Chapter 2

Unit I: Diversity of Living World

Plant Kingdom

Learning Objectives

The learner will be able to,

- *Outline the classification of plants*
- *Illustrate the life cycles in plants*
- *Recognize the general characteristic features and reproduction of Algae*
- *Describe the structure, reproduction of Chara*
- *Recognize the general characteristic features of Bryophytes*
- *Describe the structure, reproduction of Marchantia*
- *Recognize the general characteristic features of Pteridophytes*
- *Describe the structure, reproduction of Selaginella*
- *Describe the general characteristic features of Gymnosperms*
- *Explain the structure, reproduction of Cycas*
- *Recognize the salient features of Angiosperms*

Chapter Outline

Traditionally organisms existing on the earth were classified into plants and animals based on nutrition, locomotion and presence or absence of cell wall. Bacteria, Fungi, Algae, Bryophytes, Pteridophytes, Gymnosperms and Angiosperms were included under plant group. Recently, with the aid of molecular characteristics. Bacteria and Fungi were segregated and placed under separate kingdoms. Botany is one of the oldest science in the world because its origin was from time immemorial as early men explored and identified plants for the needs of food, clothing, medicine, shelter etc., Plants are unique living entities as they are endowed with the power to harvest the light energy from the sun and to convert it to chemical energy in the form of food through the astounding reaction, **photosynthesis**. They not only supply nutrients to all living things on earth but sequester carbon-di-oxide during photosynthesis, thus minimizing the effect of one of the major green house gases that increase the global temperature. Plants are diverse in nature, ranging from microscopic algae to macroscopic highly developed angiosperms. There are mysteries and wonders in the plant world in terms of size, shape, habit, habitat, reproduction etc., Although plants are all made up of cells there exists high diversity in form and structure (Table 2.1).

2.1 Classification of Plants

Classification widely accepted for plants now include Embryophyta which is divided into Bryophyta and Tracheophyta. The latter is further divided into Pteridophyta and Spermatophyta (Gymnospermae and Angiospermae). An outline Classification of Plant Kingdom is given in Figure 2.1

Table 2.1: Total Number of Plant groups in the World and India		
Plant group	Number of known species	
	World#	India*
Algae	40,000	7,357
Bryophytes	16,236	2,748
Pteridophytes	12,000	1,289
Gymnosperms	1,012	79
Angiosperms	2,68,600	18,386

** Singh, P. and Dash, S.S. 2017-Plants discoveries 2016-New Genera, species and new records, BSI, India.*
 # Chapman, A.D. 2009. Number of living species in Australia and the world 2nd edition. Australian government, Department of environment, water Heritage and Arts.

Figure 2.1: Classification of Plant Kingdom

2.2 Life Cycle Patterns in Plants

Alternation of Generation

Alternation of generation is common in all plants. Alternation of the haploid gametophytic phase (n) with diploid sporophytic phase (2n) during the life cycle is called alternation of generation. Following type of life cycles are found in plants (Figure 2.2).

Haplontic Life Cycle

Gametophytic phase is dominant, photosynthetic and independent, whereas sporophytic phase is represented by the zygote. Zygote undergoes meiosis to restore haploid condition. Example: *Volvox*, *Spirogyra*.

Diplontic Life Cycle

Sporophytic phase (2n) is dominant, photosynthetic and independent. The gametophytic phase is represented by the single to few celled gametophyte.

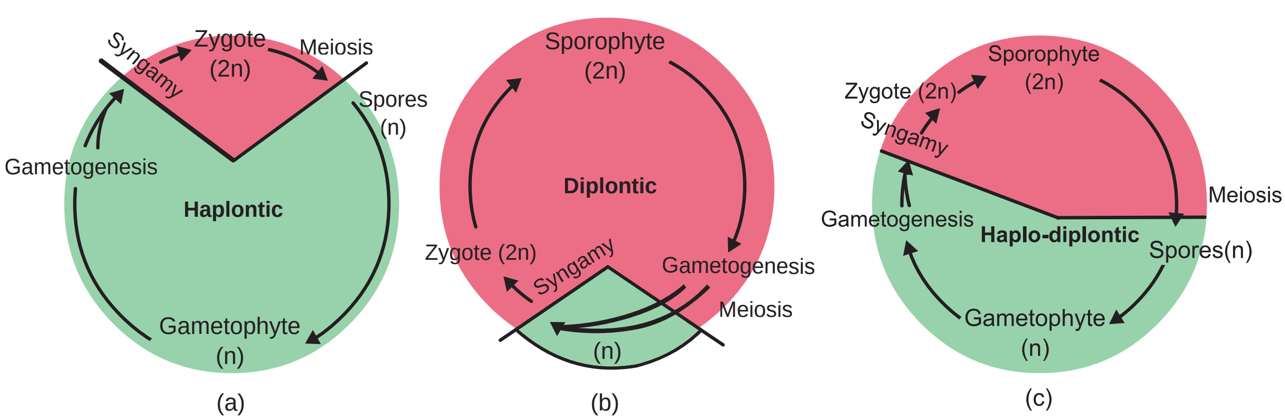


Figure 2.2: Life cycle patterns in plants a) Haplontic, b) Diplontic, c) Haplo-diplontic

The gametes fuse to form zygote which develops into sporophyte. Example: *Fucus,* gymnosperms and angiosperms

Haplodiplontic Life Cycle

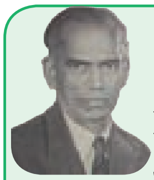
This type of life cycle is found in bryophytes and pteridophytes which is intermediate between haplontic and diplontic type. Both the phases are multicellular. but they differ in their dominant phase.

In bryophytes dominant independent phase is gametophyte and it alternates with short-lived multicellular sporophyte totally or partially dependent on the gametophyte.

In pteridophytes sporophyte is the independent phase. It alternates with multicellular saprophytic or autotrophic, independent, short lived gametophyte(n).

2.3 Algae

Rain brings joy and life to various organisms on earth. Have you noticed some changes in and around you after the rain? Could you identify the reason for the slippery nature of the terrace and green patches on the wall of our home, green colour of puddles and ponds? Why should we clean our water tanks very often? The reason is algae. Algae are simple plants that lack true roots, true stems and true leaves. Two-third of our earth's surface is covered by oceans and seas. The photosynthetic plants called algae are present here. More than half of the total primary productivity of the world depends on this plant group. Further, other aquatic organisms also depend upon them for their existence.



M.O.Parthasarathy (1886-1963) 'Father of Indian Phycology'. He conducted research on structure, cytology, reproduction and taxonomy of Algae. He published a Monograph on Volvocales. New algal forms like *Fritschiella, Ecballocystopsis, Charasiphon* and *Cylindrocapsopsis*. were reported by him.

Algae are autotrophs, and grow in a wide range of habitats. Majority of them are aquatic, marine (*Gracilaria,* and *Sargassum*) and freshwater (*Oedogonium,* and *Ulothrix*) and also found in soils (*Fritschiella,* and *Vaucheria*). *Chlorella* lead an endozoic life in hydra and sponges whereas *Cladophora crispata* grow on the shells of molluscs. Algae are adapted to thrive in harsh environment too. *Dunaliella salina* grows in salt pans (**Halophytic alga**). Algae growing in snow are called **Cryophytic algae**. *Chlamydomonas nivalis* grow in snow covered mountains and impart red colour to the snow (**Red snow**). A few algae grow on the surface of aquatic plants and are called **epiphytic algae** (*Coleochaete,* and *Rhodymenia*). The study of algae is called **algology** or **phycology**. Some of the eminent algologists include F.E. Fritsch, F.E. Round, R.E. Lee, M.O.Parthasarathy Iyengar, M.S. Randhawa, Y. Bharadwaja, V.S. Sundaralingam and T.V.Desikachary.

2.3.1 General Characteristic features

The algae show a great diversity in size, shape and structure. A wide range of thallus organisation is found in algae. Unicellular motile (*Chlamydomonas*), unicellular non-motile (*Chlorella*), Colonial motile (*Volvox*), Colonial non motile (*Hydrodictyon*), siphonous (*Vaucheria*), unbranched filamentous (*Spirogyra*), branched filamentous (*Cladophora*), discoid (*Coleochaete*) heterotrichous (*Fritschiella*), Foliaceous (*Ulva*) to giant kelps (*Laminaria* and *Macrocystis*). The thallus organization in algae is given in Figure 2.3.

Algae are eukaryotes except blue green algae. The plant body does not show differentiation into tissue systems. The cell wall of algae is made up of cellulose and hemicellulose. Siliceous walls are present in diatoms. In *Chara* the thallus is encrusted with calcium carbonate. Some algae possess algin, polysulphate esters of polysaccharides which are the sources for the alginate, agar agar and carrageenan. The cell has a membrane bound nucleus and cell organelles like chloroplast, mitochondria, endoplasmic reticulum, golgi bodies etc., Pyrenoids are present. They are proteinaceous bodies found in chromatophores and assist in the synthesis and storage of starch. The pigmentation, reserve food material and flagellation differ among the algal groups.

Algae reproduces by vegetative, asexual and sexual methods (Figure 2.4). Vegetative

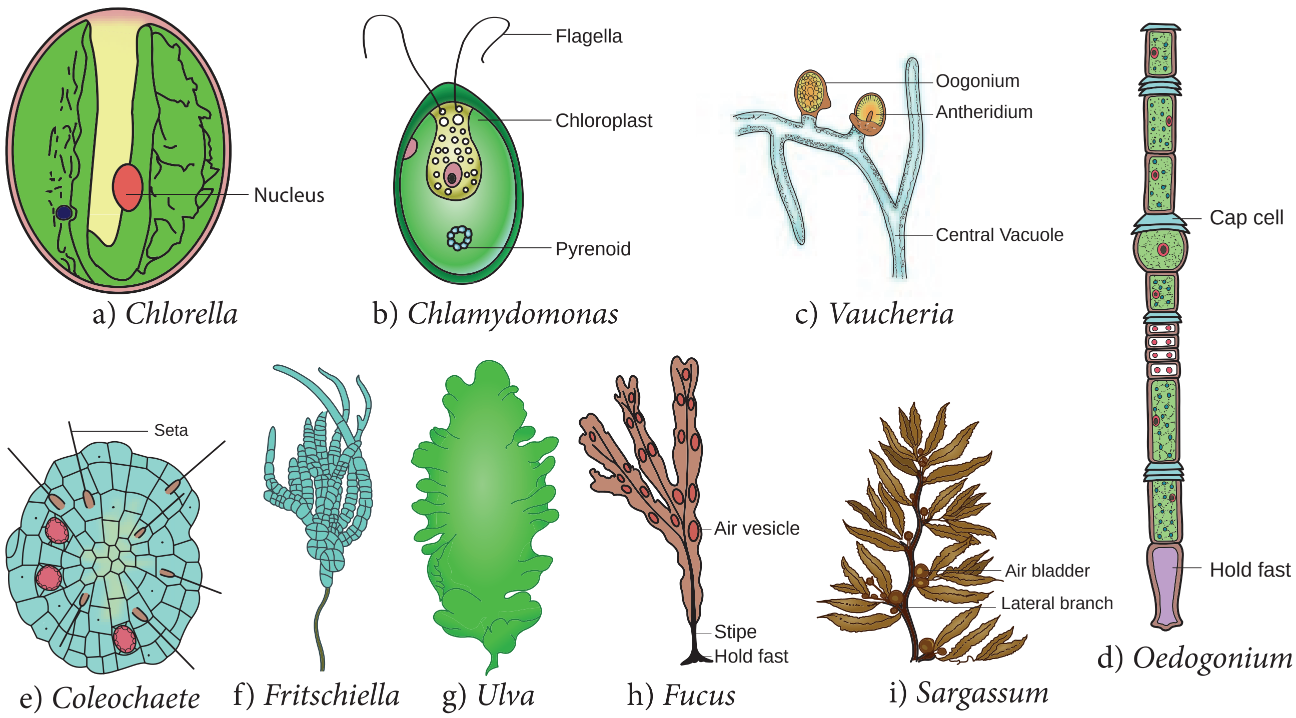


Figure 2.3: Thallus organization in Algae

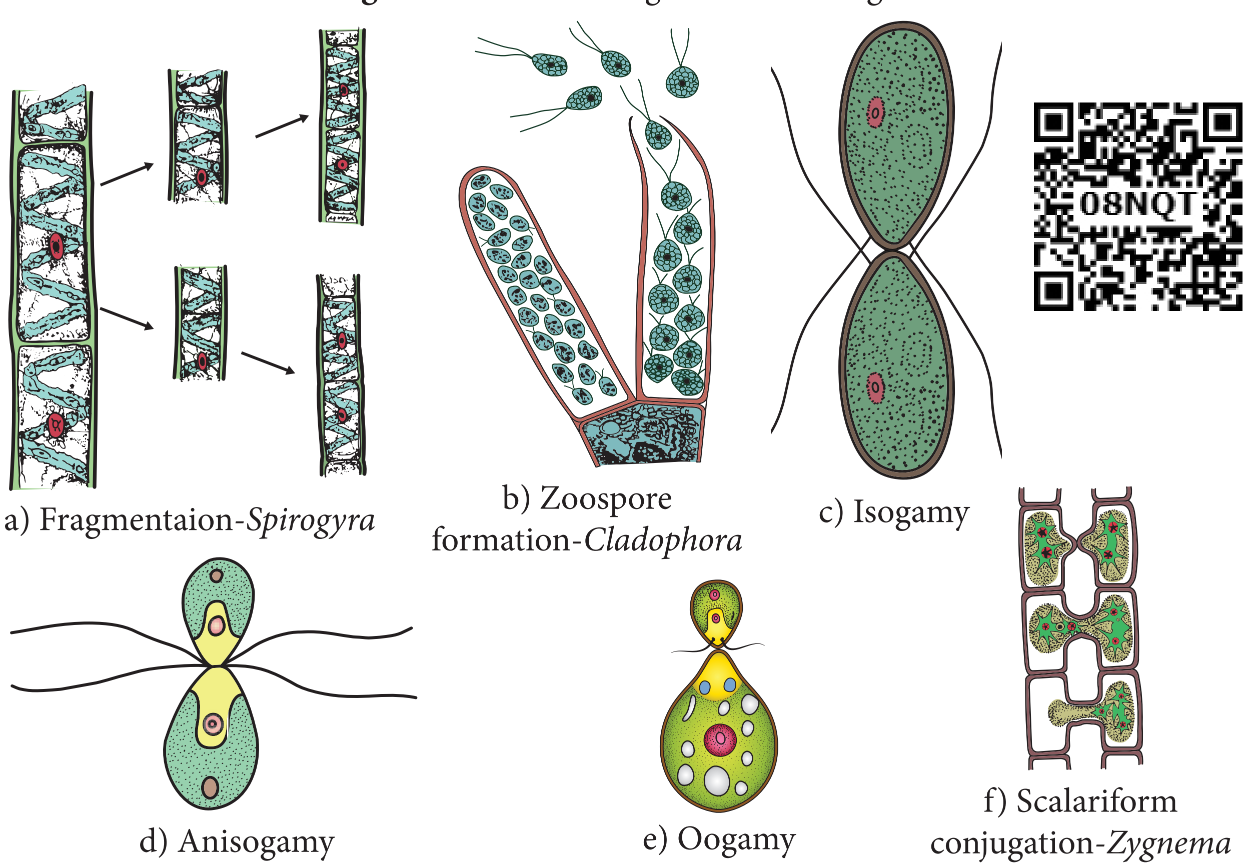


Figure 2.4: Reproduction in Algae

reproduction includes fission (In unicellular forms the cell divides mitotically to produce two daughter cells Example: *Chlamydomonas)*; Fragmentation (fragments of parent thallus grow into new individual Example: *Ulothrix*) budding (A lateral bud is formed in some members like *Protosiphon* and helps in reproduction) bulbils, (a wedge shaped modified branch develop in *Sphacelaria*) akinetes (Thick walled spores meant for perennation and germinates with the advent of favourable condition Example: *Pithophora*) and Tubers (Structures found on the rhizoids and the lower nodes of *Chara* which store food materials).

Asexual reproduction takes place by the production of zoospores motile spores (*Ulothrix, Oedogonium*) aplanospore (thin walled non motile spores Example: *Vaucheria*); autospores (spores which look similar to parent cell Example: *Chlorella*); hypnospore (thick walled aplanospore – Example: *Chlamydomonas nivalis*) and Tetraspores (Diploid thallus of *Polysiphonia* produce haploid spores after meiosis).

Sexual reproduction in algae is of three types 1. Isogamy (Fusion of morphologically and Physiologically similar gametes Example: *Ulothrix*) 2. Anisogamy (Fusion of either morphologically or physiologically dissimilar gametes Example: *Pandorina*) 3. Oogamy (Fusion of both morphologically and physiologically dissimilar gametes. Example: *Sargassum*). The life cycle shows distinct alternation of generation.

> **DO YOU KNOW?**
> The Oldest recorded alga is Grypania, which was discovered in the banded iron formations of northern Michigan and dated to approximately 2100Ma

2.3.2. Classification

F.E. Fritsch proposed a classification for algae based on pigmentation, types of flagella, reserve food materials, thallus structure and reproduction. He published his classification in the book "The structure and reproduction of the Algae"(1935). He classified algae into 11 classes namely Chlorophyceae, Xanthophyceae, Chrysophyceae, Bacillariophyceae, Cryptophyceae, Dinophyceae, Chloromonadineae, Euglenophyceae, Phaeophyceae, Rhodophyceae, Cyanophyceae (Table 2.2).

The salient features of Chlorophyceae, Phaeophyceae and Rhodophyceae are given below.

Chlorophyceae

The members are commonly called **'Green algae'**. Most of the species are aquatic(Fresh water-*Spirogyra*, Marine -*Ulva*). A few are terrestrial(*Trentipohlia*). Variation among the shape of the chloroplast is found in members of algae. It is cup shaped (*Chlamydomonas*), discoid (*Chara*), girdle shaped, (*Ulothrix*), reticulate (*Oedogonium*), spiral (*Spirogyra*), stellate (*Zygnema*) and plate like (*Mougeoutia*).

Chlorophyll 'a' and Chlorophyll 'b' are the major photosynthetic pigments. Storage bodies called pyrenoids are present in the chloroplast and store starch. They also contain proteins. The cell wall is made up of inner layer of cellulose and outer layer of pectin. Vegetative reproduction takes place by means of fragmentation and asexual reproduction is by the production of zoospores, aplanospores and akinetes. Sexual reproduction is present and may be isogamous, anisogamous or oogamous. Examples for this group of algae includes *Chlorella, Chlamydomonas, Volvox, Spirogyra, Ulothrix, Chara* and *Ulva.*

Phaeophyceae

The members of this class are called **'Brown algae'**. Majority of the forms are found in marine habitats. *Pleurocladia* is a fresh water form. The thallus is filamentous (*Ectocarpus*) frond like (*Dictyota*)or may be giant kelps (*Laminaria*

Table 2.2 Classification of Algae			
Class	**Pigments**	**Flagella**	**Reserve food**
Chlorophyceae	Chlorophyll a and b Carotenoids, Xathophyll	1,2,4 or more equal anterior whiplash flagella	Starch
Xanthophyceae	Chlorophyll a and b Carotenoids Xathophyll	2, unequal anterior 1 tinsel and 1 whiplash	Fats and leucosin
Chrysophyceae	Chlorophyll a and b Carotenoids,	1 or 2 unequal or equal anterior both whiplash or 1 whiplash and 1 tinsel	Oils and leucosin
Bacillariophyceae	Chlorophyll a and c Carotenoids,	1 anterior (only in male gametes) tinsel	Leucosin and Fats
Cryptophyceae	Chlorophyll a and c carotenoids and xanthophyll	unequal anterior both tinsel flagella	Starch
Dinophyceae	Chlorophyll a and c carotenoids and xanthophyll	Two unequal (whiplash)lateral flagella in different plane	Starch and oil
Chloromonadineae	Chlorophyll a and b Carotenoids, Xathophyll	2 equal flagella	oil
Euglenophyceae	Chlorophyll a and b	One or two anterior tinsel flagella	Fats and paramylon
Phaeophyceae	Chlorophyll a and c, Xanthophyll	Two unequal whiplash and tinsel lateral flagella	Laminarin starch and fats
Rhodophyceae	Chlorophyll a, r-Phycoerthythrin	absent	Floridean starch
Cyanophyceae	Chlorophyll a, carotenoids, c-Phycocyanin,Allophycocyanin	absent	Cyanophycean starch

and *Macrocystis*). The thallus is differentiated into leaf like photosynthetic part called fronds, a stalk like structure called stipe and a holdfast which attach thallus to the substratum.

The Pigments include Chlorophyll a, c, Carotenoids and Xanthophylls. A golden brown pigment called fucoxanthin is present and it gives shades of colour from olive green to brown to the algal members of this group. Mannitol and Laminarin are the reserve food materials. Motile reproductive structures are present. Two laterally inserted unequal flagella are present. Among these one is whiplash and another is tinsel. Although sexual reproduction ranges from isogamy to oogamy, Most of the forms show oogamous type. Alternation of generation is present (isomorphic, heteromorphic or diplontic). Examples for this group include *Sargassum, Laminaria, Fucus* and *Dictyota.*

Rhodophyceae

Members of this group include '**Red algae**' and are mostly marine. The thallus is multicellular, macroscopic and diverse in form. *Porphyridium* is the unicellular form. Filamentous (*Goniotrichum*) ribbon like (*Porphyra*) are also present. *Corallina* and *Lithothamnion* are heavily impregnated with lime and form coral reefs. Apart from chlorophyll a, r-phycoerythrin and r-phycocyanin are the photosynthetic pigments. Asexual reproduction takes place by means of monospores, neutral spores and tetraspores.

The storage product is floridean starch. Sexual reproduction is oogamous. Male sex organ is spermatangium which produces spermatium. Female sex organ is called carpogonium. The spermatium is carried by the water currents and fuse with egg nucleus to form zygote. The zygote develops into carpospores. Meiosis occurs during carpospore formation. Alternation of generation is present. Examples for this group of algae include *Ceramium, Polysiphonia, Gelidium, Cryptonemia* and *Gigartina*

> **DO YOU KNOW?**
> A green alga *Botryococcus braunii* is employed in Bio-fuel production.
>
> **Algae in Health care**
>
> **Kelps** are the rich source of Iodine *Chlorella* is used as single cell Protein (SCP).
>
> *Dunaliella salina* an alga, growing in salt pan is complement to our health and provide β carotene.

2.3.3 Economic Importance

The Economic importance of Algae is given in Table 2.3

2.3.4 Chara

Class – Chlorophyceae
Order – Charales
Family – Characeae
Genus – *Chara*

Chara is commonly called as ' stone wort' It is a submerged aquatic freshwater alga growing attached to the mud of the lakes and slow running streams. *Chara baltica* grows in saline water. The thallus is often encrusted with calcium and magnesium carbonate.

Thallus structure

The plant body is multicellular, macroscopic and is differentiated into main axis and rhizoids. The rhizoids are thread-like,

Table 2.3: Economic importance of Algae

Name of the Algae	Economic importance
Beneficial activities	
Chlorella, Laminaria, Sargassum, Ulva, Enteromorpha	Food
Gracilaria, Gelidiella, Gigartina	Agar Agar – Cell wall material used for media preparation in the microbiology lab. Packing canned food, cosmetic, textile paper industry
Chondrus crispus	Carrageenan – Preparation of tooth paste, paint, blood coagulant
Laminaria, Ascophyllum	Alginate – ice cream, paints, flame proof fabrics
Laminaria, Sargassum, Ascophyllum, Fucus	Fodder
Diatom (Siliceous frustules)	Diatomaceous earth– water filters, insulation material, reinforcing agent in concrete and rubber.
Lithophyllum, Chara, Fucus	Fertilizer
Chlorella	Chlorellin -Antibiotic
Chlorella, Scenedesmus, Chlamydomonas	Sewage treatment, Pollution indicators
Harmful activity	
Cephaleuros virescens	Red rust of coffee

> **DO YOU KNOW?**
> **A Productive Cultivation in Sea**
> Algae like *Kappaphycus alvarezii, Gracilaria edulis* and *Gelidiella acerosa* are commercially grown in the sea for harvesting the phycocolloids.
>
> 
>
> **Sea Palm** It is *Postelia palmaeformis* a brown alga.

multicellular structures arise from the lower part of the thallus or peripheral cells of the lower node.They are characterised by the presence of oblique septa. The rhizoids fix the main axis on the substratum and helps in the absorption of salts and solutes (Figure 2.5).

The main axis is branched, long and is differentiated into nodes and internodes. The internode is made up of an elongated cell in the centre called axial cell or internodal cell. The axial cell is surrounded by vertically elongated small cells which originate from the node. They are called cortical cells. In *C. wallichii* and *C. corallina* the cortical cells are absent. Three types of appendages arise from the node. They are 1. Branches of limited growth 2. Branches of unlimited growth 3. Stipuloides. The growth of the main axis and its branching takes place by the apical cell.

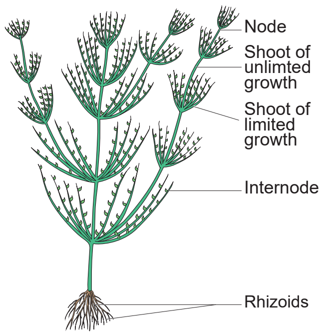


Figure 2.5: *Chara* Habit

The nodal cells are uninucleate with few ellipsoidal chloroplasts. The internodal cells are elongated and possesses a large central vacuole, many nuclei and numerous discoidal chloroplasts.

The cytoplasm is divided into outer ectoplasm and inner endoplasm. The endoplasm shows cytoplasmic streaming.

Reproduction

Chara reproduces by vegetative and sexual methods. Vegetative reproduction takes place by amylum stars, root bulbils, amorphous bulbils and secondary protonema.

Sexual reproduction - Sexual reproduction is oogamous. Sex organs are macroscopic and are produced on the branches of limited growth. The male sex organ is called antheridium or globule and the female sex organ is called Oogonium or nucule (Figure 2.6). The nucule is located above the globule. The antheridium is spherical, macroscopic and its wall is made up of eight cells called shield cells. The antheridium has spermatogenous filaments. These filaments produce antherozoids. The nucule is covered by five spirally twisted tube cells and five coronal cells are present at the top of the nucule (Figure 2.6). The centre of the nucule possesses a single egg. At maturity the tube cells separate and a narrow slit is formed. The antherozoids penetrate the oogonium and one of them fuses with the egg to form a diploid oospore. The oospore secretes a thick wall around and germinate after the resting period. The nucleus of the oospore divides to form 4 haploid daughter nuclei of which, three degenerate. The oospore or zygote germinates to produce haploid protonema. The plant body of *Chara* is haploid and The oospore is the only diploid phase in the life cycle. Therefore, the life cycle is of haplontic type. Alternation of generations is present (Figure 2.7).

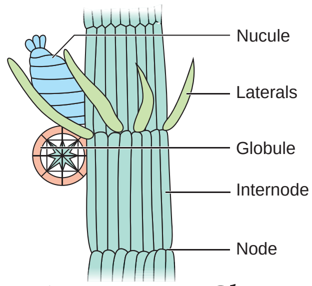


Figure 2.6: *Chara* sex organs

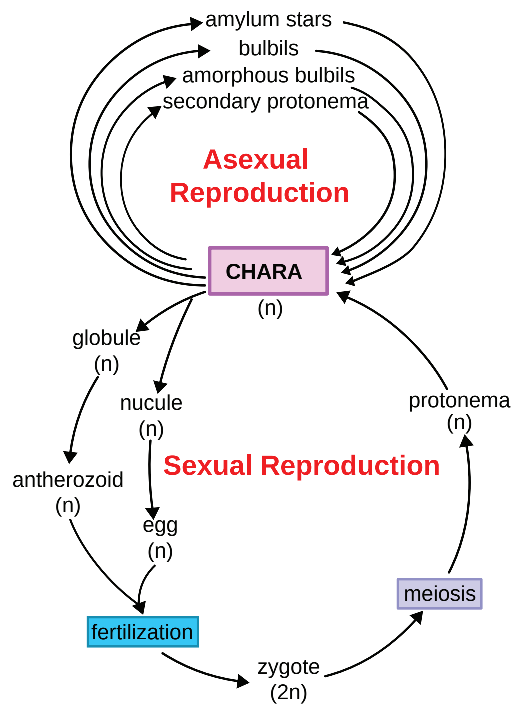


Figure 2.7: Life cycle of *Chara*

2.4 Bryophytes

Amphibians of Plant Kingdom

In the previous chapter, we noticed a wide range of thallus organization in Algae. Majority of them are aquatic. The development of heterotrichous habit, development of parenchyma tissue and dichotomous branching in some algae supports the view that colonization of plants in land occurred in the past. Bryophytes are simplest and most primitive plant groups descended from alga – like ancestors. They are simple embryophytes. Let us learn about the structure and reproduction of these primitive land plants called Bryophytes in detail.

Bryophytes are simplest land inhabiting cryptogams and are restricted to moist, shady habitats. They lack vascular tissue and hence called **'Non-vascular cryptogams'**. They are also called as **'amphibians of plant kingdom'** because they need water for completing their life cycle.

Shiv Ram Kashyap
(1882-1934)

Father of Indian Bryology. He published a book- 'Liverworts of Western Himalayas and Punjab Plains' He identified new genera like *Atchinsoniella, Sauchia, Sewardiella* and *Stephansoniella.*

2.4.1 General characteristic features

- The plant body of bryophyte is gametophyte and is not differentiated into root, stem and leaf like structure.
- Most of them are primitive land dwellers. Some of them are aquatic (*Riella, Ricciocarpus*).
- The gametophyte is conspicuous, long lived phase of the life cycle. Thalloid forms are present in liverworts and Hornworts. In Mosses leaf like, stem like structures are present. In Liverworts thallus grows prostrate on the ground and is attached to the substratum by means of rhizoids. Two types of rhizoids are present namely smooth walled and pegged or tuberculate. Multicellular scales are also present. In Moss the plant body is erect with central axis bearing leaf like expansions. Multicellular rhizoids are present. The structure and reproduction in Bryophytes is given in Figure 2.8
- Vascular tissue like xylem and phloem are completely absent, hence called 'Non vascular cryptogams'.
- Vegetative reproduction takes place by the formation of adventitious buds (*Riccia fluitans*) tubers develop in *Anthoceros.* In some forms small detachable branches or brood bodies are formed, they help in vegetative reproduction as in *Bryopteris fruticulosa*. In *Marchantia* propagative organs called gemmae are formed and help in reproduction.
- Sexual reproduction is oogamous. Antheridia and Archegonia are produced in a protective covering and are multicellular.
- The antheridia produces biflagellate antherozoids which swims in thin film of water and reach the archegonium and fuse with the egg to form diploid zygote.
- Water is essential for fertilization.
- The zygote is the first cell of the sporophyte generation. It undergoes mitotic division to form multicellular undifferentiated embryo. The embryogeny is exoscopic (the first division of the zygote is transverse and the apex of the embryo

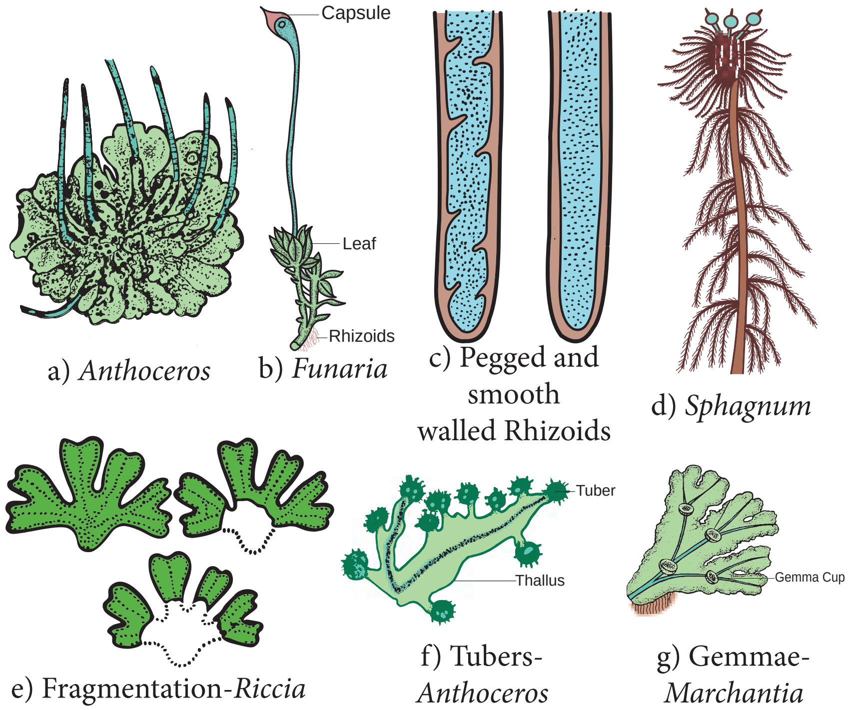


Figure 2.8: Structure and reproduction in Bryophytes

develops from the outer cell). The embryo divides and give rise to sporophyte.

- The sporophyte is dependent on gametophyte.
- It is differentiated into three recognizable parts namely foot, seta and capsule.
- Foot is the basal portion and is embedded in the gametophyte through which water and nutrients are supplied for the sporophyte. The diploid spore mother cells found in the capsule region undergoes meiotic division and give rise to haploid spores. Bryophytes are homosporous. In some sporophytes elaters are present and help in dispersal of spores (Example: *Marchantia*). The spores germinate to produce gametophyte.
- The zygote, embryo and the sporogonium constitute sporophytic phase. The green long living haploid phase is called gametophytic phase. The haploid gametophytic phase alternates with diploid sporophyte and shows heterologous alternation of generation.

2.4.2 Classification of Bryophytes

Proskauer in the year 1957 classified Bryophytes into 3 Classes namely

i. **Hepaticopsida** (*Riccia, Marchantia, Porella* and *Riella*)

ii. **Anthocerotopsida** (*Anthoceros* and *Dendroceros*)

iii. **Bryopsida** (*Funaria, Polytrichum* and *Sphagnum*).

The outline of the classification is given below

Bryophyta

Hepaticopsida (Liverworts)	Anthocerotopsida (Hornworts)	Bryopsida (Mosses)

Class: Hepaticopsida

They are lower forms of Bryophytes. They are more simple in structure than mosses and more confined to damp and shady places. They have an undifferentiated thallus. Protonernal stage is absent. Sporophyte is very simple and short lived. In some, the foot and seta are absent. Example *Riccia*.

Class: Anthocerotopsida

Gametophyte is an undifferentiated thallus. Rhizoids are unicellular and unbranched. Protonemal stage is absent. Sporophyte is differentiated into foot and capsule and seta is absent Example: *Anthoceros*.

Class: Bryopsida

These are higher forms in which the gametophyte is differentiated into 'stem' like and 'leaf' like parts and the former showing radial symmetry. Rhizoids are multi-cellular and branched. Protonemal stage is present. Sporophyte is differentiated into foot, seta and capsule. They have more differentiated structure than liverworts. They often form dense cushions. Example: *Funaria*.

2.4.3 Economic importance

Dead thalli of *Sphagnum* gets accumulated and compressed, hardened to form peat. In northern Europe (Netherlands)peat is used as fuel in commercial scale. Apart from this nitrates, brown dye and tanning materials are derived from peat. *Sphagnum* and peat are also used in horticulture as packing material because of their water holding capacity. *Marchantia polymorpha* is used to cure pulmonary tuberculosis. *Sphagnum*, *Bryum* and *Polytrichum* are used as food. Bryophytes play a major role in soil formation through succession and help in soil conservation.

DO YOU KNOW? *Buxbaumia aphylla* and *Cryptothallus mirabilis* are saprophytic bryophytes

2.4.4 Marchantia

Class - Hepaticopsida
Order - Marchantiales
Family - Marchantiaceae
Genus - *Marchantia*

Marchantia grows in cool moist shady places. *Marchantia polymorpha* is the common species.

Gametophyte

The plant body of *Marchantia* is a gametophyte. It is prostrate,dorsiventral and dichotomously branched. The thallus on the dorsal surface possess conspicuous median midrib which is marked by a shallow groove on dorsal surface. The dorsal surface appears to have rhomboidal or polygonal diamond shaped areas which indicate the outline of the underlying air chambers of the thallus (Figure 2.9).

The dorsal surface also shows crescent shaped structures called gemma cups which contain vegetative reproductive structures called gemmae. The apical notch bears an apical cell which helps in the growth of the thallus.The ventral surface the thallus bears multicellular scales and rhizoids which help in fixation and absorption of water and minerals. The rhizoids are of two types namely smooth walled or pegged (tuberculate) type. On maturation the thallus bears erect antheriophores and archegoniophores.

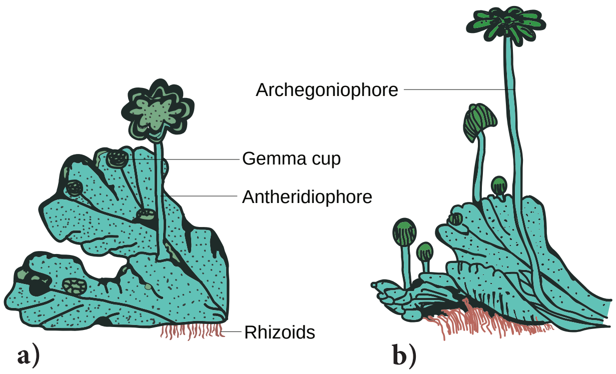


Figure 2.9: *Marchantia*
a) Thallus with antheridiophore
b) Thallus with archegoniophore

Internal structure of Thallus

In transverse section the *Marchantia* thallus shows three parts namely: epidermis, photosynthetic region and storage region (Figure 2.10).

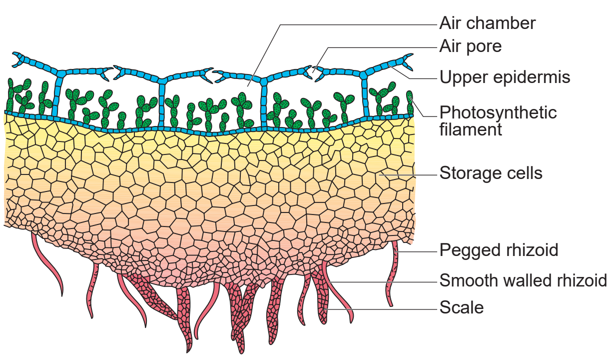


Figure 2.10: T.S. of Thallus

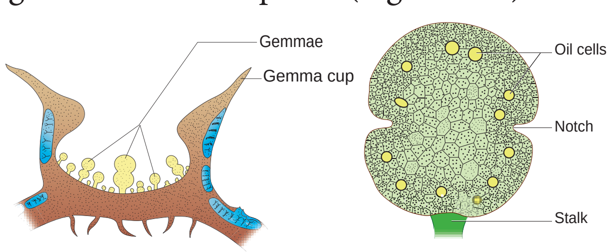
The epidermis has the upper and lower layers. The upper epidermis is single layered with thin walled parenchymatous cells. The cells possess chloroplasts. The upper epidermis is interrupted by many barrel shaped air pores which communicate with the air chambers. The pore is surrounded by 4 to 8 superimposed tiers of cells. Below the upper epidermis a number of air chambers are present in a single horizontal layer.

The floor of the chambers bears simple or branched green filaments. Cells of filaments are involved in photosynthesis. The photosynthetic region is followed by storage region. It is made up of several parenchymatous cells arranged without intercellular spaces. The cells of this region contain starch grains and protein granules. The lower epidermis possesses rhizoids and multicellular scales.

Reproduction

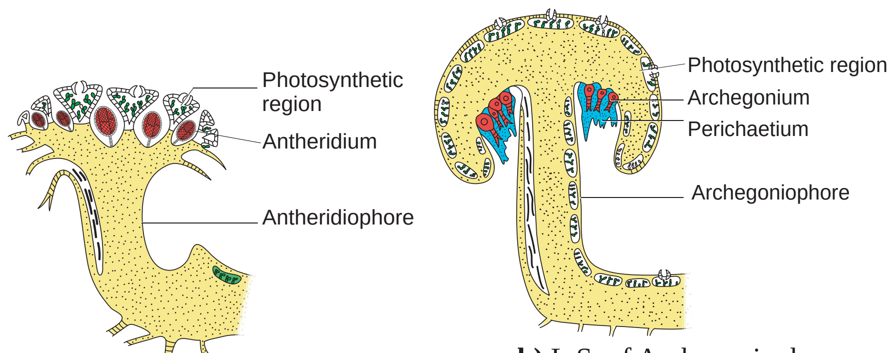
Marchantia reproduces by vegetative and sexual methods.

1.Vegetative reproduction takes place by progressive death and decay of thallus, formation of adventitious branches and by germination of gemmae. Death and decay of the thallus starts from posterior end. When it reach the point of dichotomy, two apical parts of the thallus get separated. Each one develops into an independent thallus. Adventitious branches are produced on the ventral surface of the gametophyte. The branches get separated from the parent thallus and grow into independent gametophytes. Gemmae are specialized multicellular asexual reproductive bodies. They are formed in small cupules known as gemma cups, present on the dorsal surface of the thallus. Usually the gemmae present on the male thallus form male plants and those on the female thallus give rise to female plants (Figure 2.11).



a) V.S. of Gemma cup **b)** A gemma enlarged

Figure 2.11: Vegetative reproduction in *Marchantia*



a) L.S. of Antheridiophore **b)** L.S. of Archegoniophore

Figure 2.12: *Marchantia* - Sex organs

1. Sexual reproduction:

In *Marchantia*, sex organs are borne on special stalked receptacles called the gametophores. Those bearing antheridia are called antheridiophores and archegonia bearing structures are called archegoniophores (Figure 2.12). *Marchantia* is heterothallic or dioecious. i.e., male and female receptacles are present on different thalli. The sex organs in bryophytes are multicellular. The Male sex organ is called antheridium. It produce biflagellate antherozoids. The Female sex organ is flask shaped called archegonium and produces a single egg. Water is essential for fertilization. The antherozoids are released into water and are attracted towards archegonium through chemotaxis. Although many antherozoids enter the archegonium, only one fuses with the egg to form zygote. The zygote represents the first cell of the sporophytic generation. Zygote develops in to a multicellular structure called sporophyte. (Figure 2.13).

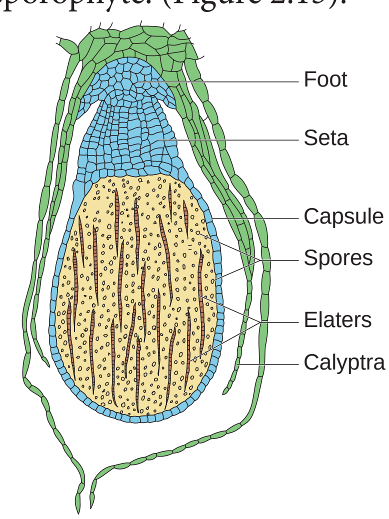


Figure 2.13: *Marchantia* - V.S. of Sporophyte

The sporophyte is not free-living but attached to the photosynthetic gametophyte and derives nutrition from it. Sporophyte is differentiated into foot, seta and capsule. The foot is bulbous and is embedded in the gametophyte. It derives nutrition from the gametophyte and transfers to the sporophyte. Seta is short and connects foot and capsule. The capsule consists of single layered jacket layer and encloses numerous haploid spores and elaters. The capsule is covered by protective covering called calyptra. On maturation the capsule dehisces and spores are released. Elaters helps in the dispersal of spores. The spores under favourable conditions germinate and develop into new gametophyte. The haploid gametophytic phase alternates with diploid sporophytic phase, thus the life cycle of *Marchantia* shows alternation of generation (Figure 2.14).

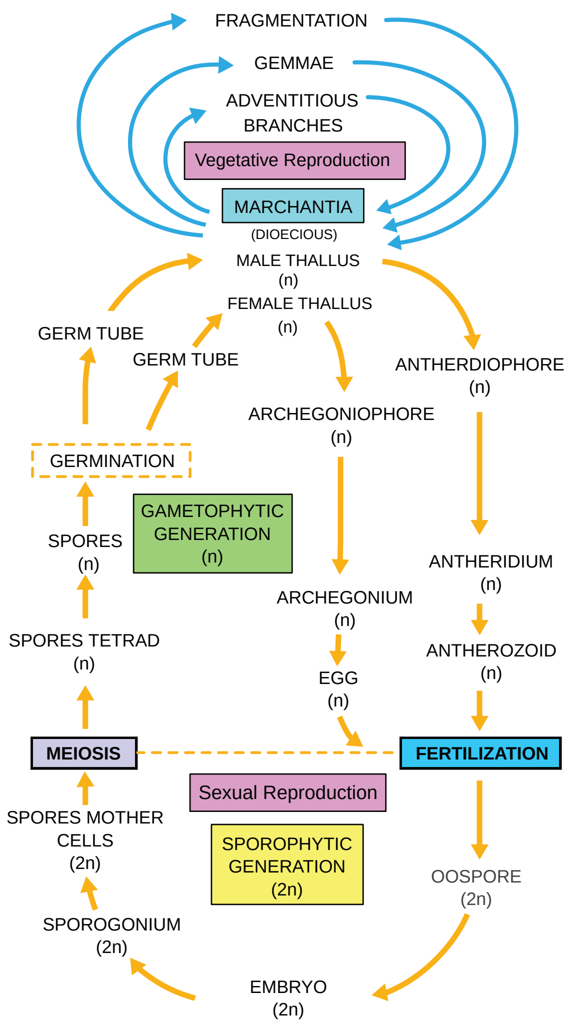


Figure 2.14: Life cycle of *Marchantia*

2.5 Pteridophytes

Seedless Vascular Cryptogams

From the previous section, we are aware of the salient features of amphibious plants called bryophytes. But there is a plant group called pteridophytes which are considered as first true land plants. Further, they were the first plants to acquire vascular tissue namely xylem and phloem, hence called vascular cryptogams. Club moss, horsetails, quill worts, water ferns and tree ferns belong to this group. This chapter deals with the characteristic features of Pteridophytes.

Pteridophytes are the vascular cryptogams and were abundant in the Devonian period of Palaeozoic era (400 million years ago). These plants are mostly small, herbaceous and grow well in moist, cool and shady places where water is available. The photographs for some pteridophytes are given in Figure 2.15.

a) *Lycopodium* (club moss) b) *Equisetum* (Horse tail) c) *Azolla* (Water fern)

Figure 2.15: Pteridophytes

2.5.1 General characteristic features of Pteridophytes:

- Plant body is sporophyte (2n) and it is the dominant phase. It is differentiated into root, stem and leaves.
- Roots are adventitious.
- Stem shows monopodial or dichotomous branching.
- Leaves may be microphyllous or megaphyllous.
- Stele is protostele but in some forms siphonostele is present (*Marsilea*)
- Tracheids are the major water conducting elements but in *Selaginella* vessels are found.

- Sporangia, spore bearing bag like structures are borne on special leaves called sporophyll. The Sporophylls get organized to form cone or strobilus. Example: *Selaginella*, *Equisetum* .
- They may be **homosporous** (produce one type of spores-*Lycopodium*) or **Heterosporous** (produce two types of spores-*Selaginella*). Heterospory is the origin for seed habit.
- Development of sporangia may be **eusporangiate** (development of sporangium from group of initials) or **leptosporangiate** (development of sporangium from single initial).
- Spore mother cells undergo meiosis and produce spores (n).
- Spore germinates to produce haploid, multicellular green, cordate shaped independent gametophytes called prothallus.
- Fragmentation, resting buds, root tubers and adventitious buds help in vegetative reproduction.
- Sexual reproduction is oogamous. Sex organs, namely antheridium and archegonium are produced on the prothallus.
- Antheridium produces spirally coiled and multiflagellate antherozoids.
- Archegonium is flask shaped with broad venter and elongated narrow neck. The venter possesses egg or ovum and neck contain neck canal cells.
- Water is essential for fertilization. After fertilization a diploid zygote is formed and undergoes mitotic division to form embryo.
- Pteridophytes show **apogamy** and **apospory.**

2.5.2 Classification of Pteridophytes

Reimer (1954) proposed a classification for pteridophytes. In this classification, the pteridophytes are divided into five subdivisions. 1. Psilophytopsida 2. Psilotopsida 3. Lycopsida 4. Sphenopsida 5. Pteropsida. There are 19 orders and 48 families in the classification.

2.5.3 Economic Importance

The Economic importance of Pteridophyte is given in Table 2.4

Table 2.4: Economic importance of Pteridophyte

Pteridophyte	Uses
Rumohra adiantiformis (leather leaf fern)	Cut flower arrangements.
Marsilea	Food
Azolla	Biofertilizer.
Dryopteris filix–mas	Treatment for tapeworm.
Pteris vittata	Removal of heavy metals from soils - Bioremediation
Pteridium sp.	Leaves yield green dye.
Equisetum sp.	Stems for scouring.
Psilotum, Lycopodium, Selaginella, Angiopteris, Marattia	Ornamental plants

2.5.4 Selaginella

Division – Lycophyta
Class – Ligulopsida
Order – Selaginellales
Family –Selaginellaceae
Genus – *Selaginella*

Selaginella is commonly called 'spike moss'. They are distributed in humid temperate and tropical rain forests. *Selaginella rupestris* and *Selaginella lepidophylla* are Xerophytic. *Selaginella kraussiana*, *Selaginella chrysocaulos*, *Selaginella megaphylla* are some common species. In few *Selaginella* species during dry season the entire plant body gets curled and become fresh, green when moisture is available. Due to this they are called **Resurrection plants**. Example *S. lepidophylla*

External morphology

Habit

The plant body of *Selaginella* is sporophyte (2n) and it is differentiated into root, stem, and leaves (Figure 2.16). There exist variations in the habit of *Selaginella*. Some species possess

Division- **PTERIDOPHYTA**

Sub division

Psilophytopsida	Psilotopsida	Lycopsida	Sphenopsida	Pteropsida
All are extinct plants. Plant body had only stem and rhizome. Roots and leaves were absent. Homosporous Spore tetrads were borne at the terminal sporangia. Example: *Rhynia*.	The plant body is rootless and have fungal association. Small, scaly appendages represent the leaves. Gametophyte is colourless and have fungal association. They are homosporous and spores are produced in sporangia or synangia. Example: *Psilotum*.	The plant body is differentiated into root, stem and leaves. Leaves are small, univeined, spirally arranged. Ligules are present. Sporophylls are arranged in the form of strobilus. Both homospory (*Lycopodium*) and heterospory (*Selaginella*) are found. Example: *Selaginella*.	The plant body is differentiated into root, stem and leaves. Stem shows jointed nodes and internodes. Small, scaly leaves are arranged at nodes in whorls. Peltate disc of sporangiophore possess compact strobilus. Homosporous but incipient heterospory is found in *Equisetum arvense*.	The plant body is differentiated into root, stem and leaves. Includes all the megaphyllous pteridophytes. leaf gap is present sporangia are organized into sorus. Both homosporus and heterosporus forms are present. Example: *Marsilea*

prostrate creeping system (*S. kraussiana*); suberect (*S. rupestris*); erect (*Selaginella erythropus*); climbing (*Selaginella alligans*). *S. oregana* is an epiphyte. Most of the species are perennials. On the basis of structure of stem and arrangement of leaves, *Selaginella* is divided into two sub genera namely Homoeophyllum and Heterophyllum.

DO YOU KNOW?

The success and dominance of vascular plants is due to the development of
- Extensive root system.
- Efficient conducting tissues.
- Cuticle to prevent desiccation.
- Stomata for effective gaseous exchange.

Homeophyllum include species with erect stem and spirally arranged leaves. (Example: *S. upestris* and *S. oregana*). Heterophyllum include species with prosrate stem with short erect branches and dimorphic leaves (Example: *S. kraussiana* and *S. lepidophylla*).

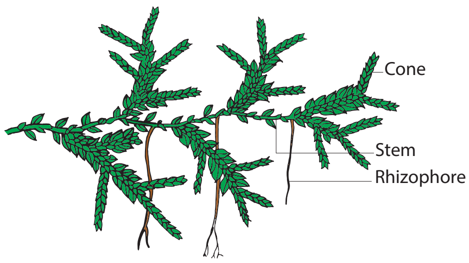


Figure 2.16: *Selaginella* Habit

Root

Primary roots are short lived and the adult plant has adventitious roots. The root may arise at the point of dichotomous branching or knot like swelling present at the basal portion of the stem. Roots are endogenous in origin.

Rhizophore

In many species long, cylindrical, unbranched and leafless structures arise from the lower side of the stem at the point of dichotomy called rhizophores. They grow vertically downwards and produce tufts of adventitious roots.

Stem

The stem may be erect, dichotomously branched or prostrate with lateral branching. The prostrate stem is dorsiventral.

Leaves

The leaves are microphyllous, sessile and simple. A single midvein is present in the leaves. The vegetative leaf as well as the sporophyll bears a small membranous tongue like structure on adaxial surface called **ligule**. The basal part of the ligule possess a hemispherical mass of thin walled cells called **glossopodium**. The function of ligule is not known, but it is viewed to be associated with water absorption, secretion and prevent dessication of shoot. The members belonging to homeophyllum type possess same type of leaves spirally arranged on the stem whereas the heterophyllum type have two types of leaves- two dorsal rows of small leaves(Microphylls) and two ventral rows of large leaves(Megaphylls).

Internal structure

Root

The transverse section of the root reveals an outermost layer called epidermis. It is made up of tangentially elongated cells. The cortex is homogeneous made up of thin walled parenchyma. The innermost layer of cortex is called endodermis. The stele is a protostele, monarch and xylem is exarch (Figure 2.17).

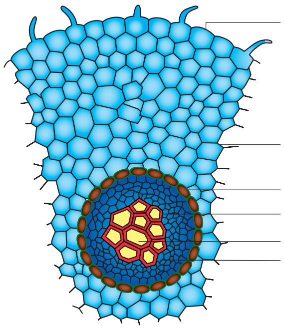


Figure 2.17: T.S. of root

Stem

The anatomy of the stem reveals the presence of epidermis, cortex and stelar region (Figure 2.18).

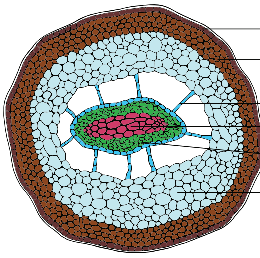


Figure 2.18: T.S. of Stem

The epidermis is parenchymatous and is covered with a thick cuticle. The cortex is parenchymatous with cells arranged without intercellular spaces. A sclerenchymatous hypodermis is noticed in *Selaginella lepidophylla*. The presence of radially elongated endodermal cells called **trabeculae** is the characteristic feature of *Selaginella*. The casparian strips are found on the lateral walls. The rapid stretching of the innermost cortical cells in comparison with stele results in air spaces and stele appears to be suspended in air space with the help of trabeculae. The stele is a protostele and exarch. A variation in number of steles is found. It may be monostelic (*S. spinulosa*); distelic (*S. kraussiana*) or polystelic (*S. laevigata*). The xylem is monarch(*S. kraussiana*) or diarch (*S. oregana*). Tracheids are present but vessels are also noticed in *S. densa* and *S. rupestris*.

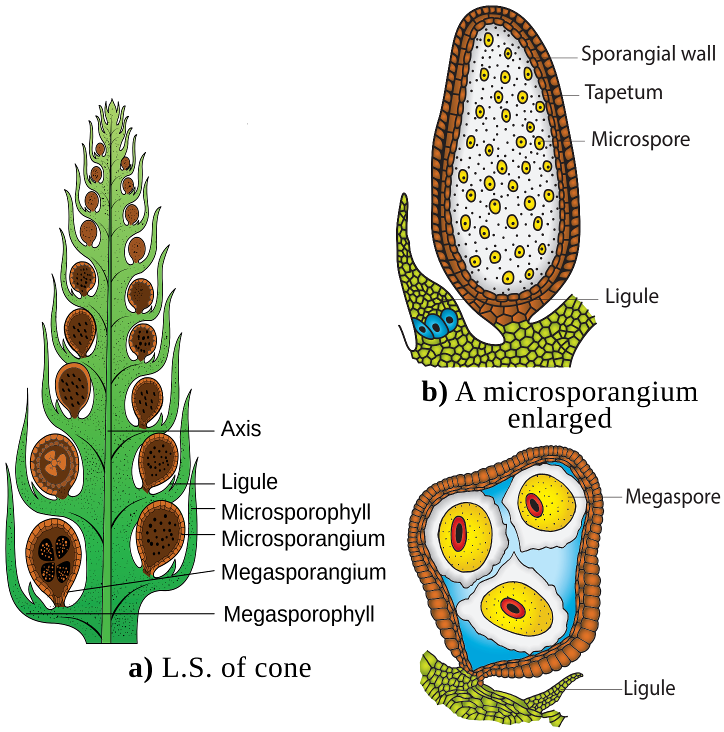
Leaf

The leaf shows upper and lower epidermis. The epidermal cells have chloroplast. Stomata occur on both surfaces. The mesophyll is made up of loosely arranged thin walled cells with intercellular spaces. There is a median vascular bundle surrounded by a bundle sheath. In vascular bundle xylem is surrounded by phloem.

Reproduction

Vegetative reproduction

Selaginella reproduces vegetatively by fragmentation, bulbil formation, tuber formation and resting buds.



a) L.S. of cone

b) A microsporangium enlarged

c) A megasporangium enlarged

Figure 2.19: Reproduction in *Selaginella*

Sexual reproduction

During sexual reproduction spores are produced (Figure 2.19). *Selaginella* is heterosporous and produces two types of spores namely microspores in microsporangium and megaspores in megasporangium. The sporangia are borne singly in the axils of microsporophyll and megasporophyll respectively. The sporophylls are arranged spirally around a central axis and aggregate to form strobili or cones. Variations in the distribution of microsporangia and megasporangia among the species are seen. In S. *selaginoides* and *S. rupestris* megasporangia are present in the basal part of the cone. *S. kraussiana* possesses a single megasporangium at the base of the strobilus. In *S. inaequifolia* one side of the strobilus bear only megasporangia and other microsporangia. Separate strobili for microsporangia and megasporangia are present in *S. gracilis.* and *S. atro-viridis*.

The development of sporangium is of eusporangiate type. The sporangial initial divides periclinally to form outer jacket initials and inner archesporial initials. The archesporial initials by repeated anticlinal and periclinal divisions form sporogenous cells. Microspore mother cells of microsporangium undergo reduction division to produce halpoid microspores. Similarly the megaspore mother cell undergoes reduction division to produce 4 haploid megaspores. The microspore and megaspore represent the male and female gametophyte and germinate inside the sporangium. The microspores produce biflagellate antherozoids. Archegonia develop in the female gametophyte. The antherozoids swim in water and reach the archegonium. Fertilization brings the fusion of male and female nucleus which result in the formation of a diploid zygote. The diploid zygote represents the first cell of sporophyte. It undergoes several mitotic division to form embryo. The embryo develops into a mature sporophytic plant.

In the life cycle of *Selaginella* alternation of sporophytic and gametophytic generation is present (Figure 2.20).

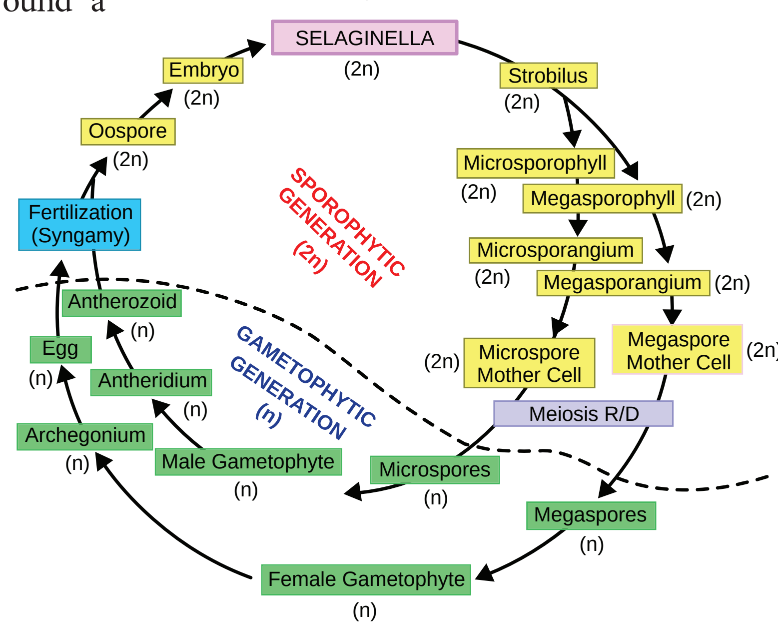


Figure 2.20: Life cycle of *Selaginella*

2.5.5 Types of Stele

The term stele refers to the central cylinder of vascular tissues consisting of xylem, phloem, pericycle and sometimes medullary rays with pith (Figure 2.21).

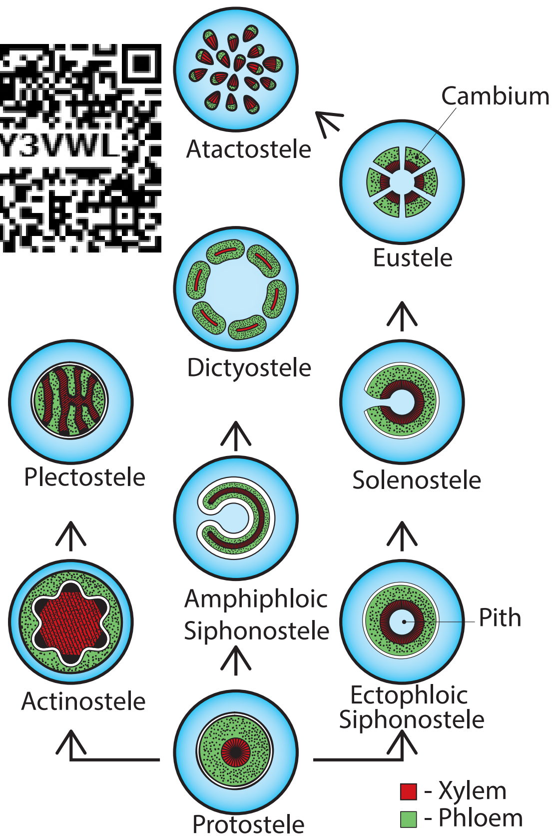


Figure 2.21: Types of Stele

There are two types of steles

1. Protostele 2. Siphonostele

1. Protostele:

In protostele phloem surrounds xylem. The type includes Haplostele, Actinostele, Plectostele, and Mixed protostele.

(i) **Haplostele**: Xylem surrounded by phloem is known as haplostele. Example: *Selaginella.*

(ii) **Actinostele**: Star shaped xylem core is surrounded by phloem is known as actinostele. Example: *Lycopodium serratum.*

(iii) **Plectostele**: Xylem plates alternates with phloem plates. Example: *Lycopodium clavatum.*

(iv) **Mixed prototostele**: Xylem groups uniformly scattered in the phloem. Example: *Lycopodium cernuum.*

2. Siphonostele:

In siphonostele xylem is surrounded by phloem with pith at the centre. It includes Ectophloic siphonostele, Amphiphloic siphonostele, Solenostele, Eustele, Atactostele and Polycylic stele.

(i) Ectophloic siphonostele: The phloem is restricted only on the external side of the xylem. Pith is in centre. Example: *Osmunda.*

(ii) Amphiphloic siphonostele: The phloem is present on both the sides of xylem. The pith is in the centre. Example: *Marsilea.*

(iii) Solenostele: The stele is perforated at a place or places corresponding the origin of the leaf trace.

(a) **Ectophloic solenostele** – Pith is in the centre and the xylem is surrounded by phloem Example *Osmunda*.

(b) Amphiphloic solenostele – Pith is in the centre and the phloem is present on both sides of the xylem. Example: *Adiantum pedatum*.

(c) **Dictyostele** – The stele is separated into several vascular strands and each one is called meristele. Example: *Adiantum capillus-veneris*.

(iv) Eustele: The stele is split into distinct collateral vascular bundles around the pith. Example: Dicot stem.

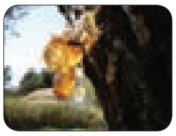
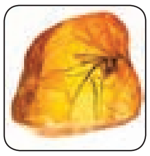
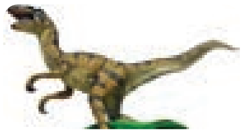
(v) **Atactostele**: The stele is split into distinct collateral vascular bundles and are scattered in the ground tissue. Example: Monocot stem.

(vi) Polycyclicstele: The vascular tissues are present in the form of two or more concentric cylinders. Example: *Pteridium*.

2.6 Gymnosperms

Naked seed producing Plants

Michael Crichton's Science Fiction is a book transformed into a Film of Steven Spielberg (1993) called **Jurassic Park**. In this film you might have noticed insects embedded in a transparent substance called amber which preserves the extinct forms. What is amber? Which group of plants produces Amber?

Amber is a plant secretion which is an efficient preservative that doesn't get degraded and hence can preserve remains of extinct life forms. The amber is produced by ***Pinites succinifera***, a Gymnosperm.

In this chapter we shall discuss in detail about one group of seed producing plants called **Gymnosperms**.

Gymnosperms (Gr. Gymnos = naked; sperma= seed) are naked seed producing plants. They were dominant in the Jurassic and Cretaceous periods of Mesozoic era. The members are distributed throughout the temperate and tropical region of the world

2.6.1 General characteristic features

- Most of the gymnosperms are evergreen, woody trees or shrubs. Some are lianas (*Gnetum*)
- The plant body is sporophyte and is differentiated into root, stem and leaves.
- A well developed tap root system is present. Coralloid roots of *Cycas* have symbiotic association with blue green algae. In *Pinus* the roots have mycorrhizae.
- The stem is aerial, erect and branched or unbranched (*Cycas*) with leaf scars.
- In conifers two types of branches namely branches of limited growth (Dwarf shoot) and Branches of unlimited growth (Long shoot) is present.
- Leaves are dimorphic, foliage and scale leaves are present. Foliage leaves are green, photosynthetic and borne on branches of limited growth. They show xerophytic features.
- The xylem consists of tracheids but in *Gnetum* and *Ephedra* vessels are present.
- Secondary growth is present. The wood may be **Manoxylic** (Porous, soft, more parenchyma with wide medullary ray -*Cycas*) or **Pycnoxylic** (compact with narrow medullary ray-*Pinus*).
- They are heterosporous. The plant may be monoecious (*Pinus*) or dioecious (*Cycas*).
- Microsporangia and megasporangia are produced on microsporophyll and megasporophyll respectively.
- Male and female cones are produced.
- Anemophilous pollination is present.
- Fertilization is siphonogamous and pollen tube helps in the transfer of male nuclei.
- Polyembryony (presence of many embryo) is present. The naked ovule develops into seed. The **endosperm** is haploid and develop before fertilization.
- The life cycle shows alternation of generation. The sporophytic phase is dominant and gametophytic phase is highly reduced. The photograph of some of the gymnosperms is given in Figure 2.22


a) *Taxus*


b) *Ginkgo*

Figure 2.22: Gymnosperms

2.6.2 Classification of Gymnosperms

Sporne (1965) classified gymnosperms into 3 classes, 9 orders and 31 families. The classes include i) Cycadospsida ii) Coniferopsida iii) Gnetopsida.

GYMNOSPERMS		
Class-I	Class-II	Class-III
Cycadopsida	**Coniferopsida**	**Gnetopsida**
Orders: 1. Pteridospermales 2. Bennettitales 3. Pentoxylales 4. Cycadales	Orders: 1. Cordaitales 2. Coniferales 3. Taxales 4. Ginkgoales	Order: 1. Gnetales

General Characters of Main classes:

Class I – Cycadopsida

- Plants are palm-like or fern-like.
- Compound, frond-like pinnate leaves.
- Manoxylic wood.

- Sperms are motile.
- Flower like structures are absent. Strobili are simple.
  Example: *Cycas, Zamia*.

Class II – Coniferopsida

- Tall trees with simple leaves of varied shape.
- Wood is pycnoxylic.
- Cone like strobili are present.
- Motile sperms are absent (except *Ginkgo biloba*). Example: *Pinus*.

Class III – Gnetopsida

- Shrubs, trees and lianas.
- Leaves are elliptical or strap-shaped, simple, opposite or whorled.
- Motile sperms are absent.
- Wood contains vessels.
- Strobili is called as inflorescence.
- Flower like structure with perianth is present. Example: *Gnetum, Ephedra*.

2.6.3 Comparison of Gymnosperm with Angiosperms

Gymnosperms resemble with angiosperms in the following features

- Presence of well organised plant body which is differentiated into roots, stem and leaves.
- Presence of cambium in gymnosperms as in dicotyledons.
- Flowers in *Gnetum* resemble the male flower of the angiosperm. The zygote represent the first cell of sporophyte.
- Presence of integument around the ovule.
- Both plant groups produce seeds.
- Pollen tube helps in the transfer of male nucleus in both.
- Presence of eustele.

The difference between Gymnosperms and Angiosperms were given in Table 2.5

Table 2.5: Difference between Gymnosperms and Angiosperms

S.No	Gymnosperms	Angiosperms
1.	Vessels are absent [except Gnetales]	Vessels are present
2.	Phloem lacks companion cells	Companion cells are present
3.	Ovules are naked	Ovules are enclosed within the ovary
4.	Wind pollination only	Insects, wind, water, animals etc., act as pollinating agents
5.	Double fertilization is absent	Double fertilization is present
6.	Endosperm is haploid	Endosperm is triploid
7.	Fruit formation is absent	Fruit formation is present
8.	Flowers absent	Flowers present

2.6.4 Economic importance of Gymnosperms

Table 2.6: Economic importance of Gymnosperms

S.No	Plants	Products	uses
1.	*Cycas circinalis, Cycas revoluta*	Sago	Starch used as food
2.	*Pinus gerardiana*	Roasted seed	Used as a food
3.	*Abies balsamea*	Resin (Canada balsam)	Used as mounting medium in permanent slide preparation
4.	*Pinus insularis, Pinus roxburghii*	Rosin and Turpentine	Paper sizing and varnishes
5.	*Araucaria* (Monkey's puzzle), *Picea* and *Phyllocladus*	Tannins	Bark yield tannins and is used in Leather industries
6.	*Taxus brevifolia*	Taxol	Drug used for cancer treatment

7.	*Ephedra gerardiana*	Ephedrine	For the treatment of asthma, bronchititis
8.	*Pinus roxburghii*	Oleoresin	Used to make soap, varnishes and printing ink
9.	*Pinus roxburghii, Picea smithiana*	Wood pulp	Used to make papers
10.	*Cedrus deodara*	wood	Used to make doors, boats and railway sleepers
11.	*Cedrus atlantica*	oil	Used in perfumery
12	*Thuja, Cupressus, Araucaria, and Cryptomeria*	whole plant	Ornamental plants/Floral Decoration

2.6.5 Cycas

Class – Cycadopsida
Order – Cycadales
Family- Cycadaceae
Genus - *Cycas*

It is widely distributed in tropical and sub tropical region of eastern hemisphere of the world. *Cycas revoluta*, *Cycas beddomei*, *Cycas circinalis, Cycas rumphii* are some of the common species. The plant body is sporophyte and resemble a small palm. The growth is very slow. It is evergreen and xerophytic in nature.

Sporophyte

The sporophyte is differentiated into root, stem and leaves. The stem is columnar bearing a crown of spirally arranged pinnately compound leaves (Figure 2.23).

External features

Root

Two types of roots are found in *Cycas*. They are the tap root and coralloid root.

The primary root persists and forms the tap root. Some of the lateral roots give rise to branches which grow vertically upward below the ground level. They branch repeatedly to form dichotomously branched coral- like roots called coralloid roots. The cortical region of the coralloid root contains the Blue green alga – *Anabaena* sp. which helps in nitrogen fixation (Figure 2.24).

Figure 2.23: *Cycas* Habit

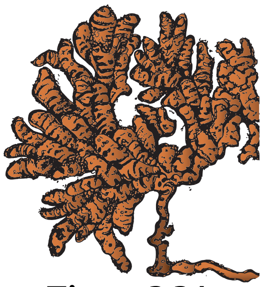


Figure 2.24: Coralloid root

Stem

The stem is columnar, unbranched and woody. It is covered with persistent woody leaf bases. The stem also bears adventitious buds at the base.

Leaves

Cycas has two types of leaves

(i) Foliage or assimilatory leaves
(ii) Scale leaves

(i) Foliage or assimilatory leaves

Foliage leaves are large, pinnately compound and form a crown at the top of the stem. Each leaf has 80-100 pairs of sessile leaflets. The apex is acute or spiny. The leaflet has a single midvein. Lateral veins are absent. Circinate vernation is present and young leaves are covered with **ramenta**.

(ii) Scale leaves

Scale leaves are brown, small, triangular and persistent which are protective in function. They are covered with ramenta.

Internal structure

T.S. of Root

The internal organization of the primary root reveals the following parts. 1. Epiblema,

2. Cortex 3. Vascular region (Figure 2.25). Epiblema is the outermost layer and is made up of single layered parenchyma. It is followed by thin walled parenchymatous cortex. The cortex is delimited by single layered endodermis. A multilayered parenchymatous pericycle is present and it surrounds the vascular tissue. The xylem is diarch in young root and tetrarch in older ones. Secondary growth is present. Coralloid root also shows similar structure but the middle cortex is characterized by the presence of Algal zone. Blue green alga called, *Anabaena* is found in this zone. The xylem is triarch and exarch.

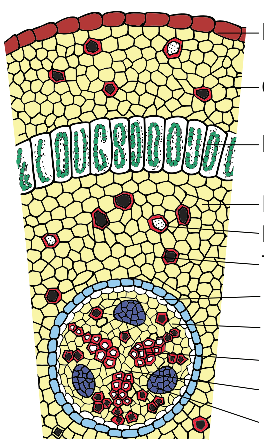


Figure 2.25: T.S. of Coralloid root

T.S. of Stem

The cross section of young stem is irregular in outline due to the presence of persistent leaf bases. It is differentiated into epidermis, cortex and vascular cylinder. It resembles the structure of a dicot stem (Figure 2.26).

The epidermis is the outermost layer and is covered with thick cuticle. It is discontinuous due to the presence of leaf bases. The cortex constitutes the major part and is made up of thin walled parenchymatous cells. The cells are filled with starch grains. Cortex also possesses several mucilage ducts and tannin cells. In young stem the vascular bundles are arranged in the form of a ring. A broad medullary ray is present. The vascular bundles are conjoint, collateral, endarch and open. Xylem is made up of tracheids and phloem consists of sieve tubes and phloem parenchyma. Companion cells are absent. The cortical region shows a large number of leaf traces. The presence of direct leaf traces and girdling leaf trace is the unique feature of *Cycas* stem. Secondary growth results in polyxylic condition. Phellogen and cork are formed which replace the epidermis. The wood formed belongs to manoxylic type.

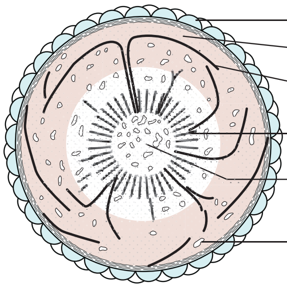


Figure 2.26: T.S. of stem

T.S. of Rachis

The outermost layer is epidermis and is covered by thick cuticle. The hypodermis is made up of two layers of sclerenchyma on the adaxial side and many layered on the abaxial side. The ground tissue is parenchymatous. The peculiar feature of the rachis is the arrangement of vascular bundle i.e., in an inverted Omega shape (Ω) pattern (Figure 2.27). Each vascular bundle is covered by a single layered sclerenchymatous bundle sheath. Vascular bundles are collateral, endarch and open. A diploxylic condition is present in the vascular bundles.(presence of both centripetal and centrifugal xylem).

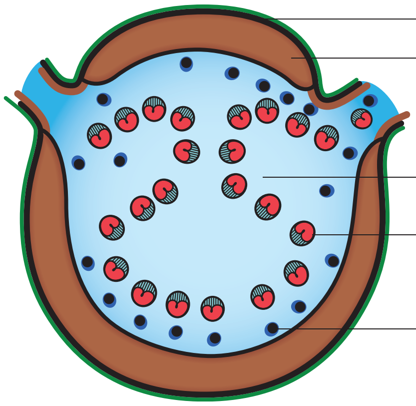


Figure 2.27: T.S. of Rachis

T.S. of Leaflet

The leaflet of *Cycas* in transverse section shows the presence of upper and lower epidermis. The epidermal cells are thick walled and are covered with thick cuticle. The lower epidermis is not continuous and is interrupted by **sunken stomata**. The hypodermis consists of sclerenchyma cells to prevent transpiration. The mesophyll is differentiated into palisade and spongy parenchyma. The cells of this layer are involved in photosynthesis. The spongy parenchyma present in close proximity to the lower epidermis bear large intercellular spaces which help in gaseous exchange.

Layers of colourless, elongated cells which run parallel to the leaf surface from the midrib to the margin of the leaflet are seen. These constitute the **Transfusion tissue** that helps in the lateral conduction of water. The vascular bundle has xylem facing upper epidermis and phloem facing lower epidermis. The protoxylem occupies the centre, hence the bundle is mesarch. The vascular bundle has a sclerenchymatous bundle sheath (Figure 2.28).

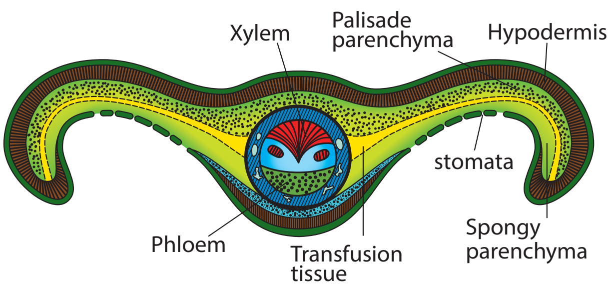


Figure 2.28: T.S. of leaflet

Reproduction

Cycas reproduces by both vegetative and sexual methods.

Vegetative reproduction

It takes place by adventitious buds or bulbils. They develop in the basal part of the stem. The bulbils on germination produce new plants.

Sexual reproduction

Cycas is dioecious i.e., male and female cones are produced in separate plants. It is heterosporous and produces two types of spores (Figure 2.29).

Male cone

The male cone or staminate cone are borne singly on the terminal part of the stem. The growth of the stem is continued by the formation of axillary buds at the base of the cone. The male cone is displaced to one side showing sympodial growth in the stem. Male cones are stalked, compact, oval or conical and woody in structure. It consists of several microphylls which are arranged spirally around a central cone axis.

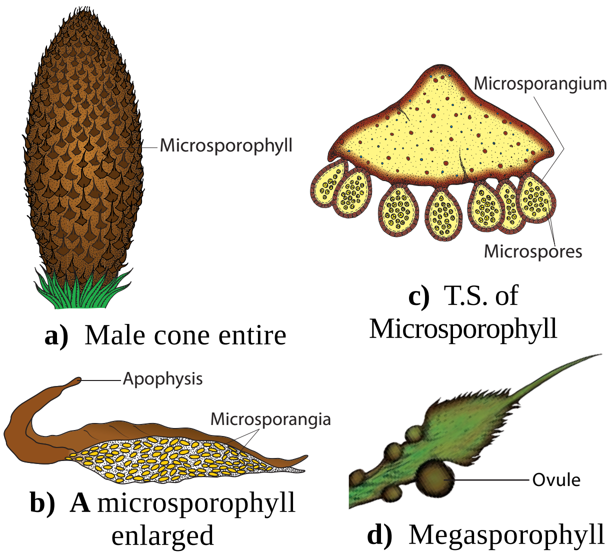


Figure 2.29: Reproduction in *Cycas*

Microsporophylls

Microsporophylls are flat, leaf-like and woody structures with narrow base and expanded upper portion. The upper expanded portion becomes pointed and is called apophysis. The narrow base is attached to the cone axis. Each microsporophyll contains thousands of microsporangia in groups called sori on abaxial (lower) surface. Development of sporangium is of eusporangiate type. The spore mother cell undergoes meiosis to produce halpoid microspores. Each microsporangium bears large number of microspores or pollen grains. Each microspore (Pollen grain) is a rounded, unicellular and uninucleate structure surrounded by outer thick exine and an inner thin intine. The microspore represents the male gametophyte.

Megasporophylls

The megasporophylls of *Cycas* are not organised into cones. They occur in close spirals around the tip of the stem of female plant. The megasporophylls are flat and measuring 15-30 cm in length. Each megasporophyll is differentiated into a basal stalk and an upper leaf like portion. The ovules are attached to the lateral side of the sporophyll. The ovules contain megaspore and it represent the female gametophyte.

Structure of Ovule

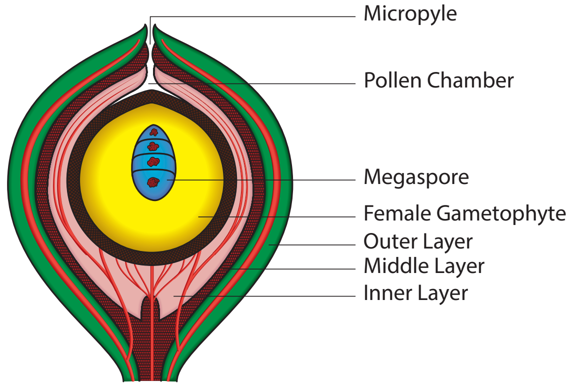


Figure 2.30: L.S. of Ovule

Cycas produces the largest ovule of the plant kingdom. The ovules are orthotropous, unitegmic and possess a short stalk. The single integument is very thick and covers the ovule leaving a small opening called *micropyle*. The integument consists of 3 layers, the outer and inner are fleshy (**sarcotesta**), the middle layer is stony called **sclerotesta**. The inner layer remains fused with the nucellus. The nucellus grows out into a beak-like structure and the upper part dissolves and forms a cavity-like structure called **pollen chamber**. A single megaspore mother cell undergoes meiosis to form four haploid megaspores. The lowermost becomes functional and others get degenerated. The nucellus gets reduced in the form of a thin papery layer in mature seeds and encloses the female gametophyte An enlarged megaspore or the embryo-sac is present within the nucellus. An archegonial chamber with 3-6 archegonia are present in the archegonial chamber below the pollen chamber (Figure 2.30).

Pollination and Fertilization

Pollination is carried out by wind and occurs at 3 celled stage(a prothallial cell, a large tube cell and a small generative cell). Pollen grains get lodged in the pollen chamber after pollination. The generative cell divides into a stalk and a body cell. The body cell divides to produce two large multiciliated antherozoids or sperms. During fertilization, one of the male gamete or multiciliated antherozoid fuses with the egg of the archegonium to form a diploid zygote (2n). The endosperm is haploid. The interval between pollination and fertilization is 4- 6 months. The zygote undergoes mitotic division and develops into embryo. The ovule is transformed into seed. The seed has two unequal cotyledons. Germination is hypogeal. The life cycle shows alternation of generations (Figure 2.31).

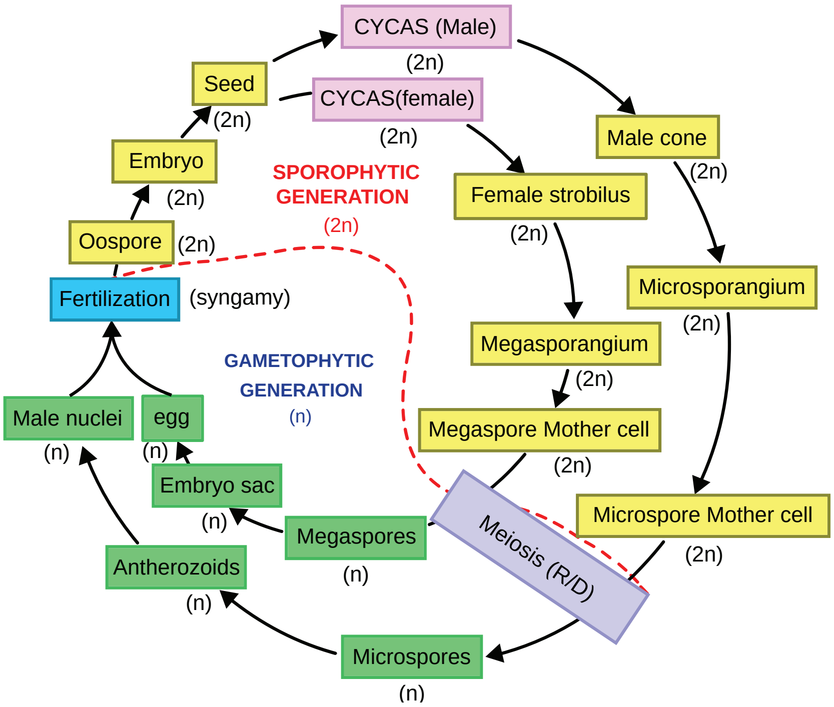


Figure 2.31: Life cycle of *Cycas*

Palaeobotany in India

The National wood fossil park is situated in Tiruvakkarai, a Village of Villupuram district of Tamil Nadu. The park contains petrified wood fossils approximately 20 million years old. The term 'form genera' is used to name the fossil plants because the whole plant is not recovered as fossils instead organs or parts of the extinct plants are obtained in fragments. Shiwalik fossil park-Himachal Pradesh, Mandla Fossil park-Madhya Pradesh, Rajmahal Hills–Jharkhand, Ariyalur – Tamilnadu are some of the fossil rich sites of India.

Some of the fossil representatives of different plant groups are given below

Fossil Algae - *Palaeoporella*, *Dimorphosiphon*

Fossil Bryophytes – *Naiadita, Hepaticites, Muscites*

Fossil Pteridophytes – *Cooksonia, Rhynia,, Baragwanthia, Calamites*

Fossil Gymnosperms – *Medullosa, Lepidocarpon, Williamsonia, Lepidodendron*

Fossil Angiosperms – *Archaeanthus, Furcula*

Prof. Birbal Sahni (1891-1949)

Father of Indian Palaeobotany. He described Fossil plants from Rajmahal Hills of Eastern Bihar. *Pentoxylon sahnii*, *Nipanioxylon* are some of the form genera described by him. Birbal Sahni Institute of Palaebotany is located in Lucknow.

2.7 Angiosperms

In the previous section, the characteristic features of one of the spermatophyte called Gymnosperms were discussed. Spermatophytes also include plants bearing ovules enclosed in a protective cover called ovary, such plants are called Angiosperms. They constitute major plant group of our earth and are adapted to the terrestrial mode of life. This group of plants appeared during the early cretaceous period (140 million years ago) and dominates the vegetation on a global scale. The sporophyte is the dominant phase and gametophyte is highly reduced.

2.7.1 Salient features of Angiosperms

- Vascular tissue (Xylem and Phloem) is well developed.
- Flowers are produced instead of cone
- The Ovule remains enclosed in the ovary.
- Pollen tube helps in fertilization, so water is not essential for fertilization.
- Double fertilization is present. The endosperm is triploid.
- Angiosperms are broadly classified into two classes namely Dicotyledons and Monocotyledons.

2.7.2 Characteristic features of Dicotyledons and Monocotyledons

Dicotyledons

Morphological features

Reticulate venation is present in the leaves. Presence of two cotyledons in the seed. Primary root radicle persists as tap root.

Flowers tetramerous or pentamerous.

Tricolpate (3 furrow) pollen is present.

Anatomical features

- Vascular bundles are arranged in the form of a ring in stem.
- Vascular bundles are open (Cambium present).
- Secondary growth is present.

Monocotyledons

Morphological features

Parallel venation is present in the leaves. Presence of single cotyledon in the seed. Radicle doesn't persist and fibrous root is present.

Flowers trimerous.
Monocolpate (1 furrow) Pollen is present.

Anatomical features

- Vascular bundles are scattered in the stem
- Vascular bundles are closed (Cambium absent).
- Secondary growth is absent.

Current Angiosperm Phylogeny Group (APG) System of classification doesn't recognize dicots as a monophyletic group. Plants that are traditionally classified under dicots are dispersed in several clades such as early Magnolids and Eudicots.

Summary

Plant Kingdom includes Algae, Bryophytes, Pteridophytes, Gymnosperms and Angiosperms

The life cycle in plants fall under three types 1. Haplontic,2. Diplontic and 3. Haplodiplontic

Algae are autotrophic, chlorophyll bearing organisms. The Plant body is not differentiated into root like, stem like or leaf like structures. A wide range of thallus organization is found in algae. They reproduce vegetatively through fragmentation, tuber and akinete formation. Zoospores, autospores and hypnospores are produced during asexual reproduction and sexual reproduction occurs through isogamy, anisogamy and oogamy.

Chara is a fresh water alga and is popularly called "Stone Worts". The plant body is multicellular, macroscopic and is differentiated into main axis and rhizoids. Sexual reproduction is oogamous.

Bryophytes are the simplest land plants. They are called amphibians of plant kingdom or nonvascular cryptogams. The plant body is gametophyte. The sporophyte depends upon gametophyte. Conducting tissues like xylem and phloem is absent. Vegetative reproduction takes place through fragmentation, formation of adventitious bud and gemmae. Sexual reproduction is oogamous. Water is essential for fertilization.

Marchantia belongs to the class Hepaticopsida. The thallus is dorsiventral and is attached to the substratum by means of rhizoids. The internal structure of the thallus reveals the presence of photosynthetic region and a storage region. Vegetative reproduction takes place through fragmentation and formation of gemmae. The sexual reproduction is oogamous. Sporophyte bears spores. Alternation of generation is present.

Pteridophytes are also called vascular cryptogams. The plant body is sporophyte and is long lived, which is differentiated into root, stem and leaves. They may be homosporous or heterosporous. The sporangia with spores are found in sporophylls. The sporophylls organise to form cones or strobilus. The spores germinates to produce haploid, multicellular heart shaped independent gametophyte called prothallus. Sexual reproduction is oogamous. The life cycle shows alternation of generation.

The term stele includes central cylinder of vascular tissues comprising xylem, phloem, pericycle, endodermis and pith . There are two major types of stele namely protostele and siphonostele.

Selaginella belongs to the class Lycopsida. The plant body is sporophyte. It is differentiated into stem, leaf, rhizophore and roots. Heterospory is found and two types of spores namely microspores and megaspores are produced in sporangia. The microsporangia and megasporania are borne on sporophylls. The sporophylls are organized to form cone. Sexual reproduction is oogamous. Alternation of generation is present.

Gymnosperms are naked seed producing plants. The plant body is sporophyte and it is the dominant phase. Coralloid roots are found in *Cycas*. The roots of *Pinus* possess

mycorrhizal association. Two types of branches called long shoot and dwarf shoot are present. Stem shows secondary growth. Spores are produced in cones. Pollen tube helps in fertilization. The endosperm is haploid. Alternation of generation is present

Cycas belongs to cycadopsida. The plant body is sporophyte and looks like a small palm tree. Apart from taproot coralloid roots are present. It is dioecious, microsporophylls are organized into male cone. Ovules are borne on megasporophylls which are not organized into cone. Fertilization results in zygote and it develops into embryo. Alternation of generation is present.

Angiosperms are highly evolved plant group and their ovules remain enclosed in an ovary. A wide range of habit is present. These include trees, shrubs, herbs, climbers, lianas. Double fertilization is present. The endosperm is triploid. They are classified into dicotyledons and monocotyledons.

Evaluation

1. Which of the plant group has gametophyte as a dominant phase?
   a. Pteridophytes
   b. Bryophytes
   c. Gymnosperm
   d. Angiosperm
2. Which of following represents gametophytic generation in pteridophytes?
   a. Prothallus
   b. Thallus
   c. Cone
   d. Rhizophore
3. The haploid number of chromosome for an angiosperm is 14, the number of chromosome in its endosperm would be
   a. 7 b. 14 c. 42 d. 28
4. Endosperm in gymnosperm is formed
   a. At the time of fertilization
   b. Before fertilization
   c. After fertilization
   d. Along with the development of embryo
5. Differentiate halpontic and diplontic life cycle.
6. What is plectostele? give example.
7. What do you infer from the term pycnoxylic?
8. Mention two characters shared by gymnosperms and angiosperms.
9. Do you think shape of chloroplast is unique for algae. Justify your answer?
10. Do you agree with the statement 'Bryophytes need water for fertilization'? Justify your answer.
11. List the classes of algae.
12. Mention the pigments and storage food of Dinophyceae.
13. What is Nucule?
14. Differentiate nodal and internodal cells of *Chara*.
15. Explain the internal structure of *Cycas* rachis.