PLANT KINGDOM

INTRODUCTION

- Plant kingdom includes eukaryotic, autotrophic or photosynthetic and non-motile organisms.
- Plant kingdom includes five major plant groups i.e. Algae, Bryophyte, Pteridophyte, Gymnosperms and Angiosperms as proposed by R.H. Whittaker in 1969.
- Main characters of plant kingdom are–
  - presence of cellulosic cell wall.
  - non-motile, except some aquatic forms.
  - reproduction is primarily sexual.
  - photosynthetic mode of nutrition, e.g., different types of algae (green, brown, red algae), bryophytes, gymnosperms and angiosperms.

TYPES OF CLASSIFICATION

- There are various types of classification in angiospermic plants.
- All taxonomists, from Aristotle to Linnaeus, proposed artificial system of classification.
- **Artificial system of classification** is based on few morphological characters. It is primitive or oldest system of classification.
- **Natural system of classification** was based on all the possible characters and therefore, this system is practically more useful.
- **Phylogenetic system of classification** was proposed by "Sokel and Sneath". Plants are classified on the basis of numbers of similarities and dissimilarities. In this, importance to any one character is not given, all characters have the same importance. While, in natural classification, floral (reproductive) characters have more importance than vegetative (root, stem and leaves) characters.
- In **Traditional system of classification** (Eichler, 1883), plant kingdom is divided into two subkingdoms-cryptogams and phanerogamae (Refer flow chart 3.1)

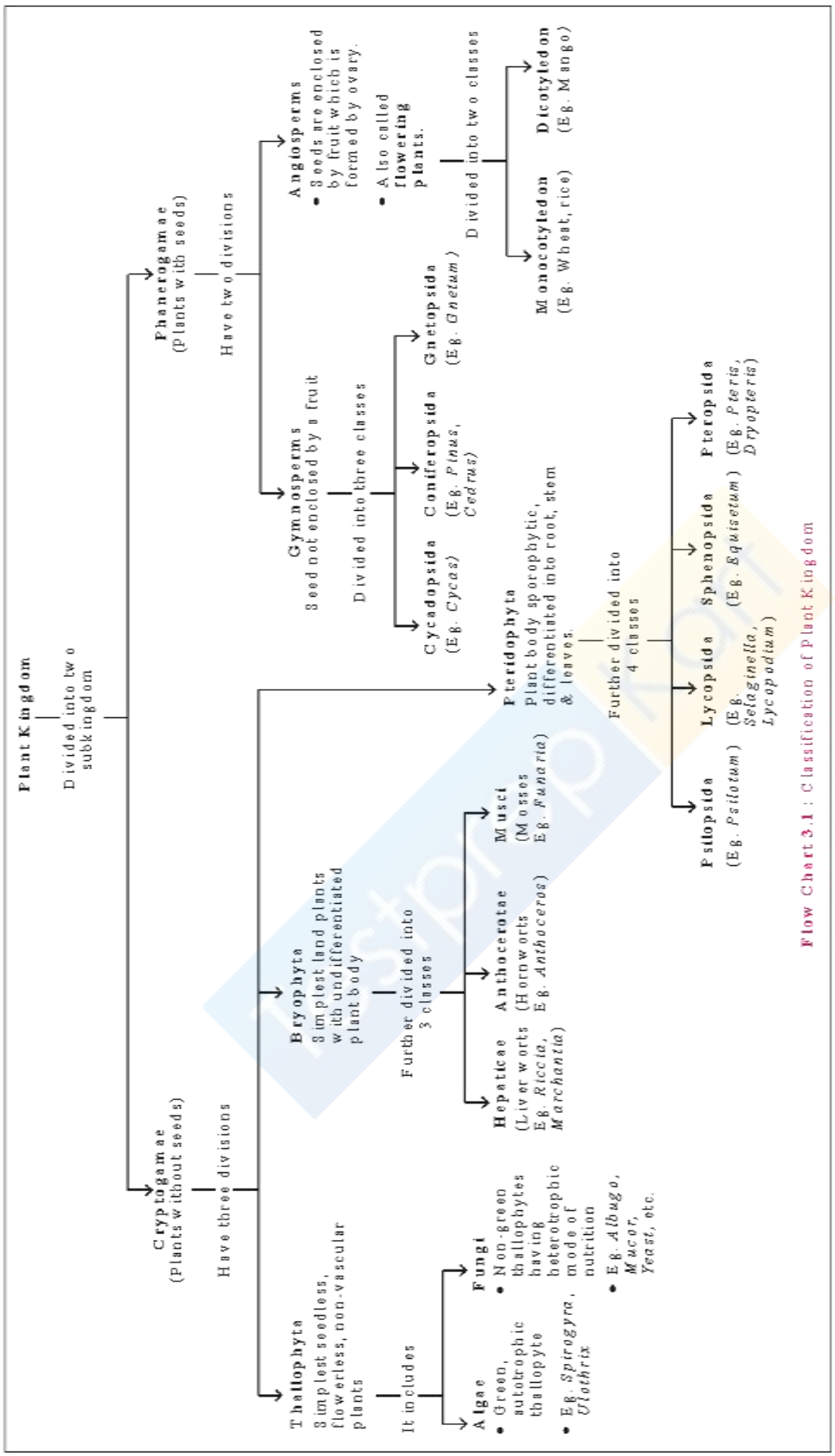
ALGAE

- The branch of botany dealing with the study of algae is called **phycology** or **algology**.
- Structure and reproduction of algae was written by Fritsch. He is known as the father of algae.
- Algae are defined as chlorophyllous and thalloid avascular plants with no cellular differentiation.
- Algae are plants because they have chlorophyll a, cellulosic cell wall and starch as reserve food.
- Large marine algae are generally known as seaweeds or kelps.
- Algae are mostly found in fresh water as well as in salt water.
- They occur in a variety of other habitats also like moist stones, soils and wood.
- The body or thallus of multicellular algae ranges from microscopic unicellular (Chlamydomonas), colonial (Volvox), aggregates of cells, fine filaments (Ulothrix), to flattened sheets of cells.
- All kinds of reproduction are found in algae like vegetative, asexual and sexual.
- **Vegetative reproduction** occurs through fragmentation. Each fragment develops into a thallus.

- **Asexual reproduction** occurs through the production of different types of spores like zoospores, hypnospores, akinetes, endospores, cysts, etc. The most common being the zoospores. They are flagellated (motile) and on germination gives rise to new plants.
- **Sexual reproduction** takes place through fusion of two gametes.
- Sexual reproduction is of two types on the basis of the size of gametes–Isogamous and heterogamous (anisogamous and oogamous).
- **Isogamy** occurs commonly in unicellular algae, where male and female gametes are morphologically similar but differ in physiology. E.g., Ulothrix.
- **Anisogamy** is the fusion of gametes where male gametes are comparatively smaller in size and more active than female gametes which are larger and sluggish. E.g. Chlamydomonas.
- **Oogamy** is the most advanced type of sexual reproduction where fusion of one large, non-motile (static) female gamete with a smaller motile male gamete takes place. E.g. Volvox, Fucus.
- Water a suitable medium for the fusion of gametes during sexual reproduction.

Table : Common names of Algae

	Scientific name of algae	Common Name
1.	*Spirogyra*	Pond silk or pond scum
2.	*Chara*	Stonewort
3.	*Ulva*	Sea lettuce
4.	*Sargassum*	Gulf weed or Sargasso weed
5.	*Macrocystis*	Giant Kelp
6.	*Thallassiophyllum*	Sea fern
7.	*Cosmarium & Closterium*	Desmids
8.	*Batrachospermum*	Frog spawn algae
9.	*Acetabularia*	Umbrella plant
10.	*Nostoc*	Hair vegetable
11.	*Fucus*	Rock weed
12.	*Chlorella*	Space algae
13.	*Hydrodictyon*	Web of water (beautiful algae)
14.	*Nereocystic*	Sea palm
15.	*Laminaria*	Sea apron or sea kelp
16.	*Pyrrophyta*	Fire algae
17.	*Volvox*	Rolling algae



- Plants growing on snow or ice are called as **cryophytes**. Different algal forms produce a specific colour effect while growing as cryophyte. E.g., yellow-green by Chlamydomonas yellowstonensis, red by C. nivalis, black by Scotiella nivalis and purple-brown by Ancylonema nordenskioldii.
- Plants growing in hot water are called as **thermophytes**. Some blue-green algae grow in hot water springs at about 70°C. E.g., Oscillatoria brevis.

- Several algal forms grow on other plants (algae, angiosperms) as **epiphytes**. E.g., Oedogonium, Cladophora, Vaucheria, etc.
- Some blue-green algae grows as **endophytes** inside other plants. E.g., Anabaena growing inside the leaf of Azolla (fern), Nostoc inside the thallus of Anthoceros (hornwort) and Anabaena, Nostoc, Oscillatoria inside the coralloid roots of Cycas.
- Algae growing on the bodies of animals are described as **epizoic**. E.g., Cladophora crispata grows on snail shell, Characium grows on the antennae of mosquito larvae, Cyanoderma (red alga) and Trichophilus (green alga) grows on scales of sloth.
- Algae growing inside the body of animals are called **endozoic**. E.g., Chlorella grow within the tissue of Hydra. Some blue-green algae also grow in the respiratory tracts of animals. The blue-green algae which grow endozoically inside the protozoans are called as **cyanellae**.
- Some algae like Chlorella, Nostoc, etc. growing in symbiotic relationship with members of Ascomycetes and Basidiomycetes (Fungi) constitute the **lichen**.
- The alga Cephaleuros virescens grows as a parasite on the tea leaves. In addition, Rhodochytrium, Phyllosiphon are other parasitic algal forms.
- Several members of algae are unicelled. They may be motile (Chlamydomonas) or non-motile (diatoms). Some forms have a thick wall and become sedentary for certain duration in their life history. They are called as **coccoid**. E.g., Chlorella, Chlorococcus etc.
- Most of the algal groups (except blue-green and dinoflagellates) shows eukaryotic cell structure. The cell wall is made up of **cellulose**. Some red algae (Corallina) have impregnation of $CaCO_3$.
- The red alga Cephaleuros virescens causes **red rust** of tea thus destroying the tea leaves. Similar diseases are caused by the species of Cephaleuros to coffee plant, Piper and Citrus sp.
- Algae grow abundantly in water reservoirs where excess of nutrients are available to them. This algal growth floats on the water surface and look like foam or soap lather. It is called **water bloom**. E.g., Microcystis, Anabaena, Oscillatoria, etc.
- Algae are useful to man in a variety of ways, like-
  - Chlorella and Spirulina are used as food and fodder. Chlorella is rich in protein and carbohydrates. Spirulina platensis is one of the richest sources of protein.
  - Certain marine brown algae and red algae produce large amounts of hydrocolloids (water holding substances). E.g.- **Alginic acid** are extracted from the members of phaeophyceae such as Laminaria, Macrocystis and **Carrageenan** is extracted from red algae Chondrus crispus. (Irish moss).
  - **Agar**, dried gel like non-nitrogenous extract from red algae, is used as a medium in the cultures of bacteria, fungi and algae. It is largely prepared from Gelidium.
  - Laminaria digitata and Fucus sp. are largely known for the extraction of iodine, hence used to treat goitre.

CLASSIFICATION OF ALGAE

Fritsch divided algae into 11 classes on the basis of type of pigments, nature of reserve food material and mode of reproduction. The three major classes are - **Chlorophyceae**, **Phaeophyceae** and **Rhodophyceae**.

Table : Divisions of algae and their main characteristics

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

CHLOROPHYCEAE

- Chlorophyceae are commonly called as green algae.
- Most green algae live in fresh waters and few are marine. Some are terrestrial and some can grow anywhere on moist surface.
- The plant body may be unicellular, colonial or filamentous.
- They are usually green in colour due to the dominance of pigments chlorophyll a, b and xanthophyll, which are localized in definite chloroplasts.
- Chloroplast generally contain one or more storage bodies called pyrenoids. Pyrenoids contain proteins besides starch. Some algae may store food in the form of oil droplets also.
- Green algae usually have a rigid cell wall made of an inner layer of cellulose and an outer layer of pectose. They store starch. For these reasons, they are believed to be ancestors of land plants.
- Vegetative reproduction usually takes place by fragmentation or by formation of different types of spores.
- Asexual reproduction is by flagellated zoospores produced in zoosporangia.
- The sexual reproduction shows considerable variation in the type and formation of sex cells and it may be isogamous, anisogamous or oogamous.
- Green algae exhibit three types of life cycles-haplontic, diplontic and diplohaplontic. Examples are : Chlamydomonas, Volvox, Ulothrix, Spirogyra and Chara.

SPIROGYRA

- It is an unbranched filamentous green alga of stagnant fresh waters which forms floating masses (supported by bubbles of oxygen) called pond scum. A sheath of mucilage occurs on the outside. It gives a silky touch. Hence, Spirogyra is also called water silk or mermaid's tresses.
- The thallus is an unbranched and uniseriate filament where cells are arranged in a single row. In some species, hold fast is present (e.g., S. fluviatilis).
- The cells are elongated and cylindrical.
- The cell wall is two layered–the outer is of pectic substance and the inner of cellulose. The outer part (pectin) dissolves in water to form a mucilaginous sheath. Due to this reason, Spirogyra filaments are slippery.
- Ribbon (spiral) shaped chloroplasts (wavy margin) with pyrenoids and a large central vacuole.
- Nucleus occurs inside the central vacuole where it is suspended by means of cytoplasmic strands.

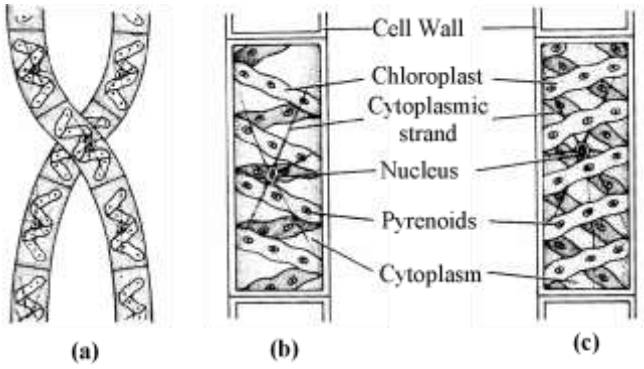


Fig : *Spirogyra* (a) Two Filaments
(b) and (c) Detailed structure of a cell

- Normally, asexual reproduction is absent in Spirogyra. It occurs only occasionally by the formation of akinetes, aplanospores and azygospores (parthenospores).
- Sexual reproduction takes place towards the end of growing season usually in the late spring. Sexual reproduction in Spirogyra is called conjugation. It involves the fusion of two morphologically identical, but physiologically dissimilar gametes.

ULOTHRIX

- It is a green unbranched filamentous algae found in slow running streams. The common species U.zonata occurs in cold water whereas U.flacca is marine. U.implexa occurs in estuaries (where river meets the sea) as lithophytes.
- Due to presence of protopectin, Ulothrix filaments appear as wet threads.
- The Ulothrix reproduces vegetatively, asexually as well as sexually.
- Asexual reproduction occurs through fragmentation, zoospores, palmella stage, aplanospores, hypnospores and akinetes.
- Sexual reproduction occurs through isogamy.
- Life cycle is haplontic.

PHAEOPHYCEAE

- The phaeophyceae are commonly called as brown algae.
- They are found primarily in marine habitats.
- They range from simple branched, filamentous forms (Ectocarpus) to profusely branched forms as represented by kelps, which may reach a height of 100 metres.

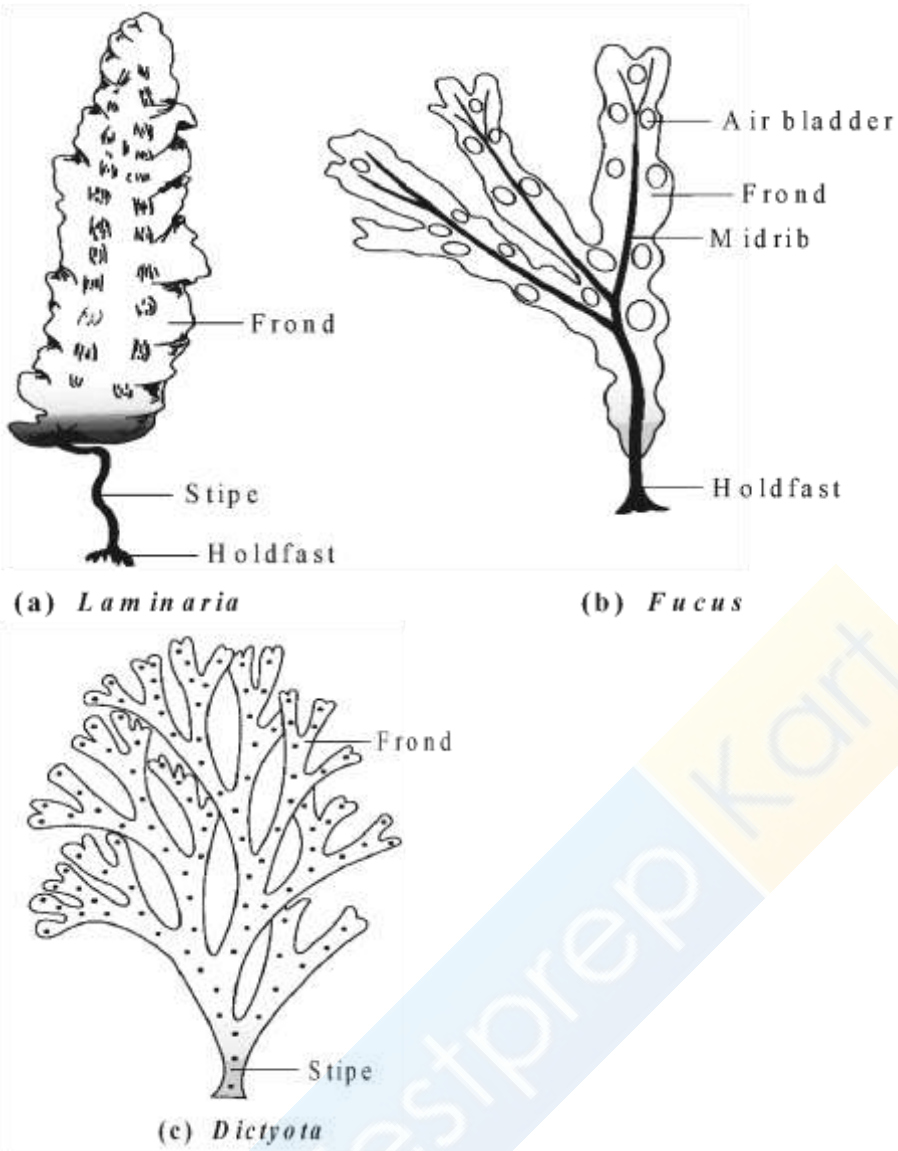


Fig. : Brown algae

- They possess chlorophyll a, c, carotenoids and xanthophylls (such as fucoxanthin for brown colour and diatoxanthin).
- Food is stored as complex carbohydrates, in the form of laminarin or mannitol.
- The vegetative cells have a cellulosic wall usually covered on the outside by a gelatinous coating of alginic acid. The protoplast contains, in addition to plastids, a centrally located vacuole and nucleus.
- The plant body is usually attached to the substratum by a holdfast, and has a stalk, the stipe and leaf like photosynthetic organ-frond.
- **Vegetative reproduction** takes place by fragmentation.
- **Asexual reproduction** in most brown algae is by biflagellate zoospores that are pear-shaped and have two unequal laterally attached flagella.
- **Sexual reproduction** may be isogamous, anisogamous or oogamous. Union of gametes may take place in water or within the oogonium (oogamous species). The gametes are pyriform (pear-shaped) and bear two laterally attached flagella.
- Life cycle is **diplohaplontic** or **diplontic**.
- The common forms are Ectocarpus, Dictyota, Laminaria, Sargassum and Fucus.

RHODOPHYCEAE

- Rhodophyta are commonly called **red algae** because of the predominance of the red pigment, **r-phycoerythrin** in their body. Majority of the red algae are marine with greater concentrations found in the warmer areas.

They occur in both well-lighted regions close to the surface of water and also at great depths in oceans where relatively little light penetrates.

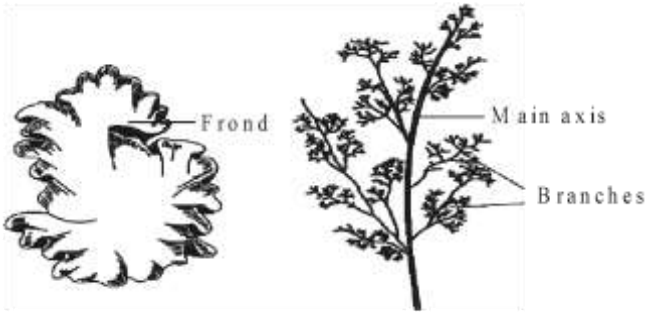


Fig. : Red algae

- The red thalli of most of the red algae are multicellular. Some of them have complex body organisation.
- The food is stored as **floridean starch** which is very similar to amylopectin and glycogen in structure.
- The red algae usually reproduce vegetatively by fragmentation.
- They reproduce asexually by non-motile spores and sexually by non-motile gametes.
- Sexual reproduction is **oogamous** and accompanied by complex post fertilization developments.
- The common members are: Polysiphonia, Porphyra Gracilaria, Gelidium and Batrachospermum.
- **Batrachospermum** is the only freshwater algae found growing in well aerated water but it is not red.

BRYOPHYTES

- The division bryophytes includes the simplest & primitive land plants. It occupies a position in between algae and pteridophyte.
- Bryophytes are **first amongst land plants** which occur in damp and shady habitats.
- It includes mosses and liverworts.
- Bryophytes are also called **amphibians of the plant kingdom** because these plants can live in soil but are dependent on water for sexual reproduction. They usually occur in damp, humid and shaded localities. They play an important role in plant succession on bare rocks/soil.
- Dominant plant phase in bryophytes is free living thalloid gametophytes. The gametophyte is thalloid in primitive forms (Riccia) and differentiated into rhizoids, stem and leaves in higher bryophytes (mosses). Gametophyte lack **vascular tissues** (xylem and phloem).
- **Rhizoids** are **organs of absorption and fixation**.
- The sex organs in bryophytes are multicellular. The male sex organ (called **antheridium**) produces biflagellate motile antherozoids. The female sex organ (called **archegonium**) is flask-shaped with tubular neck and swollen venter and produces a single egg. Archegonium appears first time in bryophytes in plant kingdom. The antherozoids are released into water where they come in contact with archegonium. An antherozoid fuses with the egg to produce the zygote. Zygotes do not undergo reduction division immediately. They produce a multicellular body called a **sporophyte**.
- The sporophyte is not free-living but attached to the photosynthetic gametophyte and derives nourishment from it. Some cells of the sporophyte undergo reduction division (meiosis) to produce haploid spores in sporogonium.

- The sporogonium is short lived & differentiated into either foot, seta and capsule. The foot is an anchorage and absorptive organ and remain embedded in gametophyte. The seta is cylindrical to conduct food from gametophyte to capsule. The spores, produced by **sporogonium** are all alike (homosporous). Then these spores germinate to produce gametophyte.
- Asexual reproduction is absent.
- The life cycle of bryophytes consists of two distinct phases– the **gametophytic phase** and the **sporophytic phase**.

The haploid gametophyte is dominant, long lived, green and independent whereas the diploid sporophyte is short lived and dependent upon the gametophyte. The two phases are morphologically distinct.

- The bryophytes are fundamentally terrestrial plants but require the presence of water to complete their life cycle. The water is required for dehiscence of antheridia, liberation of antherozoids, transfer of antherozoids from antheridia to archegonia, opening of archegonial neck, and the movement of antherozoids into the archegonial neck.
- Bryophytes in general are of little economic importance but some mosses provide food for herbaceous mammals, birds and other animals. Species of Sphagnum, a moss, provide peat that have long been used as fuel, and because of their capacity to hold water as packing material for trans-shipment of living material. Mosses along with lichens are the first organisms to colonise rocks and hence, are of great ecological importance. They decompose rocks making the substrate suitable for the growth of higher plants. Since mosses form dense mats on the soil, they reduce the impact of falling rain and prevent soil erosion.

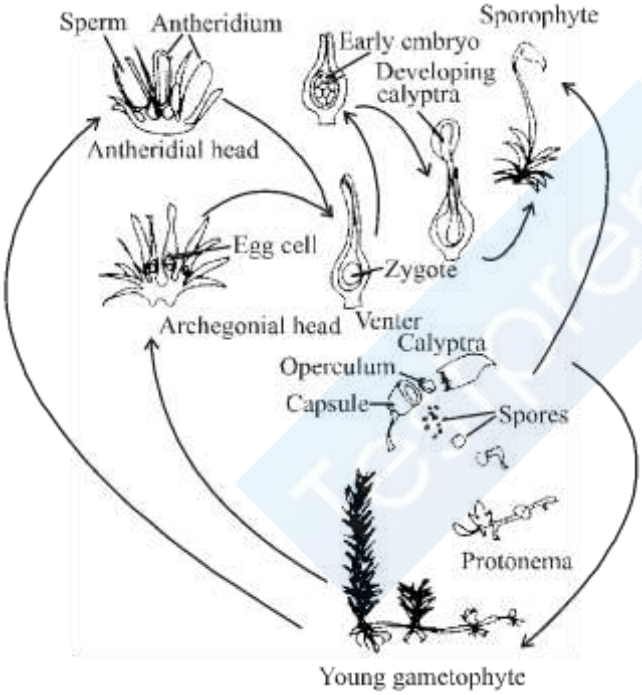


Fig. : Life cycle of Bryophyte

CLASSIFICATION OF BRYOPHYTES

• Campbell (1940), Smith (1955), Takhtajan (1953) divided bryophyta into **three classes** namely **Hepaticae** (Eg. Riccia and Marchantia), **Anthocerotae**, (Eg. Anthoceros) and **Musci** (E.g. Funaria, Sphagnum, Polytrichum etc.). Proskauer (1957) changed the names of these classes in accordance with the recommendations of the code, into **Hepaticopsida**, **Anthocerotopsida** and **Bryopsida**. The latin word Hepatica means liver.

HEPATICOPSIDA

- The plants of this class are **commonly called liverworts** because the gametophytic plant body has liver like appearance.

- Liverworts usually grow in moist, shady habitats such as bank of streams, marshy ground, damp soil and bank of trees.
- 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.
- **Elaters** are generally present (E.g. Marchantia) but absent in some plants also, E.g. Riccia. Elaters are hygroscopic and help in dispersal of spores.
- Examples of liverworts are - Riccia, Marchantia, Pellia, Porella, etc.

RICCIA

- The main plant body of Riccia is gametophytic (n). It is small, green, flat and fleshy. The thallus is dorsiventral and dichotomously branched. The thalli are present in the form of patches called **rosettes**. Scales are found on the margins, while rhizoids are present in the mid-rib region of thallus.
- Rhizoids are unicellular and unbranched and are of two types – smooth and tuberculate. Rhizoids help in fixation. In submerged species, (e.g., R. fluitans) scales and rhizoids are not present.
- Riccia **reproduces by both vegetative and sexual method**.
- Riccia reproduces vegetatively by progressive death and decay, persistent apices (R. discolor), adventitious branches (R. fluitans), tubers (R. billardieri, R. discolor, R. perennis) and by rhizoid (R. glauca).
- **Sexual reproduction is of oogamous type** in Riccia. Antheridia and archegonia are the male and female sex organs respectively.
- Most of the species are monoecious or homothallic, i.e., male and female sex organs are present on the same thallus. A few species are dioecious or heterothallic, i.e., antheridia and archegonia are present on different thalli. Common dioecious species of Riccia are R.himalayensis and R. frostii.
- There are **2 generations in the life cycle** of Riccia. The main plant body is **gametophytic (n)**. The gametophytic phase starts with formation of spores and ends with fertilization. The second phase is **sporophytic phase (2n)**, which starts with zygote and ends with reduction division of spore mother cell. The sporophytic phase is dependent upon gametophyte. Thus, there is heteromorphic or heterologous alternation of generations in Riccia. So life cycle in Riccia is diplohaplontic.

ANTHOCEROPSIDA

- Anthoceropsida is **commonly known as hornworts** because of typical horn like appearance of their sporophyte or sporogonium.
- The gametophyte are thalloid, distinctly dorsiventral.
- Thallus internally shows homogenous tissues, mucilage cavities inhabited by some algae.
- Thalloid gametophyte do not possess air chambers & scales.
- Rhizoids are present.
- Each cell of thallus has a single large chloroplasm with a pyrenoid.
- Sex organs are present on dorsal surface of thallus.
- **Sporophyte** is horn like. It is long, differentiated into capsule and meristematic zone. Sporogenous tissue develops from the amphithecium and endothecium, which forms sterile central columella.

- The sporophyte is partially dependent on the gametophyte. Eg. Anthoceros.
- Important examples of anthoceropsida are Anthoceros, Megaceros, Dendroceros, etc.
- The gametophyte of Anthoceros are thallose dorsiventrally flattened and variously lobed.
- The thallose of Anthoceros is internally not well differentiated. It has **endophytic** Nostoc colonies.
- 1-3 celled sterile pseudoelaters are found in Anthoceros.
- Apospory is observed in some species of Anthoceros.

MUSCI OR BRYOPSIDA

- Bryopsida are commonly called as mosses.
- The gametophyte is differentiated into prostrate protonema and an erect gametophore (leafy stage).
- They bear multicellular branched rhizoids.
- The protonema stage, develops directly from a spore. It is a creeping, green, branched and frequently filamentous stage. The leafy stage develops from the secondary protonema as a lateral bud. They consist of upright, slender axis 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 fertilization, the zygote develops into a sporophyte, consisting of a foot, seta and capsule.
- The sporophyte in mosses is more elaborate than that in liverworts. 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.

FUNARIA

- Funaria is known as **common moss or green moss or cord moss**.
- The main plant body of Funaria is gametophyte and is of two forms.
  - Juvenile form (creeping protonema).
  - Adult form (leafy gametophore).
- Protonema is the branched filamentous portion which is produced by germination of spores. It is ephemeral or short lived.
- Leafy gametophore develop from buds produced on protonema and is made up of axis with spirally arranged leaves. It is 1 –3 cm in height, green and is monopodially branched. The main branch of leafy gametophore bears male reproductive organs, i.e., antheridia and the side branch is female branch.

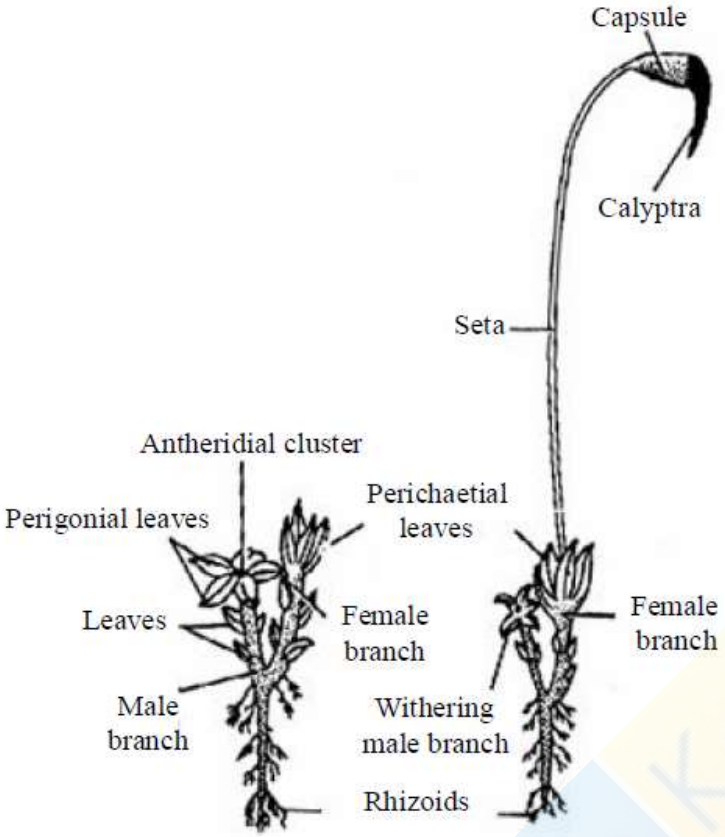


Fig. : Funaria plant showing male and female branches

- Funaria reproduces both by vegetative and sexual methods.
- **Vegetative reproduction** takes place by fragmentation, primary protonema, secondary protonema, bulbils, gemma and apospory.
- The Funaria plants are monoecious and autoecious, i.e., male (antheridia, club shaped) and female (archegonia, flask shaped) reproductive organs are produced on the same plant but on different branches. Male organs mature first and hence Funaria plants are **protandrous**.
- There are **two generations in the life cycle** of Funaria, i.e., **gametophytic generation (n)** which is independent and complex and **sporophytic generation (2n)** which is partially dependent upon gametophytic generation. These two generations follow each other in regular sequence. This is called **heteromorphic or heterologous alternation of generations**.

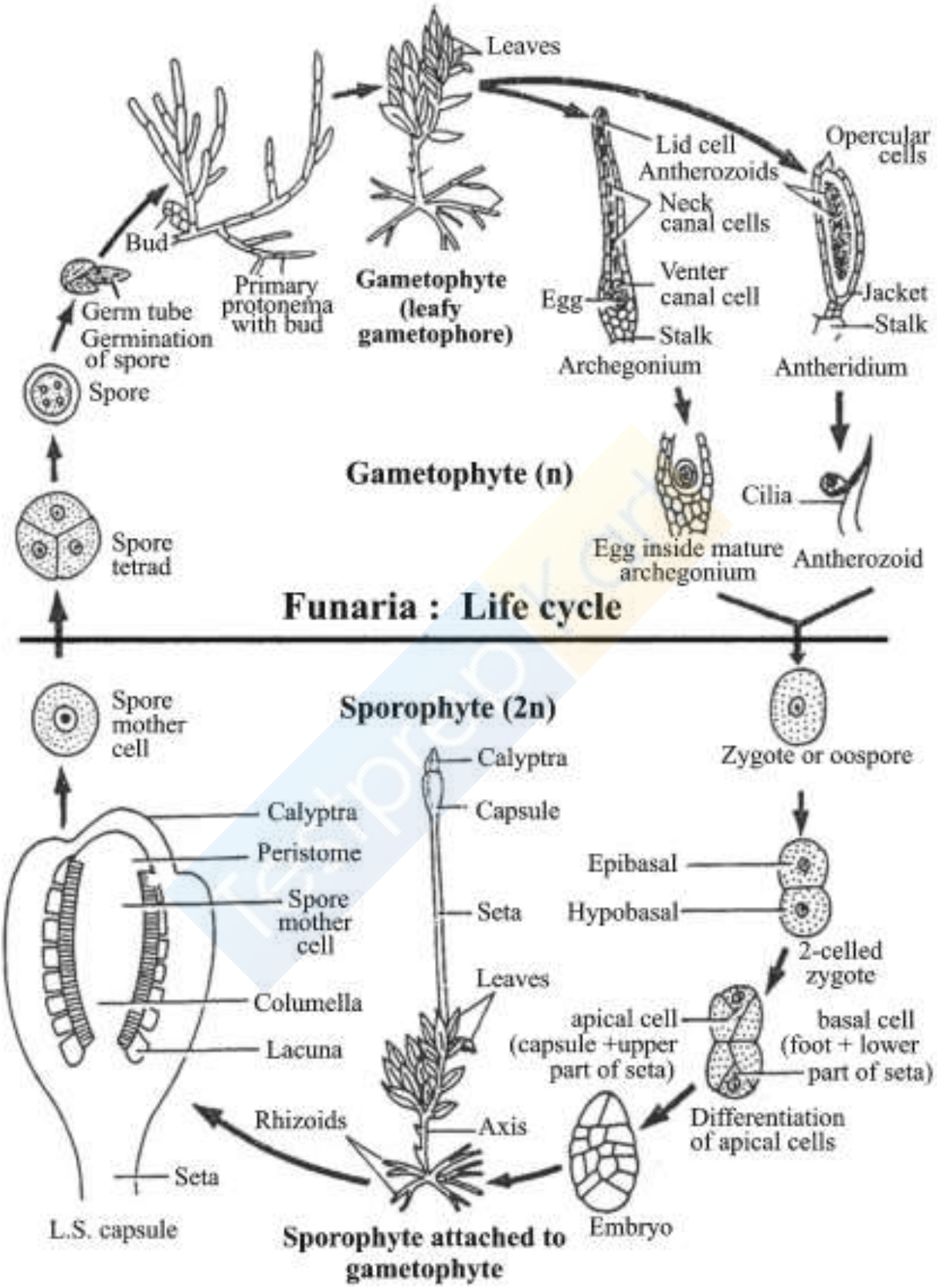


Fig. : Life Cycle of Funaria

PTERIDOPHYTES

- Pteridophytes are also called **vascular cryptogams** as they possess xylem and phloem.
- They are nicknamed as **botanical snakes** as they evolved after bryophytes (botanical amphibians).
- The pteridophytes include **horsetails** and **ferns**.
- Pteridophytes are used for medicinal purposes and as soil-binders. They are also frequently grown as ornamentals.
- They are the **first terrestrial plants to possess vascular tissues** - xylem and phloem.
- They are found in cool, damp, shady places though some may flourish well in sandy-soil conditions.
- Salvinia, Azolla and Ceratopteris are true aquatic ferns.
- Some species of Selaginella and Adiantum are xerophytes.
- Marsilea occurs as a terrestrial, amphibious as well as an aquatic plant.
- In pteridophytes, the main plant body, sporophyte is differentiated into true root, stem and leaves . These organs possess well-differentiated vascular tissues.
- The leaves in pteridophyta are small (microphylls) as in Selaginella or large (macrophylls) as in ferns.
- The sporophytes bear sporangia that are subtended by leaf-like appendages called sporophylls. In some cases, sporophylls may form distinct compact structures called strobili or cones (e.g., Selaginella, Equisetum). The sporangia produce spores by meiosis in spore mother cells.
- The spores germinate to give rise to inconspicuous, small but multicellular, free-living, mostly photosynthetic thalloid gametophytes called **prothallus**. These gametophytes require cool, damp, shady places to grow. Because of this specific restricted requirement and the need for water for fertilization, the spread of living pteridophytes is limited and restricted to narrow geographical regions.
- The **gametophytes bear sex organs** called antheridia and archegonia.

Antheridia are completely embedded in the prothallus while archegonia are partially embedded. Antherozoids, the male gamete released from antheridia, are uninucleate, spirally coiled biflagellate or multiflagellate structures (ferns).

- Water is required for transfer of antherozoids to the mouth of archegonium. Fusion of male gamete with the egg present in the archegonium result in the formation of zygote.

Zygote thereafter produces a multicellular well-differentiated sporophyte which is the **dominant phase of the pteridophytes**.

- In majority of the pteridophytes, all the spores are of similar kinds; such plants are called **homosporous**. Genera like Selaginella and Salvinia which produce two kinds of spores-macro (large) and micro (small) spores are known as **heterosporous**. The megaspores and microspores germinate and give rise to female and male gametophytes, respectively. The female gametophytes in these plants are retained on the parent sporophytes for variable periods. The development of the zygotes into young embryos take place within the female gametophytes. This event is a precursor to the seed habit, considered an important step in evolution.

CLASSIFICATION OF PTERIDOPHYTES

The pteridophytes are further classified into four classes:

- **Psilopsida** (Psilotum)
- **Lycopsida** (Selaginella, Lycopodium)
- **Sphenopsida** (Equisetum)
- **Pteropsida** (Dryopteris, Pteris, Ferns, Adiantum)

PSILOPSIDA

- These are the **most primitive** and **oldest known land inhabiting plants**, which are **rootless**.
- They are also called as **Whisk Ferns**.
- Most of the members of psilopsida are known only as fossils except a few living members, E.g., Psilotum.

LYCOPSIDA

- They are commonly called as **club moss**, or **ground pine** although they are neither moss nor pine. E.g., Selaginella, Lycopodium.
- Selaginella is commonly called the little club moss or spike moss. Selaginella is mainly found in damp shaded places.
- The plant body is **sporophytic (2n)**, which is an evergreen and delicate herb having adventitious roots.
- The plants show great variation in their morphology. Some species are prostrate growing upon the surface (e.g., S.kraussiana), some are suberect (e.g., S.trachyphylla) and others are climbers (e.g., S.allegans).
- Reproduction takes place by vegetative and sexual (by spores) method.
- **Sexual reproduction** : The reproductive structure in Selaginella is **strobilus** or **spike**. It is a sessile structure and develops at the terminal ends of the branches.

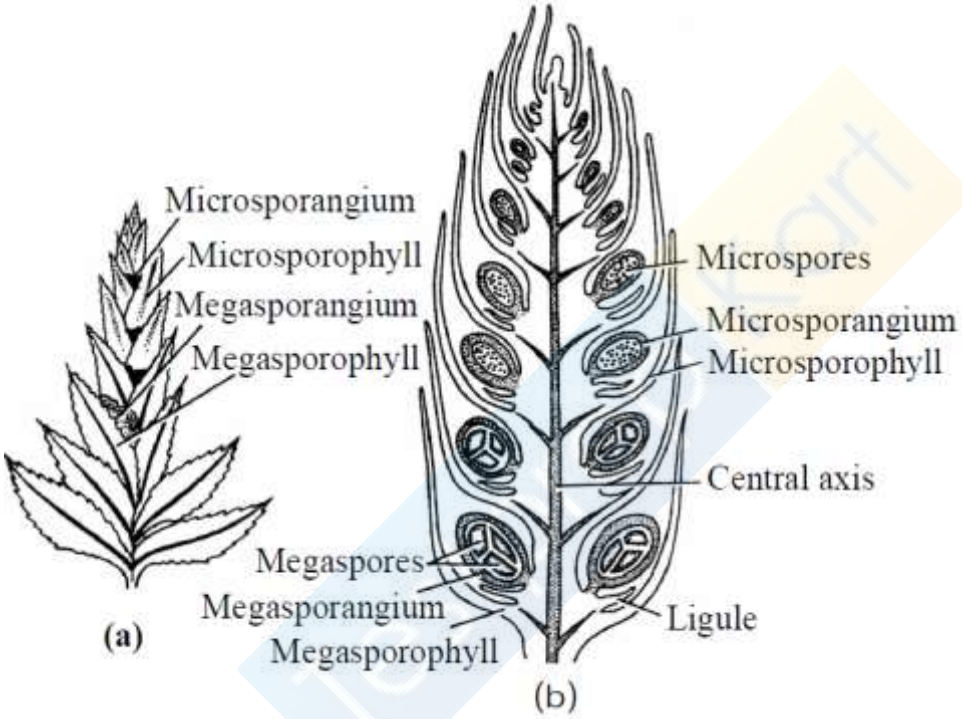


Fig. : Selaginella :
(a) A strobilus showing compactly arranged sporophylls
(b) L.S. through strobilus

- The sporangia are of two types : megasporangia and microsporangia.

○ **Megasporangia** are borne on megasporophylls. Megasporangium is pale greenish and contains chalky white, yellow or orange megaspores.

The megasporangium is four-lobed structure with a 2-layered jacket, one layer of tapetum and a large number of megaspore mother cell. However, only one megaspore mother cell is functional. After meiosis it produces 4 megaspores out of which 1-3 may degenerate. In S.rupestris, there is only a single megaspore.

○ **Microsporangia** are borne on microsporophylls having a large number of small spores. Thus; Selaginella is heterosporous. Microsporangium is pale yellow, oval or spherical body, with 2-layered jacket, one layered tapetum and a number of microspore mother cells undergo meiosis and form haploid microspores. The main body consists of a wall having two layers, inside which are present numerous small microspores (400-2000).

SPHENOPSIDA

- The members of this class are commonly known as **horsetails**.

- Equisetum is the **only living genus of Sphenopsida**.
- The sporophyte has true roots, stem and leaves.
- The stem are jointed having distinct nodes and internodes.
- The stele may be a protostele or siphonostele.
- All species are homosporous with autotrophic gametophytes or prothalli. The prothalli may be monoecious or dioecious and exosporic.

PTEROPSIDA

- Members of this class are commonly called **ferns**. These are the widely distributed vascular cryptogams, E.g., Marsilea, Adiantum, Pteris.
- The plants are **perennials**, widely distributed in damp shady places of the tropics.
- Fern Dryopteris filix-mas is commonly known as **Beech fern** or **Male shield fern** or **Hay scented fern**.
- Fern plant is sporophytic (2n) with an underground rhizomatous stem, large aerial leaves or fronds and adventitious roots.
- Rhizome is sparingly branched in Dryopteris, moderately branched in Pteris and Adiantum and profusely branched in Pteridium.
- Adiantum is commonly called "**Maidenhair fern**" or **walking fern** because it propagates vegetatively by its leaf tips).
- Younger parts of leaves and rhizome are surrounded by brown hairy structures called scales or ramenta. Leaf bases are persistent. Young leaves shows circinate vernation.

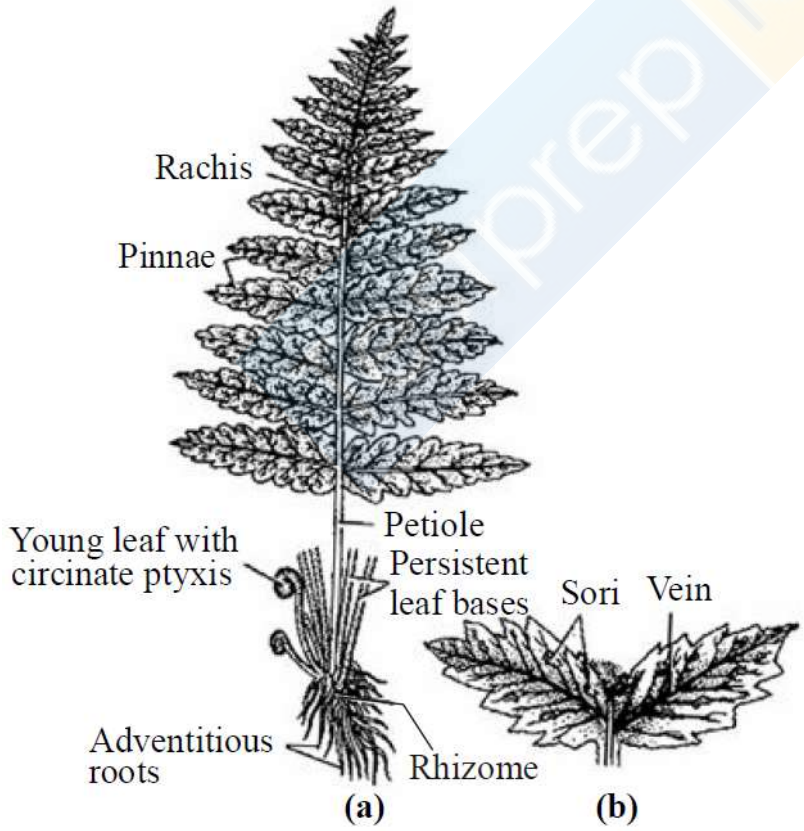


Fig. : Dryopteris (a) Plant showing habit (b) Fertile pinnule

- **Vegetative reproduction** can occur through fragmentation of rhizome and adventitious buds and these on separation gives rise to a new fern plant.

- **Sexual reproduction** takes place through spores. Spores are born in sporangia. The spores are of one kind only (homosporous). When leaves are mature they bear groups of sori on the under surface of fertile pinnae. Such fronds are called sporophylls.

Table : Common Names of some Pteridophytes

S. No.	Common Name	Botanical Name
1.	Rootless pteridophyte	*Salvinia*
2.	Xerophytic Fern	*Woodsia elongata, Drynaria, Adiantum insicum.*
3.	Smallest Fern	*Annogramma leptaphylla*
4.	Club Moss	*Lycopodium*
5.	Spike moss	*Selaginella*
6.	Bird's nest moss	*Selaginella rupestris*
7.	Sanjeevini	*S. bryopteris*
8.	Walking Fern	*Adiantum*
9.	Male Shield Fern	*Dryopteris*

GYMNOSPERMS

- Term gymnosperm was introduced by Theophrastus. It is a connecting link between pteridophytes and angiosperms.
- Gymnosperms are seed bearing, non-flowering plants.
- Gymnosperms are more ancient than angiosperms.
- All gymnosperms are perennial and include medium-sized trees or tall trees and shrubs.
- One of the gymnosperms, the giant redwood tree Sequoia is one of the tallest tree species. Oldest gymnosperms is S. gigantea (4000-5000 years) and smallest gymnosperm is Zamia (25 cm).
- 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 specialised roots called coralloid roots are associated with N_2- fixing cyanobacteria.
- The stems are unbranched (Cycas) or branched (Pinus, Cedrus).
- In Cycas, 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.
- The gymnosperms are **heterosporous** which produces haploid microspores and megaspores. The two kinds of spores are produced within sporangia that are borne on sporophylls.
- The two types of sporophylls aggregate to form compact cones or strobili.
- The strobili bearing microsporophylls and microsporangia are called **microsporangiate or male strobili**. 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.
- The cones bearing megasporophylls with ovules or megasporangia are called **macrosporangiate or female strobili**. The male or female cones or strobili may be borne on the same tree (Pinus) or on different trees (Cycas).

- 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. They are carried in air currents and come in contact with the opening of the ovules borne on megasporophylls.
- The pollen tube carrying the male gametes grows towards archegonia in the ovules and discharge their contents near the mouth of the archegonia. Following fertilization, zygote develops into an embryo and the ovules into seeds. These seeds are not covered.
- Types of Gymnospermous wood are -
  - **Monoxylic wood** : The wood formed in one ring due to persistent cambium e.g., Pinus.

Cambial activity is short lived, cortex and pith are broad, parenchymatous rays are broad, wood is soft and commercially useless. E.g., Cycas.
  - **Pycnoxylic wood** : The wood is formed in more than one ring due to ephimeral nature of cambium.

Cambial activity is long lived, cortex and pith are reduced, parenchymatous rays are few, wood is hard and compact, wood is commercially most important and used as good quality timber. E.g., Pinus.
  - The wood of Cedrus deodara is used for making railway sleepers. It is also used as a structural timber and making bridges. The wood of Callitris verrucosa, Pinus roxburghii, P. wallichiana, P. pinaster, P. lambertiana etc. is used for making furniture. Juniperus virginiana wood is used for making pencils. The gymnosperm Agathis australis is perhaps the largest timber producing tree of the world.

CLASSIFICATION OF GYMNOSPERMS

Gymnosperms are classified into three classes (Sporne, 1965). They are **Cycadopsida** (e.g. Cycas), **Coniferopsida** (e.g. Pinus, Ginkgo) and **Gnetopsida** (e.g. Gnetum)

PINUS

- Pinus is an evergreen, perennial plant of xerophytic nature. Mostly the species are tall and straight. The whorled branching gives a typical conical or excurrent appearance to the plant (due to apical dominance).
- The plant body is sporophyte and the plants are monoecious.
- The plant body is differentiated into roots, stem and leaves.

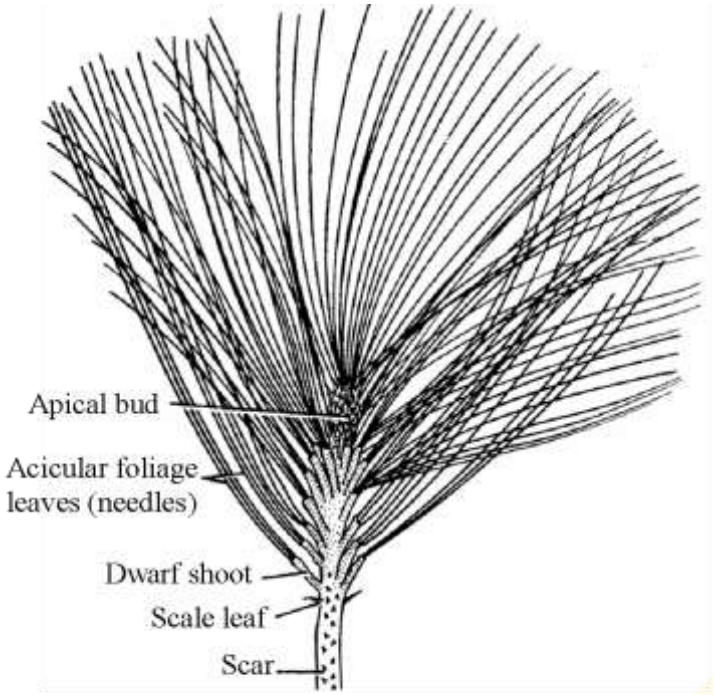


Fig : pinus

Fig. : Pinus

- Pinus reproduces only by means of spores. Unlike Cycas, here the micro and megasporophylls form compact male and female cone or strobilus respectively.
- Pinus plant is **sporophyte** (2x), **heterosporous** (producing two types of spores – microspore and megaspore), **monoecious** (male and female cones are borne on the same plant) and **autoecious** (male and female cones are borne on different branches).

CYCAS

- Cycas is an evergreen palm-like plant. It is the only genus of family Cycadaceae represented in India.

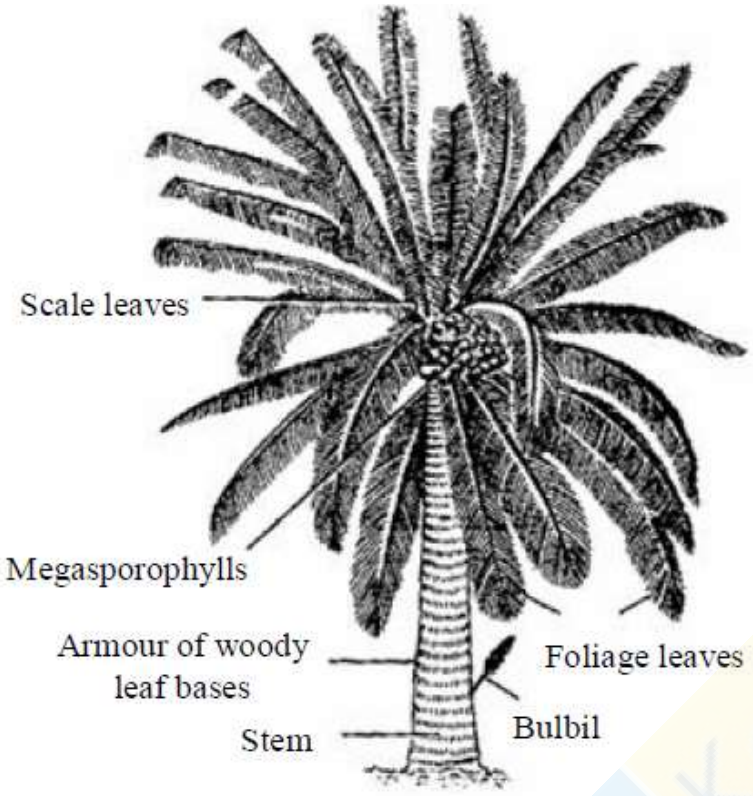


Fig. : Cycas

- Cycas plants are dioecious and reproduce by following methods :

○ **Vegetative propagation** : It occurs by means of bulbils (resting adventitious buds) which are produced on the stem in the axil of scale leaves. They break up from the parent plant and germinate to give rise to new plant.

○ **Sexual reproduction** : Plant of Cycas is sporophyte (2n) and dioecious. The sexual reproduction is of oogamous type, i.e., takes place by the fusion of distinct male and female gametes. The male and female gametes are formed by the germination of micro and megaspores which are born on microsporophylls and megasporophylls. The microsporophylls are grouped together to form a compact conical structure called male cone, whereas the megasporophylls are not aggregated to form a cone, they are produced at the apex of the stem in succession with the leaves.

ANGIOSPERMS

- Angiosperms are flowering plants in which pollen grains and ovules are developed in specialised structures called flowers.
- In angiosperms, the seeds are enclosed by fruits.
- They provide us with food, fodder, fuel, medicines and several other commercially important products.
- 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 embryo sacs. 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 fertilization**, 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 fertilization. During these events, the ovules develop into seeds and the ovaries develop into fruit.
- The **smallest angiosperm** is Wolffia. The plant body of Wolffia consists of tiny flat oval green stem (phylloclade) having a few small roots. The plants are about 1 mm in diameter and found free floating in aquatic habitats like ponds, etc.

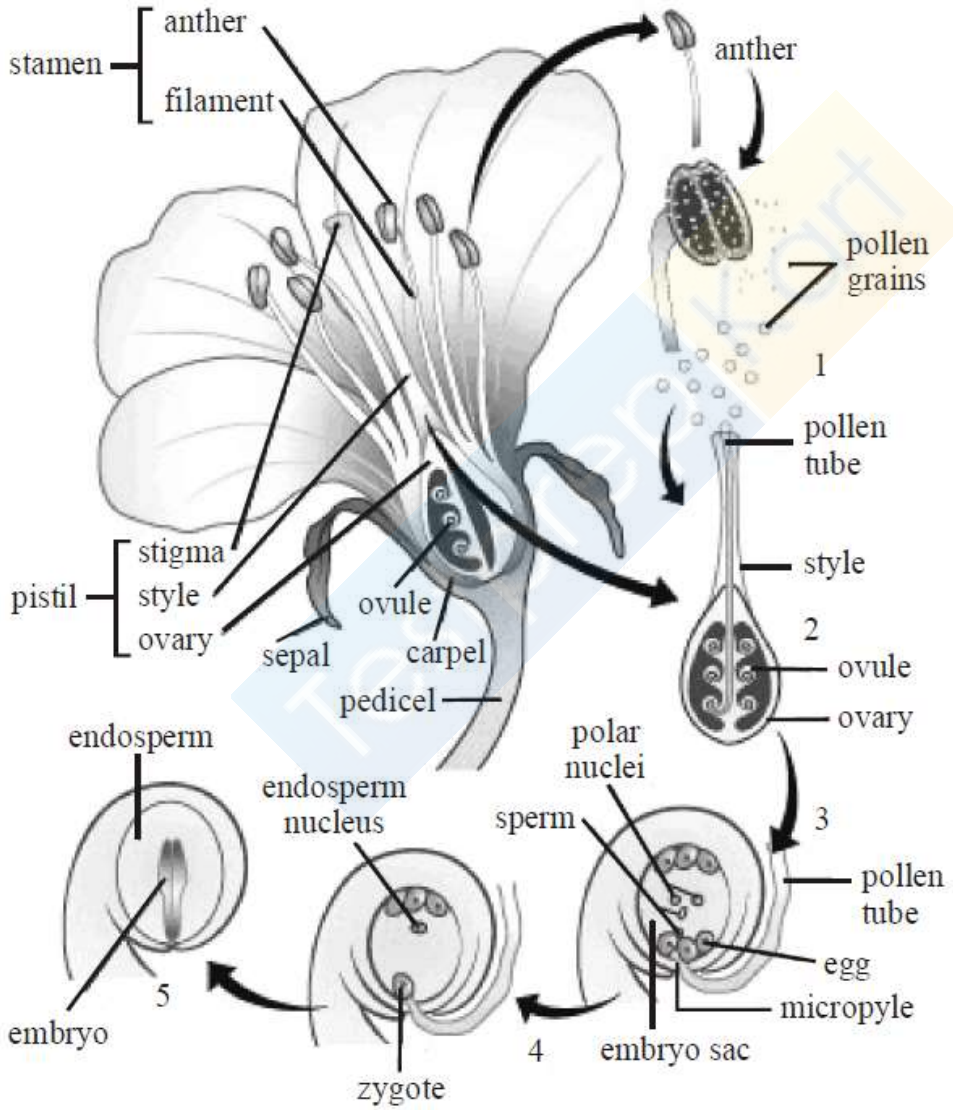


Fig. : Life cycle of an angiosperm

- The **tallest angiosperm** is Eucalyptus. Their trees may attain a height upto 100 meters or more.
- The plants of angiosperms is divided into two major groups – dicotyledons and monocotyledons.

Dicotyledons show the following distinguished characteristics

- Tap roots are found in the members of this group.
- The leaves in members of these class exhibit reticulate (net like) venation.

- The flowers are tetramerous or pentamerous having four or five members in the various floral whorls, respectively.
- The vascular bundles arranged in a ring, numbering 2–6, open and with cambium.
- The seeds of dicotyledons are with two cotyledons as the name indicates.

Monocotyledons show the following distinguished characteristics

- Adventitious roots are found in the members of this group.
- The leaves are simple with parallel venation.
- The flowers are trimerous having three members in each floral whorl.
- The vascular bundles scattered in the ground tissue, many in number, closed and without cambium.
- The seeds of monocotyledons are with one cotyledons as the name indicate. E.g., Cereals, bamboo, sugarcane, palms, bananas, lilies and orchids.

- Depending upon the habit of plants, the angiosperms belong to the following categories

○ **Herb** : These are small, soft, non-woody plants without persistent parts above ground. The height of plants usually reaches upto 1 m. The plants may be annual (Brassica), biennial (Sugar beet) or perennial (Canna). The perennial herbs usually possess underground rhizomes which form the new aerial shoots every year. The plants of banana are perennial herbs.

○ **Shrubs** : These are woody plants of relatively low height (1-4 m). They typically branch at or near the base and do not have a main trunk, e.g., Rose. They are mostly perennial.

○ **Trees** : These are perennial woody plants with one main trunk. The trunk may or may not be branched. These are of the following types :

▪ **Caudex** : The stem is unbranched and usually bears a crown of leaves at the apex, e.g., Date-palm.

▪ **Excurrent** : The lower part of stem is thicker which gradually tapers above. Branches arise from the main stem in acropetal succession and plant appears conical, e.g., Pinus.

▪ **Deliquescent** : The apical bud of the main stem dies after some time and branches and sub-branches spread in different directions, e.g., Tamarindus, Ficus, etc.

○ **Culms** : In these plants, nodes and internodes are extremely clear. Internodes of such plants are usually hollow. These plants are grasses but cannot be considered as herb or shrub or tree, e.g., Bambusa (Bans).

PLANT LIFE CYCLES AND 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 fertilization 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.
- Different plant groups, as well as individuals representing them, differ in the following patterns:

○ 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 Chlamydomonas represent this pattern.

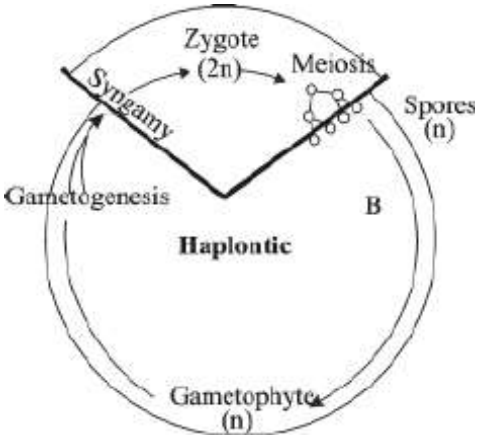


Fig. : Life cycle of Haplontic Organisms

- 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 life cycle is termed as **diplontic**. All seed-bearing plants i.e. gymnosperms and angiosperms, follow this pattern.

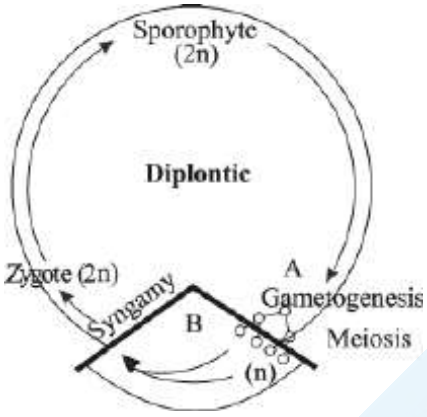


Fig. : Life cycle of Diplontic Organisms

- 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 short-lived multicellular 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 a multicellular, saprophytic/autotrophic, independent but short-lived haploid gametophyte. Such a pattern is known as haplo-diplontic life cycle. All pteridophytes exhibit this pattern.

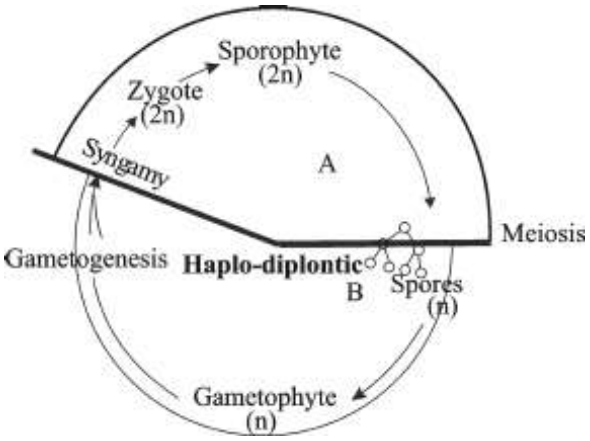


Fig. : Life cycle of Haplo-diplontic Organisms

- While most algal genera are haplontic, some of them such as Ectocarpus, Polysiphonia, Kelps are haplo-diplontic. Fucus, an alga is diplontic.