03

Evolution and Diversity of Organisms

The theories of origin of life and natural selection to analyze the process of evolution of life

Origin of life on earth

Condition of earth before life

Earth and the other planets of the solar system were formed about 4.6 billion years ago. At the beginning of the solar system, planet Earth was being bombarded by chunks of rocks and ice.

The first atmosphere was probably thick with water vapour, along with various compounds released by volcanic eruptions, including nitrogen and its oxides, carbon dioxide, methane, ammonia, hydrogen and hydrogen sulphide. The neutral atmosphere then turned to be a reducing one. The first atmosphere had little oxygen. Later earth was cooled down and the water vapour condensed into the ocean. Some of the hydrogen quickly escaped into the space. Volcanic eruptions, lightening, extreme UV radiation, hydro thermal vents and alkaline vents along with the Earth's reducing atmosphere favored the synthesis of organic molecules essential for the origin of life. These simple organic molecules then polymerized to form macromolecules such as proteins and nucleic acids. Further, the formation of self-replicating organic molecules made life possible on earth.

Evolution of Biological Diversity

1. Biochemical evolution

Direct evidence for life on early earth comes from fossils of micro-organisms that are about 3.5 billion years old. Observations and experiments in chemistry, geology and physics have provided evidence, for the appearance of the first living cells. The theory of the biochemical evolution arouse from the hypothesis based on chemical and physical processes on early earth. The emerging force of natural selection could have produced the first cells through a sequence of four main stages.

1. Atmospheric conditions of early earth facilitated the abiotic synthesis of small organic molecules such as amino acids and nitrogenous bases from inorganic molecules

2. Polymerization of the above small organic molecules leads to the formation of organic macromolecules.

a. Amino acids $\xrightarrow{\text{polymerization}}$ proteins

b. N-base + sugar+ phosphate $\longrightarrow$ Nucleic acids

3. Organic macromolecules were packed into membranes, to produce protocells

4. Nucleic acids gained self replicating capability, which made inheritance possible for the cells.

2. Origin of protocell

Haldane suggested that the early oceans were a solution of organic molecules "primitive soup" in which life arose. Recent studies related to the volcanic-atmosphere and alkaline vents show the abiotic synthesis of organic molecules. Another source of organic molecules may have been meteorites. RNA accumulated into lipid bound vesicles and formed "protocells" which exhibited enzyme catalyzed activities and were able to grow, replicate and evolve. The early genes and enzymes would have been RNA which enabled replication of RNA. Other molecules that were in the primitive soup were also collected in the protocell. Growth occurred by addition of lipids to the membrane by collision of micelles. When the protocell becomes too large, it divided to form two protocells with RNA included.

3. Origin of photosynthetic organisms

Fossils of the first photosynthetic organism, today's cyanobacteria, originated before 2.7 billion years ago. As a result of photosynthesis iron (Fe^{2+}) ion were oxidized. Once all of the dissolved iron has precipitated, additional O_2 dissolved in the water until the water bodies became saturated with O_2. The increase of photosynthetic bacteria contributed to the increment of the amount of atmospheric oxygen which had accelerated the origin of chloroplast.

4. The origin of first eukaryote

The fossils of the first eukaryotic organisms were estimated as from about 1.8 billion years ago. These eukaryotic single cellular organisms later evolved in to multicellular organisms. The appearance of structurally complex eukaryotic cells sparked the evolution of greater morphological diversity than was possible for the simple prokaryotic cells. After the first eukaryotes appeared, a great range of unicellular forms evolved. It gave rise to diversity of some single-celled eukaryotes which evolved in to multicellular forms, such as the varieties of algae, plants, fungi and animals. Fossils of the oldest known protists similar to small red algae were dated as 1.2 billion years ago.

5. Diversification of Eukaryotes

Many present day animal phyla appeared in the early Cambrian period. Several animal groups which include, porifera, sponges, cnidarians (Sea anemones and their relatives) and molluscs appeared in the late Proterozoic. According to the DNA analysis, sponges evolved 700 million years ago. Ancestors of arthropods, chordates and other animal phyla originated 670 million years ago. The first food chains on earth appeared when animals started to depend on algae or plants as consumers and with the arrival of many groups of animals, functioning food webs began to appear. Colonization of land by fungi, plants and animals began after about 500 million years ago. Plants that colonized land possess vascular systems to transport water and minerals and water proof coating of wax to prevent the water loss. With the emergence of large trees, differentiation as roots, stems and leaves began and diversified since 40 million years ago. Plants and fungi colonized the land together by interacting with each other. Arthropods (insects and spiders) were the first group of animals to colonize the land. The earliest tetrapods formed about 365 million years ago which were evolved from lobed-finned fish. The divergence of human lineage from other primates was initiated 6-7 million years ago. The origin of the human species took place 195,000 years ago.

Geological eons and eras of evolution

- Eons: Hadean, Archaean, Proterozoic, Phanerozoic
- Eras: Eon Phanerozoic covers the 3 eras, Palaeozoic, Mesozoic, Cenozoic

1. Hadean eon

- Origin of Earth

2. Archaean eon

- Oldest known rocks on Earth's surface
- Oldest fossils of cells (prokaryotes) appeared
- Concentration of atmospheric oxygen begins to increase

3. Proterozoic eon

- Diverse algae and soft-bodied invertebrate animals appeared
- Oldest fossils of eukaryotic cells appeared

Eon Phanerozoic covers the 3 eras; Palaeozoic, Mesozoic, Cenozoic

1. Palaeozoic era

- Sudden increase in diversity of many animal phyla
- Marine algae becomes abundant; colonization of land by diverse fungi, plants, and animals
- Diversification of vascular plants
- Diversification of bony fishes, first tetrapods and insects appeared
- Amphibians dominated
- Extensive forests of vascular plants

- First seed plants appeared
- Origin and radiation of reptiles
- Origin of most present-day groups of insects
- Extinction of many marine and terrestrial organisms
- Diversification of early vascular plants

2. Mesozoic era

- Cone-bearing plants (gymnosperms) dominated
- Dinosaurs evolved, radiated
- Origin of mammals
- Gymnosperms continued as dominant plants, dinosaurs dominated, abundant and diverse
- Flowering plants (angiosperms) appeared and diversified, many organisms including dinosaurs become extinct

3. Cenozoic era

- Major radiation of mammals, birds, and pollinating insects
- Dominance of angiosperm increased and their radiation continued, radiation of most present day mammalian orders
- Origins of many primate groups, continued radiation of mammals and angiosperms, earliest direct human ancestors
- Appearance of bipedal human ancestors
- Origin of genus Homo

Theories of evolution

Evolution can be defined as a change in the genetic composition of a population from generation to generation (descent with modification) over a long period of time. This may take millions of years.

Theories of evolution are

- Theory of Lamarck.
- Darwin - Wallace theory (Theory of Natural selection)
- Neo Darwinism

Theory of Lamarck

Lamarck published his hypothesis in 1809. He explained his hypothesis using two principles.

1. Use and disuse
2. Inheritance of acquired characteristics

1. Use and disuse - The parts of the body that are used extensively become larger and stronger. If not used, they deteriorate.

   e.g.- Giraffe stretching its neck to reach leaves on higher branches.

2. Inheritance of acquired characteristics – Organism acquired adaptation during their life time according to the needs of enviro off spring is better adapted to live in that environment e.g. long muscular neck of the giraffe had evolved over many generations as giraffes stretch their necks even higher

Darwin - Wallace theory (Theory of natural selection)

Darwin observed two phenomena from the environment. His observations were;

The populations of a species vary in characteristics among their inheritance traits.

Each species produces more offspring than their environment could accommodate.

The above observations were interpreted by Charles Darwin as,

Certain traits of a population which are capable of exhibiting qualities for better surviveal and their reproduction can produce more offspring.

Variation in abilities for survival and production among a population may enhance the abundance of favorable characteristics in that population.

Some favorable characteristics for survival and reproduction are;

- Escaping from predators - defense
- Tolerating physical conditions – stress conditions
- Obtaining food
- Resistance against disease
- Fertilizing probability
- Number of offspring produced

Process of natural selection

- Over production
- Variation
- Competition and survival of the fittest
- Natural selection of favourable traits

Neo-Darwinism

Neo-Darwinism generally denotes the integration of Charles Darwin's theory of natural selection, Mendelian genetics as the basis for biological inheritance and knowledge of population genetics.

Hierarchy of taxa on scientific basis

Methods of artificial and natural classification

Arrangement of organisms into groups on the basis of the common characteristics is called classification. Taxonomy is the scientific study on classification, identification, nomenclature and description. This includes placing groups of organisms in a hierarchical sequence.

Two methods of classification

(1) Artificial classification - grouping is based on a few pre selected unifying characters.

- The characters are selected first according to convenience and organisms are grouped based on the selected criteria
- Evolutionary relationships are ignored
- Only system used before 18th century
- Easy to use, easy to expand by adding more groups

e.g. Plants can be classified as cereals, ornamental plants, medicinal plants, poisonous plants etc. Animals can be classified as two legged, four legged, six legged, eight legged etc.

(2) Natural classification - grouping based on true relationships.

- Represent s evolutionary relationships based on phylogeny- evolutionary history of a species or groups of species
- Systems developed after then study of evolution.
- Based on many characteristics.

Characteristics used can be morphological, anatomical, cytological or molecular biological such as DNA and RNA base sequences

e.g. Plants can be classified into phyla; Bryophyta, Lycophyta, Pterophyta, Cycadophyta, Coniferophyta and Anthophyta etc. Animals can be classified into Cnidaria, Platyhelminthes etc.

History of classification

The early classification systems were all artificial systems and were mostly based on human uses.

Aristotle was the first to classify organisms scientifically. He divided organisms into plants and animals. Animals were further classified according to criteria such as mode of locomotion, reproduction and presence or absence of red blood cells. Aristotle's pupil Theophrastus classified plants according to habit. e.g. trees, shrubs and herbs, and according to lifespan e.g. annuals, biennials and perennials.

Up to the time of Linnaeus scientists have used many different methods for naming of organisms. Carolus Linnaeus(1753), Swedish botanist, introduced binomial nomenclature and also classified about 6,000 plants into a hierarchical order of taxa, classification level such as; Species, genus, order, and class. His classification of flowering plants was based on the number of stamens and styles of flower. He identified two kingdoms of organisms; plants and animals.

With the discovery of the microorganisms the scientists understood that there were organisms which could not be assigned into either plants or animals. To get over this difficulty Ernest Haeckel (1866) introduced a third kingdom: Protista. He also introduced the taxon Phylum and classified many organisms.

With the discovery of the electron microscope biologists identified prokaryotic and eukaryotic cellular organization. Robert H Whittaker (1969) introduced the five kingdom system of biological classification; Monera, Protista, Fungi, Plantae and Animalia. His classification was based on the nature of cellular organization, unicellular or multicellular and mode of nutrition.

With the acceptance of Darwin's theory of the evolution and unitary origin of life, taxonomists began to use natural systems with interpreting evolutionary relationships. With the recent advancement of molecular biology and the use of molecular methods in studying evolutionary relationships it became apparent that in the very early evolution some prokaryotes differ as much from each other as do from eukaryotes. Such difficulties have lead biologists to adopt three Domain system of classification. The three domains are Bacteria, Archea and Eukarya, which are taxonomic ranks higher than the Kingdom. Carl Woese (1977) introduced this three domain system.,

In this tree of life the first major split in the history of life occurred when bacteria diverged from others. Eukarya and Archea are mostly related to each other than bacteria.

Present system of classification and its basis

The present system of classification is mainly based on the rapid advance of molecular biology and the new information on the evolutionary relationships of organisms.

- the sequence of bases of DNA of important genes
- the sequences of bases of DNA of mitochondria and chloroplasts
- the base sequence of ribosomal RNA
- the sequence of amino acids in common proteins
- the molecular structure of cellular components

are used as important taxonomic criteria in modern systematics.

However, the kingdom Protista is not a natural group. It is an artificial group including organisms which have different evolutionary origins.

Viruses do not have cellular organization, and therefore do not belong to any of the kingdoms. They are also an artificial group considered separately.

Hierarchy of Taxa from Domains to Species

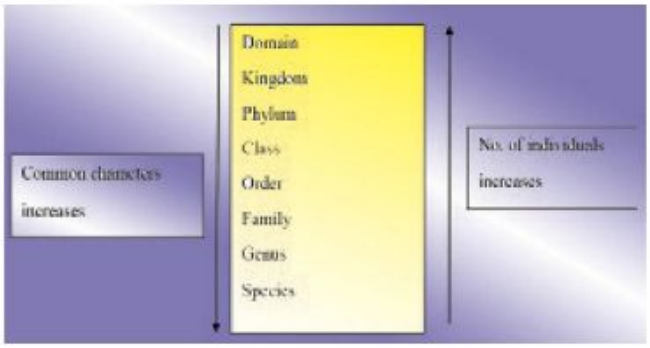
The taxonomic unit at any level/ rank of the hierarchy is called a taxon (plural-taxa). Each taxon has a rank and a name.

e.g. *Panthera* is a taxon at the Genus level/ rank

Mammalia is a taxon at the Class level/ rank

Under the hierarchical system there are levels/ ranks of taxa. Each Domain is divided into kingdoms. A Kingdom is divided into phyla (singular phylum), phylum into classes .etc. Many of these categories may also be subdivided.

e.g. Super class, Sub-family, Subspecies, etc.



From domain to species, the number of shared characteristics among the members in the taxa increases. From species to domain, the number of individuals in the taxon increases.

Biological definition of a species

Species is a group of organisms who shares similar characteristics and has the ability to interbreed and produce viable and fertile offspring.

Other definitions of species

- Morphological species concept- use of morphological criteria to distinguish species such as body shape and other structural features

- Ecological species concept–defines species in terms of its ecological niche and the sum of how members of the species interact with the non living and the living components of their environment
- Phylogenetic species concept – defines the species as the smallest group of individuals that share a common ancestor.

Binomial nomenclature

In classification, use of common names for organisms, causes confusion. More over some common names do not actually reflect the kind of organism they signify.

e.g. Jelly fish (a Cnidarian)
Cray fish (a Crustacian)
Silver fish (an insect)
Star fish (an Echinoderm)

Further, a given organism has different names in different languages. Carolous Linnaeus (1707-1778) proposed a binomial system of nomenclature of species, which was accepted worldwide to avoid ambiguity.

According to the binomial nomenclature the name of an organism has two parts:

First is the generic name, to which the species belongs and the second is a specific epithet, the unique for each species within the genus. Generic name is usually a noun and the specific epithet an adjective describing a particular feature.

e.g. *Homo sapiens- Homo* means man, *sapiens* means intelligent

Related species have the same generic name with different specific epithets.

e.g. *Dipterocarpus zeylanicus* and *Dipterocarpus grandiflorus*

Dipterocarpus zeylanicus means fruit with two wings, and endemic to Sri Lanka.

Dipterocarpus grandiflorus means fruit with two wings and having large flowers.

International codes of Binominal nomenclature

Biologists have adopted sets of rules or Codes of nomenclature. These codes are slightly different for plants, animals, bacteria and viruses. Some of the important rules for naming plants, fungi, bacteria and animals are as follows.

- Two species of organisms cannot have the same name.
- Each species has a generic name and a specific epithet, both together forming the species name or scientific name.
- The Name should be made up of Latinized words written in the Roman script.
- It should be underlined when hand written and italicized when printed.
- The first letter of the generic name must be capitalized the and specific epithet must be in simple letters.

In scientific writing, the name of the author who gave the name is indicated by a capital letter, an abbreviation or full word at the end of the name, which is not Latinized.

e.g. *Cocos nucifera L.*, (L for Linnaeus).

A third word can be used to represent a subspecies or a variety, example *Panthera parduskotiya* (Sri Lankan leopard).

- **Use of keys**
  - Used to group organisms and identify them
  - Keys do not show the evolutionary relationships
  - The Commonly used key is the dichotomous key
  - Some examples are given below

Example 1: **Silverfish, Butterfly, House fly, Beetle**

1. Possesses wings …… (2)
   Do not possess wings …… Silverfish
2. Possess two pairs of wings …… (3)
   Do not possesses two pairs of wings……Housefly
3. Possesses a proboscis ……Butterfly
   Do not possess a proboscis ……,.Beetle

Example 2: **Snake, Earthworm, Frog, Sea anemone, Butterfly**

1. Radially symmetrical body ……Sea anemone
   Not having a radially symmetrical body ……(2)
2. Possess legs……(3)
   Do not possesses legs ……(4)
3. Wings present…… Butterfly
   Wings absent…… Frog
4 Body covered by scales …… Snake
   Body is not covered by scales …… Earthworm

Domains

There are three domains. They are;

a) Domain – Bacteria- consists of one kingdom. Kingdom - Bacteria
b) Domain –Archaea-consists of one kingdom. Kingdom - Archaebacteria
c) Domain –Eukarya-consists of four kingdoms.

Kingdom - Protista

Kingdom - Fungi

Kingdom - Plantae

Kingdom - Animalia

The diversity of organisms within the Domain Bacteria

Key characteristics of Domain Bacteria

- They are prokaryotic
- They are unicellular, colonial, filamentous
- Most of them are found in size between 0.5 to 5μm
- Well adapted to most of the 'normal' habitats (both land and water)
- Most of them contain peptidoglycan in their cell walls
- According to the amount of peptidoglycan present in the cell wall they are classified as Gram positive and Gram negative bacteria
- Most of their cell walls are surrounded by a sticky layer of polysaccharides or proteins called capsule
- Most of them have flagella for motility. Bacterial flagellum differs from eukaryotic flagellum as they are not covered by a plasma membrane and absence of 9+2 structure of microtubules.
- Possess diverse nutritional modes-Autotrophs, heterotrophs
- Posses diverse metabolic modes- obligate aerobes, obligate anaerobes, facultative anaerobes, etc.
- Some are capable of performing nitrogen fixation- e.g. *Rhizobium sp.*, some cyanobacteria
- Rapid reproduction by binary fission. Some perform conjugation as a sexual method.
- Certain bacteria use bacterial chlorophyll as a photosynthetic pigment.

Key Characteristics of Cyanobacteria

- Prokaryotic organisms
- Photosynthetic
- Most are unicellular and oxygen generating and solitary. But some are linked to form filaments or colonies sheathed in mucous
- Some have the ability of fixing atmospheric nitrogen

Key characteristics of Domain Archaea

- They are prokaryotic and unicellular.
- They lack peptidoglycan in their cell walls which are made up of proteins and polysaccharides
- The size of most of them is between 0.5-5 μm
- They include extreme halophiles and extreme thermophiles
- Some Archaeabacteria live in more moderate environments-Methanogens
- Other species inhabits the anaerobic guts of cattle, termites and other herbivores

Key characteristics of Domain Eukarya

- They are Eukaryotic
- Vary in size
- Most of them are multicellular
- Habitats are diverse
- Diverse in nutrition
- Mostly aerobes
- Most of them exhibit sexual reproduction (some protists are only known to reproduce asexually)

Table 3.1: A comparison of the three domains of life

	Characteristic	Bacteria	Archea	Eukarya
1	Cellular organization	Prokaryotic	Prokaryotic	Eukaryotic
2	Cell wall composition	Peptidoglycan	Proteins and polysaccharides (lack peptidoglycan)	Cellulose, Hemicellulose, Pectin and Chitin
3	Membrane lipids	Unbranched hydrocarbons	Some branched hydrocarbons	Unbranched hydrocarbons
4	Genetic Composition			
	Histones associated with DNA	Absent	Present in some species	Present
	Circular chromosomes	Present	Present	Absent
	Introns in genes	Very rare	Present in some genes	Present in many genes

5	Protein synthesis			
	RNA polymerase	One kind	Several kinds	Several kinds
	Initiator amino acids for protein synthesis	Formyl-methionine	Methionine	Methionine
6	Response to antibiotics Streptomycin and Chloramphenicol	Growth inhibited	Growth not inhibited	Growth not inhibited
7	Growth at temperatures > 100°C	No	Some species	No
8	Habitats	Diverse habitats	extreme environmental conditions-volcanic pits/ hot springs/ salt marshes etc.	Diverse habitats
9	Examples	Bacteria, cyanobacteria; *Nostoc, Anabaena ,, Escherichia coli, Salmonella typhi*	Archaebacteria; *Methanococcus Thermococcus., Helobacteria* .	Protists fungis plants and animals

The diversity of organisms within the kingdom Protista

Key characteristics of Kingdom Protista

- Most of them are unicellular, although there are some colonial and multi cellular species
- It is a polyphyletic group (originated from more than one ancestor) and an artificial group in classification.
- Found in freshwater, marine and damp soil, some are symbionts.
- Unicellular, colonial or multicellular.
- Some are photoautotrophs, some are heterotrophs and some are mixotrophs (combination of photoautotrophic and heterotrophic nutrition).

Euglena

- Unicellular, lack cell wall and pellicle present.
- Chloroplasts are present.
- They have one or two flagella
- They have eye spot
- Contractile vacuole is present
- They have a pocket at one end of the cell from which one or two flagella emerged.

Paramecium

- Habitat is freshwater
- Lack cell wall but pellicle is present, unicellular
- Cilia may completely cover the cell surface
- They have two types of nuclei- mega nucleus and micronucleus
- Contractile and food vacuoles are present
- Oral groove is present

Amoeba

- Aquatic (marine and freshwater) forms are free living others are parasitic.
- Lack cell walls, unicellular organisms
- They form pseudopodia which are used to locomote and feed
- They do not have definite shape.
- Food vacuoles are present

Ulva

- Macroscopic marine forms.
- Cell wall present
- Multicellular thallus differentiated into leaf like blades and root like holdfast.
- Green in colour (green algae)

Gelidium

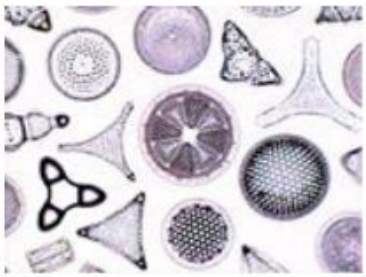
- Marine.
- Cell walls present
- Multicellular thallus with hold fast.
- It is greenish red in colour (red algae)

Sargassum

- Marine
- Comparatively larger and complex
- Thallus is plant- like; it consists of a root like holdfast ,stem like stipe and leaf like blade.
- Multi cellular, thallus is supported by gas filled bulb shape floats.
- Appear in olive green or brown colour (brown algae)

Diatoms

- It is aquatic (fresh water and marine)
- Unicellular, having glass like, wall consists of two parts that overlap (presence of silica)
- Highly diverse group regarding the shape and markings in the surface
- Golden brown in colour (golden brown algae)



The diversity of organisms within the kingdom Plantae

Kingdom Plantae

Evolutionary relationships among major groups of plants

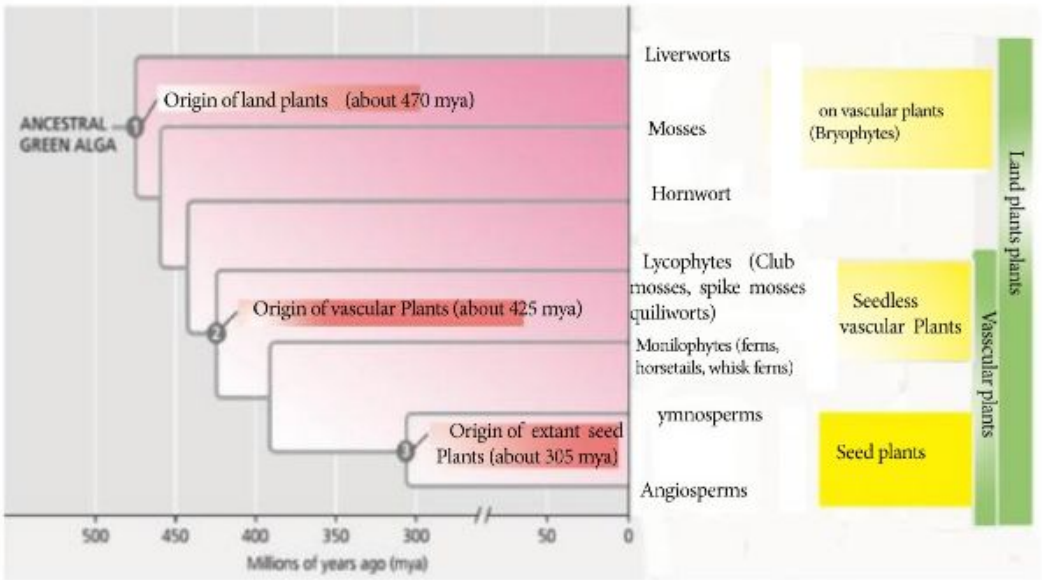
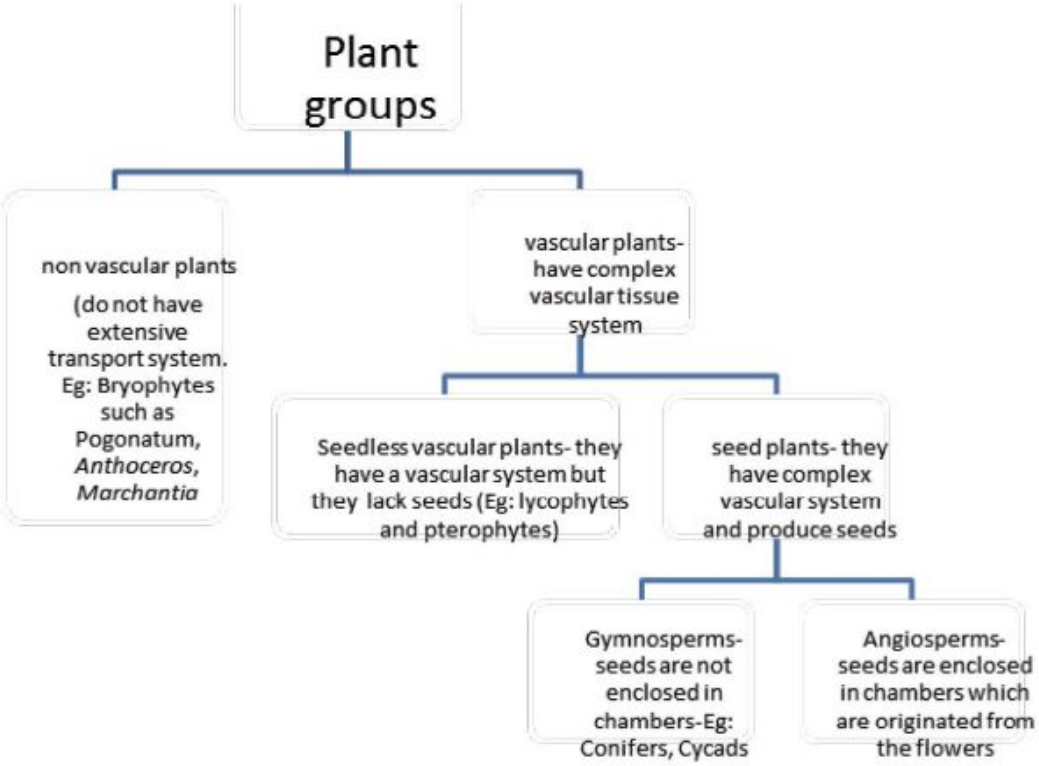


Fig 3.1 Evolutionary relationship of major groups of plants

It is believed that members of the kingdom Plantae were evolved from a group of chlorophytes/ green algae. Most of them are terrestrial organisms. Chlorophyte algae lack key traits of land plants, walled spores produced in sporangia, multicellular gametangia, dependent embryo and apical meristem. They evolved in the terrestrial environment.

Plant groups can be distinguished based on the presence or absence of an extensive system of vascular tissue. Based on that there are two major groups of plants the can be seen; they are Vascular plants and Non-vascular plants.



Diversification of Kingdom Plantae

- Non-vascular plants
  - Phylum Bryophyta - Mosses- *Pogonatum*
  - Phylum Hepatophyta- *Marchantia*
  - Phylum- Anthocerophyta- *Anthoceros*
- Vascular seedless plants
  - Phylum – Lycophyta- *Selaginella*
  - Phylum – Pterophyta- *Nephrolepis*
- Vascular seed plants

- Gymnosperms- Phylum – Cycadophyta (*Cycas sp.*),
  Phylum- Coniferophyta (*Pinus*), Phylum – Gnetophyta (*Gnetum*)
- Angiosperms- Phylum – Anthophyta (all flowering plants)

Non-vascular plants

One way to distinguish a group of plants is to see whether or not they have an extensive system of vascular tissue that transport water and nutrients throughout the plant body. Most present day plants do have a complex vascular tissue system and therefore, are called vascular plants. Plants that do not have an extensive transport system are described as non vascular plants. Non vascular plants are informally named as Bryophytes.

e.g. *Marchantia, Pogonatum, Antheroceros*

Bryophytes share some derived traits with vascular plants, but lackin many innovations of vascular plants such as presence of true stems, roots and leaves.

Diversity of Bryophytes

Phylum- Hepatophyta e.g. *Marchantia* (liverworts).

Phylum Anthocerophyta e.g. *Anthoceros* (hornworts)

Phylum Bryophyta e.g. *Pogonatum* (mosses)

Characteristic features of phylum Bryophyta

e.g. *Pogonatum*

- Especially common in moist terrestrial places.
- Haploid gametophyte is dominant stage of the life cycle, photosynthetic and independent.
- Gametophytes are differentiated into 'leaves', 'stems' and rhizoids. They have no vascular tissues. Archegonia and antheridia are typically carries on separate female and male gametophyte. Therefore gametophyte is dioecious.
- Male plant produces flagellated sperm which can swim through a film of water for fertilization.
- Sporophytes are usually green and photosynthetic when young. However, they are not independent. They attach to their parental gametophytes and absorb nutrients and water from the female gametophyte.
- Sporophytes have specialized pores called stomata which are also found in all vascular plants.
- They are homosporous.

Vascular plants cover about 93% of the existing plant species. They can be further divided into two groups.

1. Seedless vascular plants
2. Seed plants

Seedless vascular plants

Seedless vascular plants lack seeds and disperse by means of spores. They are categorized into two groups.

1. Lycophytes
2. Pterophytes

Even though, both pterophytes and lycophytes are seedless plants, pterophytes share a more recent common ancestor with seed plants.

Fossils and living seedless vascular plants provide evidence for plant evolution during Devonian and Carboniferous periods. The ancestors of vascular plants already have had some derived traits of modern vascular plants; however, they lack roots and some other adaptations.

Fossils suggest that, the ancestors of vascular plants had gametophyte and sporophytes that were about equal in size. However among the living vascular plants sporophyte generation is large and more complex. For example in ferns, leafy plants are the sporophytes

Significant features of seedless vascular plants;

1. Transportation through Xylem and Phloem

Vascular plants have two types of vascular tissues; Xylem and Phloem

Xylem consists of tracheids, fibers and parenchyma cells- conducts water and minerals.

Cell walls of tracheids and fibers are strengthened by the polymer lignin. These tissues permit plants to grow tall. This may facilitate them to obtain a high amount of light for photosynthesis and ease the spore dispersal.

Phloem- this tissue has cells arranged in tubes. They distribute sugars, amino acids and other organic products among different parts of the plant.

2. Evolution of roots

Roots are organs that absorb water and nutrients from the soil. They anchor the plants and allow the shoot system to grow taller. They are to replace the rhizoids seen in bryophytes. Root tissues of living plants resemble stem tissues of the early vascular plants preserved in fossils.

3. Evolution of leaves- There are two types of leaves. They are microphylls and megaphylls. Microphylls are single veined and smaller in size while megaphylls are large, flattened with branched veins.

Leaves with branched vascular tissues increase the surface area for efficient photosynthesis (megaphylls).

Sporophylls and spore variations

Modified leaves that bear sporangia are known as sporophylls. Most seedless vascular plant species produce one type of sporangium and one type of spores. Therefore, they are known as homosporous.

Some plant species produce two types of sporangia and produce two kinds of spores called mega spores and microspores. This condition is known as heterosporous. Mega spores develop into female gametophyte while microspores develop into male gametophyte.

Phylum Lycophyta

- Lycophytes are terrestrial and some are epiphytes.
- The dominant plant is sporophyte.
- They produce upright stems and ground hugging stems.
- In upright stems small leaves can be found.
- Ground hugging stems produce dichotomously branching roots.
- They have strobili. In many club mosses and spike mosses sporophylls are clustered into club shaped cones/ strobili.
- They are homosporous or heterosporous.

Spike mosses are usually relatively smaller and often grow horizontally.

- All Club mosses are homosporous;
  e.g. *Lycopodium* sp.
- All Spike mosses are heterosporous.
  e.g. *Selaginella*

In some species the tiny gametophyte live above the ground and are photosynthetic. Others live below the ground and are nourished by symbiotic fungi.

Phylum Pterophyta

- Most sporophytes have rhizome (an underground stem)
- At the tip of the rhizome they produce leaves, called fronds
- Many fronds are highly dissected and feathery.
- All species are homosporous which develop into a bisexual gametophyte.
- Sporophytes are dominant
  e.g. *Nephrolepis.*

Seed plants

Vascular plants consist of seeds and are a called "seed plants". They represent the vast majority of living plant species.

Seed plants can be divided into two groups, based on the absence or presence of enclosed chambers in which seeds mature.

1. Gymnosperms
2. Angiosperms

Gymnosperms are "naked seed" plants as their seeds are not enclosed in chambers.

Angiosperms are "seed plant" group accommodating all flowering plants. Angiosperm seeds develop inside chambers called ovaries; which originate within flowers and mature into fruits.

Significant features of seed plants

1. Production of seed

A seed consists of an embryo and endosperm. Endosperms supply food to the embryo. This endosperm is surrounded by a protective coat which is known as seed coat. When seeds are mature they can be dispersed through various dispersal methods.

Seeds are key adaptations that help seed plants to become the dominant producers on land and to exhibit the vast plant diversity of today.

2. Reduced gametophyte

The evolutionary trend of gametophyte reduction continued further in the vascular plants and led to seed plants. The gametophyte of seed vascular plants is not visible to the naked eye. They are mostly microscopic.

Tiny gametophytes develop from spores and are retained within the sporangia of sporophyte. This arrangement protects the gametophyte from environmental stresses. The moist reproductive tissues of the sporophyte shield the gametophyte from UV radiation and protect them from drying out. This relationship also enables the dependant gametophyte to obtain nutrients from the sporophyte.

3. Heterospory

Seed plants are heterosporous (produce both megaspores and microspores). Each megasporangium has a single functional megaspore and each microsporangium contains a large number of microspores.

4. Production of ovules and eggs

Seed plants are unique in retaining the megasporangium within the parent sporophyte. A layer of sporophyte tissue called integument envelops which protects the megasporangium.

The entire structure, containing megasporangium, megaspore and integuments is called an ovule. Inside each ovule female gametophyte develops from a megaspore and produces one or more eggs.

5. Production of pollen and sperms

A microspore develops into pollen grain that consists of a male gametophyte enclosed within the pollen wall. The wall of the pollen is tough as it is made up of the polymer sporopollenin, which protects the pollen grain during pollination. The transfer of pollen grain towards the ovule is called pollination. When a pollen germinates, it gives rise to a pollen tube that discharges sperm (male gametes) into the female gametophyte located within the ovule.

Inside a pollen grain, a sperm producing male gametophyte is present. The sperms of seed plants do not require motility as they are carried directly in to the eggs by pollen tubes. Some gymnosperms retain the ancient flagellated condition, however flagella have been lost in the sperm of most gymnosperms and all angiosperms.

Phylum Gnetophyta

e.g. *Gnetum*

- Only gymnosperms have vessels in xylem
- Leaves of gymnosperms look like those of the flowering plants. Their seeds, look like fruits of angiosperms.

Phylum Cycadophyta

- They have palm like leaves and large cones
- They have flagellated sperms similar to those of seedless vascular plants

e.g. *Cycas*

Phylum Coniferophyta

e.g: *Pinus*

- Large trees are included such as Cyperes and Red woods.
- In conifers two types of spores are produced by separate cones.

Phylum Anthophyta - Angiosperms

Presence of flowers -

- Stamens produce microspores and these microspores develop into pollen grains
- These pollen grains contain male gametophyte/ gametes
- Carpels produce megaspores and these megaspores produce female gametophytes/ embryo sac
- Seeds are enclosed within the carpels
- Production of fruits- seeds are protected by fruits which help in their dispersal. This is one of the unique features of phylum Anthophyta. A fruit typically consists of a fertilized ovary and sometimes include other persistent floral parts. After fertilization, the ovary wall thickens and develops into fruit. Ovules develop as seed of the fruit. Thr fruit protects dormant seeds and aid in their dispersal.

Diversity of Angiosperms

The flowering plants (angiosperms) are divided into two groups based mainly on the number of cotyledons in their embryo.

These two groups are;

1. Monocotyledons- species with one cotyledons
2. Dicotyledons- species with two cotyledons

Table 3 .2- Comparison of monocots and Dicots

Class – Monocotyledoneae	Class – Dicotyledoneae
The embryos have only one cotyledon	Embryos have two cotyledons
Fibrous root system	Tap root system
Parallel veins in leaves	Reticulate veins in leaves
Flower parts are trimerous	Flowers are pentamerous or tetramerous
Perianth present in flowers (No distinct calyx and corolla)	Distinct calyx and corolla present in flowers

Pollen grains are with one opening/ aperture	Pollen grains are with three openings/ apertures
Vascular bundles in the stem do not have cambia and are scattered e.g. grasses, coconut, rice	Vascular bundles in the stem have cambia and arranged in a ring e.g. Rose, shoe flower, cucurbits

The diversity of organisms within the kingdom Fungi

Kingdom Fungi

Characteristic features of Kingdom Fungi

- Eukaryotic
- Cell walls are made up of chitin a strong but flexible polysaccharide.
- They are absorptive and heterotrophs - many of them secrete extra cellular enzymes which aid in the breaking down of complex molecules into small molecules.
- Different species live as decomposers, parasites or mutualistics.
- Few are unicellular, others forming multicellular filaments called hyphae .
- Septa can be found in hyphae. (division of hyphae into cells by septa – cross walls).
  - Septum has a hole which enables the movement of mitochondria, ribosomes, nuclei etc.
  - Fungi lack septa are known as coenocytic fungi (with many nuclei)
- Fungal hyphae produce mycelium
- Some fungi produce haustoria (to penetrate and absorb or exchange nutrients between plants and the fungi)
- Multicellular fungi produce mycelia. (a network of branched hyphae adapted for absorption of nutrition)
- They show sexual and asexual reproduction.
- They produce spores.

Characteristic features of Phylum Chytridiomycota

e.g.: *Chytridium*

- Aquatic or terrestrial .
- Some are decomposers while others are parasitic.

- Multicellular or unicellular when multicellular it is coenocytic.
- They produce zoospores which are flagellated.
- Cell walls are made up of chitin.
- Some of them form colonies with hyphae while others exit as single spherical cell.

Characteristic features of Phylum Zygomycota

e.g. *Mucor* , *Rhizopus*

- Most of them are saprotrophs and some of them are parasites or commensals.
- Mycelium is coenocytic and aseptate. Septa found only where reproductive cells are formed.
- Asexual reproduction: Produce sporangia in which genetically identical haploid spores are produced. Also by endospores produced in sporangia.
- Sexual reproduction: A Zygosporangium is produced which is a sturdy structure produced by plasmogamy and karyogamy. Zygosporangium is resistant to unfavorable environmental conditions.
  - o Zygosporangium is a multinucleated structure which is resistant to drying and freezing.
  - o They are metabolically inactive in adverse environmental conditions.
- Zygosporangium produces genetically diverse haploid spores when environmental conditions are favourable.

Characteristic features of Phylum Ascomycota

e.g. *Aspergillus, Saccharomyces, Penicillium*

- Marine or freshwater or terrestrial
- Parasitic or symbiotic.
- Most of them are decomposers.
- Unicellular or filamentous, multicellular.
- In asexual reproduction conidia are produced at the tip of the conidiphores which are specialized hyphae. (Exospores in clusters or chains)
- In sexual reproduction fusion of sexually differentiated gametangia takes place and produce sac like structure called asci.
- Ascospores are produced within asci. Generally there are eight ascospores are produced in each ascus.
- Most of these fungi produce ascocarps enclosing asci.

Characteristic features of Phylum Basidiomycota

e.g. *Agaricus,* Puffballs, Shell fungi

- They are Terrestrial.
- They are major decomposers and some are symbionts.
- Filamentous with septae and dikaryotic.
- Mycelium is the dominant stage of the life cycle.
- They produce fruiting bodies called basidiocarps during sexual reproduction. Produce basidia on the gills of the basidiocarp.
- Produce basidiospores on basidium and exogenous.

The diversity of organisms within the kingdom Animalia

Kingdom Animalia

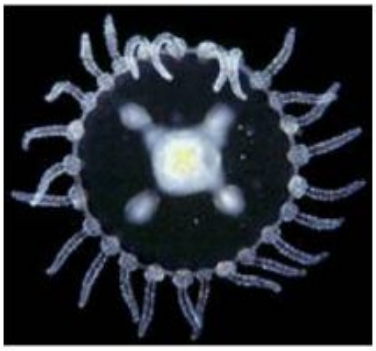
Characteristic features of Kingdom Animalia

- Multicellular
- Heterotrophic eukaryotes- they ingest food and digest them in the body using enzymes
- Cells of the animals are organized into tissues.
- Most of them reproduce by sexually.
- Some show radial symmetry and some others show bilateral symmetry.

Phylum Cnidaria

Characteristic features of each example are not necessary

e.g. *Hydra,* Sea anemone, *Obelia,* Corals and Jelly fish



Obelia,

Jelly fish

Hydra

Coral polyp

- Majority of them are marine, except a few fresh water species. Some are macroscopic.
- Simple organization: diploblastic or just 2 body cell layers- an outer layers of ectoderm and inner layer of endoderm sandwitched between these two layers is a acellular layer of mesoglea
- They have a simple gastrovascular cavity which is a sac with a central digestive compartment. This cavity is lined by endodermis with a single opening (mouth) only.
- They show radial symmetry with two body forms polyp and medusa. Polyps are cylindrical forms attached to the substrate by the aboral end of the body. Tentacles are found around the mouth.
- Medusa resembles a flattened mouth down version of the polyps and they are free living.
- Some cnidarians exist only as polyps or only as medusa. Others have both polyp and medusa forms in their lifecycles.
- Tentacles are armed with cnidocytes which functioning defense and capturing prey.
- They have nematocysts which contain stinging thread.

Phylum Platyhelminthes

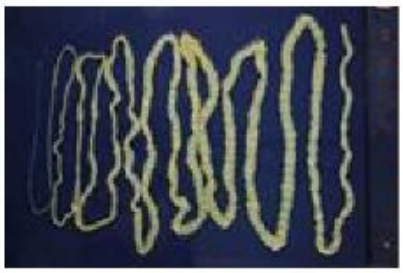
Characteristic features of each examples are not necessary

e.g. *Planaria, Taenia , Fasciola*

Fasciola

Planaria

- Commonly known as flatworms.
- Free living (*Planaria*) or parasitic (flukes and tapeworms).
- They are found in marine, fresh water and in damp terrestrial habitats.
- Body is dorsoventrally flattened. Some have elongated tape like body forms without true segmentation.
- Triploblastic with all three germ layers (ectoderm, mesoderm and endoderm). Signs of cephalization present but are not distinct.



Taenia

- No body cavities, circulatory, respiratory and skeletal systems.The gaseous exchange is by simple diffusion through body wall.
- Sensory organs are found only in free living examples. Eye spots are found in the head.
- First appearance of little complex nervous and sensory system. A pair of anterior ganglion and two longitudinal nerve cords on central nervous system.
- Appearance of separate organs for excretion: Nitrogenous excretory system consists of protonephridia. These are a network of tubules with ciliated structures called flame bulb. These are used to maintain the osmotic balance.
- They have incomplete digestive system only with mouth without anus. Branched gastrovascular cavity is present for digestion. Some are having eversible pharynx.
- Free living examples have cilia for the locomotion.
- Some show asexual reproduction by regeneration. All are bisexual. Except tape worms (*Taenia*). Others have cross fertilization which is internal. In parasitic forms there are several larval stages, direct development in free living examples without larval stages.

Phylum Nematoda (charactcristic features of eachexamples are not necessary)

e.g. round worms, hook worms, pin worms

round worm

hook worm

pin worm

- Most of them are free living in marine, few are fresh water and damp soil environments and parasitic in plants and animals.
- They are bilateral symmetrical. Triploblastic with pseudocoelomic .Their body forms are cylindrical with tapered ends. Body size varies from microscopic to macroscopic. They do not show distinct cephalization and segmentation. The sensory papillae are found on the anterior end of the body. Body is covered by tough cuticle and undergoes ecdysis.
- No circulatory and respiratory systems. Gaseous exchange is by simple diffusion through body wall. They have an Alimentary canal.
- Body wall is composed only of longitudinal muscles. They do not have special locomotary structures. Longitudinal muscles in the body wall are involved in locomotion.
- The Sexual reproduction is by internal fertilization. Sexes are separated and females are larger than males.

Phylum Annelida

Characteristic features of each examples are not necessary

e.g. Earthworms, Leeches and regworms.

Earth worm

Leech

- They can be marine, freshwater or in damp soil.
- They are segmented worms with cylindrical bodies
- They are Triploblastic.
- Coelom (true body cavity) is present for the first time.
- The first animals to show cephalization.
- Nervous system well developed; dorsal cerebral ganglion, ventral nerve chord, circumenteric connectives.
- Clitellum, Parapodia, setae and suckers are found in some examples. Clitellum is for external fertilization. Parapodia is used for locomotion and respiration. Seate are present for locomotion and suckers for locomotion and ingestion in ecto parasitic forms.

Phylum Mollusca

Characteristic features of each examples are not necessary

e.g. Oysters, Clams, Slugs, Snails, Octupus, Squids, Chitons and tusks shells

Squid

Octopus

Snail

clam

chiton

tusk shell

Oyster

- Majority are marine. Some inhabit freshwater and land. Some are bilateral symmetrical and few are asymmetrical.
- They are soft bodied and non-segmented. Calcareous shell is secreted as a protective exoskeleton. Coelomic.
- Body is divided into three parts:
  - o muscular foot is used for locomotion
  - o visceral mass contains most of the internal organs
  - o mantale is to secrete the shell
- Shell could be internal or external.
- Many molluscs possess radula (a minutely toothed, chitinous ribbon) in the mouth for feeding.
- Most molluscs have separated sexes and their gonads are located in visceral mass.

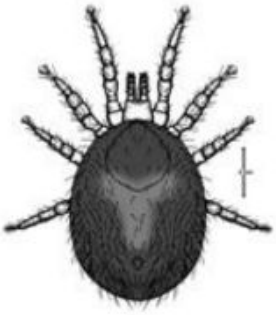
Phylum Arthropoda

Characteristic features of each examples are not necessary

e.g. Insects, Spiders, Prawns, Crabs, Scorpions, Ticks, Mites, Millipedes and Centipedes.

Spider

Scorpion



Mite

Tick

Centepede

Millepede

- One of the most successful animal groups on earth with the highest number of species. They live everywhere – air, water, soil
- They have segmented bodies with "jointed legs"
- They have a chitinous exoskeleton (skeleton on the outside) Because of exoskeleton these animals can't grow continuously and needs periodic molting
- The nervous system is well developed with primitive dorsal brain.
- The nerve cord is solid, segmented and ventrally located.
- They have many and varied sense organs.
- They have an open blood circulatory system; Blood is pumped by a heart into the body cavities (haemocoel), where tissues are surrounded by the blood. No capillaries.
- Respiration
  - In aquatic animals- Gills
  - In terrestrial animals- Tracheal system of chitinous tubes
  - In arachnids - Book lungs
- Excretion is by Malphigian tubules They excrete uric acids
- Reproduction: Sexes separate [Dioecious]

Phylum Echinodermata

Characteristic features of each examples are not necessary

e.g.sea stars, brittle stars, sea lily, feather star, sea cucumber, sea urchins and sand dollars

Sea star

Sea lily

Brittle star

Sand dollar

Sea cucumber

- They are exclusively marine. Triploblastic and coelomic, slow moving or sessile.
- Adults are penta radial symmetrical without head and segmentation.
- Deuterostomes.
- Thin epidermis covers the endoskeleton of hard calcareous plates.
- Water vascular system is a network by hydraulic canals branching into tube feet which function in locomotion and feeding.
- Digestive system is usually complete, but the mouth is on the underside and the anus on the top surface of the animal.
- Circulatory system is reduced and closed without a heart. Sexes are separated with external fertilization. Larval forms are bilaterally symmetrical.
- Well developed nervous system. Intelligent animals.

The characteristic features to study organisms belonging to phylum Chordata

Phylum Chordata

Characteristic features of Phylum Chordata

- Longitudinal, flexible rod called notochord located between digestive tube and nerve cord. It is extending from anterior to posterior providing support in at least embryonic stage.
- Dorsal, hollow, single nerve cord located dorsal to the notochord.
- In all chordate embryos there are slits or clefts in pairs either side of pharynx (pharyngeal sits) that opens to the outside of body. In terrestrial, adult chordates it disappears and remains in the aquatic adults and larval forms of terrestrial chordates as respiratory structures.
- Muscular tail that extends posterior to the anus present in the embryonic stages. In some terrestrial adult it is reduced.

(Characteristic features of each examples of following classes are not necessary)

Characteristic features of class Chondrichthyes

e.g. Skates, Sharks

- All are aquatic
- Skeleton composed predominantly of cartilage
- Fins for locomotion
- Caudal fin is heterocercal.
- Gills without operculum.
- Body is covered with placcoid scales.
- Eggs are fertilized internally. Some are ovoviviparous and others are oviparous or viviparous.
- Reproductive tract, excretory duct and digestive tract empty into the cloaca, a common chamber that has a single opening to the outside.

Characteristic features of Class Osteichthyes

- All are aquatic
- Having a skeleton composed of bones.
- Gills are covered by a bony flap called operculum.
- Swim bladder for control the buoyancy.
- Caudal fin is homocercal.
- Body is covered by flatten bony scales called ctenoid and cycloid scales.
- Most are fertilized externally some have internal fertilization.
- Most species are oviparous.

e.g. Carp, Tuna,

Characteristic features of Amphibia

- First animals to invade land but need water to complete life cycle, live in both water and on land.
- They are found only on land or fresh waters. No marine species.
- First species to poses limbs, body is somewhat elevated by these limbs to help locomotion in terrestrial environment.
- Some are limbless but some are tetrapods.
- Ectothermic- changes body temperature according to environmental temperature. This restricts metabolism.
- Body is covered with thin, moist skin. No scales. Sensitive to environmental changes.
- Nictitating membrane covers the eye and tympanic membrane is found behind the eye.
- Most amphibians show external fertilization. Eggs without shells.

e.g. Toad, Frog, *Ichthyophis*

Characteristic features of Reptilia

- They are the first animal to live a complete terrestrial life.
- Possess limbs for locomotion and digits.
- Body is covered with keratinized scales to prevent from desiccation and abrasion.
- Poses lungs for aerial respiration.
- They are ectothermic (cold blooded)
- Live in terrestrial and aquatic habitats.
- Internal fertilization. They lay shelled eggs (calcareous) on land.

  e.g. Lizards, Snakes, Turtles, Crocodiles and Alligators

Characteristic features of Aves

- Body is covered by keratinized feathers.
- Hind limbs are converted to flight.
- Many adaptations to help flying: light body, wings, bones with air cavities, high metabolism, restrictions in body size
- They are having a beak without teeth.
- They are endothermic.
- Birds have colour vision and excellent eye sight.
- Internal fertilization, lay shelled eggs

  e.g. Crow, Parrot, Humming birds, Eagles etc.

Characteristic features of Mammalia

- Nourish young by producing milk with mammary glands.
- Body covered with hair for insulation.
- They are endothermic group of animals and most of them have high metabolic rate.
- They have differentiated teeth.
- They have an efficient respiratory system with lungs.
- A complete circulatory systems and a four chambered heart.
- Muscular diaphragm is found to help respiration.
- They have a larger brain with compared to the other group of vertebrates. Very intelligent animals. Learning skills and a good memory.
- Different methods of communication.
- Show relatively long periods of parental care.

  e.g. Bat, whales, monkeys, cows