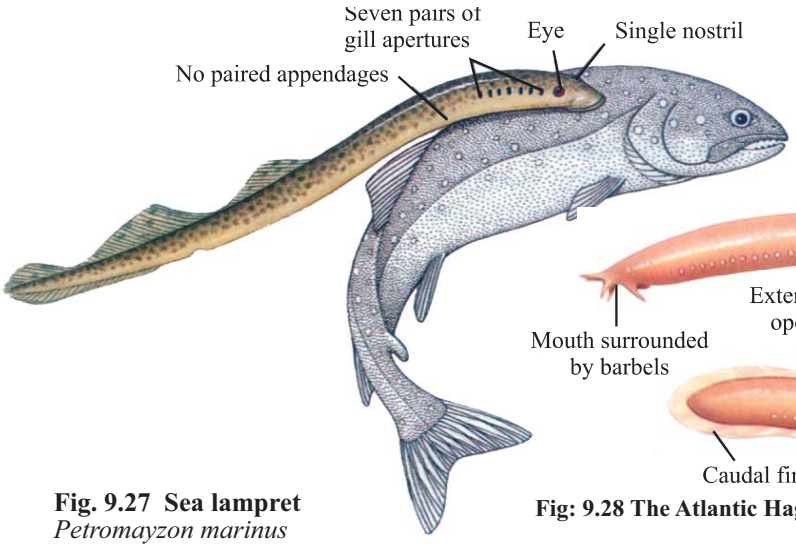


Fig. 9.27 Sea lampret
Petromayzon marinus

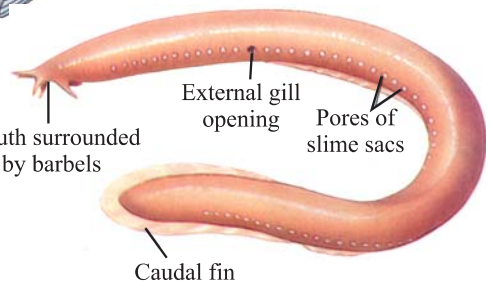


Fig: 9.28 The Atlantic Hagfish *Myxine* glutinosa

Evolutionary Adaptations in Super Class Agnatha

Body is long slender limbless, slimy skin offer minimum resistance to water. Laterally compressed, tail with caudal fin provides greater forward thrust. **Buccal funnel** and toothed tongue form a device for blood sucking in absence of jaws. Ability to draw in and expel out water through the gill slits carries on respiration. Very large numbers of eggs are laid. Burrowing life of the larvae gives them protection against carnivores and filter feeding best suits their nearly sedentary life in burrows.

b. SUPER CLASS GNATHOSTOMATA

It is divided into six classes: Chondrichthyes, Osteichthyes, Amphibia, Reptilia, Aves and Mammalia.

1. CLASS CHONDRICHTHYES

The chondrichthyes are popularly called the cartilaginous fishes. The cartilaginous skeleton is considered as a degenerate character rather than primitive character. It includes the sharks, dogfishes, rays, skates and chimaeras. The general characteristics of class Chondrichthyes are: Body is laterally compressed and spindle (fusiform) shaped. Mouth is ventral. Olfactory sacs are not connected to mouth cavity.

Jaws Evolve

The gnathostomates have jaws. The tooth bearing bones of the head. Jaws are believed to have evolved from the first pair of gill arches of agnathans.

Skin is tough and covered with minute **placoid scale**. The pectoral and pelvic fins are paired. There are two dorsal fins. The caudal fin is **heterocercal**. Endoskeleton is entirely cartilaginous. Digestive tract leads into the cloaca. Stomach is J shaped. The circulatory system consists of two-chambered heart. There is one atrium and one ventricle. There are 5-7 pairs of aortic arches. Respiratory system includes 5-7 pairs of gills, without operculum. Swim bladder is absent.

Sexes are separate. Gonads are paired. Fertilization is internal. Most forms are oviparous or viviparous. Skates and Rays are bottom dwelling fishes. The pectoral fins of these fishes are much enlarged and are used for swimming like wings. Two members of this group are of special interest are Sting rays and Electric rays. The tail of the sting rays is long and whip like and have sharp spines, which can inflict dangerous wounds. Electric Rays have certain dorsal muscles modified into powerful electric organ which can give severe shock and stun their prey.

Evolutionary Adaptations in Class Chondrichthyes

Spindle shaped body, slippery skin, presence of scales on the body protect the animal. Ventral mouth is suited for capturing prey at the bottom of the sea. Internal fertilization, nourishment and protection of the embryo in the mother's body are evolutionary adaptive feature.

Economic Importance of Chondrichthyes

They provide food. Some shark and rays are eaten in many countries. They provide products of commercial value. Oil is obtained from the liver of

many sharks, which is a source of vitamin A and D. Shark skin leather is used for shoes and bags. Pituitary gland of shark yields an extract of medical use. Sharks feed on crustaceans, lobsters, crabs, and other fishes, which form human food.

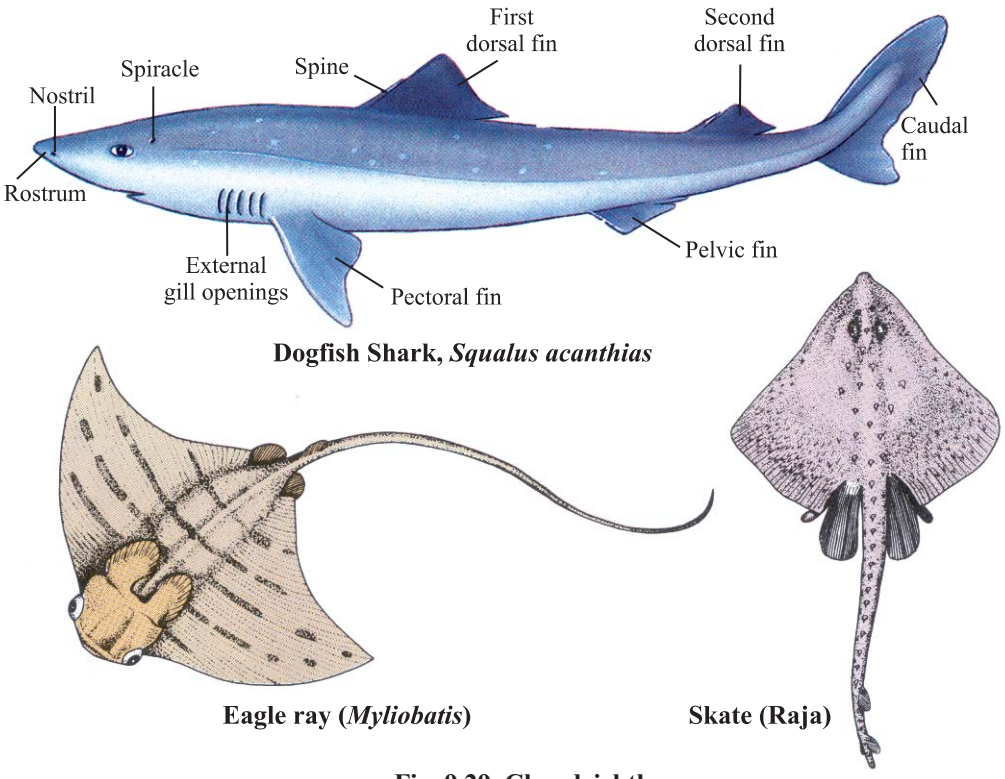


Fig. 9.29 Chondrichthyes

2. CLASS OSTEICHTHYES

The general characteristics of class Osteichthyes (bony fishes) are: Body is usually spindle-shaped and stream lined for active movement through water. Endoskeleton is partly or wholly bony. Vertebrae are numerous. Pelvic girdle is often absent. Notochord persists in a greatly reduced form.

Skin usually contains dermal scales embedded in the dermis. The scales are **ganoid**, **cycloid** or **ctenoid**. Both median and paired fins are present. These are supported by cartilaginous or bony rays in the distal part. Pelvic and pectoral fins are paired while dorsal fin is single. The caudal fin is **homocercal**. Mouth is usually terminal i.e. anterior end often bears numerous teeth. Jaws are well developed. Anus is present and cloaca is absent.

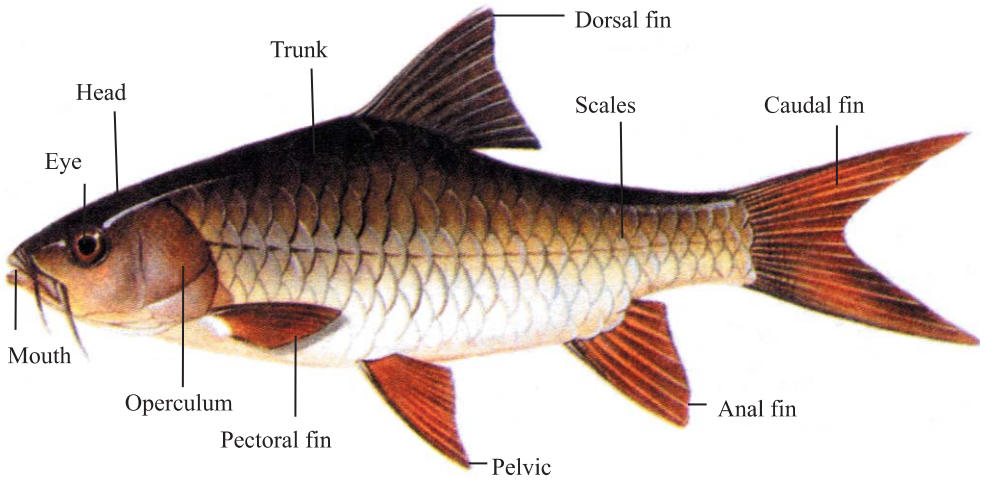


Fig: 9.30 ***Labeo rohita***

The four pairs of gills are supported by a **bony arch**. They are covered by **operculum**. Spiracles are mostly lacking. **Swim bladder** is usually present with or without connection with the pharynx. Swim bladder helps in bouyancy. Heart is two chambered, having only one atrium and one ventricle. There are four pairs of **aortic arches**. Red blood cells are oval and nucleated. Brain has ten pairs of cranial nerves. Sexes are separate. Gonads are paired. Fertilization is generally external. Most forms are **oviparous**, some are ovaviviparous or even **viviparous**.

Evolutionary Adaptations in Class Osteichthyes

Body is laterally compressed spindle shaped and has slimy skin, strong segmental muscle for efficient swimming device. **Gills** help in respiration. **Air** or **swim bladder** enables the fish to easily shift from one depth to another. **Gill rakers** check the loss of food. Lack of teeth in the jaws is correlated to the herbivorous diet.

Economic Importance of Osteichtheys

They provide food and important marine food fishes include cod, herring and salmon etc. Popular fresh water food fishes are trout, carp, cat-fish and mullet. They provide products of commercial value. Fish oil, fish meal and liquid glue are important fish products. Liver of cods yield oil, which is a source of vitamins A and D.

Adaptations to Aquatic Life in Fishes

Streamline body offers little resistance to water while fishes are swimming. **Swim bladder** is present in bony fishes, except a few. It may or

may not be connected to pharynx. It helps in bouyancy and with its help fish can float high or sink lower in water. The swim bladder is filled with oxygen, carbon dioxide and nitrogen. The gases may be secreted by the glands in the swim bladder. When the swim bladder is connected to pharynx the bladder may be filled by gulping of air.

Fig: 9.31 Sea Horse

Fins help in swimming. They keep balance of fish in water. Fins are paired and unpaired. Pectoral and pelvic fins are paired. Dorsal, caudal and anal fins are unpaired fins. Heart has two chambers. Afferent and efferent branchial system present. Gills are the respiratory organs having network of blood capillaries. Gills are adapted to receive oxygen dissolved in water and remove carbon dioxide. Kidney is **mesonephros**. It is modified for excretion in the aquatic environment.

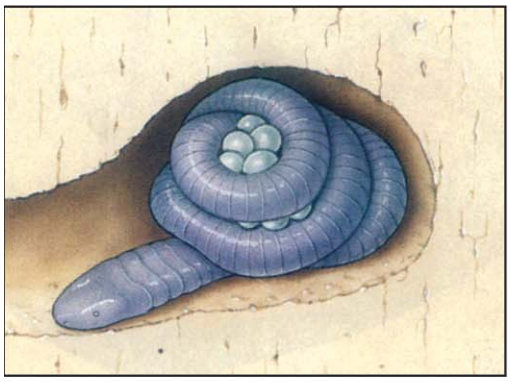
Fig: 9.32 Lobe-Finned Fish, The Coelacanth, *Latimeria*, is a living Fossil.

Limbs Evolve

All the animals which are called tetrapods have four limbs. The lobe-finned fishes of the Devonian period are ancestral to the amphibians, the first tetrapods. Animals that live on land use limbs to support the body, especially since air is less buoyant than water. Lobed-finned fishes and early amphibians also had lungs and internal nares as means to respire air.

3. CLASS AMPHIBIA

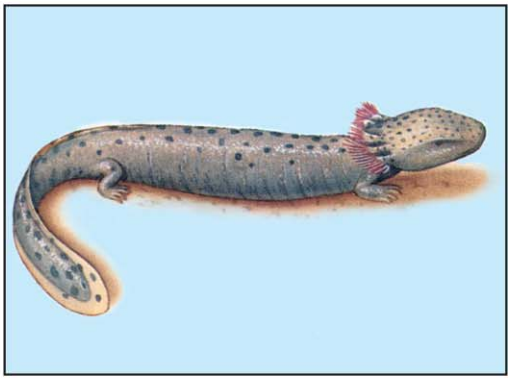
The general characteristics of class Amphibia are: Body varies considerably in forms. Body is divisible only into head and trunk. Most have



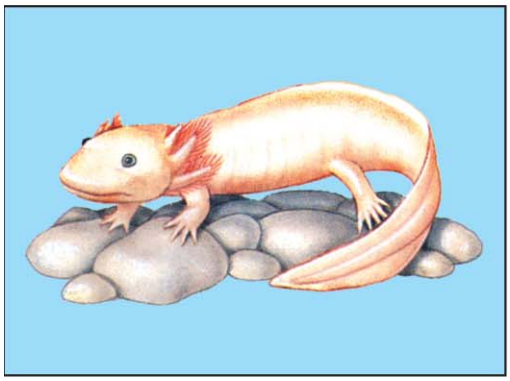
A Female Caecilian

Spotted Salamander

Longtail Salamander



Common Mud Puppy *(Necturus)*



Axolotl *(Ambystoma)*

Frog *(Rana)*

Fig: 9.33 Amphibians

two pairs of pentadactyl limbs with 4-5 or fewer digits. Some are without legs e.g. Caecilians. Webbed feet often present e.g. frogs. Skin is often smooth, moist and rich in glands. It is highly vascular and may be respiratory. Scales are generally absent. In some glands are poisonous, chromatophore pigment cells are present in the skin.

In larval stage respiration takes place by **gills** and in the adults by lungs and skin. Heart is three chambered with respect to atria and ventricle. **Sinus venosus**, **truncus arteriosus** are present. Double circulation takes place through the heart. Sexes are separate. Gonads are paired. Fertilization may be external or internal Most forms are oviparous.

Development takes place through **metamorphosis**. Amphibians are **anamniotes**. Body temperature is variable i.e. poikilothermic (ectotherms) and most forms undergo hibernation in winter. The examples of amphibians are Frogs, Toads, Salamanders etc.

Evolutionary Adaptations in Class Amphibia

Amphibians mark the transition from aquatic to terrestrial life in vertebrates. Their notable adaptation on land are: Limbs for movement on solid substratum. Lungs for breathing air. Internal nares to make breathing possible by keeping mouth closed. Slimy skin for protection against desiccation. Changed in circulatory system to provide respiration by lungs and skin. There is reduction in bones to make the body lighter.

Critical Thinking

What limits the ability of amphibians to occupy the full range of terrestrial habitats and allows other terrestrial vertebrates to live in them successfully?

Transition from Aquatic to Land Habitat

Amphibians are on the borderline between aquatic and true terrestrial animals. The animals live in moist condition or in water. So the amphibians are not a successful group owing to their dependence on water as habitat, reproduction and development.

4. CLASS REPTILIA

The general characteristics of class Reptilia are: Body form varies. There are two pairs of pentadactyl limbs, each typically with five digits. Skin is rough, cornified and dry, which is adapted to land life. Heart is incompletely four chambered, having two atria and partly divided ventricle.

Tortoise

Lizard

Corel Snake

Alligator

Fig: 9.34 Reptiles

Crocodiles have completely four chambered heart. Reptiles are cold blooded animals i.e. piokilothermic (ectotherms) and hibernate in winter. Sexes are separate. Gonads are paired. Fertilization is internal. Most forms are oviparous. Eggs are large, amniotic and have large yolk eggs. Eggs are enclosed by leathery or limy shell for protection. Embryo is protected by three embryonic membranes known as amnion, allantois and chorion.

Evolutionary Adaptations in Class Reptilia

Reptiles show the advancement over the amphibians in having (a) a dry skin which enables them to live away from water (b) limbs better suited for rapid locomotion and raising the body off the ground (c) separation of oxygenated and deoxygenated blood in the heart (d) complete ossification of the skill (e) a neck movable independent of the body (f) better mechanism of breathing (g) fertilization is internal (h) egg with shell for protection on land (i) claws for defence.

The Amniote Egg Evolves:

It is adaptive for land animals to have a means of reproduction that is not dependent on external water. Reptiles practice internal fertilization and lay eggs that are protected by a shell. The amniote egg contains extraembryonic membrane, which protect the embryo. One of the membranes, the amnion, is a sac that fills with fluid and provides a "private pond" within which the embryo develops.

5. CLASS AVES

The general characteristics of class Aves are: Body of aves is streamlined and is boat shaped. It is divisible into a head, neck, a trunk and a tail. Neck is very long and tail very short. There are two pairs of pentadactyl limbs. The forelimbs are modified to form wings. The hind limbs are large, strong and adapted for perching, walking or swimming. Each foot usually bears four toes armed with horny claws. The skin is covered by an epidermal horny exoskeleton of **feathers** all over the body and scales on the feet. Due to air spaces skeleton is light. Skull has large sockets. Jaws extend into horny beak. Teeth are absent. Heart is four chambered, having two atria and two ventricles. There is only right aorta. It curves to the right side and then bends backward. Birds are endothermic. Respiration takes place only by lungs. Lungs are compact, spongy. A system of thin walled air sacs lying among the viscera maintains the supply of fresh air through the lungs. Voice box the **syrinx** lies at the junction of the trachea and bronchi. Alimentary canal has muscular structure called gizzard, which is used for crushing food. Excretory system consists of a pair of kidneys. The ureter open into the cloaca and the urinary bladder is absent. The urine is semisolid and uric acid is main nitrogenous waste. Sexes are separate. Fertilization is internal. Eggs are large with much yolk. Only one ovary and oviduct is functional. Some birds have secondarily lost the power of flight and are called running birds, e.g. Ostrich, Kiwi, etc.

Evolutionary Adaptations in Class Aves

Birds show the following evolutionary adaptations: An insulated covering over the body. Better aeration of blood in the lungs, taking place during both inspiration and expiration. Complete separation of venous and arterial blood in the heart. Birds have an active life and a high rate of metabolism. Very rapid locomotion is provided by the power of flight. A regulated body temperature that keeps them equally active all the year round. A highly developed power of producing sound. More efficient eyes with

Kiwi

Penguin

Duck

Parrot

Fig: 9.35 Birds

double means of accommodation. Better ears having cochlea with an **organ of Corti**. Patterns of behaviour, such as care for the young ones, nest building, courtship and affection for the mate and migration, which are practically unknown in reptiles.

6. CLASS - MAMMALIA

The general characteristics of mammals are: Body is variously shaped and divisible into a head, a neck, a trunk and a tail. There are two pairs of pentadactyl limbs. These are variously adapted for walking, running, burrowing and swimming or flying. Skin is glandular, mostly covered by hair. **Coelom** is completely divided into anterior smaller thoracic cavity and posterior larger cavity by a muscular partition the diaphragm, which is present only in the mammals. Endoskeleton is fully ossified. Skull has two **occipital condyles**, large **cranium**. Each half of the lower jaw consists of a single one, the dentry and articulates directly with skull. External ear or pinna is present. There is a chain of three bones in the ear incus, malleus and stapes (sta-pez).

Mammals have deciduous and permanent teeth. In some mammals for example in man there are two sets, one in early life the milk teeth and later the permanent teeth. Heart is four chambered. Only left aortic arch is present. RBC are non-nucleated. Mammals are warm blooded (endothermic) animals. Voice apparatus is well developed, and consists of **larynx** and **epiglottis**. Mammals give birth to their young ones. Mammals feed them on milk produced by mammary glands of mother.

Classification of Mammals

Mammals are classified into three subclasses: (1) Prototheria-Egg laying mammals. (2) Metatheria-Pouched mammals. (3) Eutheria-Placental mammals.

SUB-CLASS PROTOTHERIA - The Monotremes

It is a connecting link between reptiles and mammals and provides evidence of evolution and origin of mammals from reptiles. Certain members of this sub-class are adapted for aquatic life e.g. Duck bill platypus, which has a bill similar to that of a duck and has a webbed toes. The mammalian feature of the monotremes is that the female has mammary glands and they feed their youngs. The reptilian features includes the presence of cloaca and cloacal opening (instead of separate opening for digestive and urinogenital system). Monotremes are found in Australia. The examples of monotremes are Duckbill platypus and Echidna-spiny ant eater.

Duckbill Platypus *(Ornithornhynchus)* **Spiny Ant Eater *(Trachyglossus)***

Fig: 9.36 The Monotremes

Science, Technology and Society Connections

Demonstrate an understanding of the connection of extinction of species with that of human activities.

SUB CLASS METATHERIA – The Marsupials

The females have an abdominal pouch the **marsupium**, where they rear their young. The young when borne are immature. The nipples are in the pouch. The mother feeds the young ones and carries them in the pouch till they are matured enough. The Marsupials are found in Australia and America. The examples of marsupials are: Opossum, Kangaroo and Tasmanian wolf.

Kangaroo

Koala

Fig: 9.37 The Marsupials

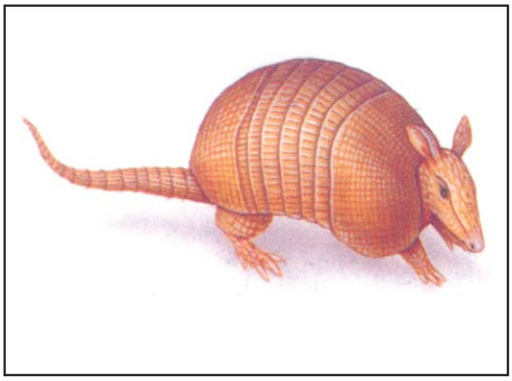
SUB-CLASS EUTHERIA – The Placentalis

Development of young one takes place inside the body of the mother. The young's are borne fully developed. Developing placental mammals are dependent on **placenta** an organ of exchange between maternal blood and fetal blood. Nutrients are supplied to the growing offspring, and wastes are passed to the mother for excretion. The young ones are born at a relatively advanced stage of development. So these mammals are called placental mammals. All the placental mammals have maximum mammalian characteristics. In some hair have been modified into scales in pangolin, and spines in porcupine. Examples of the placentalis are man, whale, elephant, horse, rat, mice, bat, dolphin, cat, tiger, lion, monkey, gorilla etc.

Evolutionary Adaptations in Class Mammalia

Mammals show the following evolutionary adaptations: A regulated body temperature. This makes them independent of environmental change, keeping active throughout the year, whereas reptiles must hibernate during much of the year. An insulating coat of hair that aids in regulating body

temperature. Complete separation of venous and arterial blood in the heart. More efficient mechanism of respiration due to the presence of a diaphragm. An active life and a high rate of metabolism. A better developed larynx. A separate respiratory passage that avoids interference in breathing during feeding. Better developed senses of smell, sight and hearing. A more highly developed nervous system. Large cerebrum and cerebellum provide for better coordination in all activities and for learning and retentive memory. Patterns of behaviour, such as care and nursing of the young, in most of these features the mammals resemble the birds.



Armadillo *(Dasypus)*

Panda

Tiger

Lion

Fig: 9.38 The Placentalis

Critical Thinking

How are the characteristics of the phyla of chordates related to their way of life?

Science, Technology and Society Connections

Trace the position in the phylogeny of major groups of animals.

Exercise

SECTION I : MULTIPLE CHOICE QUESTIONS

Select the correct answer

1. All animals are
   A) autotrophs B) heterotrophs
   C) unicellular D) motile
2. Which of the following is not included in grade bilateria
   A) cnidarians B) nematodes
   C) annelids D) molluscs
3. Which of the following classes of animals includes the first verteberates to appear on Earth?
   A) agnatha, the jawless fishes
   B) chondrichthyes, the sharks
   C) osteichthyes, the bony fishes
   D) tunicata, the sea squirts
4. Which of these does not pertain to a protestome?
   A) spiral cleavage B) blasto pore—anus
   C) schizocoelom D) annelids
5. Sponges belong to the phylum.
   A) aschelminthes B) arthropoda
   C) porifera D) mollusca
6. Which of the following is not a parasite
   A) annelida B) nematoda
   C) platyhelminthes D) porifera
7. Which of the following most clearly demonstrates the evolutionary relationship between annelids and arthropods?
   A) a complete digestive tract B) an exoskeleton.
   C) radial symmetry D) body segments

8. Reptiles are much more extensively adapted to life on land than amphibians in that reptiles
   A) have shelled eggs
   B) have a complete digestive tract
   C) are endothermic
   D) go through the larva stage
9. Amphibians arose from
   A) cartilaginous fish B) jawless fish
   C) ray finned D) bony fishes with lungs
10. Which of these does not pertain to a deuterostome?
   A) blastopore is associated with the anus
   B) spiral cleavage
   C) enterocoelom
   D) echinoderms and chordates
11. Which of the following has a gastrovescular cavity?
   A) sponges B) earthworms
   C) roundworms D) flatworms
12. Which of the following is not a subphylum of chordata
   A) hemichordata B) urochordata
   C) cephalochordata D) vertebrata

1. Write four distinct features of animals.

SECTION II : SHORT QUESTIONS

2. Name the criteria for animal classification.
3. To what life style is radial symmetry an adaptation? Bilateral symmetry?
4. How radial and intermediate cleavage occurs in eggs.
5. Give three features of platyhelminthes for parasitic mode of life.
6. Give three distinguishing features of Aschelminthes.
7. Write five salient features of phylum arthropoda.

8. List any six harmful roles of insects.
9. List the similarities between echinoderms and chordates.
10. Give three reasons why urochordates are classified as chordates.
11. Why amphibians are not considered a very successful group of vertebrates?
12. What does the term amphibian mean?
13. Distinguish between ectothermic and endothermic. Give an example of an ectothermic and an endothermic.
14. Name two phyla of animals that are radially symmetrical and two that are bilaterally, symmetrical.
15. List the vertebrate class (or classes) in which we find each of the following. (a) a skeleton of cartilage. (b) a two-chambered heart. (c) The amniotic egg. (d) A four chambered heart. (e) Placenta. (f) Lungs supplemented by air sacs.
16. Identify the phyla that have the following characteristics: (a) radial summetry (b) a coelomate (c) pseudocoelomate (d) alternation of sexual and axesual stages (e) cnidocytes.
17. Write three main differences between prototheria, metatheria and eutheria.

SECTION III : EXTENSIVE QUESTIONS

1. Write the characteristics of animals.
2. Describe in detail the criteria for animal classification.
3. Write the salient feature of phyla, Mollusca and Echinodermata.
4. Write the economic importance of the all the phyla, which includes the invertebrates.
5. Write the evolutionary adaptations of all the phyla, which include the invertebrates.
6. Write the general characteristics of annelids.
7. Arthropods and vertebrates are highly successful groups of animals on land. Explain with reference to adaptive features for existence on land.

8. Write notes on: (a) polymorphism, (b) alternation of generation (c) corals (d) invertebrates (e) fresh water annelids (f) metamorphosis (g) branchiostoma (h) classification

9. Write the characteristics of invertebrate chordates.

10. Write the evolutionary adaptation of all the classes of phylum chordata.

11. Describe the ways, which amphibians are adapted to life on land, and in what ways they are still restricted to a watery or moist environment.

12. List the adaptations that distinguish reptiles from amphibians and help them adapt to life in dry terrestrial environment.

13. How do mammals differ form birds? And what adaptations do they share?

14. Artropods and verteberates are highly successful groups of animals on land. What characteristics shared by arthropods and vertebrates are adaptive to a land existence?

ANSWER MCQS

1. B 2. A 3. A 4. B 5. C 6. D 7. D 8. A 9. D 10. B

11. D 12. A

SUPPLEMENTARY READING MATERIAL

1. Ruppert, E.E. and R.D. Barnes. Invertebrate Zoology, 6th Ed. Saunders College Publishing, Philadelphia, 1994.

3. Hickman, C.P. Roberts, L.S. Larson M. Integrted Principles of Zoology. 9th Ed. Mosby. St. louis, Missouri. 1993.

USEFUL WEBSITES

1. www.prenhall.com/~audesirk

2. www.mhhe.com/sciencemath/biology/mader/ (click on biology)