Plant Kingdom

Introduction:

- Our understanding of the plant kingdom has changed over time.
- Fungi, and members of the Monera and Protista having cell walls have now been excluded from Plantae though earlier classifications put them in the same kingdom.
- Hence, the cyanobacteria that are also referred to as blue green algae are not 'algae' any more.
- Algae, Bryophytes, Pteridophytes, Gymnosperms and Angiosperms are the true plants which are autotrophic in nature.

Classification:

Artificial System of Classification :

- Used superficial morphological characters.
- Based on a few characteristics like habit, colors, number and shape of leaf.
- Mainly based on vegetative characters.
- Such system developed by Linnaeus.

Natural System of Classification :

- Based on natural affinities among organisms
- Included external as well as internal features like anatomy, embryology and phytochemistry.
- Developed by George Bentham and J. D. Hooker

Phylogenetic System of Classification :

- Based on evolutionary relationships between the various organisms.
- Organism belongs to same taxa have a common ancestors.
- Developed by Hutchinson.

***Numerical Taxonomy* :**

- Carried out using computers
- Based on all observable characteristics
- Data processed after assigning number and codes to all the characters.

***Cytotaxonomy* :**

- Based on cytological information.
- Gives importance to chromosome number, structure and behaviour.

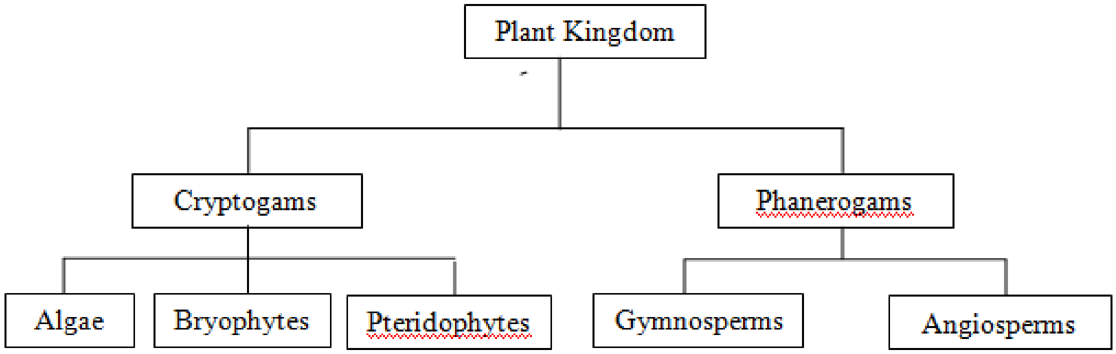
Chemotaxonomy :

- Based on chemical constituents of the plants.

Characteristics of Plant Kingdom:

1. Multicellular eukaryotes
2. Photosynthetic, some insectivorous and parasitic
3. Presence of Plastids – two types – photosynthetic & storage
4. Cell structure – cell wall cellulosic – reserve food is starch/related carbohydrate; mature cells contain large central vacuole.
5. Reproduction – vegetative reproduction quite common; asexual reproduction occurs in algae (spore formation). Sexual reproduction shows progressive evolution. Embryo absent in algae.
6. Alternation of Generations – life cycle has two phases, diploid sporophytic & haploid gametophytic – alternate with one another – phenomenon known as alternation of generation; duration of these phases & their nature as free living/dependent differ among different groups of plants.

Classification of Plant Kingdom:



Algae:

- Chlorophyll bearing, simple, thalloid, autotrophic and mostly aquatic organisms. Moist stone, soils and wood are the other habitat.
- The size ranges from microscopic unicellular forms like *Chlamydomonas*, to colonial forms like *Volvox* and to filamentous forms like *Ulothrix* and *Spirogyra*. A few marine forms such as kelps, form massive plant bodies.
- Reproduce vegetatively by fragmentation.
- Reproduce asexually mostly by producing motile spore called **zoospores.**
- Reproduce sexually by producing gametes.
    - ***Isogamous*****:** both gametes are same size and motile (***Chlamydomonas & Spirogyra***)
    - ***Anisogamous*****:** both gametes are dissimilar in size but motile.
    - ***Oogamous*****:** male gamete is smaller but motile, female gamete is large and non-motile (***Volvox, Fucus***)

Importance of Algae :

- At least half of the total carbon dioxide fixation on earth carried out by them.
- Increase oxygen level in the environment.
- Many species like *Laminaria*, *Sargassum* etc. are used as food.
- **Agar** obtained from *Gelidium* and *Gracilaria* is used in ice-creams and jellies and also used to culture bacteria.
- **Algin** obtained from brown algae and **carrageen** from red algae used commercially.
- *Chlorella* and *Spirullina* are unicellular algae, rich in protein and used as food supplement even by space travellers.

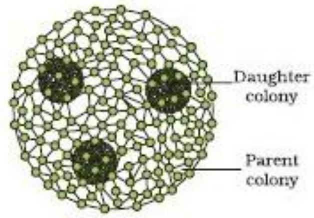
The algae are divided into three main classes: **Chlorophyceae, Phaeophyceae and Rhodophyceae.**

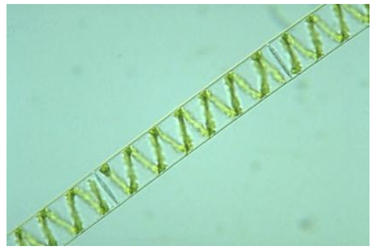
Classes	Common Name	Major Pigments	Stored Food	Cell Wall	Flagellar Number and Position of Insertions	Habitat
Chlorophyceae	Green algae	Chlorophyll *a, b*	Starch	Cellulose	2-8, equal, apical	Fresh water, brackish water, salt water
Phaeophyceae	Brown algae	Chlorophyll *a, c,* fucoxanthin	Mannitol, laminarin	Cellulose and algin	2, unequal, lateral	Fresh water (rare) brackish water, salt water
Rhodophyceae	Red algae	Chlorophyll *a, d,* phycoerythrin	Floridean starch	Cellulose	Absent	Fresh water (some), brackish water, salt water (most)

Chlorophyceae :

- Commonly known as **Green algae**.
- Main pigment is chlorophyll 'a' and 'b'.
- Unicellular, colonial or filamentous.
- Cell wall has inner layer of cellulose and outer layer of pectose.
- Have **pyrenoid** as the storage body for starch and proteins.

e.g., *Chlamydomonas, Volvox, Spirogyra*.



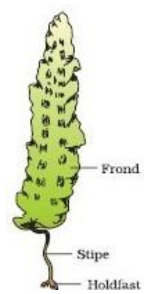


Phaeophyceae :

- Commonly known as **Brown algae** and mainly found in marine habitat.
- They possess chlorophyll a, c, **carotenoid**, **xanthophylls** and **fucoxanthin**.
- Cell wall has cellulose and lignin or gelatinous coating of **algin.**
- Has **mannitol** and **laminarin** as reserve food material.
- Body divisible into **holdfast**, **stipe** and **frond**.
- Reproduce asexually by biflagellate pear-shaped zoospores.

e.g., *Ectocarpus, Fucus, Laminaria*.

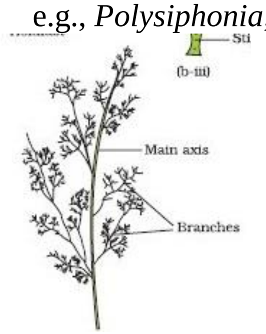


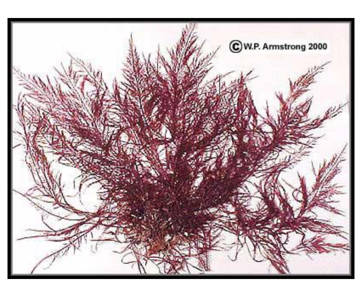


Rhodophyceae :

- Commonly known as **red algae**.
- Red color is due to predominance of red pigment r-phycoerythrin in their body along with chlorophyll a, d.
- Found on surface as well as great depths in oceans.
- Cell wall made of cellulose, pectin and **polysulphate esters**.
- Reserve food material is **floridean starch** similar to amylopectin and glycogen in structure.
- Reproduce asexually by non motile spores and sexually by non motile gametes (**Oogamous** type)

e.g., *Polysiphonia, Porphyra, Gelidium*.





Bryophytes:

Bryophytes are non-vascular cryptograms characterised by independent gametophyte, parasitic sporophytes, jacketed sex organs and an embryo stage. Bryophytes include the various mosses and liverworts that are found commonly growing in moist shaded areas in the hills.

- **Occurrence** – terrestrial plants, generally found in moist, humid & shaded places like damp soils, wet rocks & tree trunks. Require a thin layer of water over the surface of substratum for sexual reproduction & protection from desiccation. Hence known as Amphibians of plant kingdom.
- **Structure** – Plant body gametophyte; either thalloid/foliose/erect. Attachment occurs with the help of unicellular/multicellular rhizoids. Foliose forms, stem-like & leaf like structures occur but are not being non-vascular & gametophytic.
- **Reproduction** – Vegetative reproduction by **fragmentation**.

  Asexual reproduction by **gemmae** formed in **gemma cups**.

  Sexual reproduction :
  - Main plant body is gametophyte.
  - The sex organs in bryophytes are multicellular.
  - Male sex organ is called antheridium which produces biflagellate antherozoids as male gamete.
  - Female sex organ is archegonium is flask shaped and produces a single egg.
  - Fertilization takes place in water results in formation of zygote.
  - The zygote developed into a multicellular body called sporophyte which remains parasitic on female gametophyte.
  - The sporophyte differentiated into foot, seta and capsule.
  - Some cells of the capsule undergo meiotic division to produce haploid spores. These spores germinated into an independent gametophyte.
  - Moss gametophyte consists of two stages
  - First stage is called protonema stage which developed from the spore and is creeping, green, branched.
  - Second stage is leafy stage which developed from the protonema stage as a lateral bud. They consist of upright, slender axes bearing spirally arranged leaves.

Ecological Importance

- Biological Succession – Moss stage is the second seral stage in succession over rocky substratum producing a number of pits over the surface of the rock causing cracks & helping in soil formation.
- Prevention of soil erosion – Mosses form dense mats over the soil reducing the impact of falling rain so that soil erosion is prevented.
- Bogs – excessive growth of *Sphagnum* in shallow waters results in the formation of bogs.

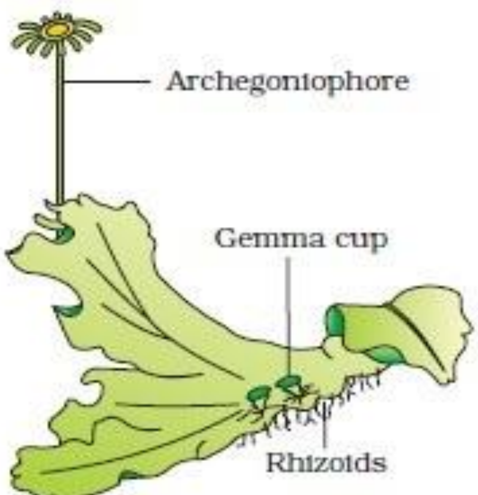
Economic Importance

- Food for herbaceous animals.
- Sphagnum in form of peat is used as fuel and also used for trans-shipment of living material as it has water holding capacity**.**

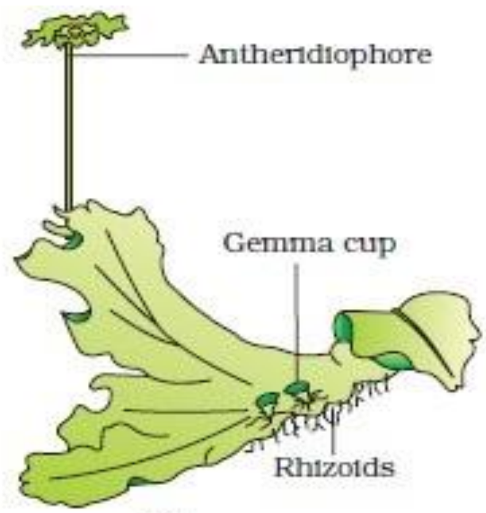
The bryophytes are divided into liverworts (hepaticopsida), mosses (bryopsida) and hornworts (anthoceropsida).

Liverworts

- The liverworts grow usually in moist, shady habitats such as banks of streams, marshy ground, damp soil, bark of trees and deep in the woods.
- The plant body of a liverwort is thalloid, e.g., *Marchantia*.
- The thallus is dorsiventral and closely appressed to the substrate.
- The leafy members have tiny leaf-like appendages in two rows on the stem-like structures.
- Asexual reproduction in liverworts takes place by fragmentation of thalli, or by the formation of specialised structures called gemmae (sing. gemma). Gemmae are green, multicellular, asexual buds, which develop in small receptacles called gemma cups located on the thalli. The gemmae become detached from the parent body and germinate to form new individuals.
- During sexual reproduction, male and female sex organs are produced either on the same or on different thalli.
- The sporophyte is differentiated into a foot, seta and capsule. After meiosis, spores are produced within the capsule. These spores germinate to form free-living gametophytes.



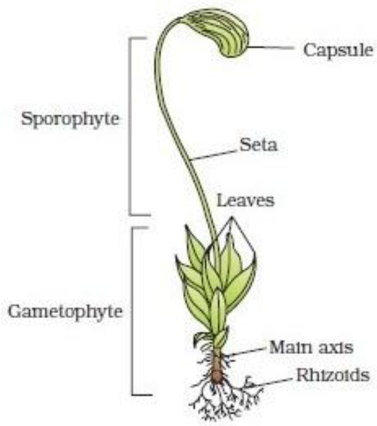
(a)

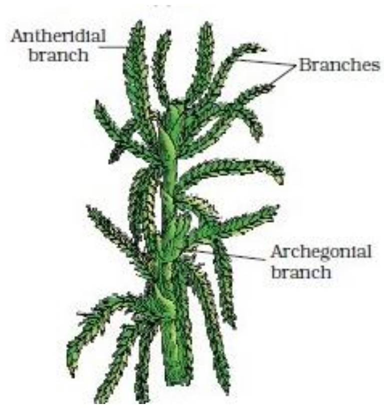


(b)

Mosses

- The predominant stage of the life cycle of a moss is the gametophyte which consists of two stages.
- The first stage is the protonema stage, which develops directly from a spore. It is a creeping, green, branched and frequently filamentous stage.
- The second stage is the leafy stage, which develops from the secondary protonema as a lateral bud. They consist of upright, slender axes bearing spirally arranged leaves. They are attached to the soil through multicellular and branched rhizoids. This stage bears the sex organs.



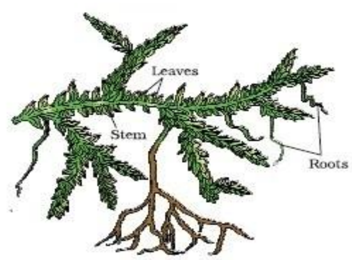


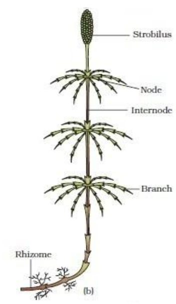
- Vegetative reproduction in mosses is by fragmentation and budding in the secondary protonema.
- In sexual reproduction, the sex organs antheridia and archegonia are produced at the apex of the leafy shoots.
- After fertilisation, the zygote develops into a sporophyte.
- The sporophyte in mosses is more elaborate than that in liverworts. It has an embedded foot, stalk like seta and a capsule.
- The capsule contains spores.
- Spores are formed after meiosis. The mosses have an elaborate mechanism of spore dispersal.
- Common examples of mosses are *Funaria*, *Polytrichum* and *Sphagnum*

Pteridophytes:

Seedless vascular plants characterised by dominant sporophytic phase and an inconspicuous independent gametophytic phase. They are also called vascular cryptogams.

- Pteridophytes include horsetails and ferns.
- Evolutionarily, they are the first terrestrial plants to possess vascular tissues – xylem and phloem.
- Pteridophytes are found in cool, damp, shady places though some may flourish well in sandy-soil conditions.
- First terrestrial plant possesses vascular tissue like **xylem** and **phloem**.
- The plant body differentiated into true root, stem and leaf. The main plant body is **sporophytic**.
- Leaves may be small (**microphyll**) as in Selaginella or large (**macrophyll**) as in ferns.





- Sporangia having spores are subtended by leaf-like appendages called **sporophylls**. (Sporophylls may be arranged to form **strobili** or **cones**.)
- In Sporangia, the spore mother cells give rise to spores after meiosis.
- Spores germinate to form haploid gametophytic structure called **prothallus** which is free living, small, multicellular and photosynthetic.
- Prothallus bears **antheridia** and **archegonia** which bear **antherozoids** and **egg cell** respectively which on fertilization form zygote.
- Zygote developed into multicellular, well differentiated **sporophyte**.
- Most of pteridophytes produce similar kinds of spores hence called **homosporous.**
- Genera like *Selaginella* and *Salvinia* which produce two kind of spores, macro (large) and small (micro) spores are known as **heterosporous**.
- Microspore and macrospore germinate and gives rise to male and female gametophyte respectively.
- The female gametophytes in these plants are retained on the parent sporophyte for variable period.
- The development of zygote into young embryo takes place within the female gametophytes.
- This events is a precursor to the **seed habits** considered an important steps in evolution
- Pteridophytes further classified into four classes: Psilopsida (*Psilotum*), Lycopsida (*Selaginella*), Sphenopsida (*Equisetum*) and Pteropsida (*Pteris*).

Economic Importance:

- Pteridophytes are used for medicinal purposes and as soil-binders.
- Also frequently grown as ornamentals.
- Starchy pith of tree ferns are edible.

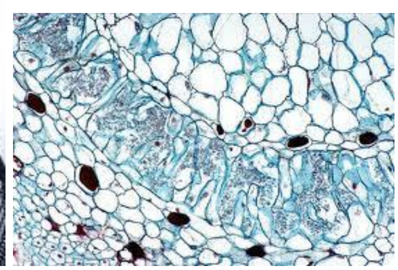
Gymnosperms:

- The gymnosperms (*gymnos* : naked, *sperma* : seeds) are plants in which the ovules are not enclosed by any ovary wall and remain exposed, both before and after fertilisation.
- Gymnosperm includes medium-sized trees or tall trees and shrub. One of the gymnosperms, the giant redwood tree *Sequoia* is one of the tallest tree species.







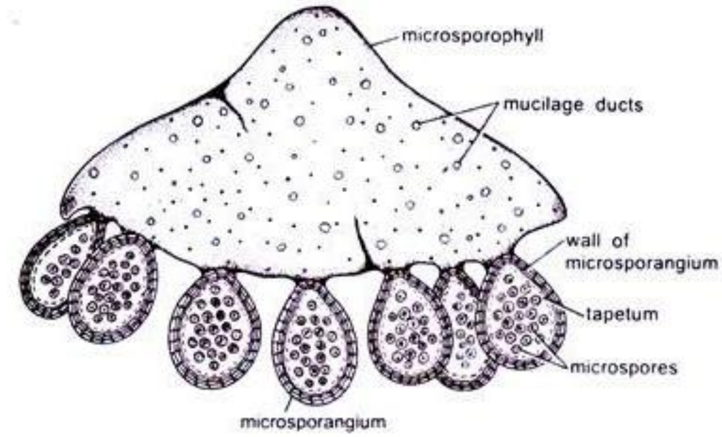


- The roots are generally tap roots. Roots in some genera have fungal association in the form of mycorrhiza (*Pinus*), while in some others (*Cycas*) small specialized roots called coralloid roots are associated with N_2- fixing cyanobacteria.
- The stems are unbranched (*Cycas*) or branched (*Pinus, Cedrus*).
- The leaves may be simple or compound. In *Cycas* the pinnate leaves persist for a few years. The leaves in gymnosperms are well-adapted to withstand extremes of temperature, humidity and wind. In conifers, the needle-like leaves reduce the surface area. Their thick cuticle and sunken stomata also help to reduce water loss.

Reproduction:

- Gymnosperms are heterosporous. They produce haploid microspores and megaspores.
- The two kinds of spores are produced within sporangia that are borne on sporophylls which are arranged spirally along an axis to form lax or compact strobili or cones.
- **Male strobili or cone** has **microsporophylls** which bear **microsporangia** having microspores.

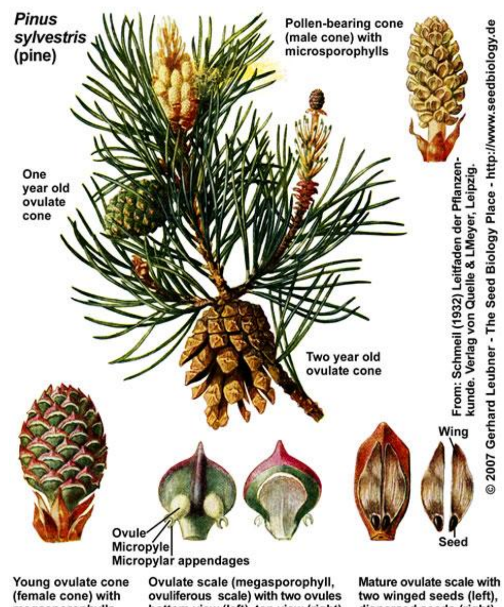
Male cone of Cycas



Microsporophyll with microsporangia of cycas

- The microspores develop into a **male gametophytic** generation which is highly reduced and is confined to only a limited number of cells. This reduced gametophyte is called a **pollen grain**. The development of pollen grains take place within the **microsporangia.**
- **Female cone or strobili** has **megasporophylls** which bear **megasporongia** having **megaspores** which are enclosed within the **megasporangium** (Nucellus).
- The male or female cones or strobili may be borne on the same tree (*Pinus*) or on different trees (*Cycas*).

Female cone of *Cycas*



Reproductive Structure of Pinus

- The megaspore mother cell is differentiated from one of the cells of the nucellus. The nucellus is protected by envelopes and the composite structure is called an **ovule**. The ovules are borne on **megasporophylls** which may be clustered to form the female cones.

The megaspore mother cell divides meiotically to form **four megaspores**. One of the megaspores enclosed within the megasporangium (nucellus) develops into a **multicellular female gametophyte** that bears two or more **archegonia** or female sex organs. The multicellular female gametophyte is also retained within megasporangium.

- Unlike bryophytes and pteridophytes, in gymnosperms the male and the female gametophytes do not have an independent free-living existence. They remain within the sporangia retained on the sporophytes.
- The pollen grain is released from the microsporangium.
- Pollen grains carried in air currents reach ovules, form pollen tube which reach archegonia and release male gametes which fertilize egg cell and form zygote which produce embryos. Ovules develop into seeds which are not covered.

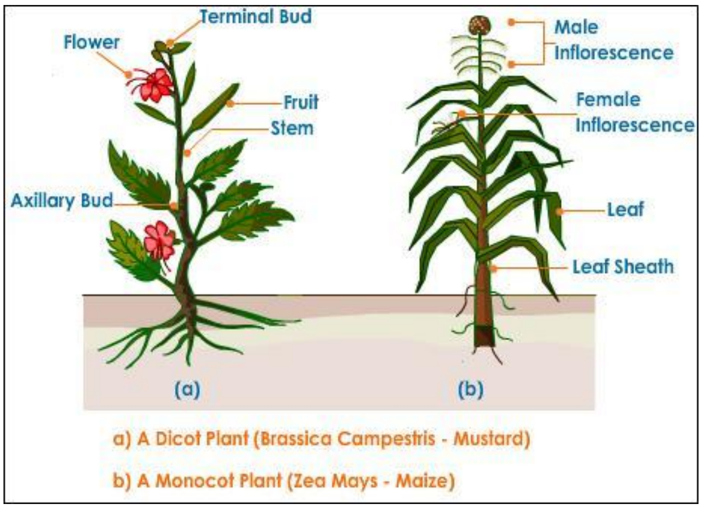
Economic Importance:

- Gymnosperms are source of soft wood, fuel wood and paper pulp.
- Roasted seeds of *Pinus geradiana* and seed kernels of *Gnetum, Cycas* and *Gingko* are edible. Sago grains can be obtained from stems of *Cycas*.
- Resin of *Pinus* yields turpentine & rosin. Other commercial copal and Canada balsam.
- Ephedrine used in treating astma and bronchitis is obtained from stems of *Ephedra*. Drugs from *Taxus* are taxol (anticancer), sedative from seeds) and an antihistamic (from leaves).

Angiosperms:

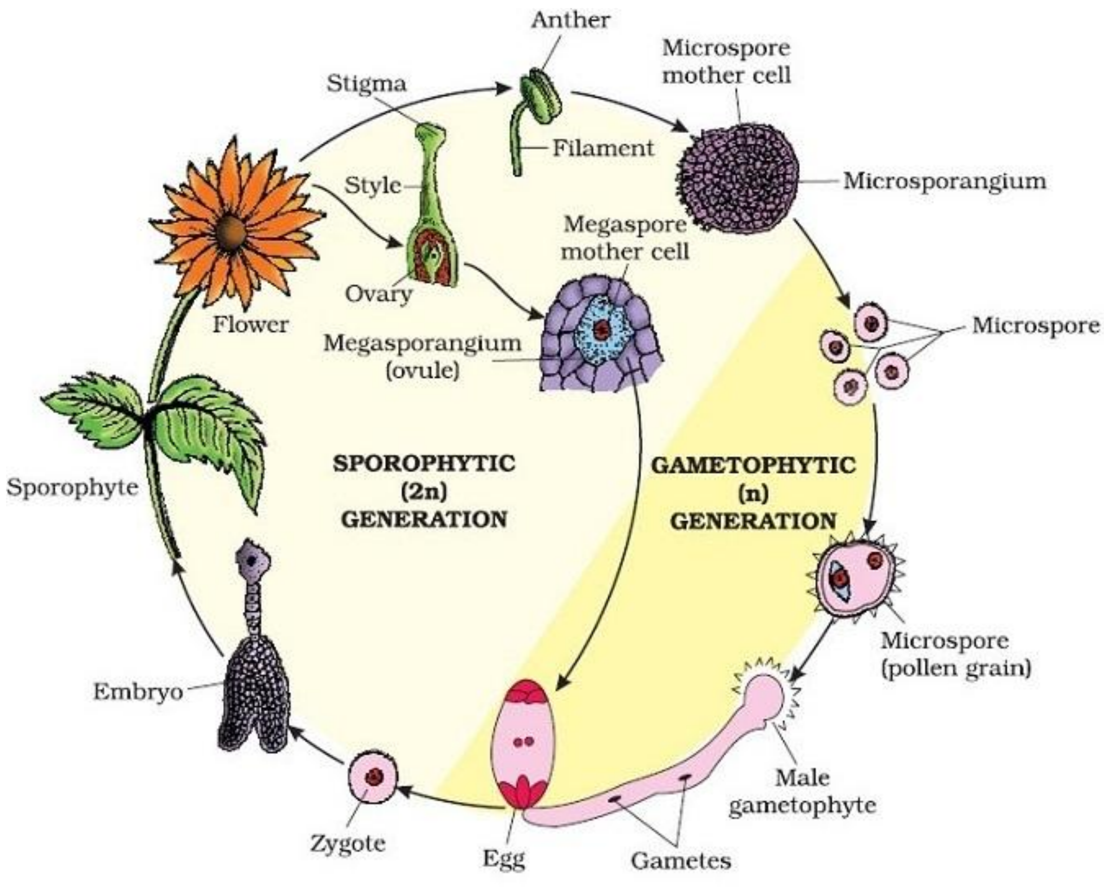
- In the angiosperms or flowering plants, the pollen grains and ovules are developed in specialized structures called **flowers**.
- In angiosperms, the seeds are enclosed by fruits.
- The angiosperms are an exceptionally large group of plants occurring in wide range of habitats.
- They range in size from tiny, almost microscopic *Wolfia* to tall trees of *Eucalyptus* (over 100 metres).

- They provide us with food, fodder, fuel, medicines and several other commercially important products.
- They are divided into two classes : the **dicotyledons** and the **monocotyledons**



- The dicotyledons are characterised by having two cotyledons in their seeds while the monocolyledons have only one.
- The male sex organs in a flower is the stamen. Each stamen consists of a slender filament with an anther at the tip. The anthers, following meiosis, produce pollen grains.
- The female sex organs in a flower is the **pistil** or the **carpel**. Pistil consists of an ovary enclosing one to many **ovules**. Within ovules are present highly reduced female gametophytes termed **embryosacs**. The embryo-sac formation is preceded by meiosis. Hence, each of the cells of an embryo-sac is haploid. Each embryo-sac has a three-celled **egg apparatus** – one **egg cell** and two **synergids**, three antipodal cells and two polar nuclei. The polar nuclei eventually fuse to produce a diploid secondary nucleus.
- Pollen grain, after dispersal from the anthers, are carried by wind or various other agencies to the stigma of a pistil. This is termed as pollination.

- The pollen grains germinate on the stigma and the resulting pollen tubes grow through the tissues of stigma and style and reach the ovule. The pollen tubes enter the embryo-sac where two male gametes are discharged.
- One of the male gametes fuses with the egg cell to form a zygote (**syngamy**).
- The other male gamete fuses with the diploid secondary nucleus to produce the triploid **primary endosperm nucleus (PEN).**
- Because of the involvement of two fusions, this event is termed as **double fertilisation**, an event unique to angiosperms.
- The zygote develops into an **embryo** (with one or two cotyledons) and the PEN develops into endosperm which provides nourishment to the developing embryo. The synergids and antipodals degenerate after fertilisation. During these events the ovules develop into seeds and the ovaries develop into fruit.



Plant Life Cycles & Alternation of Generations:

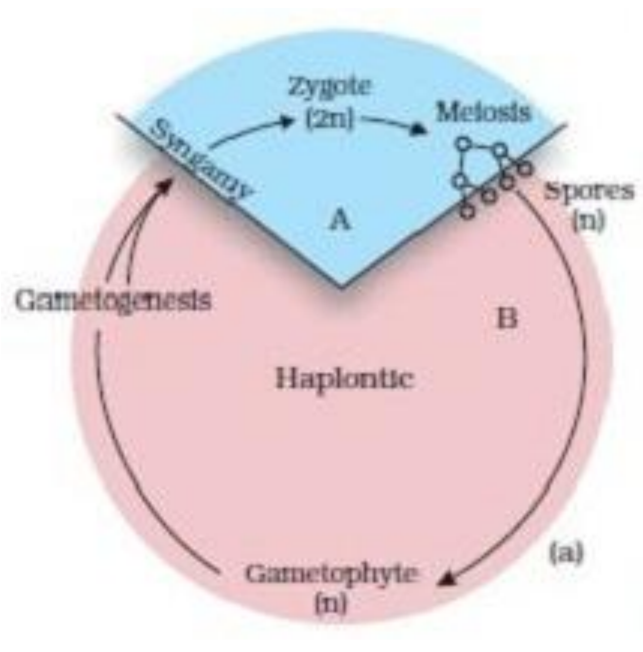
Alternation of Generations:

- In plants, both haploid and diploid cells can divide by mitosis.
- This ability leads to the formation of different plant bodies - haploid and diploid.
- The haploid plant body produces gametes by mitosis. This plant body represents a gametophyte.
- Following fertilisation the zygote also divides by mitosis to produce a diploid sporophytic plant body.
- Haploid spores are produced by this plant body by meiosis.
- These in turn, divide by mitosis to form a haploid plant body once again.
- Thus, during the life cycle of any sexually reproducing plant, there is an alternation of generations between gamete producing haploid gametophyte and spore producing diploid sporophyte.

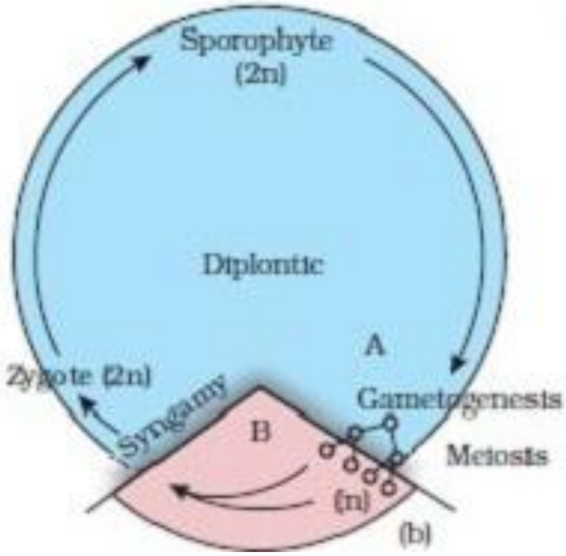
Plant Life Cycle:

Life cycle is a series of changes that occur in the life of an organism including reproduction. Depending upon the dominant phase, life cycle is of three types viz. haplontic, diplontic and haplodiplontic.

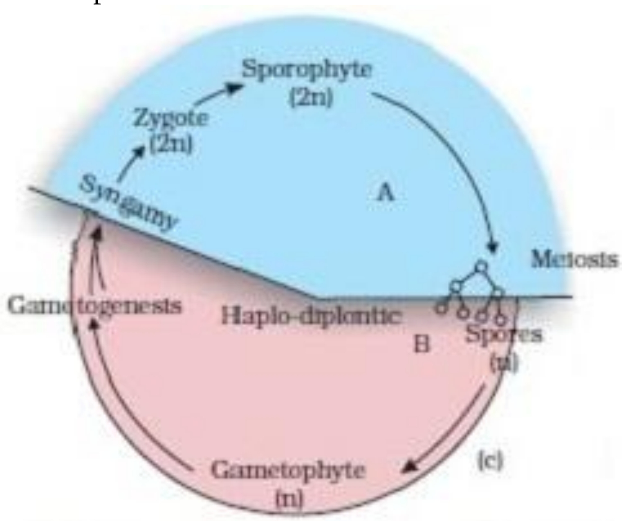
1. **Haplontic:** Sporophytic generation is represented only by the one-celled zygote. There are no free-living sporophytes. Meiosis in the zygote results in the formation of haploid spores. The haploid spores divide mitotically and form the gametophyte. The dominant, photosynthetic phase in such plants is the free-living gametophyte. This kind of life cycle is termed as haplontic. Many algae such as *Volvox*, *Spirogyra* and some species of *Chlamydomomas* represent this pattern (Figure).



2. **Diplontic:** On the other extreme, is the type wherein the diploid sporophyte is the dominant, photosynthetic, independent phase of the plant. The gametophytic phase is represented by the single to few-celled haploid gametophyte. This kind of lifecycle is termed as diplontic. All seed-bearing plants i.e. gymnosperms and angiosperms, follow this pattern (Figure).



3. **Haplodiplontic:** Bryophytes and pteridophytes, interestingly, exhibit an intermediate condition (Haplo-diplontic); both phases are multicellular and often free-living. However, they differ in their dominant phases.



A dominant, independent, photosynthetic, thalloid or erect phase is represented by a haploid gametophyte and it alternates with the shortlived multicelluler sporophyte totally or partially dependent on the gametophyte for its anchorage and nutrition. All bryophytes represent this pattern.

The diploid sporophyte is represented by a dominant, independent, photosynthetic, vascular plant body. It alternates with multicellular, saprophytic/autotrophic, independent but short-lived haploid gametophyte. Such a pattern is known as haplo-diplontic life cycle. All pteridophytes exhibit this pattern (Figure). Interestingly, while most algal genera are haplontic, some of them such as *Ectocarpus*, *Polysiphonia*, kelps are haplo-diplontic. *Fucus*, an alga is diplontic.