MSCBOT-505

M. Sc. I Semester

LABORATORY PRACTICAL-I

DEPARTMENT OF BOTANY

SCHOOL OF SCIENCES

UTTARAKHAND OPEN UNIVERSITY

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CONTENTS

BLOCK-1 FUNGI, LICHEN, VIRUSES AND BACTERIA

UNIT-1 MORPHOLOGICAL STUDY OF REPRESENTATIVE MEMBERS OF FUNGI

1.1 OBJECTIVES

After reading this unit students will be able-

- To know about morphological (thallus) structure of selected fungi- *Synchytrium, Mucor, Taphrina, Puccinia, Ustilago, Agaricus, Alloymces, Phytophthora, Pilobolus, Saccharomyces, Fusarium*
- To identify different reproductive structures (asexual and sexual) found in different fungi species
- To study about identifying features of fungi species

1.2 INTRODUCTION

The fungi are eukaryotic organisms without chlorophyll. The fungi are placed in a separate kingdom myceteae, fungi are studied under a special branch of biology known as *mycology*. Fungi are generally terrestrial organisms, however some marine and fresh water fungi species are also known. Large numbers of fungi are pathogenic to plants, and animals. Some fungi are also known to be present in beneficial association with other organisms e.g. Mycorrhizae (which is an association between fungi and roots of vascular plants), lichens (an association between algae and fungi). Most of the fungi are saprophytes and grow on dead organic matter, other fungi species are parasitic. Fungi are usually aerobic although anaerobic fungi species are also known. Fungi are known to reproduce sexually as well as asexually. Asexual mode of reproduction occurs through budding, binary fission and through spore formation. Asexual spores produced in fungal species include Anthrospores, Sporangiospores, Chlamydospores, Blastospores and Conidiospores. Sexual reproduction takes place by union of compatible nuclei to produce Zygospores, Ascospores and Basidiospores. The vegetative structure of a fungus is called thallus. It varies in complexity and size, ranging from unicellular yeasts to multicellular moulds. Here it should be noted that fungi are in general represented by yeast and moulds. Yeast is a unicellular fungus, producing moist to waxy colony in culture. A mould produces leathery, cottony or profuse powdery growth on medium. It consists of a mass of intercoiling branched, threadlike structures called hyphae. The mass is known as mycelium. Depending on the fungal type, the hyphae may be septate or aseptate. The hyphae grow on or within the surface of nutrient media to get nutrients. This represents vegetative mycelium. Some of the specialized hyphae arise upward away from the medium surface. It is called the aerial mycelium on which the reproductive structure or spores are formed.

1.3 MORPHOLOGICAL STUDY OF REPRESENTATIVE MEMBERS OF FUNGI

1.3.1-*Synchytrium*

Aim: To study about plant pathogen *Synchytrium endobioticum*

Classification

Kingdom: Mycota
Division: Eumycota
Class: Chytridiomycetess
Order: Chytridiales
Family: Synchytriaceae
Genus: *Synchytrium*

Comments:

1. *S. endobioticum* occurs as obligate parasite and is found in tropical as well as temperate part of the world. The fungus is found as a parasite in the epidermal cells of the host.
2. *S. endobioticum* causes the black wart disease of potato (*Solanum tuberosum*). In India the disease is common in region of Darjeeling and West Bengal.
3. The disease is common in areas with a cool moist climate as *S. endobioticum* does not survive in hot environment.
4. *S. endobioticum* possesses a unicellular and non filamentous thallus.
5. *S. endobioticum* is endobiotic and holocarpic.
6. Thallus forms a mass of naked, uninucleate amoeboid mass of protoplasm.
7. A double layered chitinous wall develops around the thallus.
8. The fungus is found as a parasite in the epidermal cells of the host.

Aim: To study about reproductive structure of *Synchytrium endobioticum*

Comments:

1. The asexual phase of the life cycle of this parasitic fungus starts with the infection of the host by the parasite.

2. *S. endobioticum* is present in the wart tissue of potato tuber or in soil in the form of resting sporangia which remain viable for a long period.

3. Under favourable conditions the resting sporangium or spore germinates producing haloid zoospores which are released by the rupture of the enclosing membrane.

4. Zoospore swims and reaches a potato plant and gets attached to surface (tuber or stolon) of host plant. Zoospore then retracts its flagellum and germinates by forming a germ tube.

5. Germ tube pierces the cuticle and the wall of the epidermal cell of host where it develops into a uninucleate intracellular thallus. The unicellular pathogen thallus secretes a wall around it which is differentiated into an outer, thick, golden yellow exospore and an inner, thin, hyaline endospore.

6. The zoospores present in sporangium which come out from sporangial wall and may reinfect the host.

7. Sexual reproduction takes place through gametes (planogametes) formed during unfavorable conditions.

8. Gametes are formed in same way as zoospores are formed.
9. Fusion of isogametes forms a zygote which after swimming for some time penetrates host cell.
10. Zygote undergoes hyperplasia (repeated cell division)
11. Zygote is converted into resting sporangium.
12. Under favourable conditions zoospores divides meiotically into many uninucleate, haploid spores.

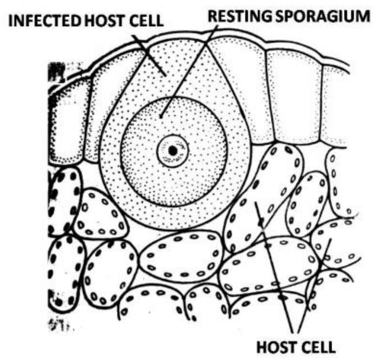

Fig.1.1: Host cell with resting *Synchytrium* spore

1.3.2-*Mucor*

Aim: To study about morphology of fungus *Mucor*

Classification

Kingdom: Mycetae
Division: Amastigomycota
Class: Zygomycetes
Order: Mucorales
Family: Mucoraceae
Genus: *Mucor*

Comments:

1. The vegetative plant body is eucarpic and consists of white cottony coenocytic much-branched mycelium.
2. The mycelia ramify all over the substratum.
3. The hyphae are usually prostrate, but some of them penetrate into the substratum and serve the function of both anchorage and absorption of nutrients.
4. The hyphal wall is microfibrillar, consisting mainly of chitin-chitosan.
5. The protoplast contains many nuclei, mitochondria, endoplasmic reticulum, ribosomes, oil droplets, small vacuoles and other substances.
6. *Mucor* reproduces by vegetative, asexual and sexual means.
7. *Mucor* reproduces vegetatively through fragmentation and asexually by formation of sporangiospore, oidia and chlamydospore.
8. During favourable condition, the nonmotile spores known as sporangiospores or aplanospores are formed inside the sporangium.

9. Oidia are thin walled structures formed by mycelium which grow in a medium rich in sugar. After detachment, the oidia increase by budding (similar to yeast). This stage is called torula stage. Formation of mycelium occurs later.
10. During unfavourable condition, formation of chlamydospores occurs which are thick-walled, nutrition rich, intercalary mycelium segments developed by septation of mycelium. When conditions become favourable chlamydospores germinate to give rise to mycelium.
11. Sexual reproduction takes place during unfavourable condition through gametangial copulation, during which gametangia conjugate to form zygospore.
12. In heterothallic species, zygospores are formed by union of two gametangia developed from mycelia of compatible strains; however in homothallic species, the uniting gametangia develop from mycelia that are derived from single spore.
13. Zygote germinates (after resting period) producing a promycelium.

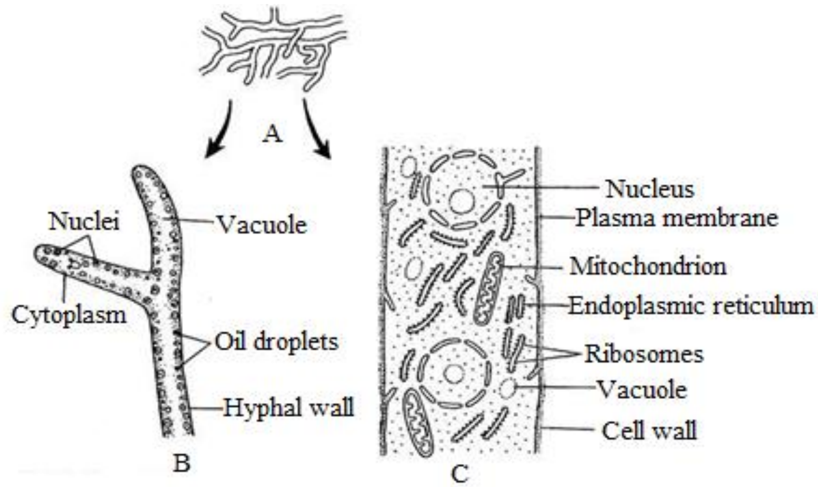

Fig.1.2 A- Vegetative mycelim of Mucor, B-Light microscopic view of hyphae. C- Electron microscopic view of hypha

1.3.3-*Taphrina*

Aim: to study about morphological features and reproductive structure of *Taphrina*

Classification

Kingdom: Mycetae

Division: Amastigomycota

Class: Ascomycetes

Order: Taphrinales

Family: Taphrinaceae

Genus: *Taphrina*

Comments:

1. The genus *Taphrina* includes several fungal pathogens which cause hypertrophic malformations of buds, leaves, twigs, flowers and fruits producing diseases known as leaf curl, blister and fasciatiom.

2. In woody twigs often unnatural, profuse, tufted branching **"witches broom"** is .developed. *Taphrina deformans* causes peach leaf curl disease and *T. cerasi* causes witches' broom of cherries.
3. Somatic mycelium grows intercellularly and forms a network under the epidermis, or the cuticle of the host tissue.
4. Its cells are irregular in size and shape and are dikaryotic.
5. Generally mycelium is annual; however in some species it is perennial also.
6. Asexual reproduction occurs through uninucleate, thin-walled spores also known as conidia.
7. The conidia develop from the ascospores through the process of budding. Conidia once formed bud indefinitely produces secondary, tertiary, etc., conidia.
8. Conidia germinate by germ tubes which penetrate through cuticle of young leaf and cause infection in the host tissue.
9. Sexual reproduction is accomplished by the development of palisade-like layer of rectangular asci which are produced from the dikaryotic cells of a compact mycelial layer.
10. These cells are the ascogenous cells, which are ovoid, pyriform, or dome-shaped. During the development of an ascus the ascogenous cell elongates perpendicularly to the host surface. Its nuclei fuse forming a diploid nucleus
11. The diploid nucleus then divides mitotically into two daughter nuclei of which one moves to the distal end and the other remains at the base. The elongated ascogenous cell now divides into two unequal cells by a transverse septum. The upper larger cell is the ascus mother cell (which forms ascus) and the lower smaller cell is the stalk cell.
12. Nucleus divides reductionally into daughter nuclei which again divide mitotically to form eight haploid nuclei resulting in formation of 8 ascospores.
13. There is no development of ascocarp. Mature asci are exposed by the rupture of the cuticle or epidermis of the host tissue. The ascospores produce small, round or ovoid uninucleate blastospores (conidia) by budding.

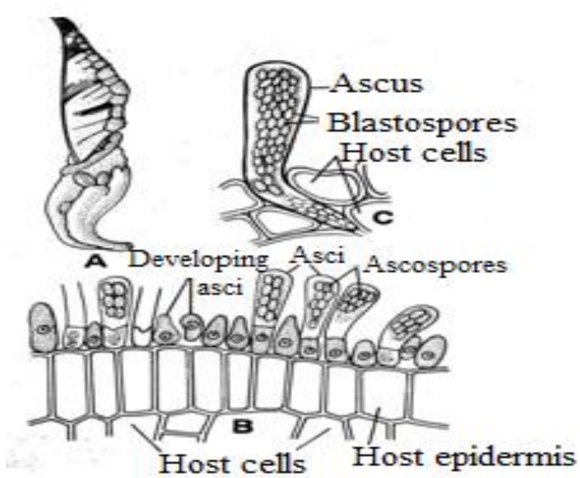

Fig. 1.3: A- Infected leaf of Peach, B-Naked asci at different stages of development, C-Ascus with many blastopores

1.3.4-*Puccinia*

Classification

Kingdom: Mycetae
Division: Amastigomycota
Class: Basidiomycetes
Order: Uredinales
Family: Puccinaceae
Genus: *Puccinia*

Comments:

1. *Puccinia graminis* is obligate parasite, polymorphic, macro cyclic and heteroecious rust.
2. It affects wide range of hosts including wheat, barley, oats and rye. Grass hosts include *Agrostis, Dactylis* and *Agrophyron.*
3. Heteroecious i.e., it requires two unrelated hosts such as wheat (*Triticum aestivum*) the primary host and Barberry (*Berberis vulgaris*), the secondary host; to complete the life cycle
4. The vegetative body is mycelium which is of two types: dikaryotic and monokaryotic.
5. Both the types are septate, much branched, grow intercellularly and produce special haustoria, which penetrate the host cell.
6. Simple pore if present in the septum, maintains protoplasmic continuity between neigh-bouring cells. The cell wall is composed of chitin and glucan. The cytoplasm also contains vacuoles, oil globules, glycogen bodies etc.
7. The dikaryotic mycelium (n + n) occurs in wheat plant i.e., the primary host and the monokaryotic mycelium occur on barberry plant i.e., the alternate host of the pathogen.
8. Macrocyclic i.e., it has extended life cycle and consists of five types of spores i.e., uredospores, teleutospores, basidiospores, pyncniospores or spermatia and aeciospores.
9. Uredospores and teleutospores grow on wheat, the primary host; basidiospores in soil or on dead plants upon soil that developed from teleutospore; and the pycniospores and aeciospores on barberry plant, the alternate host of the pathogen.
10. The uredosorus develops on wheat plant from the dikaryotic mycelium produced by germination of aeciospore, which comes from barberry plant.
11. The uredospores develop in groups under the epidermis, called uredosorus, which appear in the form of reddish-brown pustules.
12. Uredospores are stalked, oval, unicellular, brown, and thick walled with 4-round equatorial germ pores. The uredospores in favourable condition (i.e., in winter season) again germinate , thus infect the wheat plant
13. At the end of wheat season, the uredosori also produce teleutospores along with uredospores.
14. The teleutospores are stalked, spindle-shaped, thick and smooth-walled with round or pointed apex, 2-celled and slightly constricted at the septum.
15. The teleutospores become exposed by rupturing the host epidermis. It acts as a resting spore and survives during unfavourable condition and germinates by producing one germ tube from each cell.

16. Basidiospores are unicellular, thin-walled and very small.
17. The basidiospores survive for few days and infect only the leaves of alternate host (barberry). They germinateby producing mycelium.
18. Pycnidia (formed by mycelium) are generally present on upper surface of leaves and are flask shaped with a pore called an ostiole.
19. Unbranched hyphae present near ostiole are called periphysis.
20. Pycinidiophores are discharged through ostiole and help in producing dikaryotic mycelium.
21. Dikaryotic mycelium forms ascidial cup and ascidia are present on lower surface of leaves.
22. Large number of elongated cells called a ascosphores are present at the base of ascidia.
23. Each sporophore cuts into a smaller and larger cell. Smaller cell is disjunctor cell and larger cell is aecidiospore, which are blown away by wind and infect wheat plant and cannot reinfect barberry plants.

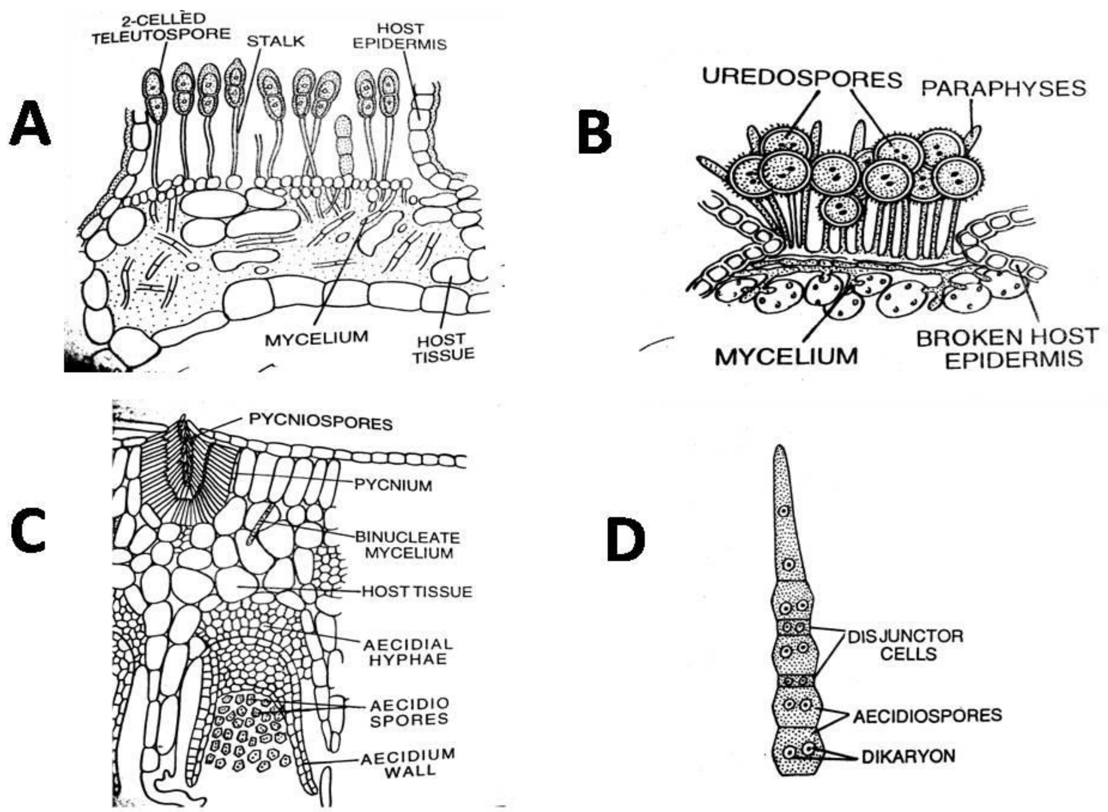

Fig.1.4: A- *P.gramnis tritici* V.S through telium showing stalked teleutospores, mycelium and host tissue, B- V.S, through uredium showing uredospores, mycelium and host tissue, C- V.S infected leaf of *Berberis* through pycnia and aecidia, D- structure of Aeciophore

1.3.5-*Ustilago*

Aim: To study about characteristic features of *Ustilago*

Classification

Kingdom: Fungi
Phylum: Basidiomycota
Class: Basidiomycetes
Order: Ustilaginales
Family: Ustilaginaceae
Genus: *Ustilago*

Comments:

1. *Ustilago* is the largest genus of the family Ustilaginaceae which is represented by more than 400 cosmopolitan species.
2. All species are parasitic and infect the floral parts of wheat, barley, oat, maize, sugarcane, Bajra, rye and wild grasses.
3. The name Ustilago is derived from Latin word *ustus* which means burnt. Representative members of the genus produce black, sooty powdery mass of spores on the host plant giving a 'burnt' appearance. Hence it is also known as smut fungus.
4. The fungus is of much economic importance, because it causes heavy loss to various economically important plants. This genus is very common in U.P., Bihar, Punjab and Madhya Pradesh.
5. The mycellium is branched, septate, hyaline, and intercellular, with or without haustoria.
6. Primary mycelium is monokaryotic (uninucleate) and formed by the germination of basidiospores. It is of very short duration.
7. Secondary mycelium is formed by the dikaryotisation of the primary mycelium.

Aim: To study about various reproductive structure of *Ustilago*

Comments:

1. Both asexual and sexual reproduction occurs in *Ustilago*.
2. It takes place by fragmentation, budding of basidiospores and formation of conidia.
3. *Ustilago* is autoecious organism as its life cycle is completed on a single host.
4. No sex organs are present.
5. Two types of spores are produced during life cycle of *Ustilago*, Teliospores and basidiospores.
6. Teliospores are also known as chlamydospores, smut spores or bi-nucleate brand spores.
7. Teliospores are produced by the secondary mycelium (dikaryotic mycelium).
8. During the time of flowering secondary mycelium becomes active and forms a dense mass of hyphae within the host tissues.
9. The protoplast of each bi-nucleate cell rounds off and secretes a thick wall around itself, resulting in smut spores formation.
10. When spores mature, the gelatinous matter disappears and the spores get separated from one another.
11. The smut spores are disseminated by wind, insects or water.

12. Under favorable conditions of moisture and temperature and teliospores fall on substratum such as soil, twigs or leaves and germinate.
13. Basidiospore is thin walled, uninucleate and oval to round in shape.
14. Basidiospore germinates by producing a germ tube either on the soil or on the young host plant.
15. The germ tube is haploid (monokaryotic), it fuses with opposite strain to form a dikaryotic cell (a process known as plasmogamy). Dikaryotic cell develops dikaryotic mycelium (diplodization or dikaryotisation).
16. This dikaryotic mycellium further produces the teliospores.

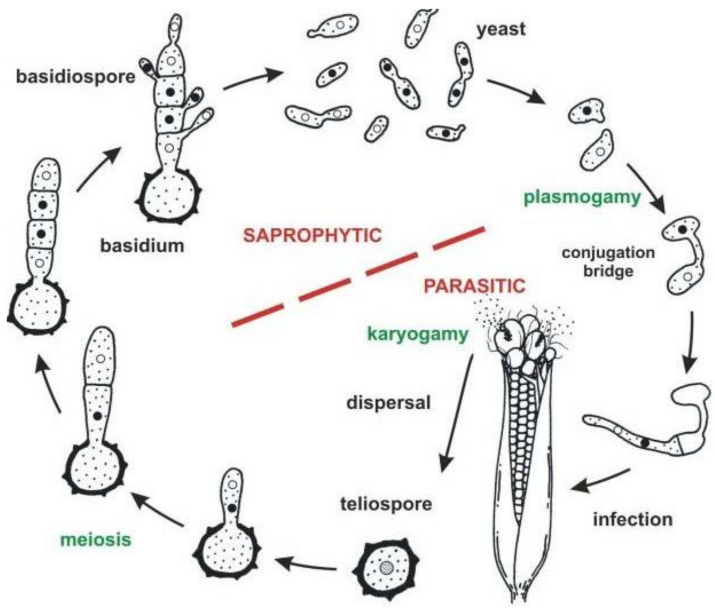

Fig.1.5: Teliospores and basidiospores of *Ustilago* life cycle.

1.3.6-*Agaricus*

Aim: To study about vegetative and reproductive structure of *Agaricus*

Classification

Kingdom: Fungi
Division: Amastigomycotina
Class: Holobasidiomycetidae
Order: Agaricales
Family: Agaricaceae
Genus: *Agaricus*

1. *Agaricus* is a saprophytic fungus commonly known as mushroom.
2. It grows on damp and dead organic matter. It is found on soil humus, decaying litter on forest floors, in the fields and lawns, wood logs and manure piles.
3. Vegetative mycelium is found under soil in form of thick tangled wooly mass known as spawns.

4. Hyphae are septate, hyaline with oil globules vacuoles and thin cytoplasm.
5. Cells of hyphae are uninucleate initially which later undergo process of dikaryotization and become dikaryotic.
6. The aerial portion constitutes fruiting body.
7. When young, the frutification is small, spherical or pear shaped, this is called “button Stage”.
8. From the study point of view the mushroom can be divided into two parts: (a) the stalk or stipe, which is a fleshy, pinkish- white portion usually broader at the base, (b) the other part is somewhat more complex and termed as cap or pileus.
9. When young the pileus is spherical in shape and more or less button like and remains completely enclosed by a thin whitish membrane known as “velum”.
10. At maturity, the velum ruptures and remnants of it remain surrounding the stipe which are termed annulus.
11. The pileus becomes umbrella- like expanded portion on the terminal end of the stipe.
12. Under the pileus a gill cavity is present and in this cavity a large number of thin, vertical plate like structures which run out towards the edge of pileus like the radiating bars of a wheel are termed ‘gills’ or ‘lamellae’.
13. The gills vary in number from 300-600 in each pileus.
14. On both the surfaces of each gill thousands of basidiospores are produced.
15. The mature pileus is two to five inches in diameter; its top is white, cream coloured and bears many fine silky hairs or scales.
16. At first the flesh is white, but later on it changes into pinkish in colour.
17. The gills are at first flesh coloured or pink but as the fructification matures they become dark brown in colour.
18. On each gill a spore bearing layer is developed which is termed, the hymenium
19. The stipe of mushroom is composed of an interwoven mass of hyphae, and in sectional view a tissue like structure is seen, which is false tissue, known as pseudoparenchyma.
20. The hyphae of central region are more loosely interwoven and posses much air spaces while the hyphae of outer region are more compact. The central portion is termed medulla and the outer one, the cortex.
21. The vertical section of gill exhibits trama, hymenium and sub-hymenium.
22. The hyphae of the trama bend outwards on both the surfaces of the gills and terminate layer of small, rounder celss, called the ‘sub-hymenium’.
23. Outside to it, on both the surfaces of the gill, layers of clavate, palisade like cells is developed which is called the ‘hymenium’.
24. The large cells of the hymenial layer are termed basidia and the shorter are known as paraphyphae.
25. At the terminal ends of the basidia, two or four sterigmata are developed. A single basidiospore develops on each sterigma.
26. The basidiospores are small, rounded haploid and uninucleate.

27. The basidiospores germinate to produce primary monokaryotic, branched and septate mycelium.

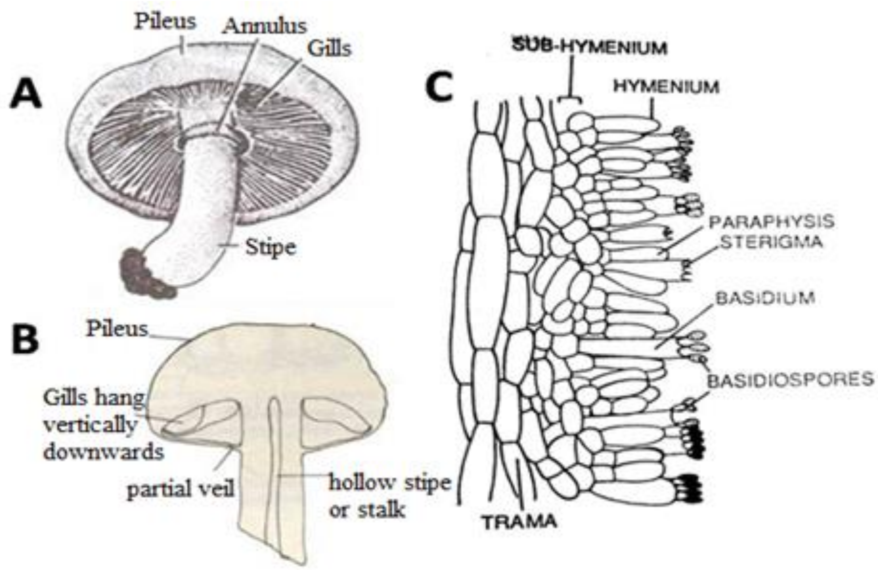

Fig.1.6: Mature fruting body of *Agaricus* and vertical section through sporophore: A, B- Mature basidiocarp, C- V.S. through gill

1.3.7-*Alloymces*

Aim: To study about occurrence and structure of thallus

Classification

Kingdom: Fungi
Division: Mastigomycotina
Class: Chytridiomycetes
Order: Blastocladiales
Family: Blastocladiaceae
Genus: *Allomyces*

Comments:

1. The genus *Allomyces* was first discovered in India by EJ Butler (1911). Later on its distribution was found worldwide.
2. *Allomyces* genus comprises five species among which *A. arbuscula, A. macrogynus and A. javanicus* are of utmost significance.
3. *Allomyces* is saprophyte in nature, soil dweller and inhibits wet soil.
4. Thallus in *Allomyces* species is hyphal and is called mycelium.
5. It is filamentous and remains attached to substratum through branched rhizoidal hyphae.
6. From this rhizoidal system arise single stout hyphae which forms lower portion and is trunk like. This portion undergoes several dichotomous branching to form branched part of mycelium.
7. On terminals ends of branches are borne reproductive organs.

8. Hyphae are multinucleate and coenocytic.
9. Septa in *Allomyces* are also known as false septa as they do not completely separate protoplasm of adjacent segments.
10. Hyphal wall is made up of chitin, beta-glucan and ash.
11. Along with numerous nucleic, mitochondria, there are present concentric granules in cytoplasm of hyphal segments.
12. These concentric granules act as plugs for septal pores to prevent loss of protoplasm in case of damage.

Aim: To study about reproductive structure of *Allomyces*

Comments:

(A) Asexual reproduction

1. Vegetative thalli are of two types: haploid gametothalli and diploid sporothalli.
2. The two thalli cannot be distinguished from one another in vegetative phase but can be identified in reproductive phase when gametothalli bear gametangia and sporothalli produce sporangia.
3. Gametothallus is concerned with sexual reproduction. It is homothallic.
4. Sexual reproduction occurs by planogametic copulation.
5. Planogametes in Allomyces are anisogametes and uniflagellate.
6. Female gametes are uninucleate uniflagellate, and almost double the size of male gametes.
7. Male gametes are uninucleate uniflagellate, and smaller than female gametes. They are orange or red in colour due to presence of carotenoid pigment.
8. Both male and female gametes are released into water from respective gametangia.
9. Plasmogamete discharge female gamete releases a hormone called sirenin which acts as chemoattractant and directs the movement of male gametes towards female gametes.
10. Male and female gametes fuse in pairs resulting in formation of binucleate cells.
11. After plasmagamete the two nuclei fuse to form zygote by a process known as karyogamy.
12. Zygote in motile and biflagellate. It moves for 5-10 minutes and then comes to rest, flagella are retracted and wall is secreted around the zygote.
13. Zygote germinates immediately, a basal germ tube is formed which branches to form rhizoidal system.
14. Body of zygote enlarges by elongating in opposite direction to from thick trunk like hyphal tube which further branches to form sporothallus.

(B) Sexual reproduction

1. Sporathallus formed from zygote is concerned with vegetative reproduction.
2. Sporothallus produces two types of sporangia, a colorless thin walled mitosporangia and thick walled reddish brown resting sporangia called as meiosporangia.
3. Both types of sporangia are borne on same thallus.

4. Multinucleate tip of ultimate hyphae swells and functions as mitosporangium which mitozoospores are produced.
5. Mitospores are uninucleate, diploid, uniflagellate and opisthocont.
6. Mitozoospores are dispersed through pores present in sporangial wall. These swim for a while, then come to rest, retract flagella and secrete a wall around the zoospore.
7. Zoospore is naked (without cell wall) uninucleate with posteriorly located nucleus with a distinct nucleolus.
8. Cytoplasm of zoospore lacks ribosomes and endoplasmic recticulum. However, ribosomes are present in nuclear cap which are released during encystment.
9. Zoospores contain lipid bodies and a function kinetosome.
10. The cyst germinates immediately to form basal germ tube, which grows and gets branched to form rhizoidal system.
11. Main body of cyst elongates and grows in opposite direction to form a thicker germ tube which grows branches to give rise to dichotomously branched part of diploid sporothallus.
12. Initial development of meiosporangia is identical to mitosporangia. However, there is present an additional thick pitted wall external to original sporangial wall.
13. Mature meiosporangia undergo resting period of 2-6 weeks hence called as resistant or resting sporangia.
14. After resting period meiosporangia germinate with meiotic nuclear division and number of nuclei increases.
15. Meioszoospores are uninucleate, uniflagellate, opisthocont, haploid and are smaller than diploid mitozoospores.
16. Meiozoospores are released in water through cracks which occur in wall of meiosporangium.
17. After release they swim for some time, and then become stationary, flagella are retracted and a wall is secreted around the zoospore.
18. Germination of meiozoospore is similar to mitozoospore but germination of meiozoospore produce an alternate haploid plant in life cycle known as gametothallus.

1.3.8-*Phytophthora*

Aim: To study about morphology and reproductive structure of *Phytophthora*

Classification

Kingdom: Mycetae
Division: Mastigomycotina
Subdivision: Diplomastigomycotina
Class: Oomycetes
Order: Peronosporales
Family: Pythiaceae
Genus: *Phytophthora*

Comment:

1. The mycelium is coenocytic, aseptate, hyaline and profusely branched.
2. The cell wall consists of glucan unlike others and chitin is absent.
3. Cytoplasm contains large number of nuclei, mitochondria, endoplasmic reticulum, ribosomes, vacuoles and many oil globules.
4. The mycelium is intracellular, and directly kills the invaded cells However; in some cases it is intercellular.
5. Some species of the genus also develop haustoria for absorbtion of food material.
6. The modes of reproduction in *Phytophthora* include Vegetative, asexual and rarely by sexual methods.
7. In many species of *Phytophthora* including *P. colocasiae* and *P. parasitica* vegetative reproduction occurs through Chlamydospores.
8. These Chlamdospores are vegetative reproductive bodies which germinate by giving rise to 3-11 germ tubes and generally develop sporangia at their tips.
9. Asexual reproduction occurs by sporangia.
10. Growth of sporangia is favored by low temperature (12-20°C) and high relative humidity.
11. The sporangiophores arise directly from the internal mycelium and emerge out of the host singly or in clusters through stomata or by piercing through the epidermal wall.
12. The sporangia may vary in shape and are deciduous (fall off) and are disseminated by water or are blown by the wind.
13. On falling upon a suitable host and under favourable temperature and moisture the sporangia germinate.
14. At high temperature (20-30°C), the sporangium germinates directly by a germ tube and behaves as conidia. The germ tube enters through a stomata and infects the leaf.
15. However, lower temperature (12°C) and presence of moisture favors indirect germination which occurs by formation of zoospores.
16. The protoplasm of the sporangium gets divided into many uninucleate polyhedral pieces which rounds up and undergoes metamorphosis to form zoospore.
17. Zoospores are kidney shaped, biflagellate and contain flagella on lateral side.
18. The zoospores are released by the bursting of the sporangial wall. After their release they swim for some time after which come to rest and are encysted. Zoospores germinate by a germ tube.
19. Sexual reproduction in *Phytophthora* is oogamous. The fungus is heterothallic, requires two opposite strains (+ and –) for sexual reproduction to occur.
20. The male reproductive organ is called antheridia. Antheridium can be amphigynous in which anthreidium is attached to oogonium as a collar (*P. infestans*) or it can be Paragynous in which anthreidium is attached laterally to the oogonium (*P. cactorum*).
21. The antheridium arises earlier than the oogonium showing a protandrous condition.
22. The mature antheridium is funnel shaped and forms a collar like structure at the base of the mature oogonium. The two nuclei divide mitotically and forms 12 nuclei out of which only one nuclei survives.

23. The female reproductive organ is called as oogonia, which is initiated laterally or below the antheridium on a hypha from other strain. The young oogonium pierces the developing antheridium.
24. When young, it is multinucleate with dense cytoplasm. When mature it becomes vacuolated and differentiates into an outer multinucleate periplasm and a central uninucleate ooplasm.
25. The nucleus of the ooplasm divides mitotically and out of the two one survives and functions as oosphere nucleus
26. A mature oospore consists of an outer thick wall called exospore and an inner thin wall endospore.

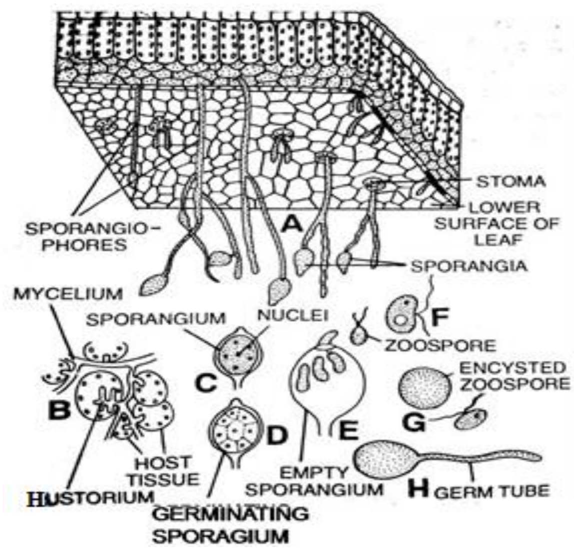

Fig. 1.7: A- Sporangiophores coming out of infected leaf, B- Intercellular mycelium with haustoria, C- Sprangium, D,E-Sporangium germination, F- Biflagellate zoospores, G- Encysted zoospore, H- germination of encysted zoospore.

1.3.9-*Pilobolus*

Aim: To study about occurrence and characteristic features of *Pilobolus*

Classification

Kingdom: Mycetae
Division: Amastigomycotina
Subdivision: Zygomycotina
Class: Zygomycetes
Order: Mucorales
Family: Pilobolaceae
Genus: *Pilobus*

Comments:

1. Pilobolus-a coprophilous fungus grows in laboratory only on media containing dung decoctions.
2. The somatic phase of the fungus is a eucarpic thallus which consists of mycelium.

3. The hyphae are coenocytic, aseptate, hyaline branched and remain submerged in the substratum, feeding on dung.
4. Asexual reproduction occurs mostly by aplanospores produced within the sporangium.
5. Some hyphae which are to produce sporangia become upright and come out of the substratum. Erect sporangiophores develop from the trophocyst. The trophocyst may be terminal or intercalary in position.
6. The sporangiophores are phototrophic. Each sporangiophore at maturity consist of trophocyst, embedded in the substratum, a long straight stalk which is enlarged at its tip to form a sub-sporangial vesicle capped by a small black columellate sporangium containing 15-30 thousand spores.
7. Sexual reproduction rarely occurs in Pilobolus and takes place in adverse conditions.
8. Fusion of two multinucleate similar gametangia of opposite strains leads to the formation of thick walled Zygospores.
9. The zygospore undergoes a period of dormancy and rest after which it germinates and forms a sporangiophore and sporangium.
10. Meiosis takes place during germination and the spores are haploid. However, the zygospore can also germinate by the germ tube directly.

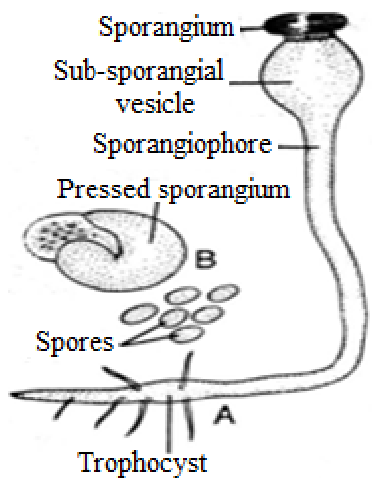

Fig. 1.8: A-Sporangiophore of *Pilobus* bearing sporangium, B- Sporangium releasing spores

1.3.10-*Saccharomyces*

Aim: To study about morphological characteristics of *Saccharomyces*

Classification

Kingdom:	Mycetae
Division:	Amastigomycotina
Subdivision:	Ascomycotina
Class:	Ascomycetes
Order:	Endomycetales
Family:	Saccharomycetaceae
Genus:	*Saccharomyces*

Comments:

1. *Saccharomyces* commonly called as yeast are unicellular eukaryotes.
2. *Saccharomyces* have widespread distribution and are found in all parts of world.
3. Cells of *Saccharomyces* are ova or spherical in shape.
4. Cell wall is primarily made up of chitin.
5. Electron micrographs reveal cell wall to contain three layers, outermost layer of protein-mannan and chitin; the middle layer of glucan and the innermost layer of proteinglucan.
6. Protoplast is differentiated into outer cytoplasm and central nucleus.
7. Being unicellular organism, thallus is represented by minute cell.
8. During the process of multiplication by budding cells mar remain attached to one another forming psedomycelium.
9. *Saccharomyces* are non-mycelial fungi which lacks spore formation
10. Most of the *Saccharomyces* species possess ability to ferment sugars.
11. Cytoplasm is granular and contains nucleus, mitochondria, golgi apparatus, endoplasmic reticulum, ribosome, glycogen bodies, oil globules etc.

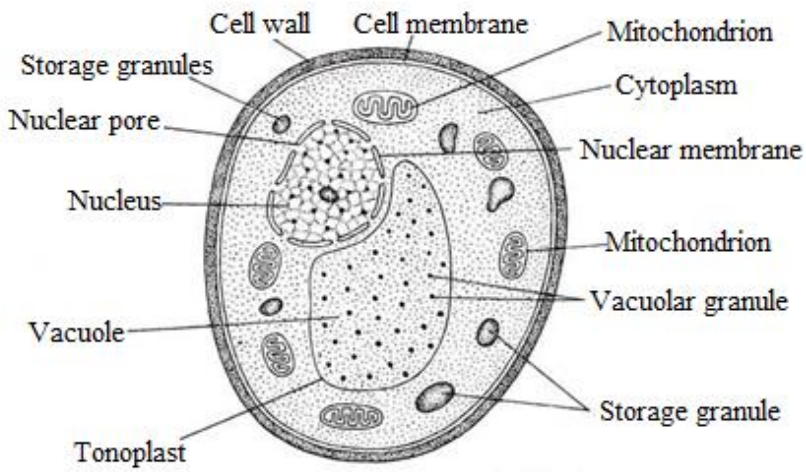

Fig. 1.9: Cellular structure of *Saccharomyces*

Aim: To study about different modes of reproduction in *Saccharomyces*

Comments:

1. Vegetative reproduction takes place by fission and budding
2. During favourable condition single cell give rise to two daughter cells of equal size. During the process of fission, a constriction appears in middle of the cell and simultaneously nucleus undergoes division. After migration of each nucleus, one at each side, a partition wall is formed in middle of the mother cell and the cell divides into two cells.
3. Budding also takes place under favourable condition. In budding, a bud formation occurs at a point on the surface of mother cell by swelling of a portion of protoplasm.
4. The nucleus divides and out of two nuclei one remains in mother cell and other goes to newly formed bud. Bud enlarges and eventually gets separated from the mother cell.

5. Asexual reproduction occurs during unfavorable condition by formation of thick walled spore, called as endospore
6. During endospore formation nucleus divides to form four nuclei. The protoplast also divides into four units, each having one nucleus and hence four endospores are formed.
7. When conditions become favorable, endospore germinates by budding and buds grow individually.
8. Sexual reproduction also occurs during unfavourable condition by a process called as conjuagtion. Two vegetative cells (called as ascospores) behave as gametangia. Two such cells come in close contact and a conjugation tube is formed, the intervening walls between then cells dissolve.
9. Nuclei of both the gametangia come to the conjugation tube and fuse to form diploid zygote. The zygote behaves as an ascus. The diploid nucleus of zygote undergoes meiotic division forming 8 ascospores. The ascospores are liberated by breaking the ascus wall and behave as individual cell.

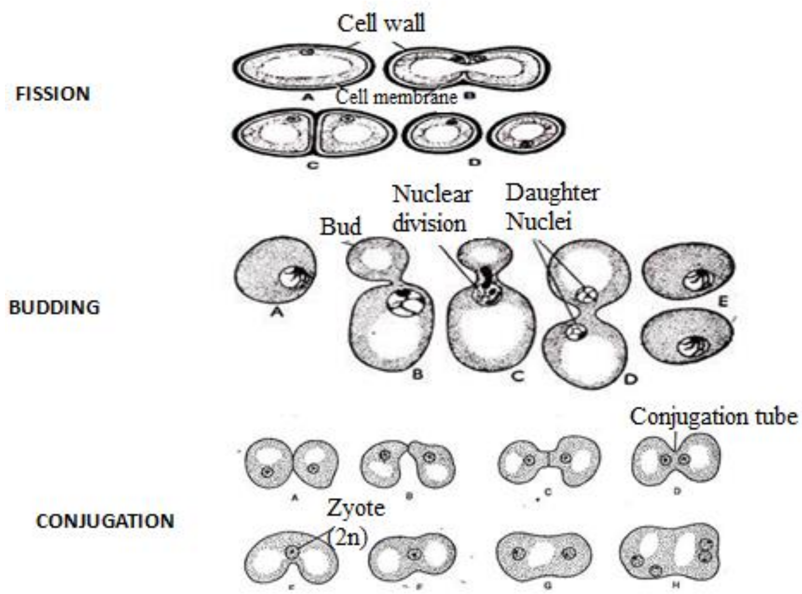

Fig. 1.10: Different modes of reproduction in *Saccharomyces*

1.3.11-*Fusarium*

Aim: To study about plant pathogenic fungi *Fusarium*

Classification

Kingdom: Mycetae
Division: Amastigomycotina
Subdivision: Deuteromycotina
Class: Deuteromycetes
Order: Moniliales
Family: Tuberculariaceae
Genus: *Fusarium*

Comments:

1. *Fusarium* is a facultative parasite found in soil as saprophyte.
2. It infects several plant species through roots or other underground parts.
3. It is known to cause diseases such as stem canker, foot rot, wilt and rot of stored fruits,
4. The hyphae are septate and branched, and penetrate the root tissue of the host to reach xylem vessels and tracheids.
5. Mycelium is extensive. In extreme cases of infection a white crust of mycelium is observed over the external surface of the host.
6. Mycelium often forms compact resting bodies of thick walled hyphae which are known as sclerotia.
7. Asexual reproduction in *Fusarium* occurs through macroconidia, microconidia and chlamydospores.
8. Macroconidia are large, multicellular generally 2-4 celled conidia.
9. The conidia are septate with 3.5 transverse septa.
10. Each conidium is 15-30µ long 3-5µ broad.
11. The conidiophores are short, simple or branched.
12. The macroconidia are generally found over the host surface.
13. They are produced at tips of simple or branched conidiophores.
14. Macroconidia are elongated, sickle shaped or cresent shaped.
15. Microcondia are small, round or oval in shape.
16. Microconidia are formed at the tip of hypha; branch.
17. The microconidia are developed in the vessels of the host plant.
18. Each conidium is 5-15 µ long and 3-4 µ broad.
19. Both macroconidia and microconidia are produced in large numbers and are carried by wind.
20. When these conidia fall on a new substratum, they tend to germinate and cause new infection.
21. Chlamydospores are usually found in chains.
22. Chlamydospores are round, ova and thick walled
23. Presence of Chlamydospores is confined to xylem vessels
24. They separate from parent hyphae when mature and function as resting spores .
25. Under favorable conditions chlamydospores germinate through germ tube to give rise to fresh mycelium.

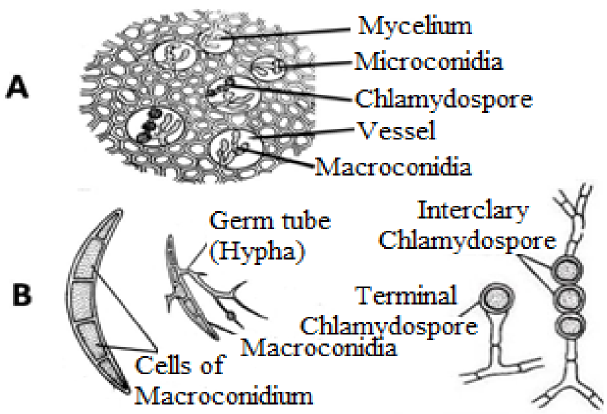

Fig. 1.11: A-T.S. of infected root with mycelium, microconidia, macroconidia and Chlamydospores, B- Germinating macroconidia and types of Chlamydospores

1.4 SUMMARY

1. *Synchytrium endobioticum* is a parasitic on flowering plant and is found to be distributed in tropical as well as temperate region of world.
2. It is a causative organism of wart disease of potato.
3. It affects different parts except roots.
4. Asexual reproduction occurs through the zoospores.
5. Sexual reproduction occurs through planogamete.
6. Mucor has non septate mycelium, rhizoids are absent.
7. Sporangia in mucor are without apophysis.
8. *Taphrina* is a parasite on vascular plants.
9. *Taphrina* is a parasite on vascular plants.
10. The genus lacks production of sex organs.
11. Species of genus causes mal formation in lost tissue.
12. Symptoms such as leaf curl pockets, blesters and witches broom are observed in plants infect with *Traphrina.*
13. A sexual reproduction occurs by small uninucleate haploid yeast like blastospores.
14. Sexual reproduction occurs through ascospores no fruiting body or ascocarp is formed.
15. Species of *Puccina* are also known as rust.
16. All species of *Puccinia* are obligate parasite.
17. Mycelium is well developed branched and septate.
18. Mycelium called dikaryotic.
19. Different types of spores such as used uredospores, telutospores, aecidospores are formed.
20. Most of the species of genus *Ustiligo* are parasites on vascular plants.
21. Some species are parasites on cereals.
22. Smut caused by *Ustiligo* genus are classified as loose smut or covered smut.
23. Mycelium is well developed, branched and septate. It can be monokaryotic or dikaryotic.
24. Hyphae of allomyces are multinucleate coenocytic.

25. Vegetative thalli are of two types of sporangia.
26. Sexual reproduction occurs by planogametes copulation.
27. Sporothallus produces two types of sporangia mito sporangia and micro sporangia.
28. Mitozoospore is uninucleate, diploid and uniflagellate.
29. Mesozoospore is uninucleate, haploid and uniflagellate. They are smaller than mitozoospore.
30. Some Species of genus *Phytophthora* are saparophytes but most live or parasite on flowering plants.
31. Genus *Phytophthora* is known to cause serious plant disease called as late blight of potato.
32. Mycelium is endophytic, branched aseptate, coenocytic and modulated.
33. A sexual reproduction occurs by biflagellate zoospore.
34. Sexual reproduction is oogamous.
35. *Pilobolus* is a coprophilous genus.
36. Mycelium is branched, coenocytic with oil and glycogen granules.
37. *Saccharomyces* are unicellular eukaryotes and commonly known as yeast.
38. Asexual reproduction occurs by budding or fission.
39. Sexual reproduction by conjugation.
40. *Fusarium* is facultative parasite found in soil as saprophyte.
41. It infects host through roots or underground parts.
42. Mycelium is made up of profusely branched hyaline hyphae.
43. *Fusarium* reproduces only asexually by means of macroconida and microconidia.

1.5 GLOSSARY

Chlymadospore: A thick-walled hyphal cell which functions like a spore.
Kinetosome: A basal body (synonymous with basal granule, kinetosome, and in older cytological literature with blepharoplast) is a protein structure found at the base of a eukaryotic undulipodium (cilium or flagellum)
Perennation: Perennation is the ability of organisms, particularly plants, to survive from one germinating season to another,
Planogametic copulation: Planogametic copulation involves the fusion of two naked gametes one or both of which are motile
Plasmogamy: Plasmogamy is a stage in the sexual reproduction of fungi, in which the cytoplasm of two parent cells (usually from the mycelia) fuses together without the fusion of nuclei, effectively bringing two haploid nuclei close together in the same cell.
Pseudohyphae: Pseudohyphae are distinguished from true hyphae by their method of growth, relative frailty and lack of cytoplasmic connection between the cells.
Rust: Rusts are plant diseases caused by pathogenic fungi
Sclerotia: A sclerotium plural sclerotia is a compact mass of hardened fungal mycelium containing food reserves.
Sporothallus: Thallus producing spores, usually restricted to asexual spores.

Teleutospore: Teliospore (sometimes called teleutospore) is the thick-walled resting spore of some fungi (rusts and smuts), from which the basidium arises

Uredeospore: Uredeospore a thin-walled, red, summer spore of a rust fungus, produced usually on the leaves or stems of grasses and capable of reinfecting other grasses of the same species.

1.6 SELF ASSESSMENT QUESTION

1.6.1 Multiple Choice Questions:

1. Uredospores in *Puccinia* are
(a) Multinucleate, stalked and round (b) Binucleate, stalked and round
(c) Binucleate, unstalked and round (d) Multinucleate, unstalked and round

2. *Phytophthora*
(a) Eucarpic inter or intracellular parasite (b) Eucarpic interparasite
(c) Eucarpic intraparasite (d) Monocarpic intraparasite

3. Which of the following statement about *Phytophthora* is not true?
(a) Biflagellate zoospores emerge through papilla
(b) Asexual reproduction occurs via sporangia or conidia
(c) Anthridium is uninucleate
(d) Sexual reproduction is of oogamous type

4. Species of *Ustilago*
(a) are parasites in nature but many species grows saprophytes
(b) are saprophytes in nature but many species grows as parasites
(c) are parasites only
(d) are saprophytes only

5. Which of the following statement about *Sacchromyces* is not true?
(a) *Sacchromyces* are multicelluar eukaryotes
(b) Asexual reproduction occurs by budding or fission
(c) Cell wall consists of chitin
(d) Sexual reproduction occurs through conjugation

6. Mycelium of *Taphrina*
(a) is intercellular and consist of septate hyphae of binucleate cells
(b) is intercellular and consist of septate hyphae of uninucleate cells
(c) is intercellular and consist of non septate hyphae of binucleate cells
(d) is intercellular and consist of septate hyphae of multinucleate cells

7. *Puccinia* causes
(a) Smuts (b) Rusts
(c) Both a and b (d) None of the above

8. Which of the following is not a characteristic feature of *Agaricus*
(a) Presence of Spawns (b) Presence of fleshy stalk
(c) Multinucleate and diploid basidiospores (d) Presence of gills

9. Only asexual mode of Reproduction is found in
(a) *Puccinia* (b) *Saccharomyces*
(c) *Phytophthora* (d) *Fusarium*

9. Association between fungi and roots of vascular plant is known as
(a) Lichens (b) Mycorrizae
(c) Antagonistism (d) Commensalism

1.6.2 State whether following statements are true or false:

1. Species of genus *Taphrina* are parasites.
2. Sexual reproduction in yeast occurs by budding.
3. Teleutospores are unstalked, dark brown and double celled.
4. Well defined sex organs are produced in *Taphrina* for sexual reproduction.
5. *Fusarium* reproduces only asexually.
6. Glycogen granules are found to be scattered in cytoplasm of *Saccharomyces*.
7. *Fusarium* is obligate parasite.
8. Microconidia are developed over the host surface.
9. Chlamydospores in *Fusarium* are generally found in chains.
10. *Phytophthora* are parasites on higher plants.
11. Anthridium in *Phytophthora* may be paragynous or amphigynous.
12. *Synchytrium endobioticum* causes wart disease of potato.
13. Damping off of Brinjal is caused by *Phytophthora*.
14. Multiflagellate zoospores are formed during asexual reproduction in *Phytophthora*.
15. *Synchytrium endobioticum* belongs to class oomycetes.
16. Anthridium in *Phytophthora* is multinucleate.
17. Species of *Puccinia* are also known as rust.
18. *Ustilago* belongs to class chytridiomycetes.
19. Basidiospores in *Agaricus* are multinucleate.

1.6.3 Fill up the following blanks:

1. Mycelium of *Taphrina* grows inside walls of ________________ cells of host.
2. *Saccharomyces* are commonly called as _______________

3. Sexual reproduction in *Saccharomyces* occurs by ____________
4. *Puccinia* species are known to cause disease called as_________
5. *Fusarium* possesses _______types of conidia.
6. Zygote of *Saccharomyces* divides meiotically to form __________ascopores.
7. *Agaricus* are commonly called as ______________
8. Sexual reproduction in *Phytophthora* is _____________
9. ____________causes wart disease of potato.
10. Thallus of *Synchytrium endobioticum is* ____________ *and* _____________
11. In *Phytophthora* male and female nuclei fuse to form ___________
12. *Ustaligo* belongs to class____________
13. ___________reproduction in *Phytophthora* occurs through sporangia.
14. All species of ____________are obligate parasites.
15. Basidiospores germinate to form____________

1.6.4 Very short answer type questions:

1. Name the disease caused by *Phytophthora*?
2. To which class and family does *Phytophthora* belongs?
3. What do you understand by the term rust?
4. Why mycelium of *Puccinia* is called dikaryotic?
5. Define basidiocarp?
6. What type of uredospores are produced in *Puccinia*?
7. Mention the food reserves found in *Taphrina*?
8. Name different type of spores found in life history of *Puccinia?*
9. Define microconidia*?*
10. What are spawns?
11. Define dikaryotization?

1.6.1 Answer Key: 1-b, 2-a, 3-c, 4-a, 5-a, 6-a, 7-b, 8-c, 9-d, 10- b

1.6.2 Answers Key: 1-True, 2-True, 3-False, 4-False, 5-True, 6-True, 7-False, 8-False, 9-True, 10-True, 11-True, 12-True, 13-True, 14-True, 15-False, 16-False, 17-True, 18-True, 19-False

1.6.3 Answers Key: 1-Epidermal, 2-Yeast, 3- Conjugation, 4-Rust, 5-Two, 6-Eight, 7-Mushroom, 8- Oogamous, 9- *Synchytrium endobioticum*, 10-Unicllualr and non-filamentous, 11-Oospore, 12- Teliomycetes, 13- Asexual, 14- *Ustilago*, 15-Mycelium.

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1.9 TERMINAL QUESTIONS

1.9.1 Short answer type question

1. With the help of well labeled diagram describe about the structure of *Saccharomyces*?
2. Describe about reproductive structure of *Taphrina*?
3. Differentiate between Uredospores and Teleutospores?
4. Enlist different characteristic features of *Ustilago*?
5. How does macroconidia differ from microconidia?
6. Describe about vegetative structure of *Fusarium*?
7. Explain about the structure of Basidiocarp of *Agaricus*?
8. Write down taxonomic position of *Agaricus*, *Puccinia* and *Phytophthora*?

1.9.2 Long answer type question

1. Describe about identifying features of *Taphrina*?
2. Describe about structure and reproduction of *Saccharomyces*?
3. Explain about different types of spores formed in life history of *Puccinia*?
4. Mention the characteristic features of reproductive bodies of *Fusarium*?
5. How does reproduction take place in *Phytophthora*?
6. Describe in detail about asexual and sexual reproduction in *Allomyces*?

UNIT-2 SYMPTOMOLOGY OF SOME DISEASED SPECIMENS

2.1 OBJECTIVES

After reading this unit students will be able-

- To study about various plant diseases caused by different pathogenic fungi
- To identify infected plant specimen based upon occurrence of specific symptoms
- To know about possible control methods of different plant diseases
- To study disease cycle of some of the fungi pathogen

2.2 INTRODUCTION

Large number of bacteria, viruses and fungi are known to infect different plant species and cause diseases. Among these fungi, are the most common pathogens which infect plants. Branch of science dealing with the study of the pathogens, disease caused by them, symptoms and control measures, infection cycle of the pathogens is known as plant pathology or phytopathology. Each disease is characterized by occurrence or appearance of particular type of symptoms in the infected plant which are specific to a disease. A symptom refers to a visible change in a host plant due to pathogen activity. Such symptoms are utilized to identify which type of fungi or pathogen has infected the plant. The first step of plant disease diagnosis is close observation of symptoms and signs present on infected plant as they are indications of interaction between the pathogen and the plant. These can be vegetative structures such as mycelium of a fungus, reproductive structures such as the spores or spore-bearing structures, etc. Symptoms can include a direct effect of pathogen activity, such as decay of plant parts by degradative action of extracellular enzyme released by fungi, or it can be an indirect result which include nutrient deficiency symptoms resulting from roots that are unable to absorb nutrients. Symptoms not only indicate presence of a disease, but also provide information about the type of pathogen which might have infected the plant. In some instances, the occurrence of a particular combination of symptoms is sufficient to arrive at a tentative diagnosis. However, there are symptoms which are common to wide variety of diseases, hence detailed microbiological, biochemical and molecular diagnostic methods based assays have gained importance for identification of diseases.

Some of the commonly observed symptoms in diseased plant include:

(a) **Mildews:** Mildews are a group of fungal diseases in which superficial growth of fungi can be observed on the surface of host i.e., on leaves, stem, fruits, etc. Mildews are of two types downy mildews (internal obligate parasite) and powdery mildews (external parasites).

(b) **Smuts:** Smuts are fungal diseases of cereals and grass family. In this type of disease ears turn black or sooty. Symptoms of the disease are also observed on leaves, stem and roots.

(c) **Sclerotia**: *Sclerotia* represents a compact mass of hardened fungal mycelium containing food reserves

(d) **White blisters:** These are shining white blisters like pustules found on leaves of plant. White blisters are commonly observed on cruciferous plants due to infection of *Albugo candida.*

(e) **Necrosis:** Necrosis refers of death or killing of host tissues due to attack of pathogen. When necrosis is restricted in extent and is confined to a small area it is called as **local necrosis**. As a result of this localized disease spots on host plant are obtained, these are called as **Lesions**. Local necrosis also results in open wounds which are often sunken in stem and are surrounded by living tissue, these are called as **cankers**. **Blight** is a condition when diseased part of plant undergoes discoloration and ultimately dies, the dead part turns dark brown to black in colour.

(f) **Hypoplasia :** Hypoplasia is the failure of plants or plant organs to develop fully due to attack of a pathogen resulting in either stunted growth or dwarf plant

(g) **Hypertrophy:** It is enlargement or excessive growth of a plant tissue due to attack of a pathogen.

2.3 SYMPTOMOLOGY OF SOME DISEASED SPECIMENS

1. Wart Disease of Potato

Aim: To study about occurrence and symptoms and control measures of Wart disease of potato

Wart disease of potato is also known as Black wart of potato is caused by *Synchytrium endobioticum*. The disease was first described in 1895 from Hungary. After which the disease has been reported from different regions of Europe, North America, mountainous areas of South America and South Africa. In India, Wart disease of potato was first reported by Ganguly and Paul (1953) from Darjeeling.

Effect of Wart Disease

The damage caused by the disease is frequently high since the potato tubers get de- shaped, become tasteless loosing flavor and therefore unfit for human consumption. Young tubers get deformed due to infection and have to be thrown away.

Symptoms of Wart Disease

1. Symptoms of wart disease are observed only on underground parts of plant (Fig.2.1) including tubers, buds of stems, and stolons except roots.
2. Infected parts exhibit warty and tuberous outgrowths which are cauliflower like in appearance.
3. These warty outgrowths show variation in size. They may range from small protuberances to large intricately branched systems.
4. Galls vary in shape but are mostly spherical, with corrugated surfaces.
5. In early growing season these warts are green or greenish-white in colour (if exposed to light) but they are cream or black coloured on underground parts.
6. Generally the warts are larger than the size of tuber, covering the whole tuber. In advanced stages, the warts become dark black in colour and are susceptible to attack of saprophytic fungi.
7. The wart usually consists of distorted proliferated branched structures grown together into a mass of hypertrophied tissue
8. Aerial symptoms are not usually apparent. There may, however, be a reduction in vigour. Warts can be found in severe attacks on the upper stem, leaf and flower. Leaf stalks may develop hypertrophic 'wings'. Above-ground galls are green to brown, turning black at maturity, and later decaying.

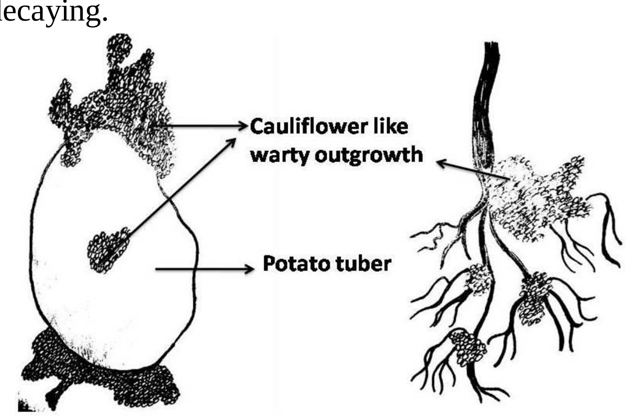

Fig. 2.1: Wart disease of potato

Control measures

(i) Prevention of entry of diseased material into healthy regions.
(ii) The diseased potato tubers should be discarded.
(iii) Soil treatment may control the disease to a large extent. These include steam sterilisation and application of mercuric chloride—copper sulphate and formalin.
(iv) Cultivation of disease resistant varieties.

Aim: To study disease cycle of *Synchytrium endobioticum*

Comments:

1. The primary infection of young potato crops growing in the field begins through the germination of resting spores which are present in the soil.

2. Resting spores germinate to form Zoospores.
3. Zoospores swimming for short interval and then get attached to underground shoot parts.
4. Flagella are withdrawn and zoospores enter the host cells and settle down at the bottom of the host cells.
5. Each of the neighboring cells start dividing repeatedly followed by swelling, ultimately resulting in the formation of wart.
6. These warts represent main symptom of disease and also contain the material for secondary infection.
7. The sporangia present in warts produce zoospores which are responsible for secondary infection.
8. Under favorable environmental conditions, rapid formation of zoospores occurs and secondary infection takes place.

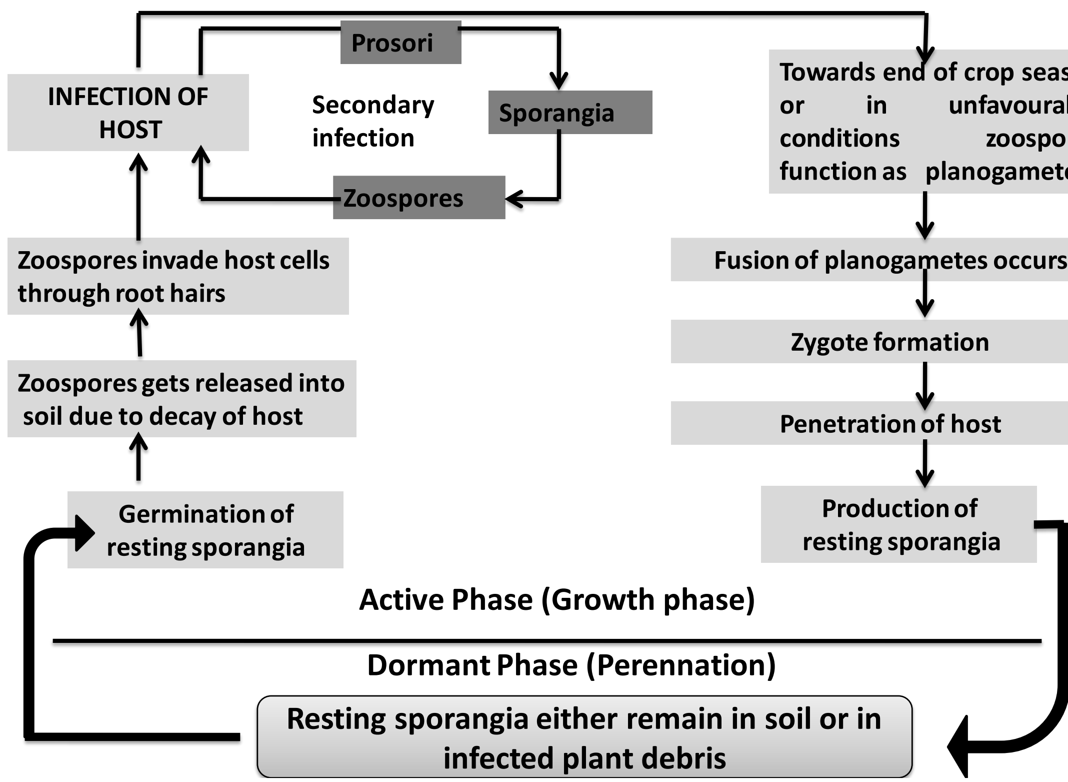

Fig.2.2: Disease cycle of wart disease of potato

2-Damping Off

Aim: To study about occurrence and control measures of damping off

Comments:

1. Damping off is caused by *Phythium*. *Phythium* is a saprophyte but also grows as facultative parasite.
2. In damping-off seedlings are attacked by fungi just at the hypocotyl or upper taproot which results in partial or complete rot and the seedlings suddenly topples.

3. Damping-off occurs in two stages, **Pre-Emergence Stage in** which young seedlings are killed before they reach the surface of the soil when the hypocotyl has just emerged and **Post-Emergence Stage** in which seedlings are out on the surface of the soil and on being infected by the pathogen they topple over and lie on the surface of the soil.
4. Damping-off disease was first of all studied in Germany by Hesse in 1874 and De Bary in 1881.
5. The thallus of the pathogen consists of freely branched coenocytic hyphae.
6. Fungus reproduces asexually by zoospores which are produced at the tip of hyphae.
7. Sexual reproduction is of oogamous type.

Symptoms of Damping-Off of Seedlings

1. The characteristic symptom of damping off includes sudden toppling over of the seedlings.
2. The fungus attacks the seedlings at or near the surface of the ground.
3. The cell wall of the rapidly growing seedlings is generally thin, and as such the tissue is particularly vulnerable.

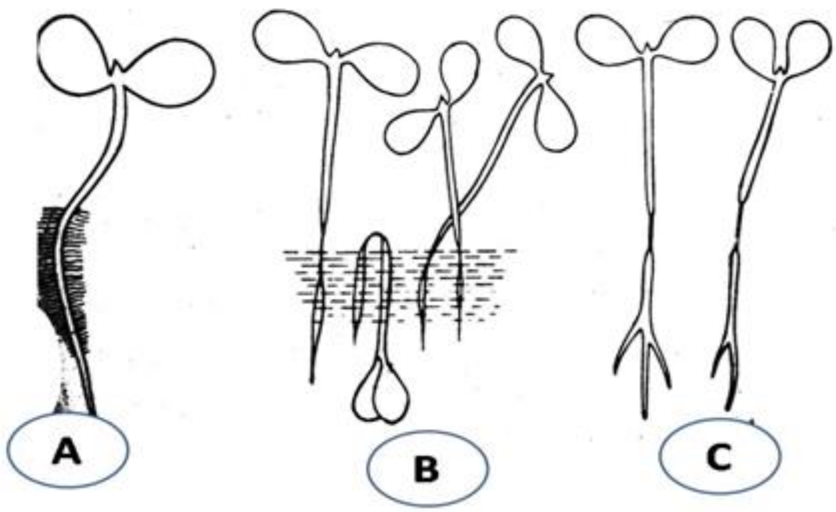

Fig. 2.3: Seedling showing damping off disease. A- Normal seed B, C- Diseased seedling

Control measures of Damping-Off of Seedlings

(i) Seed Bed Soil Preparation: The seed bed soil should be light, having good proportion of sand. An alkaline reaction in the soil favours the growth of the hence effort should be made to reduce alkaline reaction of the soil. Manure used in the seed bed should be well decomposed.

(ii) Soil Treatment: The most perfect control of damping-off is by soil treatment. Steam, dry heat, and chemicals can be utilized for sterilization of soil. Sterilization by dry heat is usually accomplished by burning wood upon sped bed soil. Seed bed soil can be sterilized by using formaldehyde diluted in the proportion of 1 part to 50 parts of water to be sprinkled over the loose soil in sufficient amount to soak it to a depth of at least 4 inches, which will mean one gallon for 2-3 square feet of soil.

(iii) Seed Treatment: Seeds can be treated with specific chemicals known as seed protectants which prevent pre-emergence damping-off. The chemicals are applied to seeds in dry or in wet form which produces a protective layer around the seed coat which helps in uninterrupted growth of seedlings. Arasan, Captan, Blitox-50, Copper sulphate, Mercuric chloride, and Semesan are some of the chemicals utilized for the purpose.

(iv) Manipulation of Watering System: Water logging should be avoided and light irrigation should be provided at frequent intervals. Availability of thin layer of sand over the soil surface helps in keeping the surface of the seed bed soil dry.

(v) Improved Cultural Practices: Overcrowding of seedlings in the seed bed should be avoided. To avoid water stagnation, seed bed soil should have proper drainage facilities and soil should be properly aerated.

3-Green Ear Disease of Bajra

Aim: To study about occurrence and symptoms of green ear disease of bajra

The green ear disease of Bajra is caused by *Sclerospora graminicola*. The disease has been reported from several countries such as India, Iran, Israel, China, Fiji, Japan and the other countries as well where Bajra crop is cultivated. In India, the disease was first reported and studied by Butler (1907) who considered the disease to be sporadic in nature not causing much damage to the crop. Mitter and Tandon (1930) reported the same disease from Allahabad region Uttar Pradesh and also confirmed the observations of Butler (1907). Presently, the disease has been reported from all the states wherever Bajra is grown as a crop of 'Kharif' season.

Symptoms of Green Ear Disease

1. There are two stages of the symptoms of green ear disease.
   (a) The downy mildew stage which is prominent on the leaves
   (b) The green ear stage which affects the inflorescence (ears).
2. The green ear stage is more prominent than downy mildew stage. This is because strain of the pathogen occurring in India has been reported to produce more oospores than sporangia.
3. The growth of plants affected is checked and the plants appear stunted and sick, pale yellow in colour. This symptom can be observed even in young plants.
4. Upper surface of leaves exhibit (shows) chlorosis and lower surface shows downy growth of fungus.
5. Later on chlorotic areas of leaves become brown and in advanced stages shredding of the leaves also occurs.
6. Bajra plants are unbranched, but infection with *S. graminicola* causes development of lateral shoots by stimulation of nodal buds. Development of lateral shoots is an abnormal character.
7. Beside this normal green colour of leaves changes either completely or partly, to whitish or brown colour. Whitening of the younger leaves is prominent along the streaks.
8. In older leaves, the colour changes to brown. In older plants, this is observed especially in the leaves from the axil of which inflorescence develops. The change of the colour of leaves is associated with twisting, folding and shredding towards the tip.
9. A large number of leaf buds develop into a large mass of either white or twisted brown leaves. The axil of these buds produce green leafy human ear like structures.

10. The disease becomes prominent when the inflorescence gets converted into green leafy ears, i.e, floral parts are transformed into leafy (twisted) structures.
11. Formation of different types of green ears can occur.
    (i) Transformation of entire ear (inflorescence) into green leafy mass.
    (ii) Conversion of lower part of the inflorescence to green leafy mass but the upper part of inflorescence bears seeds.
    (iii) Complete suppression of development of inflorescence and formation of small bunch of leafy structures.

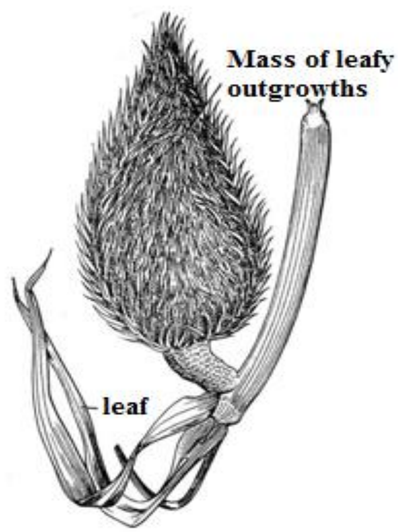

Fig.2.4: Green ear disease of Bajra

Aim: To study about disease cycle

Comments:

1. The primary infection occurs through oospores present in soil or through mycelium present in the seed produced on diseased ears.
2. Under favourable conditions, these oospores germinate, enter the young seedlings of and cause primary infection.
3. Sowing of seeds containing mycelium also causes primary infection.
4. Disease spreads systemically as the seedlings grows into mature plants.
5. During initial stages, symptoms are observed on leaves in form of downy growth of the fungus on the lower surface of leaves. Later on characteristics green ears appear on the diseased plants.
6. The secondary infection occurs through sporangiophores and sporangia produced through of primary infection.
7. Sporangia are disseminated by wind, water and insects, land on the susceptible parts of the host, and germinate producing zoopores.
8. These zoospores germinate by germ tube and cause secondary infection.
9. During the end of the growing season, the pathogen produces oospores through sexual reproduction which serve as resting spores.

10. These resting spores help keeping the pathogen to survive unfavourable conditions.
11. During harvesting of the crop, the oospores along with plant debris are left in the soil which becomes active when favorable conditions are achieved.

4- Late Blight of Potato

Aim: To study about occurrence and symptoms and control measures of Late blight of potato

Late blight of potato is caused by *Phytophthora infestans* (Mont.) De Bary. The disease is found all over the world wherever potato is cultivated. In India potato is mainly cultivated in winter. The late blight epidemics are thus rare in the plains in India because in the summer season (before winter) fungus in the soil is destroyed due to drought and high temperature. The disease occurs annually in the cooler Himalayan regions extending from Assam to Kashmir at an altitude of 6,000 ft. or more as the crop is grown in the rainy season. The disease is destructive to the crop grown in the rainy season. Beside Himalayan region disease also occurs annually in regions of Punjab, Uttar Pradesh, Bihar, and W. Bengal.

The disease is known to cause severe damage to potato.

(a) Damage caused to the foliage shortens the growing season.
(b) Short growing season consequently results in small tubers with reduced weight.
(c) Also tubers are produced in smaller numbers which reduces yield.
(d) In severe cases of infection complete loss of the crop may also occur.
(e) Infection also causes decay of tubers in the field and as well as during storage.

Symptoms of Late Blight

1. The disease first appears on top of the plants generally after the blossoming period but mostly in the month of January. The disease may appear however at any time during the growth of the plant. The occurrence of disease is dependent upon availability of conditioning factor (low temperature and high humidity) which acts as favorable environment for growth of pathogen.
2. The disease is marked by presence of small, dead, brownish to purple black areas or lesions.
3. Such lesions are found on tips and margins of the leaflets, rachis, petiole and also stem. Under favorable conditions the lesions rapidly increase in size involving the whole surface of the leaf.
4. The lesions initially appear on the leaves and petioles present near the ground, later on lesions then spreads upwards.
5. In final stages rapid and general blighting of foliage is observed. The blighted leaves curl and shrivel in dry weather.
6. A characteristic offensive odour is obtained due to decay of leaves under moist conditions.
7. Growth of fungus can be observed on lower surface of leaves (especially on dew mornings) in form of whitish powdery bloom. It is known to contain sporangiophores and sporangia

coming out through the stomata. These sporangia act as a means of disease spread during growing season.

8. Potato tubers are also infected after the top portion of plant have been blighted. There occurs brownish discoloration of the skin on infected parts of the tubers which lie near to the soil surface.
9. Such dry rot spots on potato tuber remain firm and extend to about half an inch below the surface.

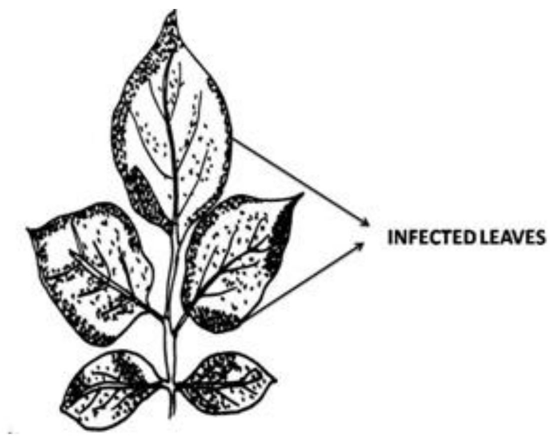

Fig. 2.5: Late blight of Potato

Control Measures of Late Blight

Several methods can be adopted for of control of the disease which includes:

1. The seeds selected for plantation should be free from infection. This requires strict and careful seed tuber inspection at the cutting time and is helpful in elimination of direct infection.
2. Storage of potato tubers should be done in cold storage rooms to reduce development of disease.
3. Cultivation of approved disease resistant varieties is an effective method of prevention of disease.
4. Different fungicides can be utilized for further control of fungus. The fungicides may be applied either through spaying and dusting. **Repeated spraying** of fungicides such as Perenox, Blitox-50 and Fytolan. Dithane Z-78, and Dithane M-22 is considered to be extremely effective method of disease control. **Dusting** the foliage with copper-lime dust is also considered effective control measure. Dusting is preferably done in the morning when the plants are wet with dew.
5. Disease can also be checked through sanitation which includes destruction and proper disposal of potato tuber refuge from pits and store houses.
6. Tuber treatment before storage tubers can be dipped with 1: 1000 mercuric chloride solution for about 90 minutes. Such tubers should be thoroughly washed before use.
7. In cool humid areas destruction of foliage a few days before harvesting also proves beneficial.

5-Loose Smut of Wheat

Aim: To study about occurrence and symptoms and control measures of Loose smut of wheat

Loose Smut of wheat is caused by *Ustilago tritici* (Pers.) Rostr. It is a very common and found in regions of Punjab, Uttar Pradesh and certain districts of Madhya Pradesh. The disease causes significant amount of damage to wheat crops.

Symptoms of Loose Smut Disease

1. Emergence of smutted ears occurs from the boot leaves a little earlier than the healthy ones. They bear loose, powdery black masses of smut spores instead of flowers.
2. Ovaries and other floral parts (except the awns and rachics) gets converted into masses of smut spores.
3. In the young spikelets before emergence each ovary has become a spore sac which bears millions of spores. The spores of each spikelet are covered by a thin greyish or silvery membrane. By the time the ear emerges from the boot leaf the membrane ruptures to expose the black powdery mass of spores.
4. The ear is generally completely destroyed except the awns and the rachis. When the wind blows the spores are blown off leaving behind the bare rachis and central axis.
5. However, all spores may not be blown by the wind, few spores may remain attached.
6. Also all the ears of wheat plant may not be smutted. It means that some may be healthy and the others diseased.

Control Measures of Loose Smut Disease

External application of chemicals is ineffective as mycelium of the parasite is present inside the grain. Most of the chemicals do not reach the fungi at first attempt and which may also cause damage to the embryo. Because the mycelium in the grain is present in dormant state therefore all the methods utilized for treatment initially make the dormant mycelium active.

(a) Hot Water Treatment: Hot water treatment includes soaking of wheat grains in water having a temperature of 26°C-30°C for about 4-5 hours. As a result grains are softened and dormant mycelium becomes active. This is followed by raising temperature of water to 54°C and maintaining the temperature for about 10 minutes. Activated mycelium is killed at this temperature. The success of the process lies in maintaining the temperature as low temperature will fail to kill the mycelium and a high temperature will kill the embryo. After the treatment the water is drained off, grains are dried and sown.

(b) Sun Heating: This method is utilized in regions of Punjab and U.P. In these regions temperature is very high in month of May and June. The grains are soaked in water in flat and shallow basins with water level about two inches above the level of grain. The basins are placed in the direct rays of the summer sun for about 4 to 6 hours. This activates dormant fungus. The water is drained off. The softened grains are spread on floor in the midday sun to dry. This kills the activated mycelium.

(c) Cultivation of disease resistant varieties is always considered to be an effective method of disease control. Np 710, Np 120, and Pb 90 are some of the disease resistant varieties of wheat.
(d) The wheat plants with infected ears, which emerge out of the boot leaves earlier than the healthy ones, may be uprooted at once and burnt. This practice is called rogueing.
(e) The grains for sowing purposes should be thrashed from uninfected wheat ears.
(f) Utilization of systemic fungicides is also useful to check the disease. Fungicides D735 (Vitavax) and F 461 (Plantavax), Benomyl and Carboxin are utilized to control loose smut of wheat.

6-Rust of Linseed

Aim: To study about occurrence and symptoms and control measures of rust of linseed

Rust of linseed caused by *Melampsora lini* is a well known disease of flax. In India flax comprises a major oilseed crop generally cultivated during October-April. The disease mainly appears in February or later, however Butler (1918) reported occurrence of the disease in early November.

Effect on crop

The disease is known to appear in epidemic form. Once the crop in the field gets infected, the disease spreads at a very fast rate in the neighboring field in the locality. Severe damage to the crop is caused. Infected plants are defoliated which reduces starch formation. Pathogen utilizes stored food reserves of host plant which decreases yield of seeds and Oil content of the content.

Symptoms of the Rust of Linseed

1. Initial symptoms pustules are observed on leaves and gradually all aerial parts of the plant get infected.
2. Orange coloured large pustules appear on the leaves. Small pustules are initially surrounded by chlorotic areas.
3. Little necrosis of the leaves is at first observed but it grows, becomes more general and leading to premature death of leaves.

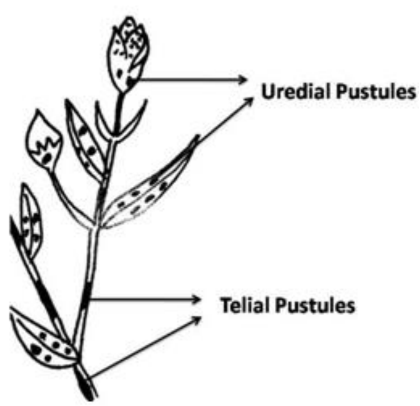

Fig.2.6: Diseased linseed plant

4. Pustules on the leaves are uredopustules containing uredospores.
5. Such uredopustules are also observed on stems.
6. Uredopustules present on leaves are round and small, those on stems are elongated and irregular.

Control Measures of the Rust of Linseed

(i) Cultivation of disease resistant varieties is effective means to control the disease.
(ii) Seed can be treated with chemicals to kill the teleutospores.
(iii) Avoidance of excessive utilization of nitrogenous manures.

Aim: To study about disease cycle

Comments

1. In temperate countries, primary infection takes place through basidiospores.
2. Basidiospores are produced by germination of teleutospores perennating in the soil.
3. In tropical countries, the teleutospores, produced at the end of growing season i.e., loose their viability because of high temperature in summers. Uredospores too are killed due to excessive temperature.

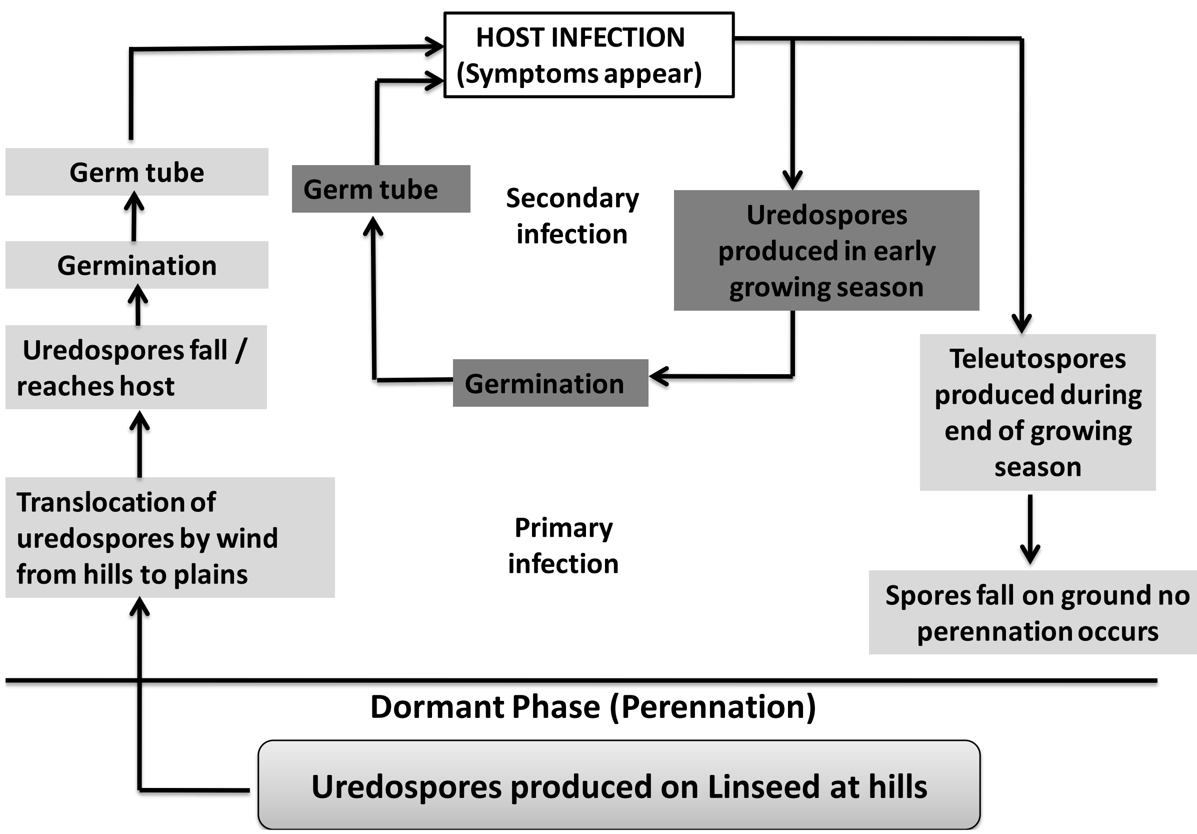

Fig. 2.7: Disease cycle of Rust of Linseed

4. Uredospores produced on linseed at hills are carried down by wind to plains where they cause infection.
5. This spread of Uredospores from hills to plains take some time, hence the outbreak of the disease in plains occurs only after 2-3months of the sowing the crop.
6. Uredospores produced from primary infection cause secondary infection.
7. Secondary infection is caused within a short time as uredeospores take very less time to germinate.

7- Red rot of Sugarcane

Aim: To study about occurrence and symptoms and control measures of red rot of sugarcane

Red rot of sugarcane is caused by *Colletotrichum falcatum* Went, the perfect stage of which is *Glomerella tucumanensis* (Speg.) Arx and Muller. It is one of the most severe diseases of sugarcane and found in all the countries wherever sugarcane is cultivated. It was first of all described from Java by Went in 1893.

Symptoms of Red Rot of Sugarcane

1. The first external symptoms of disease include drooping, withering and finally yellowing of the upper leaves.
2. This drooping and withering is followed by wilting of the entire crown, and finally the entire plant shows indications of disease and dies.
3. If the infection is not severe, the eyes frequently die and the dead areas extend out from the nodes.
4. Infection in the stem being internal, the presence of the disease is not visible externally. Upon splitting the infected cane during the early stages of the disease, one can see fibro-vascular bundles near the base are reddish in colour.
5. The protoplasm changes colour and a gummy dark-red material oozes out of the cells which fills the intercellular spaces. The soluble pigment present in this ooze, is absorbed by the cell wall which produces the characteristic red rot appearance.
6. However, the mere presence of red colour in the fibro-vascular bundles is not necessarily an indication of this disease, since the colour can also occur due to other reasons as well.
7. With increase in disease the red colour spreads to neighbouring tissues resulting in formation of irregular discoloured blotches.
8. The natural bright colour of the rind disappears and turns dull when the stems are completely rotted. The stem shrinks at the nodes Split cane gives sour smell and shows red tissue with white cross-bands.
9. Diseased tissues with a microscope will reveal more or less mycelial threads of the fungus, or if the diseased canes are split and put in a moist chamber the fungus will develop readily and be easily recognized.

Control of Red Rot of Sugarcane

Red rot of sugarcane is hard to control because the stalk from which seeds are prepared has been largely affected from the time of planting, and fungicides cannot reach the infected tissues inside a diseased seed set.

1. Plantation of carefully selected red rot-free seed sets. Seed should always be taken from disease-free nurseries examined regularly by the cane protection staff.
2. Timely rogueing and destruction of infected plants also helps in controlling and checking red rot of sugarcane.
3. Hot water treatment (50°C, for two hours) of seeds can also be utilized for controlling red rot of seed.
4. Utilization of fungicides such as Arasan (0.25 per cent.) is also utilized for disease control.
5. Cultivation of resistant varieties Co. 975, 1148, 1336 and 6611; Co. S 561, 574 is strongly recommended.
6. Practice of crop rotation reduces the chances of epidemic.

Aim: To study about disease cycle

Comments:

1. The sources of primary inoculum are the old fragmented stalks and leaves and other rubbish on which the fungus grows saprophytically; and unknowingly planted diseased stock during cultivation.
2. Ratoon crops are also source of infection.
3. The conidia that are produced in the acervuli developed along the midribs of the diseased leaves during primary infection form the secondary inoculum. They are disseminated by wind, rain splashes, irrigation water and also by insects.
4. Conidia serve as secondary means of infection.
5. The conidia germinate readily by germ tube which on coming in contact with any hard surface, e.g., soil particles or plant parts, forms appressorium from-which infection hypha is produced.
6. However conidia are short lived and serve no role in perennation. Chlamydospores (thick walled) are the means of survival.
7. The pathogen may gain entrance through the nodes at the leaf scars, through any kind of wound, through root primordia and seed-cuttings.

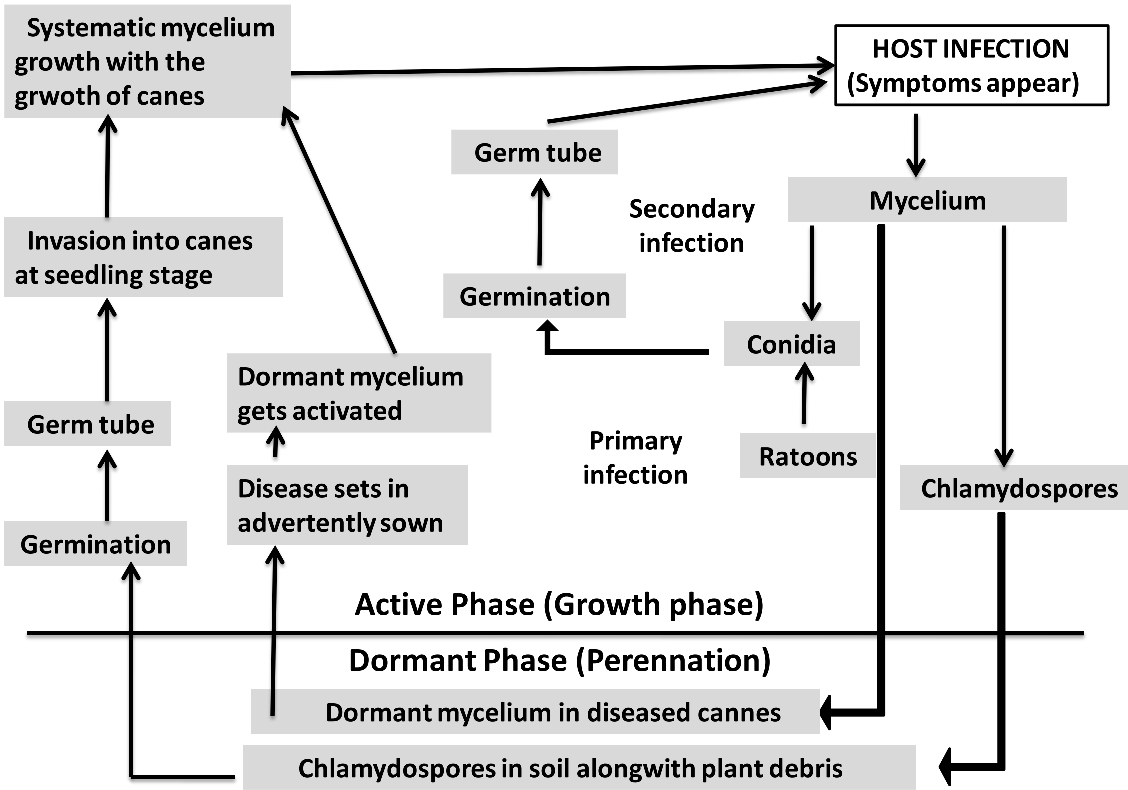

Fig.2.8: Disease cycle of Red Rot of Sugarcane

8-Downy Mildew of Pea

Aim: To study about symptoms and control measures of downy mildew of pea.

Downy mildew of pea is common disease of Pea caused by *Peronospora pisi.* Occurrence of disease is favored by wet and cool conditions.

Symptoms of Downy Mildew of Pea:

1. Appearance of yellow to brown scattered patches of discoloured areas on upper surface of leaflets and stipules.
2. Formation of downy growth in patches of variable size on the under surface corresponding with the lesions on upper surface.
3. When young downy coating is whitish, with growth the colour gradually changes to greyish-violet.
4. Sporangia are borne at the tips of the ultimate branches. The infected leaflets and stipules become reduced in size with their margins curled downwards.
5. The infected areas gradually develop into elongated blotches, and often to irregular spots.
6. With the spread of infection, blotches also appear on the pods. At young stage, the blotches are pale-green, more or less elliptical to irregular, but later on blotches turn dark to bright-brown, mottled with light-green islands. Blotch followed by the green island effect is a typical symptom of the disease.

7. Seeds lying corresponding to the infected tissues of the pods abort and become very much reduced in size.

Control of Downy Mildew of Pea

1. The fungal organism survives from season to season with the help of oospores present in the plant debris; the destruction of plant debris checks the occurrence of disease.
2. Crop rotation is another very effective control measure.
3. Spraying and dusting pea plants with fungicides
4. Are effective in limiting the spread of the disease.

9-Powdery Mildew of Pea

Aim: To study occurrence, symptoms and control measures of Powdery mildew of Pea

Powdery mildew of Pea is caused by *Erysiphe polygoni DC*, and is distributed worldwide. The fungus is an obligate parasite and also attacks other crops such as beans, coriander, cabbage, turnip etc. In India outbreak of disease occurs generally during November- December. Disease causes most damage in dry season.

Symptoms of Powdery Mildew Disease

1. First symptoms appear on the leaves in the form of white floury patches on both sides of leaves.
2. The disease then spreads to other green parts of the plant such as tendrils, pods, stems etc. The patches on the leaves originate in the form of minute discoloured specks from which powdery mass radiates on all sides.
3. In the advanced stages of the disease large areas of the host get coveted with white floury patches.
4. Infected plants impart dirty appearance. In extreme severe infections the infected leaves are shed leaving stem devoid of the leaves.

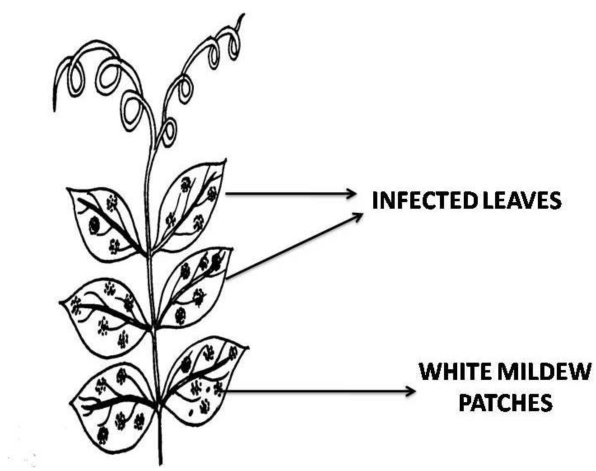

Fig. 2.9: Diseased plant with powdery mildew symptoms

Control Measures of Powdery Mildew Disease

1. Sanitation of field and destruction of debris of diseased plant is crucial to control spread of disease.
2. Crop rotation may effectively control the disease.
3. Sulphur dusting and spraying with Karathane is an effective method to control the disease.
4. Cultivation of resistant varieties such as P185, 61113, 1683, Freazer-656,etc is an effective alternate to control the disease.

Aim: To study the disease cycle

Comments:

1. The primary infection occurs through ascospores which are released into soil by disintegration of the wall of cleistothecium.
2. The ascospores germinate by germ tube under favorable conditions and causes primary infection.
3. This primary infection is caused initially in lower most leaves of the plant which later spreads to other leaves.
4. The symptoms of disease appear in form of white powdery mass. Patches of infection contain conidia and conidiophores.
5. The primary infection may also come from the conidia produced on other hosts.
6. The secondary infection of the host takes place by conidia which are produced in large numbers and are disseminated by wind.
7. Upon reaching the host the conidia germinate and cause infection.

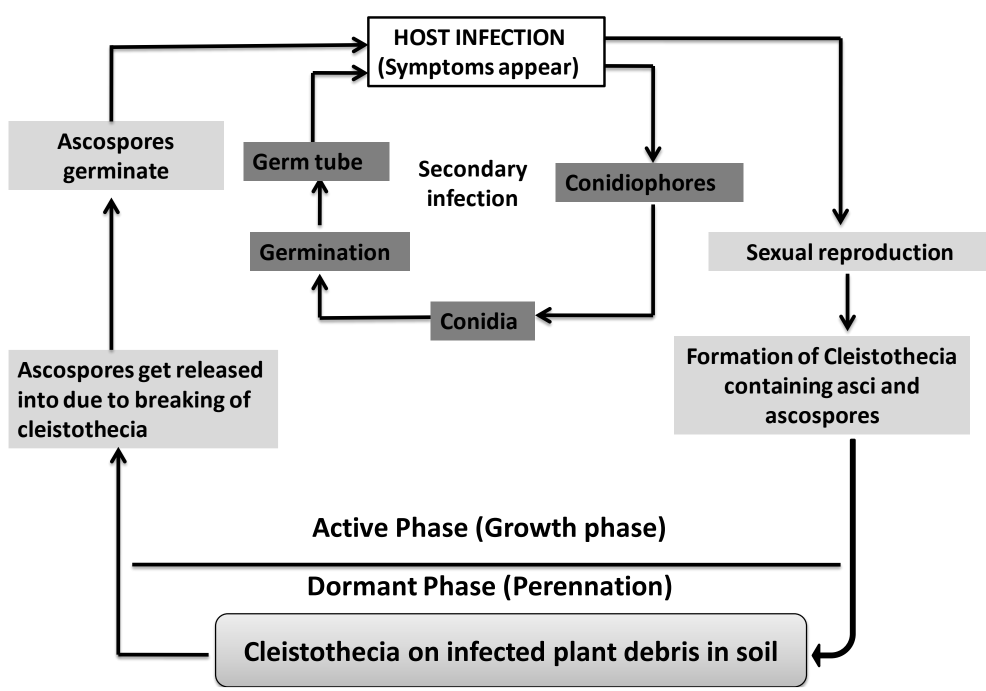

Fig. 2.10: Disease cycle of powdery mildew disease

10-White Rust of Crucifers

Aim: To study about occurrence and symptoms and control measures of white rust of crucifers

White rust is one of the common diseases of crucifers caused by *Albugo candida* (Lev.) *Kunze* or *Cystopus candidus Lev*. which is an obligate parasite. The disease is distributed worldwide wherever crucifers are cultivated. The disease is known to infect many plant species including Mustard, Rape, Radish, Cabbage, Cauliflower, Turnip etc.

Effect of White Rust Disease

Although considered unimportant in proportion to its widespread occurrence, the disease may cause serious damage in certain areas and the losses may be upto 25 percent when the floral parts get malformed and seeds are not formed at all. The disease in association with downy mildew disease of crucifers caused by *Peronospora parasitica* causes severe damage to the crop.

Symptoms of White Rust Disease

1. All the parts of the plant except roots are affected. There are two types of infection namely Local and Systemic.
2. In local infection individual spots or pustules of variable size appear on leaves, stems and inflorescence. Pustules are raised shiny white areas.
3. Pustules coalesce to form large irregular patches.
4. Pustules appear in circular or concentric arrangement with one or two central areas. Rupture of epidermis exposes white powdery mass consisting of fungal spores.
5. Systemic infection involves infection of young stems and inflorescence.
6. Infected tissues are stimulated to various types of deformities such as hypertrophy.
7. Swellings and distortion are observed due to Hypertrophy and Hyperplasia.
8. Thickening of peduncle and pedicel and swelling of stamen and carpel is observed.
9. Floral parts become fleshy, swollen, green or violet in colour and early fall of stamen occurs.
10. In case of early systemic infection growth of complete plant is affected resulting in stunted growth.

Control Measures of White Rust Disease

1. Destruction and eradication of weed is effective in controlling the disease.
2. Crop rotation discourages soil borne primary inoculum.
3. Spraying Bordeaux mixture or Dithane also checks the spread of the disease.
4. Cultivation of disease resistant varieties is another effective means to check occurrence of disease.

2.4 SUMMARY

1. Plant pathology is a branch of botany which deals with study of nature, development and control of plant diseases.
2. Several bacteria, fungi and viruses are known to infect different plants and cause diseases.
3. Each disease has a characteristics development pattern and symptoms.
4. Mildews, smuts, screloti, rust etc are common symptoms in infected plants.
5. Each pathogen requires specific environmental conditions for infection and causing disease.
6. There are specific control measures which can be adopted against each pathogen so as to check and control the occurrence of spread of disease.
7. Black wart disease of potato is caused by *Synchytrium endobioticum.*
8. The disease is characterized by development of cauliflower like warts on surface of tubers.
9. Specific chemicals such as $HgCl_{2,}$ formalin, ammonium sulphocynate etc. can be utilized for control of disease.
10. Fungus *Pythicum* causes damping off in which growth of seedlings is affected.
11. Chemicals like formalin, captan etc. are utilized to control the disease.
12. Late blight of potato is caused by *Phytophtora infestens*.
13. Development of necrotic areas or brown spots in leaves is the first symptoms of disease.
14. *Sclerospora graminicola* causes green ear disease of bajra.
15. The disease involves two stages downy mildew and green ear stage.
16. Downy mildew of pea is a common disease of pea caused by *Peronospora*.
17. A symptom in form of yellow to brown spot or lesions appears at very early stage.
18. *Albugo candida* causes white rust of crucifers.
19. The disease infects all parts of plant accept roots.
20. Disease can be controlled by sanitization, destruction of infected plants parts and debris, crop rotation and use of fungicides.
21. Loose smut of wheat is caused by *Ustilaga tritici*.
22. Disease appears when plant is in inflorescence stage.
23. Rust is disease is caused by basidomycetous fungus *Melampsora lini*.
24. Affected plant becomes bright orange in color because of presence of uredosori.
25. Control of disease includes sanitation, seed treatment, cultivation of resistant varieties and use of fungicides.
26. Red rot of sugarcane is caused by deuteromycetous fungus, *Collertotricium falcatum*.
27. Disease can be controlled through sanitation, use of fungicides and cultivation of resistant varieties.

2.5 GLOSSARY

Chlorosis: loss of the normal green coloration of leaves of plants, caused by iron deficiency in lime-rich soils, disease, or lack of light

Conidium: A spore produced asexually by various fungi at the tip of a specialized hypha.
Fungicide: A chemical utilized to destroy fungus.

Hyperplasia: Hyperplasia is the enlargement of a plant tissue due to excessive increase in the number of plant cells produced. Hyperplasia results in overdevelopment in size of plants or plant organs.

Hypertrophy: Hypertrophy is excessive growth due to the enlargement of individual cells.

Pustules: Symptoms of rust diseases vary with the host plant and often begin as chlorosis or yellowing on the upper surface of leaves. These develop into blister-like swellings or pustules

Rust: Rusts are the fungal disease of grasses and other plants which appear on the host surface as small, coloured pustules- red, brown, yellow, orange or black in colour. It is caused by the fungus of the class *uredomycetes*

Sclerotium: the hard dark resting body of certain fungi, consisting of a mass of hyphal threads, capable of remaining dormant for long periods.

Smut: Smuts are the fungal diseases of cereals and other members of grass family that cause the ears (particularly the ovaries) to turn black or sooty

Spikelet: A small or secondary spike in grasses; one of the flower clusters, the unit of inflorescence, consisting of two or more flowers and subtended by one or more glumes variously disposed around a common axis

Sporangiophore: a specialized hypha bearing sporangia

Stolon: a creeping horizontal plant stem or runner that takes root at points along its length to form new plants

Teleutospore: Teliospore (sometimes called teleutospore) is the thick-walled resting spore of some fungi (rusts and smuts), from which the basidium arises.

Uredospores: a thin-walled, red, summer spore of a rust fungus, produced usually on the leaves or stems of grasses and capable of reinfecting other grasses of the same species.

2.6 SELF ASSESSMENT QUESTION

2.6.1 Choose the most appropriate option for the following

1- In India Wart disease of potato was reported by

(a) Ganguly and Dravid (b) Ganguly and Paul
(c) Ganguly and Srivastava (d) Ganguly and Sinha

2- Smuts are

(a) Characterized by appearance of coloured lesion
(b) Fungal disease in which ears turn black
(c) Fungal disease in which white busters arte formed
(d) All are true

3-Which of the following is not a symptom of green ear disease of Bajra
(a) Chlorsis in upper part of plant
(b) Development of lateral shoots
(c) Twisting and folding of leaves
(d) Transformation of green leaves into inflorescence

4-White blisters are found on
(a) Potato infected by *Synchytrium endobioticum*
(b) Grasses infected by *Ustilago triticum*
(c) Crucifers infected by *Albugo candida*
(d) Sugarcane infected by *Sclerspora graminicola*

5-Choose the correct pair of symptoms of fungal disease
(a) Smut, rust and sclerotia
(b) Sclerotia, smut and conidia
(c) Rust, conidia and smut
(d) Rust, sclerotia and conidia.

6-Which of the following is not true about mildews
(a) In mildews superficial growth of fungi is observed on surface of host.
(b) Mildews is a group of fungal disease.
(c) Downy mildews are internal obligate parasites.
(d) Powdery Mildews are internal facultative parasites

7-Downy mildews of pea is characterized by
(a) Enhancement in size of stipules of infected plants.
(b) Appearance of blotches on pods.
(c) Cold and humid conditions restrict occurrence of downy mildews of pea.
(d) All are true.

8- Observable symptoms of red rot of sugarcane
(a) Presence of disease is visible externally since it infects stem
(b) A gummy black fluid like material oozes from diseased.
(c) Eye regions of sugarcane show extensive growth.
(d) Drooping, withering and yellowing of upper leaves.

9- Damping off is favored by
(a) Lack of aeration and over watering.
(b) Abundance of light.
(c) Lack of moisture.
(d) Abundant aeration and light

10-Different types of green ear include
(a) Transformation of entire ear into green leafy mass

(b) Conversion of lower part of inflorescence to green leafy mass.

(c) Suppression of inflorescence development and formation of small bunch of leafy structure.

(d) All the above statements are true.

2.6.2 State weather following statements is true or false

1. *Sclerospora graminicola* causes wart disease of potato.
2. Rusts are characterized by appearance of coloured pustules on surface of host plant.
3. Cool and humid condition acts as unfavourable environment for spread of downy mildew of Pea.
4. Loose smut of wheat is caused by *Ustilago tritici*.
5. Downy mildew stage of green ear disease affects inflorescence.
6. Mildews are a group of bacterial disease.
7. *Synchytrium endobioticum* is an holocarpic endoparasite.
8. Smuts are fungal disease of cereals and grass.
9. Temperatures and moisture play an important role in determining the extent of infection
10. White rust of crucifers is caused by *Peronospora.*

2.6.3 Fill up the following blanks

1) ___________ is a fungal disease of cereals and grasses.

2) Wart disease of potato is caused by _____________.

3) Mildews are a group of ___________ diseases.

4) Late blight of potato is caused by__________.

5) Appearance in ______________ on pods is a characteristics feature of

6) *Albugo candida* causes ____________of crucifers.

7) Rust of linseed is a common disease of___________.

8) Powdery mildew of Pea causes maximum damage in _________ season.

2.6.4 Very Short answer type question.

1) Define plant pathology?

2) Name the causative organism of green ear disease of Bajara?

3) What are two different stages of symptoms of green ear disease of Bajara?

4) What are fungicides?

5) Define Sclerotia?

6) How does smut differs from rust?

7) Mention a specific symptom for identification of Downy Mildew of Pea?

8) Name four plants affected by white rust of crucifers?

9) What do you understand by rogueing?

10) What is Downy Mildew of Pea?

11) Give an example of obligate fungal plants pathogen?

2.6.1 Answers Key: 1-(b), 2-(b), 3-(d), 4-(c), 5-(a), 6-(b), 7-(b), 8-(d), 9-(a), 10-(d)

2.6.2 Answers Key: 1-F. 2-T, 3-F, 4-T, 5-F, 6-F, 7-T, 8-T, 9-T, 10-F

2.6.3 Answers Key: 1-Smut, 2- *Synchytrium endobioticum*, 3-Fungal, 4-*Phytophthora infestens*, 5-Bltches, 6-White rust, 7-Flax, 8- Dry

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2.8 SUGGESTED READINGS

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2.9 TERMINAL QUESTIONS

2.9.1 Short answer type question:

1) Mention about causative organism and effect of wart disease of potato?
2) Describe about disease cycle of *Synchytrium endobioticum*?
3) What is green ear disease? Mention about different types of ears known?
4) Mention about causative organism and distribution of late blight of potato?
5) Enlist control measures adopted against late blight of potato?
6) Mention the symptoms of loose smut disease of wheat?
7) Write short notes on how late blight is spread?
8) Write short note on symptoms and causative organism of Downy Mildew of pea?
9) What are seed protectants. Mention their function with examples?
10) Describe about disease cycle of damping off?
11) Name any four plant diseases caused by fungi along with their respective causative organism?
12) Explain why occurrence of late blight epidemic is rare in plains of India?
13) Describe about disease cycle of red rot of sugarcane?

2.9.2 Long answer type question:

1) Describe about symptoms and control measures of wart disease of potato?
2) Describe the disease cycle of loose smut disease of wheat. What probable measures can be taken to check the disease?
3) What are symptoms of green ear disease of bajra. Also mention about symptoms of disease?
4) Describe the disease cycle of late blight of potato. Mention about the damage caused by late blight of potato?
5) Tabulate different fungal diseases of plants along with their causative organisms?
6) Explain about various types of symptoms observed in plants infected by pathogenic fungi?
7) Describe about causative organism, symptoms and control measures of white rust of crucifers?
8) Enlist characteristics features of rust of linseed?
9) What do you understand by damping off. Mention about its causative organism?
10) With suitable diagram explain symptoms control measure and disease cycle of powdery mildew of Pea?

UNIT-3 IDENTIFICATION OF FUNGAL CULTURES

3.1 OBJECTIVES

After reading this unit students will be able-

- To learn about different method of isolation of fungi
- To study about various macroscopic characteristics of fungi
- To learn about microscopic identification of fungi

3.2 INTRODUCTION

Fungi are eukaryotic organisms which lack chlorophyll. Fungi have a diversity of morphological appearance, depending on the species. We commonly see fungi as velvety blue and green growth on rotting fruits and vegetables like oranges, lemons, tomatoes etc. Another commonly observed fungal growth is whitish –gray furry outgrowth on bread and the mushrooms in the fields. Kingdom fungi are represented by molds and yeasts. Molds are filamentous and multi cellular whereas yeasts are unicellular**.** Growth of fungi requires moist habitats, generally in dark and availability of organic matter. They are generally terrestrial organisms, however few are fresh water or few marine species are also known. Fungi can be isolated in laboratory by culturing the sample containing fungi mycelium or spores onto culture medium. A fungus can be identified by observing its growth on slide culture and plate culture, and also by observing its hyphae and sporulating structures microscopically under low and high power. Unknown fungus can be assigned to a particular group by consulting various monographs and books on fungal systematics.

3.3 IDENTIFICATION OF FUNGAL CULTURES

3.3.1 Aim: To study about microscopic identifying features of common fungal pathogen

Requirements: Permanent slides of *Aspergillus, Penicillum, Alternaria, Mucor, Rhizopus*, microscope.

(a) *Aspergillus*

Classification

Kingdom:	Mycetae
Division:	Amastigomycota
Class:	Ascomycetes
Sub class:	Plectomycetidae
Order:	Eurotiales
Family:	Eurotiaceae
Genus:	*Aspergillus*

Identifying features

1. *Aspergillus* colonies are powdery and are of different colours yellowish (*A.flavipes*), blue green (*A.sydowi*), lime green (*A.flavus*), cinnamon to deeper brown shades with edge (*A.terreus*), blackish brown to black with slight yellowish mycelia (*A. niger*).
2. Mycelium is septate and branched.
3. Conidial apparatus developed as stalk and heads from foot cells.
4. Conidiophores septate or unseptate broadening in to elliptical, hemispherical or globose fertile vesicles.
5. Vesicles bear phialides in one series or two series.
6. From these vegetative hyphae, long, unbranched, nonseptate erect hyphae arise called conidiophores. The cell from which conidiophore arise is called foot cell.
7. It is thick walled and T-shaped and one conidiophore arises from each foot cell. 4. Conidiophores terminate into a globular structure called vesicle.
8. 6. At the tip of the sterigmata, a chain of small unicellular spores called conidia arises. These conidia are formed in basipetal manner (oldest is at the top).

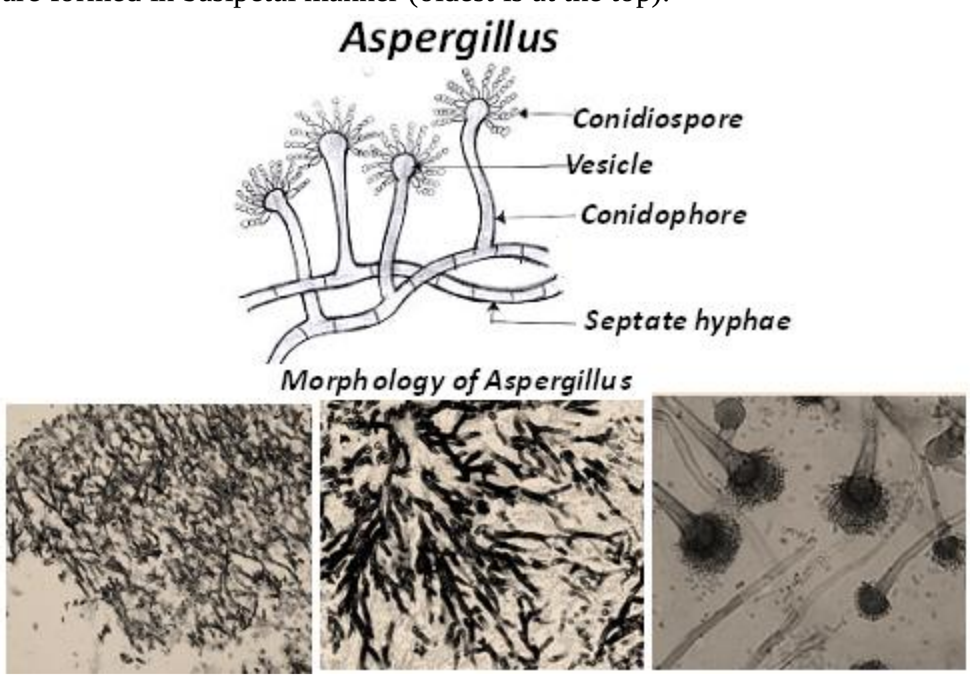


Fig.3.1 Microscopic view of *Aspergillus*

(b) *Penicillium*

Classification

Kingdom:	Mycetae
Division:	Amastigomycota
Class:	Ascomycetes
Subclass:	Plectomycetidae
Order:	Eurotiales

Family: Eurotiaceae
Genus: *Penicillium*

Identifying features

1. Colonies are of various color (i.e., green, bluish green, greyish green), central area raised or smooth, may be zonate with age.
2. Vegetative hyphae creeping, wooly cottony, floccose to semi floccose, slow or fast growing.
3. Hyphae branched and septate producing branched or unbranched conidiophores each with one, two or more vertical of phialides and metulae.
4. Foot cells are absent in *Penicillium*. Only one conidiophore arises from one cell.
5. Conidiophores branch once, twice or even more times to produce primary, secondary or tertiary branches.
6. Conidia borne in chains typically forming brush like head, not enclosed in slime.
7. Conidia globose, ovate or elliptical with smooth or rough surface.

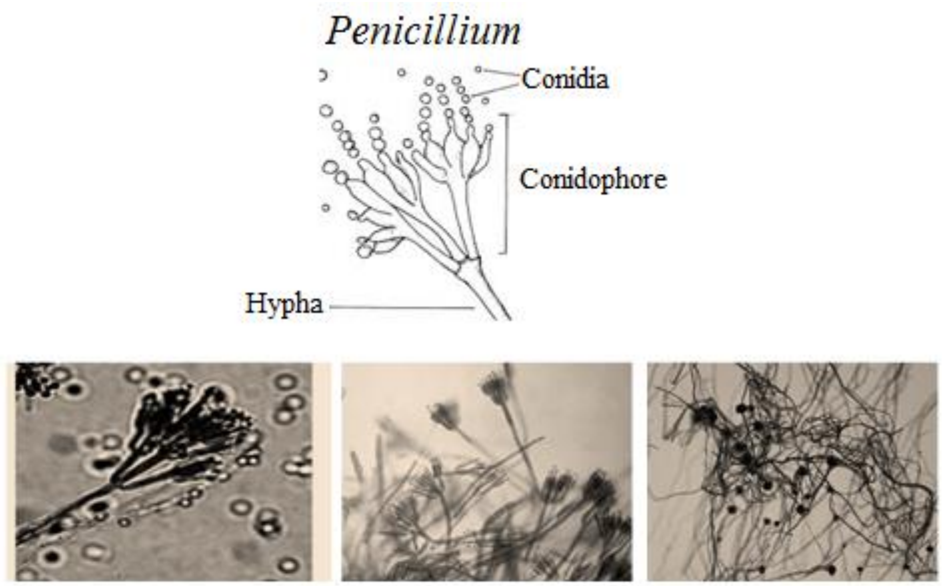


Fig.3.2: Microscopic view of *Penicillium*

(c) *Mucor*

Classification

Kingdom: Mycetae
Division: Amastigomycota
Class: Zygomycetes
Order: Mucorales
Family: Mucoraceae
Genus: *Mucor*

Identifying features:

1. Hyphae broad, branched and non septate mycelium is present.

2. Rhizoids and stolons are absent.
3. Apophysis absent or scarcely apparent.
4. Sporangiophores are ovoid in shape.
5. In *Mucor,* sporangiophores arise singly instead of a cluster as found in *Rhizopus*.
6. Sporangiophore may arise from any point in mycelium (this is again a different feature from *Rhizopus* in which sporangiophore arise from nodes i.e. junction of rhizoids and stolon).

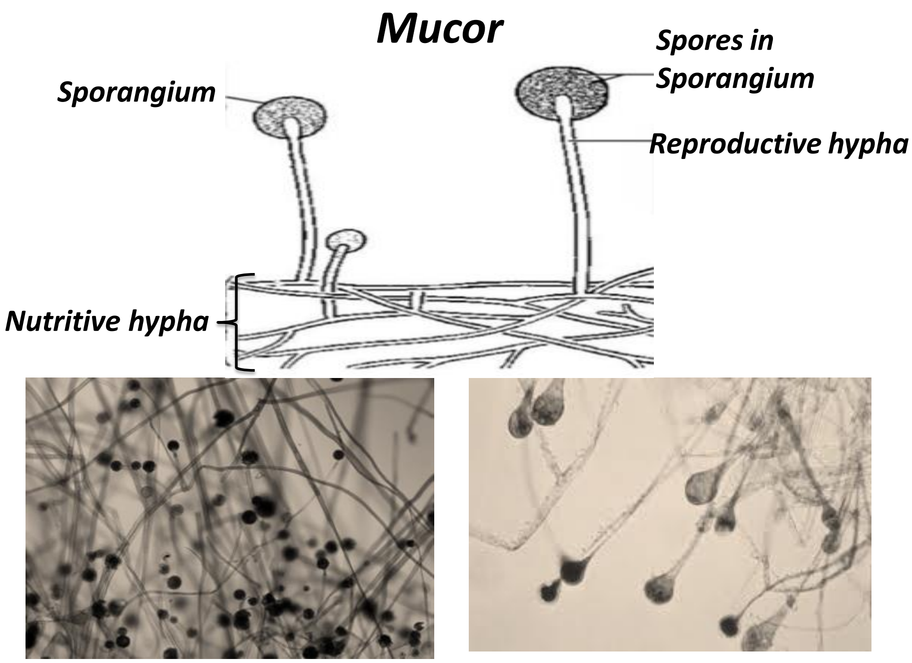


Fig.3.3 Microscopic view of *Mucor*

(d) Rhizopus

Classification

Kingdom:	Mycetae
Division:	Amastigomycota
Class:	Zygomycetes
Order:	Mucorales
Family:	Mucoraceae
Genus:	*Rhizopus*

Identifying features

1. *Rhizopus* appears as a white cottony mass, grows rapidly and spread over entire plate during vegetative phase.
2. Hyphae are aseptate and coenocytic. There are three types of hyphae.
3. Stolon grows horizontally on substratum surface.
4. Rhizoids are brown slender root like structures.

5. Sporangiophore, tufts of special, erect unbranched; hyphae growing in air arise from stolon just opposite to rhizoids.
6. Sporangiophores swell at the tip into a spherical knob like structure called sporangium. It has two zones. - Central dome shaped zone called columella, and - Peripheral sporiferous zone in which black spores called sporangiospores are formed.
7. Because of sporangiospores, sporangium appears black at maturity.

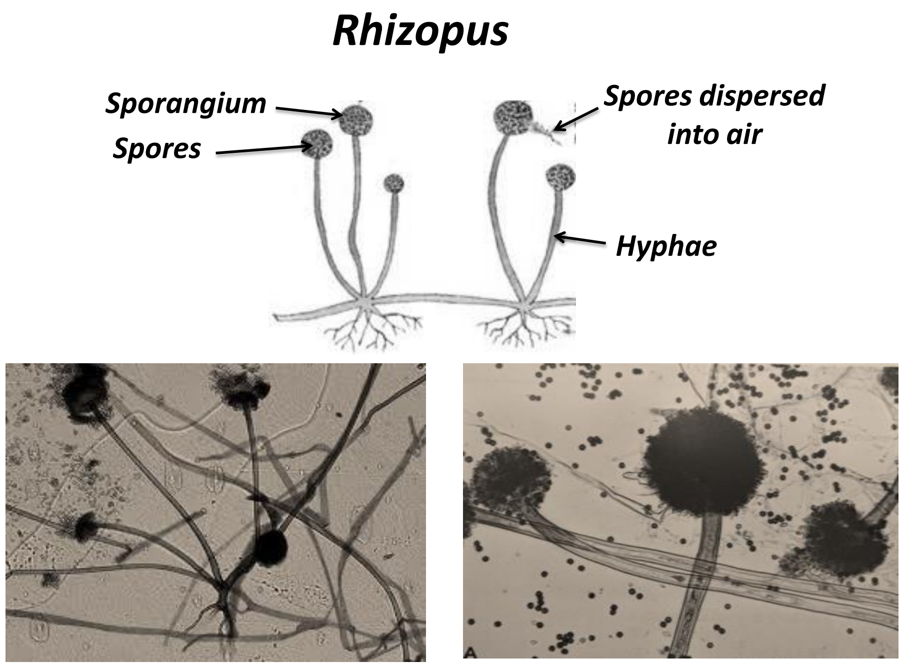


Fig.3.4 Microscopic view of Rhizopus

(e) *Alternaria*

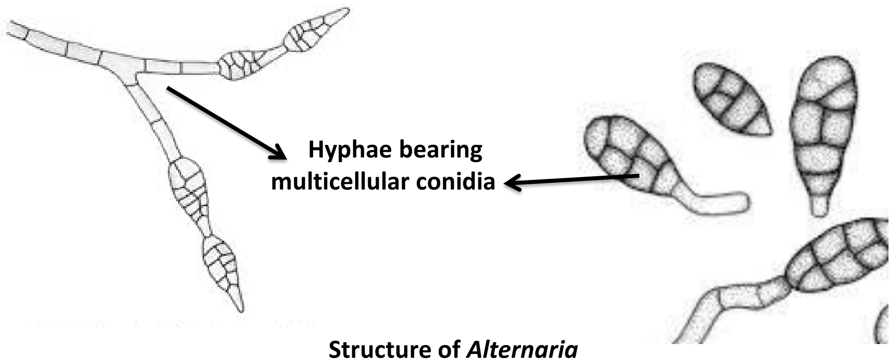
Classification

Kingdom: Mycetae
Division: Amastigomycota
Class: Deuteromycetes
Subclass: Hyphomycetidae
Order: Moniliales
Family: Dematiaceae
Genus: *Alternaria*

Identifying features

1. Alternaria colony is woody and compact. Underside is very dark coloured.
2. Colony colour is grayish green or black with gray edges rapidly spreading over entire plate.
3. Mycelium consists of short septate, branched and light brown coloured hyphae.
4. Multiply asexually by spore production or conidia formation.

5. Conidia reproduced at tips of short hyphae.



Structure of *Alternaria*

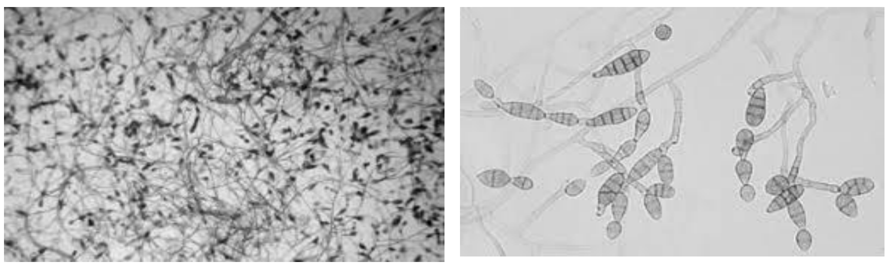


Fig.3.5 Microscopic view of *Alternaria*

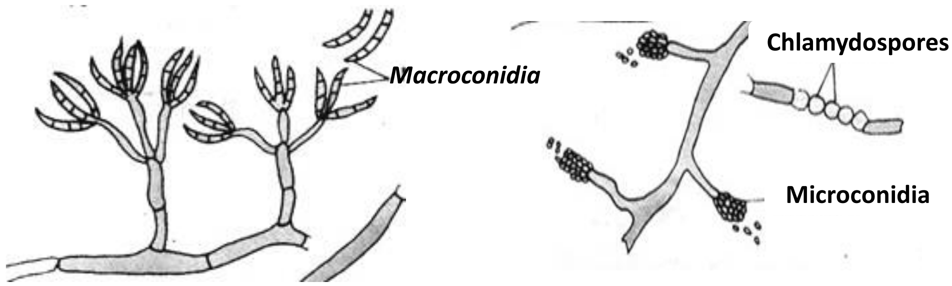
(f) *Fusarium*

Classification

Kingdom:	Mycetae
Division:	Amastigomycotina
Subdivision:	Deuteromycotina
Class:	Deuteromycetes
Order:	Moniliales
Family:	Tuberculariaceae
Genus:	*Fusarium*

Identifying features

1. Wooly, white fuzzy colonies changing colour to pink, purple or yellow.
2. Mycelium consists of septate and branched hyphae. Hyphae are colourless or have a tinge of pink, purple or yellow when young, but at maturity become dark coloured.
3. Asexual reproduction takes place by formation of three kinds of spores – Microconidia, Macroconidia and Chlamydospores.
4. Chlamydospores are round, oval and thick walled cells formed singly or in chains of two or more. These are resting spores.
5. Compact resting bodies called sclerotia are also produced which serve as a storage organ and a means of perennation.



Structure view of *Fusarium*

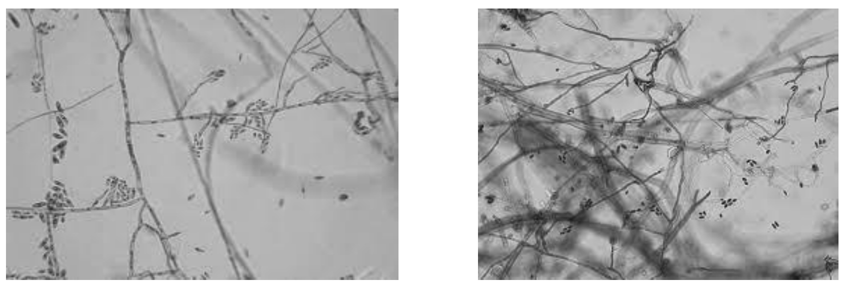


Fig.3.6 Microscopic view of *Fusarium*

3.3.2 Aim: To study about microscopic characteristic features of fungi

Different types of fungi will produce different-looking colonies, some colonies may be coloured, some colonies are circular in shape, and others are irregular. A specific terminology is used to describe common colony types. These are:

1. **Surface topography** - Some fungal colonies are free growing which covers almost entire surface of agar, however growth of some fungi colonies grow in a restricted manner.
2. **Form** – Fungal colonies can have different shapes such as circular, filamentous, etc.
3. **Size** – The diameter of the colony may also differ from species to species. Tiny colonies are referred to as punctiform
4. **Elevation** – Elevation refers to the side view of a colony which can be observed by turning the Petri dish on end.
5. **Margin/border** – Different fungi species when grown on culture medium exhibit different margins.
6. **Surface texture** - cottony or wooly (floccose), granular, chalky, velvety, powdery, silky, glabrous (smooth, creamy), or waxy.
7. **Opacity** – Fungal colonies possess varying opacity. They may be transparent (clear), opaque, translucent (like looking through frosted glass), etc.
8. **Colour** - (pigmentation) - Fungi may be colorless or brightly colored. Color may be on fungus itself, on its sporulating apparatus, on the agar, or on the bottom of the colony (reverse pigmentation).

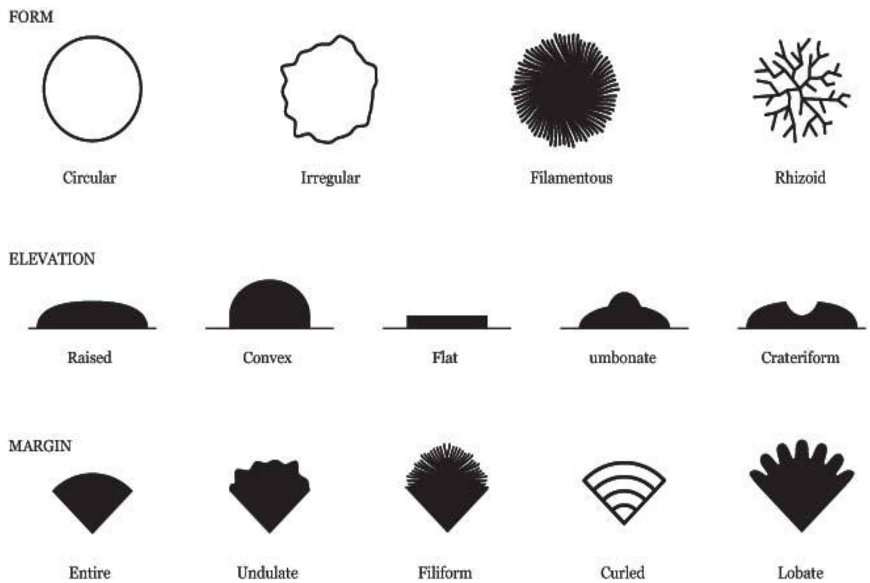


Fig.3.7 Microscopic characteristic features of fungi

3.3.3 Aim: Isolation of fungi from infected plants on PDA culture medium

Requirements:

PDA culture medium
Tartaric acid
Infected plant leaves, fruits etc
Petriplates, spreader

Composition of PDA media:

Component	Amount/ volume
Potato infusion	20gm
Dextrose	20gm
Agar	20gm
Distilled water	1 litre

Principle: Potato Dextrose Agar (PDA) is one of the most commonly utilized culture medium for isolation of fungi. It contains dextrose which acts as a carbohydrate source and hence serves the function of growth stimulator. Potato infusion present in PDA provides a nutrient base so as to achieve enhanced growth of most fungi. As in any other culture medium agar is added as the solidifying agent. Along with this specific amount of sterile tartaric acid (10%) is also added into PDA, which functions to lower the pH of the medium to 3.5. The advantage provided by this low pH is that growth of most of the bacteria is inhibited at such low pH.

Procedure:

1. Weigh all the components accurately and add 750 ml of distilled water. Heat to boiling to dissolve the components completely. Make the volume to 1 L by addition of distilled water.
2. Sterilize by autoclaving at 15 lbs pressure (121°C) for 15 minutes.
3. Culture medium should be acidified with sterile 10% tartaric acid to make the pH 3.5. About 1ml acid is required for 100 ml. of sterile and cooled medium. Culture medium should not be heated after addition of acid.
4. Pour the media in petriplates under aseptic condition and allow it to solidify.
5. Crushed plant sample (containing fungi) is spreaded onto the solidified medium.
6. Incubate the plates at 25 – 30°C with increased humidity.
7. Examine the cultures regularly for fungal growth.

Observation and result

Note the kind and pattern of growth obtained. Petriplates should be observed for at least 4 weeks before reporting negative result.

Some common features of different fungi observed on PDA agar

Fungi	Texture	Surface colour	Reverse colour	Zonation
Aspergillus niger	Velvety	White with black spores	Yellow	Heavily furrowed on reverse
A.candidus	Velvety	Creamish white	Slightly creamish	Radially furrowed on the reverse
Penicillium corylophilum	Velvety	Dark green	Colourless to Creamish	With shallow centre and radially furrowed raised margin
Fusarium oxysporum	Floccose	Magenta pink	Magenta-red turning violet	With concentric zones of dark and light reddish colouration

* Identification features mentioned in experiment 3.1 can also be utilized to identify isolated fungi.

3.3.4 Aim: To perform lactophenol cotton blue staining for presumptive identification of fungi

Lactophenol Cotton Blue (LPCB) Stain is formulated with lactophenol, which serves as a mounting fluid, and cotton blue. Organisms suspended in the stain are killed due to the presence of phenol, because phenol is a well known fungicide. The high concentration of the phenol deactivates lytic cellular enzymes thus the cells do not lyse. Cotton blue is an acid dye that stains the chitin present in the cell walls of fungi. Lactic acid present in LPCB serves to preserve the fungal structures. Cotton blue (China blue) stains chitin in the fungal cell wall and cellulose. Since cell walls of fungi are primarily chitin, this stain is an excellent choice for observing fungi in clinical specimens.

Requirements:

- Culture of Fungi (preferably bread mould for initial learning)
- Lactophenol cotton blue
- Glass slides
- Dropper
- Cover slips
- Microscope

Chemical composition of Lactophenol cotton blue stain

Component	**Quantity**
Cotton blue	0.05gm
Phenol crystals	20gm
Glycerol	40ml
Lactic acid	20ml
Distilled water	20ml

Procedure

(A) Preparation of Lactophenol cotton blue stain

1. Dissolve cotton blue in distilled water and leave the solution overnight so as to eliminate any insoluble dye present.
2. Filter the cotton blue solution next day.
3. Take lactic acid solution in a beaker and add phenol crystals to it, place the beaker on magnetic stirrer until phenol crystals are completely dissolved.
4. After phenol crystals completely dissolve, add glycerol to the solution.
5. Filtered cotton blue solution (obtained in step 2) is added to solution obtained in step 4.
6. Mix the solutions well and store at room temperature for further use.

(B) Procedure of Staining

1. Place a small drop of lactophenol cotton blue (LPCB) in the center of a clean glass slide. The slide should be placed on a light box or sheet of white paper for easier manipulation.
2. Remove a fragment of fungus culture with a teasing needle and place in the LPCB.

NOTE: Because fungal colony grows from centre towards outwards, fungus sample should be carefully taken from an area 4-5 mm from the edge. This area is expected to show characteristic structures required to identify the organism properly. The centre of the colony being the oldest usually shows an abundance of sterile hyphae, and the periphery portion will not have aged adequately to produce any characteristic structures. If proper structures are not seen in this area (4-5 mm from the edge), then mycelium can be collected from 8-10 mm from the outer edge and repeat the procedure. If characteristic structures are still not evident, the colony may be too young, or the particular organism may not sporulate on that medium.

3. Gently place cover slip onto the preparation.
4. Heat from the microscope lamp which will spread the medium evenly.
5. Pressing or tapping of coverslip should be avoided as it will break the conidia from the conidiophores and make identification more difficult.
6. The preparation can also be preserved by sealing the edges with colored nail polish. Sealing should be done only after wiping excess mounting medium.
7. Initially examine the preparation using the low power (10x) objective of a microscope. Once the fungal structures are observed view them on high power (40x, 100x).

Disadvantage:

1. The intact morphology will not be seen.

Advantages:

1. It is the most widely used method for staining and observing fungi because it's easy and fast.
2. This stain is useful for making permanent mount of the fungus which is in culture.

3.3.5 Aim: Slide culture technique for identification of fungi

Principle: Occasionally, conidia from a culture may not be observed in a Lactophenol Cotton Blue preparation. By growing the organism in a way that allows periodic observation, the precise time that conidia are at prime identifiable stage can be determined.

Equipment

(1) Sterile petri dish (15 x 100 mm).
(2) Filter paper (100 mm diameter).
(3) Sterile, distilled water.
(4) Sterile pipets (graduated or Pasteur).
(5) Sterile, rimless test tube (approx. 15 mm in diameter)--this is an optional item.
(6) Sterile scalpel.
(7) Petri dish with potato dextrose agar (PDA) or other medium of choice. Plate should contain 15 ml of agar.
(8) Sterile microscope slides and cover slips

Procedure:

(A) Slide Culture Preparation

1. Aseptically, with a pair of forceps, place a sheet of sterile filter paper in a Petri dish.
2. Place a sterile U-shaped glass rod on the filter paper. (Rod can be sterilized by flaming, if held by forceps.)
3. Pour enough sterile water (about 4 ml) on filter paper to completely moisten it.
4. With forceps, place a sterile slide on the U-shaped rod

5. Gently flame a scalpel to sterilize, and cut a 5 mm square block of the medium from the plate of Sabouraud's agar or Emmons' medium.
6. Pick up the block of agar by inserting the scalpel and carefully transfer this block aseptically to the centre of the slide.
7. Inoculate four sides of the agar square with spores or mycelial fragments of the fungus to be examined. Be sure to flame and cool the loop prior to picking up spores.
8. Aseptically, place a sterile cover glass on the upper surface of the agar cube.
9. Place the cover on the Petri dish and incubate at room temperature for 48 hours.
10. After 48 hours, examine the slide under low power. If growth has occurred there will be growth of hyphae and production of spores. If growth is inadequate and spores are not evident, allow the mold to grow for another 24–48 hours before making the stained slides.

(B) Application of Stain

1. Place a drop of lactophenol cotton blue stain on a clean microscope slide.
2. Remove the cover glass from the slide culture and discard the block of agar.
3. Add a drop of 95% ethanol to the hyphae on the cover glass. As soon as most of the alcohol has evaporated place the cover glass, mold side down, on the drop of lactophenol cotton blue stain on the slide. Examine the slide under microscope.

Interpretation

1. Cultures should be examined on daily basis. Remove slide from petri dish and wipe off any condensation on bottom of slide. Place slide on stage of microscope and observe using low power (10x) and/or high dry (45/47x). Examine for presence of different morphological structures.
2. If properly identificable structures are not observed it is possible that the fungi might not have yet reached proper growth stage. In such a case cultures should be incubated for a longer period of time and should be regularly monitored.
3. If slide culture has developed identifiable structures, then carefully lift cover slip off agar surface using a pair of sterile forceps and place on slide containing drop of LPCB. If agar block sticks to coverslip, remove using a sterile scalpel. Preparation may be preserved indefinitely by sealing edges with nail polish after removing excess mounting media.
4. Examine preparation using low power (10x) objective of a microscope and then on higher magnification.
5. If possible, report organism identification based on observed structures. If reportable structures are not seen or structures seen are nonspecific, additional testing such as repeat slide culture and/or biochemical testing may be required.

Advantages of slide culture:

1. It is a rapid method of preparing fungal colonies for examination and identification.

2. Permits fungi to be studied virtually in situ with as little disturbance as possible.
3. Fungi are identified mostly by close examination of its morphology and the characteristics it possess.

Precautions:
1. Use sterile forcep and needles for slide culture technique.
2. Aseptic conditions should be maintained.
3. Carefully remove the coverslip and agar block for semi-permanent mount so that morphologic characteristics of the fungus won't disturb.
4. Entry of air bubbles should be avoided when placing the cover-slip over a drop of stain.
5. Use sufficient amount of stain so that it completely covers the 18 mm cover-slip.
6. Remoisten the filter paper with sterile water when it becomes dry.

3.3.6 Aim: To isolate and identify fungi from different samples by Warcup method

Requirements:
- Sample (soil, fruits, vegetables)
- Sabouraud agar medium
- Rose Bengal
- Antibiotic (Aureomycin)
- Petriplates, distilled water, autoclave, incubator.

Principle: It is practically difficult to directly separate or isolate fungi from a source like soil, fruits, vegetables, etc and place under microscope for observation to identify their characteristic features. Hence there are different techniques available for to isolate fungi from a source and stimulate their growth under laboratory conditions which facilitate their easy identification under microscope. One of the methods includes serial dilution agar plate. This method was developed by Warcup in 1950; hence the method is named as Warcup method.

Procedure:
1. Soil sample in collected in sterile polybags using gloves and scapel.
2. Collected soil samples are dried in air.
3. Five autoclaved petriplates are taken and to each plate add 10, 20, 50, 90 and 120mg of dried soil. Take one petriplate as control (no soil is added to this pletriplate). Label all the plates are accordingly (P1,P2,P3,P4,P5 & C)
4. Add about 12-15 ml of melted Sabouraud medium containing antibiotic (antibiotic is added to medium to restrict the growth of bacteria) to each petriplate including control. This step should be carried out under aseptic conditions in laminar air flow.
5. Gently rotate the plates to uniformly mix soil and media.
6. Let the media solidify.

7. Incubate the plates in incubator at 25ºC for 10-12 days.
8. Plates should be regularly monitored for growth.

Result: Observe the plates for appearance of fungal colonies after 03 days of incubation till 15 days of incubation and record observations.

Observation table:

Table: Observation of fungal colony after incubation

	Days after incubation							
	03 Days		**05 Days**		**10 Days**		**12 Days**	
	Growth	Identifying features	Growth	Identifying features	Growth	Identifying features	Growth	Identifying features
C								
P1								
P2								
P3								
P4								
P5								

P1, P2, P3, P4, P5- Plates containing soil, C-control plate.
Growth should be indicated as: no growth (-), low colony number (+), moderate colony number (++), high colony number (+++). For identifying features observe macroscopic and microscopic characteristics of fungal colonies.

3.4 SUMMARY

1. Fungi are eukaryotic organisms which lack chlorophyll.
2. Fungi are found to inhabit different types of habitats.
3. Morphological appearance of fungi varies from species to species.
4. Fungi are represented by molds and yeast.
5. Molds are filamentous and multicellular.
6. Yeast is unicellular.
7. Fungi can be isolated from different sources- soil, rotten vegetables and fruits, infected leaves, etc by culturing them onto culture medium.
8. Potato dextrose agar and Sabouraud's agar medium are the most commonly utilized culture medium for isolation as well as culture fungi species.
9. Optimum temperature for fungi culture under laboratory conditions ranges around 25ºC.
10. When grown onto culture medium fungi species exhibit significant amount of variation in their cultural characteristics.

10. Fungi can be identified based upon their macroscopic and microscopic characteristics.
11. Major macroscopic characteristics utilized for fungi identification include colony colour, shape, size, texture, opacity, reverse colour, form elevation and margin.
12. Lactophenol cotton blue staining (LPCB) staining is commonly utilized for staining of fungal mycelium.
13. Microscopically fungi can be identified based upon the structure of hyphae, mycelium and spores.

3.5 GLOSSARY

Antibiotic: Antibiotics, also called antibacterials, are a type of antimicrobial drug used in the treatment and prevention of bacterial infections. They may either kill or inhibit the growth of bacteria.
Chitin: a fibrous substance consisting of polysaccharides, which is the major constituent in the exoskeleton of arthropods and the cell walls of fungi
Chlamydospores: A chlamydospore is the thick-walled large resting spore of several kinds of fungi.
Cleistothecia: It consists of very tightly interwoven hyphae and may contain millions of asci, each of which typically contains four to eight ascospores. Ascocarps are most commonly bowl-shaped (apothecia) but may take a spherical (cleistothecia) or flask-like (perithecia) form.
Conidiophores: *Conidiophores* are specialized hyphae which play an important role in asexual reproduction. They bear the conidia (asexual spores) at its tip which are not enclosed within a sac.
Fungicide: *Fungicides* are biocidal chemical compounds or biological organisms used to kill parasitic fungi or their spores.
Hyphae: *Hyphae* are the thread-like filaments that make up a multicellular fungus and release enzymes to absorb nutrients from food sources.
Metulae: One of the outermost branches of a conidiophore from which flask-shaped phialides radiate (as in molds of the genera *Aspergillus* and *Penicillium*).
Miroconidia: Aerial hyphae often produce asexual reproduction propagules termed conidia (synonymous with spores). Relatively large and complex conidia are termed macroconidia while the smaller and simpler conidia are termed microconidia.
Mold: A *mold* is a fungus that grows in the form of multicellular filaments called hypha.
Phialide: A *phialide* is an elongated and flask shaped (where it gets its name) projection rising from the vesicle in certain fungal groups, such as *Aspergillus*.
Pseudohyphae: Pseudohyphae are distinguished from true hyphae by their method of growth, relative frailty and lack of cytoplasmic connection between the cells
Rhizoid: Rhizoid is a short, thin filament found in fungi and in certain plants and sponges that anchors the growing (vegetative) body of the organism to a substratum and that is capable of absorbing nutrients. In fungi, the rhizoid is found in the thallus and resembles a root.

Sterigma: It represents extension of the basidium (the spore-bearing cells) consisting of a basal filamentous part and a slender projection which carries a spore at the tip

3.6 SELF ASSESSMENT QUESTION

3.6.1 Choose the most appropriate option:

1-Which of the following is not a macroscopic character of fungal colony

(a) Size, elevation and color (b) Size, opacity and form

(c) Margin, elevation and texture (d) All are correct

2- Which of the following is most commonly utilized culture medium for fungi

(a) PDA (b) Maconkey agar

(c) Nutrient agar (d) Citrate agar

3- *Fusarium* belongs to the order

(a) Uridinales (b) Peronosporales

(c) Liceales (d) Moniliales

4- Hyphae of Alternaria are

(a) Branched and non septate (b) Branched and septate

(c) Unbranched and non septate (d) Unbranched and septate

5- Asexual reproduction in *Fusarium* occurs by

(a) Microconidia (b) Macroconodia

(c) Chalnydospora (d) All of the above

6- Which of the following is not a component of Lactophenol cotton blue stain?

(a) Lactic acid (b) Phenol

(c) Acetic acid (d) cotton blue

7- What is the function of lactic acid in?

(a) It preserves fungal structures (b) It destroys fungal structures

(c) It preserves bacterial structures (c) Both b and c are correct

8- Slide culture method of fungal staining

(a) Is a rapid method of fungal staining

(b) Is the only method of fungal staining

(c) Does not allow viewing intact morphology of fungi

(d) All are correct

9- Which of the following is correct combination
(a) Rose Bengal, fungicide, Sabouraud agar medium
(b) Rose Bengal, antibiotic, Sabouraud agar medium
(c) Cotton blue, antibiotic, Sabouraud agar medium
(d) Rose Bengal, fungicide, potato agar medium

10- Which of the following is NOT correct about *Fusarium?*
(a) Mycelium consists of septate and branched hyphae.
(b) Asexual reproduction takes through – Microconidia, Macroconidia and Chlamydospores.
(c) Chlamydospores are round, oval and thick walled cells.
(d) *Fusarium* is not a pathogenic fungus

3.6.2 State whether following statements are true or false

1. Alternaria belongs to the class Deuteromycetes.
2. Chlamdospores are known as function as resting spores.
3. Hyphae of rhizopus are septate and coenocytic.
4. Hyphae of mucor are unbranched.
5. The function of phenol in Lactophenol cotton blue stain is to deactivate lytic enzymes.
6. Major component of cell wall of fungi is cellulose.
7. Intact fungal morphology can be observed through lactophenol cotton blue staining.
8. In Warcup method antibiotic is added to the medium to restrict growth of bacteria.
9. Mucor and rhizopus exhibit morphological similarity.

3.6.3 Fill up the following blanks:

1-Tiny fungal colonies obtained on culture media are known as_____________
2- *Alternaria* reproduces sexually by_______and________________
3- Aphysis is absent in __________
4- Cotton blue stains ____________present in fungal cell wall
5- PDA stands for______________________
6-_____________ are unicellular fungi.
7-Sporangium appears black due to presence of _____________
8-_____________are produced at the tip of hyphae in *Alternaria*.
9-Hyphae of Rhizopus are __________and ____________
10-Fungi are represented by ________ and __________.

3.6.4 Very short answer type questions

1. Name the most commonly utilized stain for staining fungi?
2. Give an example of unicellular fungi.
3. Define warcup method?
4. What are different types of surface texture which a fungal colony may exhibit?

5. Mention the function of phenol in lactophenol cotton blue.
6. Why is lactic acid added to lactophenol cotton blue?
7. Define conidia?
8. Mention the disadvantage associated with lactophenol cotton blue staining?
9. For what purpose is Warcup method utilized?
10. Name two most commonly utilized media for isolation of fungi?
11. Define sporongiophore?
12. What is bread mould?
13. What do you understand by mycelium?
14. Mention the chemical composition of fungal cell wall?

3.6.1 Answers Key: 1- (d), 2- (a), 3-(d), 4 – (c), 5- (d), 6- (c), 7 – (a), 8 – (a), 9- (b), 10 – (d)

3.6.2 Answers Key: 1-T, 2-T, 3-F, 4-F, 5-T, 6-T, 7-F, 8-F, 9-T

3.6.3 Answers Key: 1- Punctiform, 2- spore, conidia, 3- Mucor 4-Chitin, 5-Potato dextrose agar, 6- Yeast, 7 -Sporangiospores, 8 -conidia, 9 - septate, non coenocytic, 10- yeast , mould.

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3.9 TERMINAL QUESTIONS

3.9.1 Short answer type question:

1. Enlist different macroscopic characters of fungi which are utilized to describe different colony types?

2. Mention the composition of lactophenol cotton blue stain alongwith function of each component?
3. Write about composition and preparation of Sabouraud agar medium?
4. Why it is advisable to collect fungal sample from an area 4-5 cm from edge of fungal colony?
5. How is lactophenol cotton blue staining done. Mention the advantage and disadvantage associated with the technique?
6. Mention the characteristic features of *Aspergillus*. Illustrate your answer with suitable examples?
7. Enlist different characteristic features of fungi?
8. Enlist various precautions and safety measures adopted during fungi isolation and identification?
9. What is the purpose of using a humid chamber and U shaped glass rod in the Petri dish?
10. What is the importance of slide culture techniques? What precautions have to be taken while performing slide culture?
11. Mention two harmful and two beneficial impacts of fungi?
12. Differentiate between *Rhizopus* amd *Mucor*?

3.9.2 Long answer type questions

1. Outline the process involved in lactophenol cotton blue staining of fungi?
2. With well labelled diagram explain distinguishing characteristic features of *Aspergillus*, *Rhizopus* and *Mucor*?
3. What is Warcup method? How it is utilized for isolation and identification of fungi?
4. Describe about different macroscopic and microscopic features utilized in identification of fungus culture.
5. Mention how slide culture method is utilized for observing intact morphology of fungi?

BLOCK-2 ALGAE

UNIT-4 MORPHOLOGICAL STUDY OF REPRESENTATIVES OF ALGAE-I

4.1 OBJECTIVE

After reading this unit students will be able-

- To observe two different species of green algae.
- To make diagram and compare these green algae to each other.
- To observe an example of brown and red algae and compare them to green algae.

4.2 INTRODUCTION

Phycology or Algology is the study of the algae. The word **phycology** is derived from the Greek word *phykos*, which means "seaweed." The term **algology**, described in Webster's dictionary as the study of the algae, has fallen out of favor because it resembles the term *algogenic* which means "producing pain." The algae are **thallophytes** (plants lacking roots, stems, and leaves) that have chlorophyll *a* as their primary photosynthetic pigment and lack a sterile covering of cells around the reproductive cells. Algae most commonly occur in water (fresh water, marine, or brackish). However, they can also be found in almost every other environment on earth, from the algae growing in the snow of some mountains to algae living in lichen associations on bare rocks, to unicellular algae in desert soils, to algae living in hot springs. In most habitats they function as the primary producers in the food chain, producing organic material from sun light, carbon dioxide, and water. Besides forming the basic food source for these food chains, they also form the oxygen necessary for the metabolism of the consumer organisms. In such cases humans rarely directly consume the algae as such, but harvest organisms higher up in the food chain (i.e., fish, crustaceans). Some algae, particularly the red and brown, are harvested and eaten as a vegetable, or the mucilages are extracted from the thallus for use as gelling and thickening agents. On the basis of Photosynthetic Pigments algae are classified into three groups namely Green algae (*Chlorophyseae*), Brown algae (*Pheophyceae*) and Red algae (*Rhodophyceae*).

4.3 PROCEDURE

Samples of algae are in liquid, use a pipette to remove just a little alga to a slide, and cover with a cover slip. Remove excess liquid with a tissue, so that the cover slip is not floating.

Material's are-

- *Vaucheria,*
- *Chara,*
- *Batrachospermum,*
- *Polysiphonia*
- *Volvox*
- *Cladophora*
- *Oscillatoria*

- *Anabaena*
- *Spirulina*
- *Scytonema*
- *Rivularia*
- *Haematococcus*

Wherever possible, collect specimens from the ocean for use in the lab.

Part A: Green Algae

1. Prepare a wet mount of preserved *Algae* for viewing under the microscope.
2. Observe the algae under both low and high power objective lenses.
3. Make Diagram of one or two cells of *Algae* in the space provided. Note the shape of its chloroplasts. Use high power to draw the algae.
4. Label these parts on your diagram: cell wall, green chloroplast, nucleus, and single cell unit.
5. Describe the shape of the chloroplast.
6. Describe the colour of its chloroplast.
7. Describe the complete shape of the algae.

Part B: Red and Brown Algae

Most red and brown algae grow in marine habitats. Most red and brown algae are multicellular and all have nuclei within their cells. They are often found clinging to rocks along the ocean shores by a special structure called a holdfast. For this part of the lab you will need to find samples of red and brown algae.

4.4 STUDY OF REPRESENTATIVE MEMBERS OF ALGAE-I

4.4.1-*Vaucheria*

Taxonomic Position

According to F.E.Fritisch

Class- Chlorophyceae

Order-Siphonales

Family-Vaucheriaceae

Genus- *Vaucheria*

Affinities of Vaucheria with Chlorophyceae

1. Multinucleate, aseptate thallus.
2. Oogamous sexual reproduction.

Affinities of Vaucheria with Xanthophyceae

1. Siphonaceous, acellular organisation of thallus.

2. Photosynthetic pigment.
3. Discoid chloroplast.

Occurence

1. It has about 54 species. It occurs in damp grounds. Some species are marine, some are found on snow, terrestrial, amphibious species.
2. *Vaucheria zonesii* is found on snow.

Structure

1. The plant body is filamentous, branched and coenocytic.
2. The vegetative structure of this alga is aseptate. The terrestrial species remain attached to the substratum by rhizoids. This portion is devoid of chlorophyll, the rest portion of plant is chlorophyllous.
3. Just within the cell wall, a thick continuous layer of cytoplasm is present. It contains numerous chloroplast which may be circular or disc like.

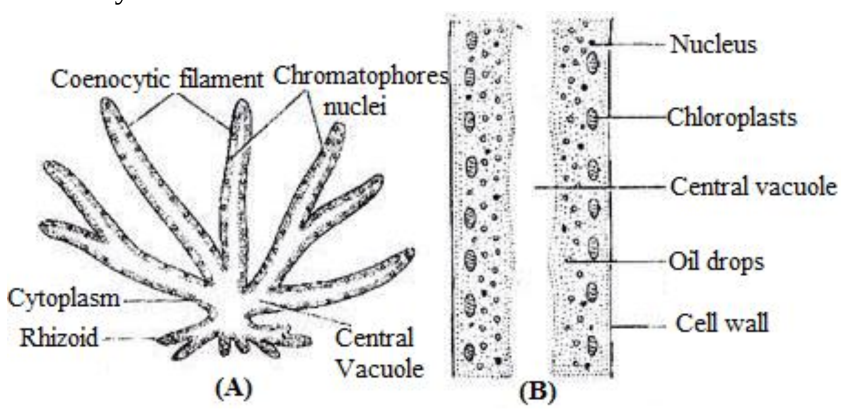

Fig.4.1: *Vaucheria* structure (A) Entire thallus (B) A part of thallus

The reserve food material is Oil; it contains chlorophyll ‘a’, chlorophyll ‘e’, carotenoids and xanthophylls. Chlorophyll ‘b’ completely absent.

Reproduction

(a) Vegetative Reproduction

It takes place by means of fragmentation. In this method the filament breaks into several fragments and each fragment is liable to produce new plant.

(b) Asexual Reproduction

It takes place by means of Zoospores, Aplanospores and by Hypnospores or Akinetes.

1. By Zoospore-The zoospore is produced in club shaped sporangia which is formed at the tip of the filament. The tip is cut off from the rest of the filament by means of a transverse septum. After the zoospore is fully developed inside the zoosporangium, a pore is developed from which zoospore is liberated. After resting period it germinates into a new filament.

2. By Aplanospores – It takes place in terrestrial species when the plant is exposed to drought condition a single aplanospore is formed in aplanosporangia which is formed at the tip of the filament. Mature aplanospore in favourable condition germinates into a new plant.

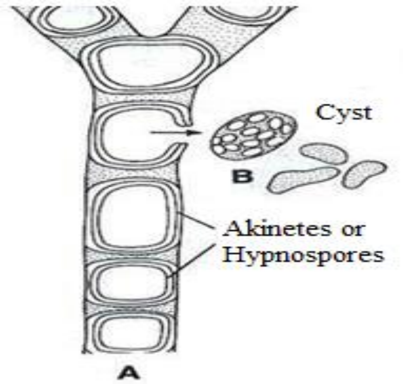

Fig.4.2 Showing Asexual reproduction by gongosira

3. By Gongosira stage-Some terrestrial and aquatic species of vaucheria, when subjected to unfavourable conditions, content of their filament divides into small segments by thick gelatinous wall, these thick walled multinucleated segments are called **akinetes, hypnospore** or **cyst**. The segmented thallus looks like an algae gongosira and this stage of vaucheria is called **Gongosira stage**.

(c) Sexual Reproduction

1. It is Oogamous type. Mostly plant is monocious rarely dioecious.
2. Mostly the species are **Protandrous** (i.e. antheridium develops before the development of oogonium).

Antheridium

1. The slender antheridium looks like a hook because the distal end of antheridium curves down and this distal end develop a pore at the tip.A septum develops just below the curved portion.
2. The nuclei divide again and again mitotically and around each nucleus cytoplasm is deposited and each gets metamorphosed into biflagellated antherozoids.

Oogonium

1. The oogonium develops as a swelling filled with nuclei, oil and chloroplast. This dense multinucleated mass of cytoplasm is called **Wanderplasm.**
2. After sometime only one nucleus survives and gets converted into an egg nucleus.

4.3.2-*Chara*

Taxonomic Position

Class- Charophyceae
Order- Charales
Family- Characeae
Genus- Chara

Occurence

1. Commonly known as Stone wort.
2. *Chara* is a fresh water alga, commonly found in fresh water pools, tanks, lakes, or slow flowing water.
3. It is a submerged species.
4. *Chara baltika* occurs in brackish water whereas *Chara fragilis* occurs in hot springs. There are about 188 species of *Chara* in world.

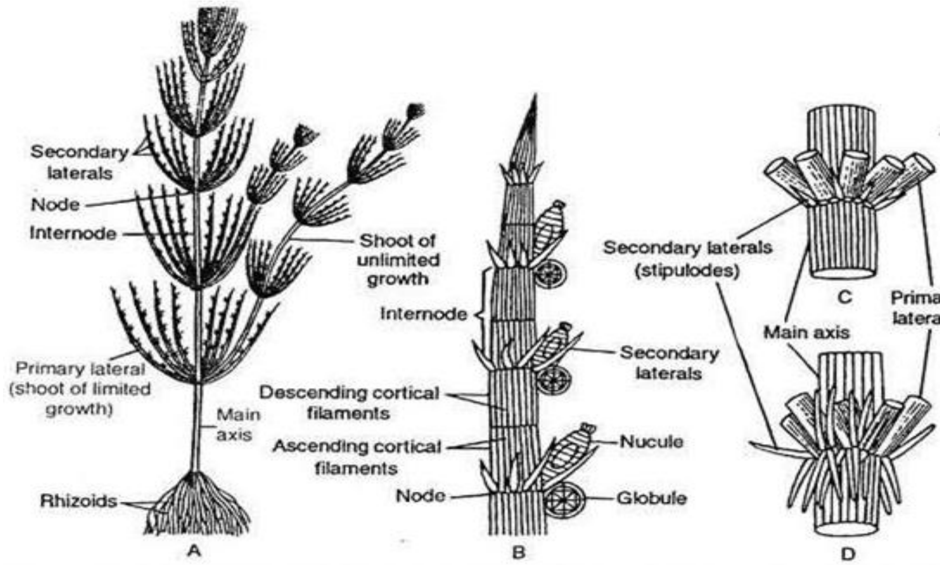

Fig.4.3- Thallus structure

Structure

1. The plant body consists of an erect, branched axis which may grow to the height of about 20-30 cm.
2. The axis has distinct nodes and internodes from each node arise a whorl of lateral branches of limited growth.
3. The plant is enchored to substratum by means of colourless multicellular rhizoids. Each cell of the filament has a cell wall made up of cellulose and calcium carbonate. The chloroplasts are discoid without Pyrenoids.

Reproduction

(a) Vegetative Reproduction

1. **By Amylum stars:** In this method some of the cells of lower nodes form a mass of special types of cells which are star shaped and contain Amylum starch. The cells are also known as Amylum stars. They can give rise to a new plant.
2. **By Bulbils**-In this method some lower nodes or some rhizoids may form bulbils (bulb like structures).These bulbils when detached give rise to new plants.
3. **By tubers-**Tubers are forms on the lower nodes or in rhizoids. The tuber is full of reserved food material. It also gives rise to new plant when detached from parent plant.

(b) Sexual Reproduction

This is highly advanced oogamous type. The male reproductive organ is known as Globule and female reproductive organ is called Nucule. These two structures are produced at node of the branches of limited growth. Nucule is always above the globule.

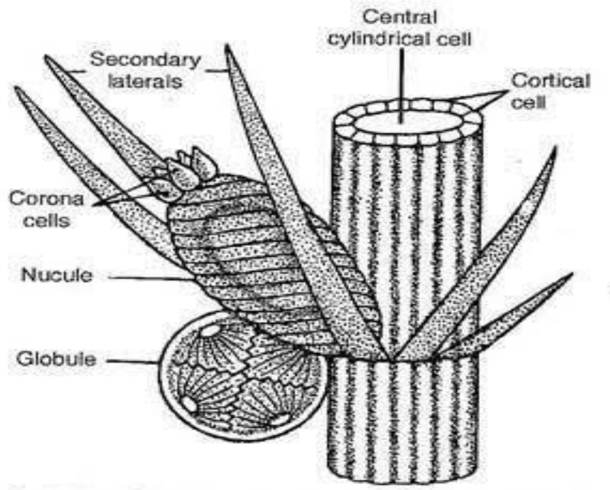

Fig.4.4- Structure of Nucule

Structure of Globule: The mature globule is circular in outline and red or orange in colour. The wall of the globule consists of 8 sheild cells. The outerwall of each shield cell is marked with numerous infoldings giving the idea that the wall of globule consists of more than 8 sheild cells. From the centre of each shield cell there arises a rod like outgrowth known as Manubrium. The manubrium consists of a primary capitulum cell at its upper end. The primary capitulum cell may divide to form secondary or tertiary cells. The secondary capitulum cell usually bears the branch uniciliate antheridial filament. Each antheridium gives rise to biflagellate single antherozoid which is spirally coiled.

Structure of Nucule: Nucule or oogonium is a short, stalked body attached to the nodes of branches of limited growth. A mature nucule consist of a large oval egg surrounded by a cover of fine 5 tubular cells which make two or more clock wise spiral turns around it. From the upper end of each tubular cell, a cell is cut off which constitutes the corona or crown of oogonia.

Development of Nucule: The nucule develops in the axial of the branches of limited growth on the adaxial side. It develops from single superficial adaxial cell. This cell undergoes 2 successive divisions forming 3 cells. The lower most cell elongates and forms Pedicel. The middle cell gives rise to 5 peripheral cells and uppermost cell act as a oogonial mother cell. Each of the peripheral cell divides transversely forming an upper smaller corona cell and the lower larger cell i.e. Tube cell. The five corona cells form a mature corona or crown of the oogonium. The 5 tube cell elongates vertically and then divides transversely to form stalk cell of oogonium. The oogonium contains single uninucleate egg which is formed by oogonial mother cell. The nucule when mature the tube cells separate from each other just below the corona to form 5 slits for the entrance of the antherozoids.

4.3.3-*Batrachospermum*

(*batracho*, frog ; *spermum*, seed)

Taxonomic Position

Class: Rodophyceae
Sub-Class: Florideae
Order: Nemelionales
Family: Batrachospermaceae
Genus: *Batrachospermum*

Occurrence

Batrachospermum is a freshwater red alga which grows in slow moving water of streams, lakes and ponds in the tropical and temperate regions.
Some of its species are found attached to stones in swift- flowing acidic water of rivers. Most of the species are annual but *B.vagum* is perennial species.

The genus is represented in India by 5 species, of these *B. moniliforme* and *B. vagum* are most common.

Thallus Structure

The mature thallus is branched, soft and gelatinous, 15-20 cm long and blue-green, violet or red in colour. The colour of the thallus depends on the intensity of light available. The thallus is differentiated into a prostrate and an erect system.The prostrate branches anchor the thallus to the substratum where as the branches of the erect system float freely on water. The thallus is uniaxial and the main or primary axis is made up of a uniseriate row of large cylindrical cell. The axis is differentiated into nodes and internodes and grows by a dome shaped apical cell.
From the nodes of the main axis two types of lateral branches develop-
[a] branches of limited growth, [b] branches of unlimited growth.

Cell Structure

The cells of the thallus are uninucleate with several discoid choromatophores along the periphery or a diffuse chromatophore.
The chromatophore is surrounded by a double layered wall and contains a single pyrenoid.

The main pigments are chlorophyll a, chlorophyll d, r-phycoerythrin and are r-phycocyanin, but due to the excess of red pigment –r-phycoerythrin the green colour of chlorophyll is completely or partially masked.

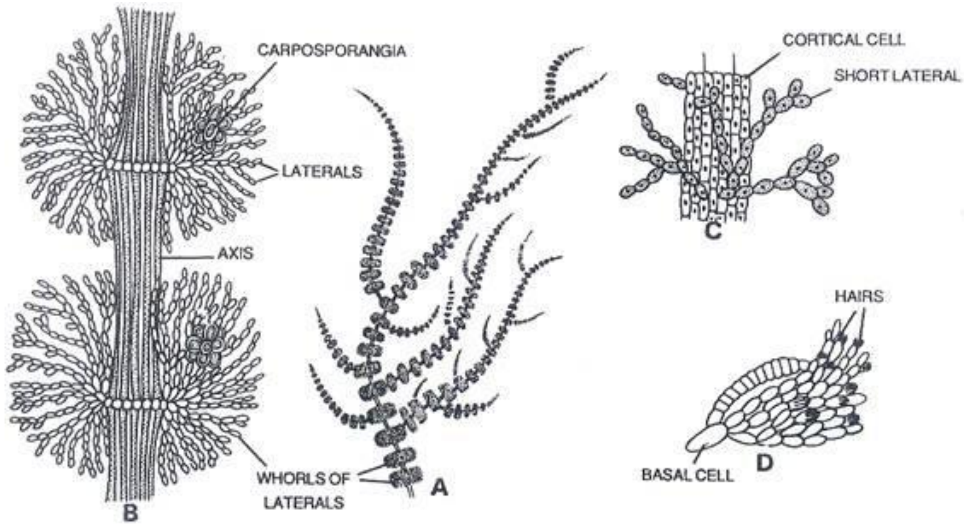

Fig.4.5: *Batrachospermum.* A. portion of plant, B. two whorls of laterals, C. short laterals, D. basal cell with laterals

Reproduction

Sexual Reproduction

1. Sexual reproduction is of advanced oogamous type.
2. Species of *Batrachospermum* are either monoecious or dioecious.
3. The male reproductive structures are called Spermatangia or antheridia.
4. Spermatiangia are unicellular, uninucleate, spherical or globose and colourless structure.
5. They develop singly or in pairs at the distal end of the branches of the limited growth.
6. Carpogonium, the female reproductive organ is a flask shaped structures.
7. It is differentiated into basal swollen egg cell and a long narrow neck called trichogyne.

Asexual Reproduction

It takes place by means of uninucleate, haploid and non-motile monospores. These spores are formed in the 'chantransia' stage and on germination again give rise to 'chantransia' stage. The erect branches of this hetrotrichous juvenile stage give rise to adult Batrachospermum plants.

Thus, in the life cycle of *Batrachospermum* are two haploid phases – gametophyte and carposporophyte. Such a life cycle with two haploid phases is called triphaic haplobiontic life cycle.

4.3.4-*Polysiphonia*

Taxonomic Position

Class- Rhodophyceae
Order- Ceramiales
Family- Rhodomelaceae
Genus- Polysiphonia

Occurence

1. It is exclusively marine algae which is cosmopolitan in distribution and represented by more than 150 species.
2. Some species of *Polysiphonia* are semiparasite. Some are epiphytes and lithophytes.

Structure

1. The Polysiphonia has a beautiful filamentous plant body; it is profusely branched and attached to the substratum by means of hold fast.
2. It is small in size and brownish red to dark purple in colour. The plant body consists of 2 types of filaments. Hence heterotrichous in nature.
3. The basal and prostrate filament creeps over the substrate and are anchored to it by means of holdfast.
4. The upright filaments arise from prostrate system. The upright system of thallus is feathery in appearance.
5. Some pericentral cells cut off small branches from their upper cell, these small branches are monosiphonous are commonly called as **Trichoblasts.**

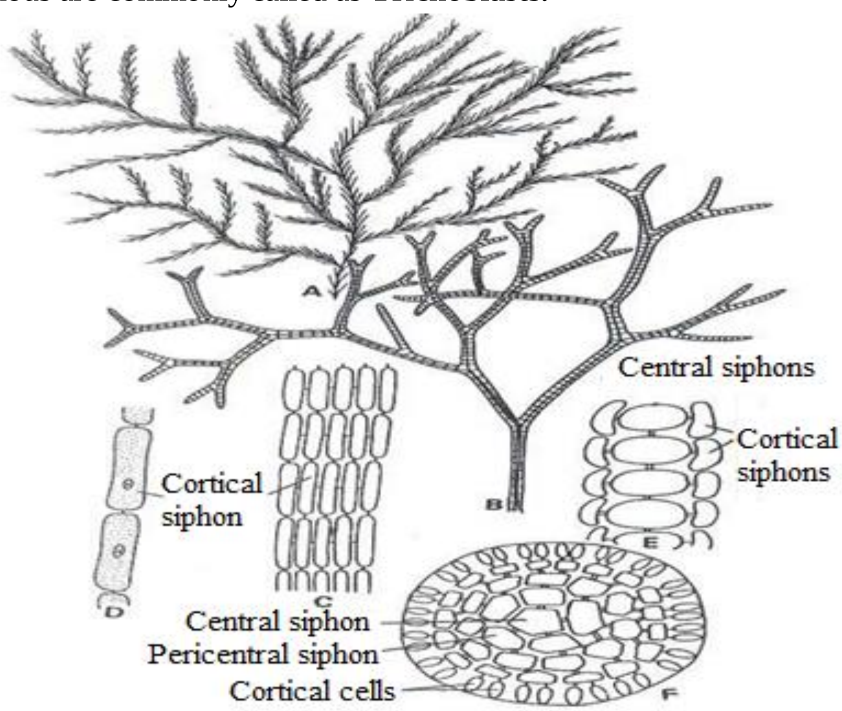

Fig.4.6: A-B: Vegetative Structure of *Polysiphonia.* C-D: Cortical siphons, E-filament showing central siphons, F-T.S of Siphonous

Reproduction

(a) Asexual Reproduction

By Tetraspore after the sexual reproduction.

(b) Sexual Reproduction

1. It is of oogamous type. Sex organs are borne on fertile trichoblasts near the apex of the thallus.
2. The spermatogonia (male reproductive part) are produced on the fertile trichoblast of the male thallus in clusters.

Development of Spermatogonia

1. Each male trichoblasts divides dichotomously and usually both the branches become fertile. These branches cut off pericentral cells; each pericentral cell behaves as spermatangial mother cell at their free ends.
2. It produces a single non motile spermatium.

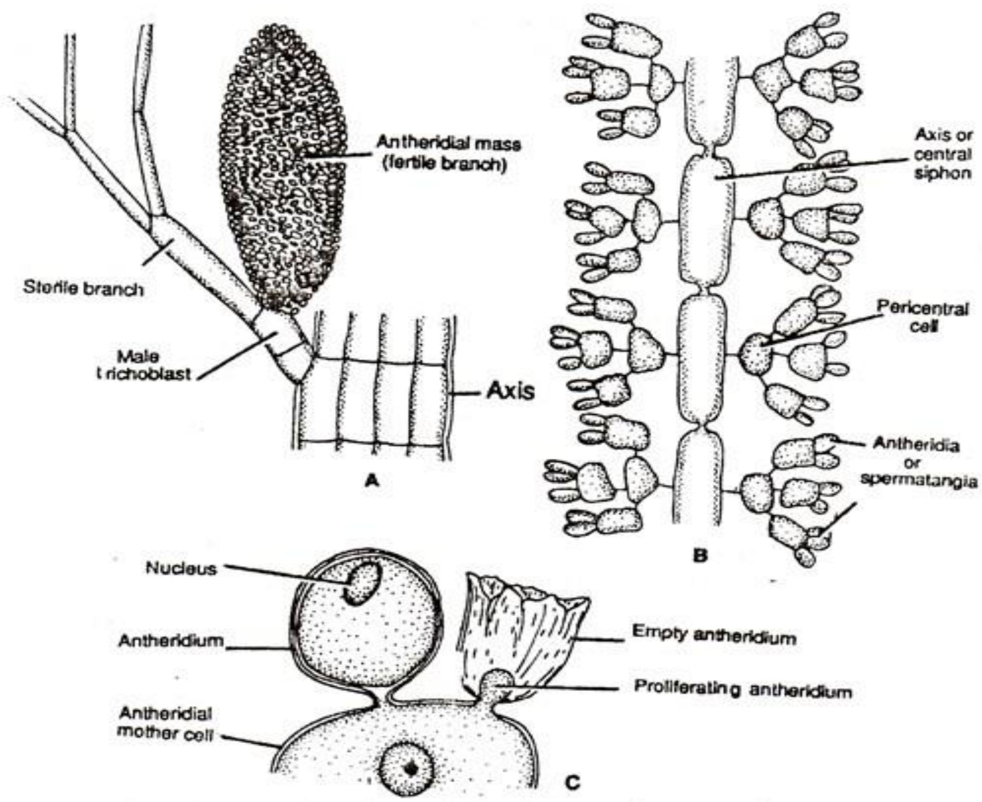

Fig.4.7 Development of spermatangium

Development of Carpogonium

1. The female reproductive organ (Carpogonium or Procarp) remains present on carpogonial branch produced upon the gently reduced fertile branch of female thallus.
2. It consists of an upper long elongated trichogyne and the lower broadened structure Carpogonia.
3. Carpogonium develop from a fertile pericentral cell which divides into an upper carpogonial branch initial and basal supporting cell.
4. The upper cell of carpogonial branch elongates to form trichogynae while its basal region broadens to form carpogonium in which female egg nucleus lies.

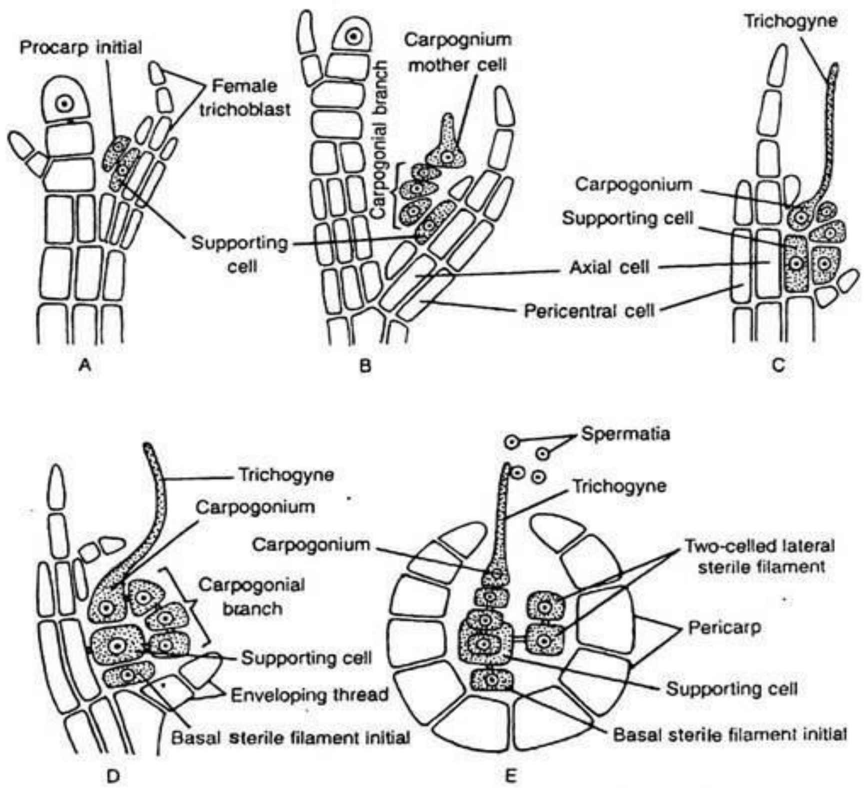

Fig.4.8 Showing development of Carpogonium

4.3.5-*Volvox*

Taxonomic Position

Class: Chlorophyceae
Order: Volvocales
Sub- order: Chlamydomonadineae
Family: Volvocaceae
Genus: *Volvox*

Occurrence

The species are all fresh water forms. They are found in still waters of puddles, ponds and pools. They are also found in temporarily formed ponds during rainy season. Sometimes the colonies are found in such a great abundance that the whole water looks green in colour.

External Features

1. The colonies are motile and found in rolling condition in still fresh water.
2. The colonies are hollow, spherical or broadly elliptical. The cells are arranged in a single layer towards periphery.
3. The number of cells in the coenobia of different species varies from 500 to 50,000. In *V. globator* there are 1500-20,000 cells in each coenobium.
4. The inner hollow of the coenobium is filled up with mucilage.

5. The complete coenobium remains surrounded by a delicate mucilaginous lamella.
6. The vegetative cells are of chlamydomonad type.
7. Each cell possesses a cup-shaped chloroplast. Each chloroplast contains a single pyrenoid. In the cavity of cup-shaped chloroplast there lies a single nucleus surrounded by cytoplasm. The cytoplasm contains several volutin granules.
8. There are 2-6 contractile vacuoles and one stigma on the lateral side in each cell.
9. The cells are biflagellate and remain interconnected by cytoplasmic plasmodesmata.
10. The cells look hexagonal from upper surface because of mutual compression.
11. Each cell is individually ensheathed by a gelatinous sheath.

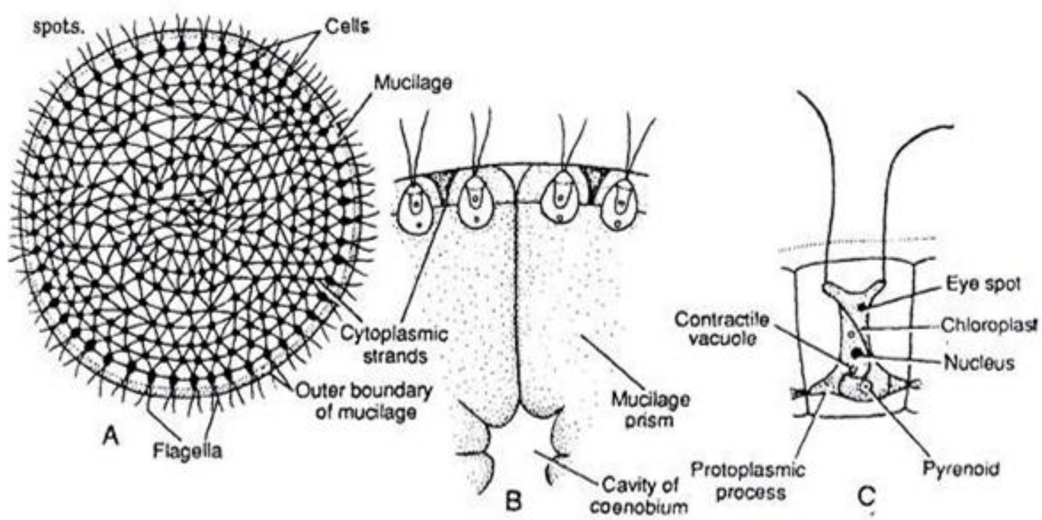

Fig.4.9: ***Volvox.*** **A- colony, B- A part of colony C- Single cell**

4.3.6-*Cladophora*

Taxonomic Position

Class- Chlorophyceae

Order- Cladophorales

Family- Cladophoraceae

Genus- *Cladophora*

Occurrence

Some species are marine and some are fresh water forms. Some species are found in streams, ponds and lakes attached to some substrata by rhizoidal bases.

External Features

1. The plant body consists of branched filaments.
2. The basal branched rhizoids are attached to the substratum and act as holdfast.
3. The branching of thallus is always lateral. However, the branching appears to be dichotomous because of a pushing aside process called 'eviction'. The branches arise from the upper ends of the cells.

4. The cells are elongated and 3 to 20 times longer than the breath.
5. The cells are arranged end to end.
6. The cells wall is three-layered consisting of chitin, pectose and cellulose layers.
7. The septa are usually stratified.
8. There is a large central vacuole.
9. The dense cytoplasm is found in peripheral region of the cell.
10. The cell is coenocytic.
11. The chloroplast is reticulate and with many pyrenoid

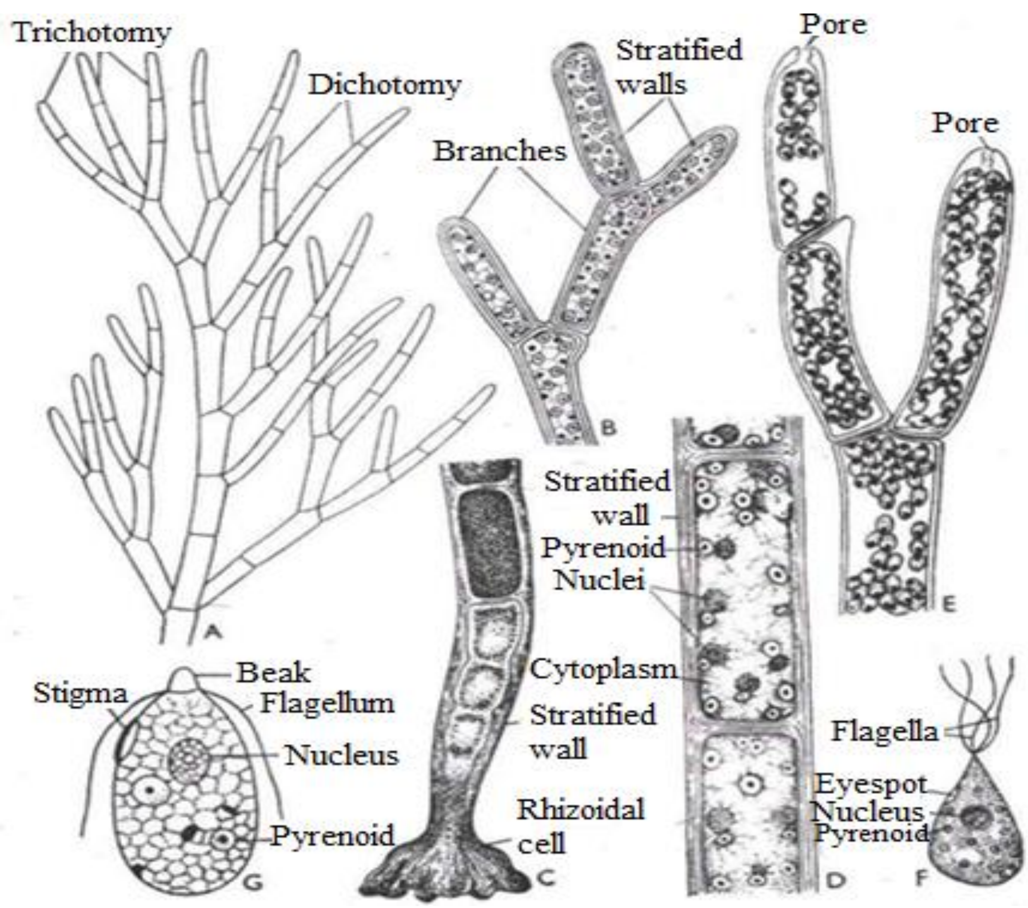

Fig.4.10: ***Cladophora sp.*** **A- Portion of filament showing nature of branching. B- Filament cell mergnified, C- Lower portion of filament, D- Structural details of cell, E- Finer branches with zoospore primodia, F- Zoospore, G- Gamete**

4.3.7 *Oscillatoria*

Taxonomic Position

Class: Cyanophyceae
Order: Nostocales
Family: Oscillatoriaceae
Genus: *Oscillatoria*

Occurrence

Oscillatoria is found in a wide variety of freshwater and sub –aerial habitats. The alga forms extensive sheets along the muddy banks of river and ponds, rocky cliffs and on damp soil. It also occurs in the form of a thin layer at the bottom of shallow ponds.

O.prolifica is a planktonic species and *O. terebriformis* is found in hot water springs *O. Selina* and *O. limosa* occur in saline waters. *O. rubescens* forms dense deep- water blooms in temperate lakes and ponds and its migration and colonization in deep water lakes is often associated with a high level of eutrophication. Some species of *Oscillatoria* have specific colours.

Thallus Structure

Oscillatoria is an unbranched filamentous alga. The filaments occur signally or are matted together to form thin or thick sheets. Each trichome is made up of many cells, arranged in uniseriate fashion. There are no constrictions between adjacent cells. All cells of a filaments are similar in a shape and structure. Their breadth is usually greater then their height, but species with narrow trichomes have cylindrical cells. The trichome is slightly different at the anterior end and shows a definite polarity. The free end is mostly rounded or convex but it is acuminate in *O. acuminata* and *O. brevis.* In some species the apical cell of the filament carries a thickened membrane, known as *Calyptra.* The above mentioned differences are due to variation in turgor pressure of the animal cell.

The trychomes are naked or are enveloped in a thin gelatinous sheath.

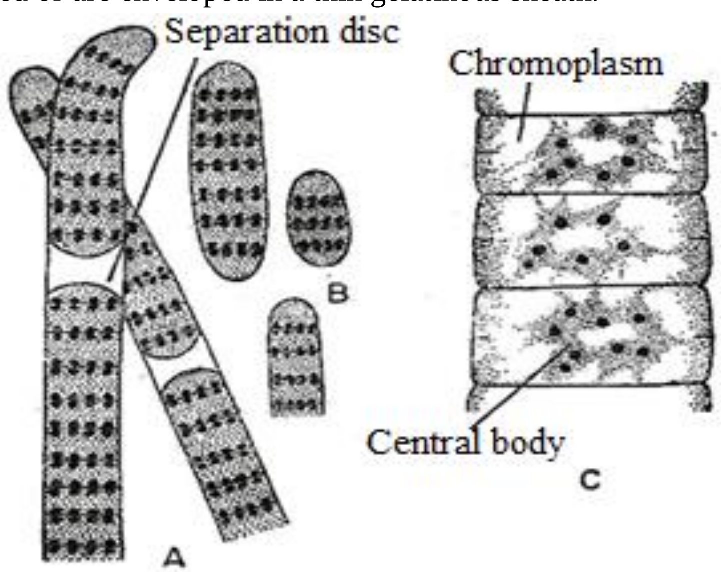

Fig.4.11: ***Oscillatoria*****, A- Filament, B- Hormogonia, C- cells magnified to show nature of protoplast**

Cell Structure

All cells of the trichome have similar structure. The cell is surrounded by a thin and firm cell wall which lies external to plasmalemma. The wall is differentiated into 4 layered, each layered is about 10 nm in thickness. In structure and composition of cell wall is similar to that of grampositive bacteria. It is composed of mucopeptide together with carbohydrates amino acid and fatty acid.

The cell exhibits a typical prokaryotic structure. The protoplast is differentiated into the peripheral pigmented *chromoplast* and the central *centroplasm*. The chromoplasm consists mainly thylakoids. The thylakoids are lamellate structures with two membranes joined at the ends, and enclose an intra thylakoid of variable width. Photosynthetic pigments are found on the surface of thylakoids. Thus membrane bound plastids, like those of eukaryotic cells, are absent. The amount of c-phycoerythrin and c-phycocyanin is higher than any other pigment.

The central origin of the cell which consists of nuclear material is termed as centroplasm or nucleoplasm. Although this region stains like the nucleus of eukaryotes and nuclear membrane and nucleoi are absent. It is not sharply differentiated and commonly interfingers with the peripheral chromoplasm.

4.3.8- *Anabaena*

Taxonomic Position

Class: Cyanophyceae
Order: Nostocales
Family: Nostocaceae
Genus: *Anabaena*

Occurrence

Anabaena is a planktonic alga, commonly found in fresh water ecosystem. Also it is not specific to freshwater habitats, at it also grows in a wide range of temperature and salinity. In fact, many blue- green algae have been found in alkaline hot springs, such as those in Yellowstone National Park. These algae can survive in temperature up to 74 degrees. Also many species of Anabaena have been found in and on top of the soil; such species are ecologically very important as they function as primary colonizers and add nutrients to the soil.

Thallus Structure

Anabaena is a filamentous blue- green alga. It is distinguished mainly on the basis of morphological characteristics, such as shape and size of trichomes, cell types, size and location of heterocysts and akinetes and plane of division. According to Desikachary (1959) the genus is identified on the basis of the presence of uniform uniseriate trichomes. The trichomes are oriented more or less parallel, almost of the same width throughout or are slightly narrowed at the ends; there are both solitary and colonial forms, the later resembling the closely related genus *Nostoc*. The cell may show deep constriction across walls and appears like strings of beads. The trichomes are not covered by firm sheath, but sometimes a hyaline, soft mucilaginous sheath may cover the trichomes.

Anabaena generally grows in long filaments of vegetative cells. However, when environmental nitrogen is low, approximately one cell out of every ten differentiates into a heterocyst. Heterocyst supplies fixed nitrogen to the neighbouring cells in return for the products of photosynthesis it receives from them. Heterocysts cannot perform photosynthesis.

Separation in the functions of vegetative cells and heterocysts is essential because the nitrogen fixing enzyme in the heterocysts- the nitrogenise does not function in the presence of oxygen. As it is essential to keep nitrogenase isolated from oxygen, heterocysts have developed structures to maintain low levels of oxygen in the cells. To prevent the entry of oxygen into the cells, the developing heterocyst builds three additional layers outside the cell wall.

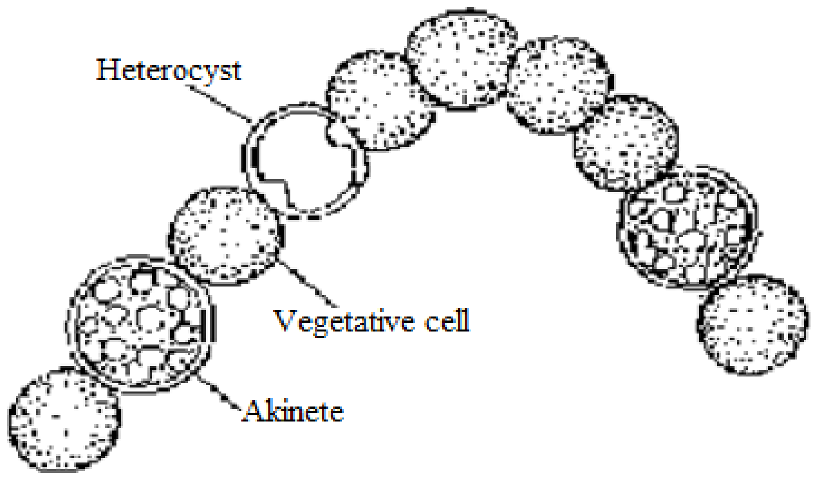

Fig.4.12: ***Anabaena***

Akinetes

Akineres are larger than vegetative cells which may appear spherical to sausage- shaped. In the trichome the akinetes may develop close to heterocysts or at a distance from them. Occasionally, akinetes develop in crenate series. The relatively thick wall of akinetes helps them to tide over unfavourable condition such as drought and low temperature. When conditions are favourable its protoplasm becomes active and grows into new trichome.

Anabaena species produce several kinds of toxins. Of those, **anatoxins** cause 'tetanus-like' muscle paralysis and **microtoxin,** whose mechanism of action is consistent with certain known carcinogens.

Nitrogen fixation by *Anabaena*

During times of low environmental nitrogen, about one cell out of every ten will differentiate into a heterocyst. Heterocysts then supply neighbouring cells with fixed nitrogen in return for the products of photosynthesis. Such nitrogen fixing cell now cannot perform photosynthesis. This separation of functions is essential. The nitrogen fixing enzyme in heterocysts is nitrogenase. It is unstable in the presence of oxygen. Nitrogenases are kept isolated from oxygen. Therefore, heterocysts have developed elements to maintain a low level of oxygen within the cell. The developing heterocysts build three additional layers outside the cell wall. These layers prevent the entrance of oxygen into the cell.

It gives heterocysts its characteristic enlarged and rounded appearance. Due to this adaptations, the rate of oxygen diffusion into heterocysts in 100 times lower than of vegetative cells.

4.3.9-*Spirulina*

Taxonomic Position

Class: Cyanophyceae

Order: Nostocales

Family: Oscillatoriaceae

Genus: *Spirulina*

Occurrence

Spirulina occurs in a wide variety of fresh water habitats, often found densely entangled with the *Oscillatoria* filaments. Some species are found in brackish water, and can tolerate high salt concentrations e.g., *S. subsalsa* can grow and multiply in solutions that are more concentrated than 3M sodium chloride solution.

It is a traditional food source in plants of Africa and Mexico. *Spirulina* is a rich source of vitamins, minerals and protein, and also contains vitamins B_{12}. It is now being widely studied for its positive antiviral, anticancer, antibacterial and antiparasitic properties. It is also used in such medical conditions as allergies, ulcers, anaemia and heavy metal poisoning. It is also used in weight loss programmes.

Thallus Structure

It is unicellular alga. The trichome consists of a single, cylindrical cell, wounded into a loose or close helix. The cell is differentiated into a peripheral pigmented chromoplasm and a central centroplasm. Cyanophycin granules are, however, absent.

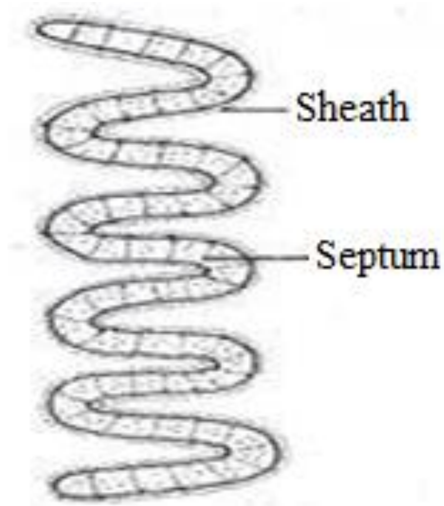

Fig.4.13 Spirulina

Movement

Spirulina shows spontaneous movements. The motion is usually creeping or gliding in the direction of the longitudinal axis and may take place both backward and forward. In some species, gliding movement is accompanied by the rotation of the trichome, taking place in the direction of coiling.

4.3.10- *Scytonema*

Taxonomic Position

Class: Cyanophyceae
Order: Nostocales
Family: Scytonemataceae
Genus: *Scytonema*

Occurrence

This filamentous blue- green alga includes about 40 freshwater or terrestrial species. They are found in brackish water, stagnant freshwater ponds, as well as on the moist soil, tree- barks and walls in the form of bluish-grey scum. *S. caldarium* has been reported from hot springs and *S. ocellatum* is the most common terrestrial species. The terrestrial species have a tremendous capacity of absorbing moisture from the atmosphere. About 33 species of *Scytonema* are recorded form India.

Thallus structure

The plant body is filamentous, and the filaments intertwine to form a scum of bluish-green, blackish-green or yellowish-green colour. Each filament, made up spherical, oval or squarish cells, is surrounded by an individual mucilaginous sheath. The sheath may be hyaline or coloured, smooth, homogeneous or lamellated. The terrestrial species, in particular, possess pigmented sheaths due to the presence of a pigment, scytonemin.

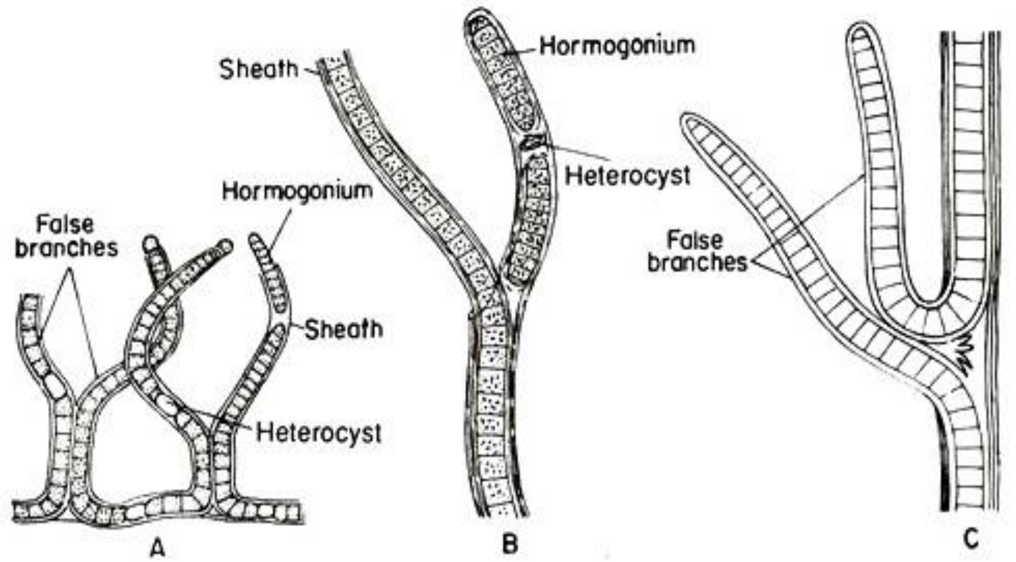

Fig.4.14. ***Scytonema sp*****. A- Filaments in cluster B- Single filament showing extended sheath**

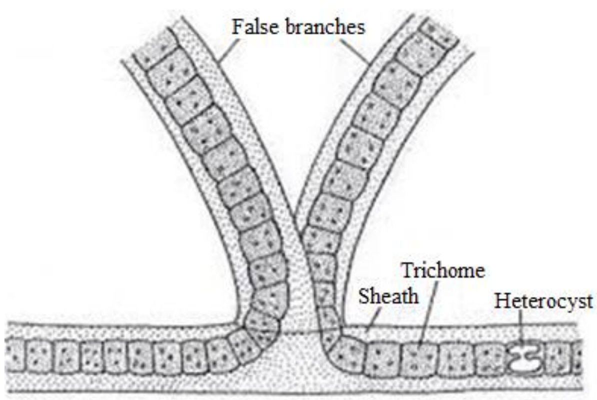

Fig.4.15- Thallus Structure

[A] Cell Structure

The cell shows a typical cyanophycean structure. The cell wall is typically polymeric in nature, composed of mucopolypeptides and muramic acids. The protoplast is differenciated into the peripheral pigmented chromoplast. The chromoplast is differenciated into the peripheral pigmented chromoplasm and the central centroplasm, in addition to chlorophyll a, the centroplasm is relatively dense and it represents the nucleus of the cell. It does not have the limiting nuclear membrane and nucleous.

[B] Branching

A characteristic feature of *Scytonema* is the presence of false branches, which are formed by the breaking of the filament. When a filament breaks, one or both the broken ends protrude out of the mucilaginous sheath and grow like branches; if both the broken ends come out of the sheath and grow like branches, it is called *germinate branching*, and if only one, then it is said to be false branching.

The false branches are formed by the following methods:

(i) By loop formation: Certain parts of the filament increase in length due to rapid cell division. Such localized growth result in loop formation that protrudes through the sheath. Eventually the loop breaks in the middle, cell division continues and two false branches are formed.

(ii) By formation of a sepration disc: Sometimes one of the intercalary cells becomes dark coloured due to the diffusion of chromatophores in the protoplast, and its cell wall becomes thin. The cell forms a biconvex separation disc due to the pressure of the adjacent cell. The disc ultimately degenerates, resulting in the breaking of the trichome. One of the broken ends protrudes through the sheath as false branch.

(iii) By rupture of filament near the intercalary heterocysts: In trichomes with intercalary heterocysts a zone of weak adhesion lies where the vegetative cell and the heterocyst abound each other. If the trichome breaks on one side of the heterocyst, a single branch is formed and if it breaks on both the side of the heterocyst, the branching is called germinate.

(iv) By degeneration of one or more intercalary cells: This is very common method of the formation of false branches. The apical cell remains active for sometime and then degenerates. Thereafter, the sub – apical cell functions as apical cell. Besides the apical and sub- apical cells, some intercalary cells also divide transversely and add to the growth of the trichome.

4.3.11-*Rivularia*

Taxonomic Position

Class- Cyanophyceae
Order- Nostocales
Family- Rivulariaceae
Genus: *Rivularia*

Occurrence

Rivularia is found in a wide variety of fresh water and terrestrial habitats. It grows on damp soil near river beds, moist rocks, or even epiphytically on some submerged plants. *R. Atra* is found in salt marshes, and species like *R.bullata*, and *R.polyotis* occur in supra- littoral and upper intertidal zones of sea coasts.

Thallus Structure

The unbranched trichomes of *Rivularia* are arranged in a radial fashion to form a spherical, hemispherical or irregular colony. The radial arrangement of trichomes in a colony is due to repeated false branching in their basal portions. The evidence for false branching is found only in young colony and is lost in a mature colony due to large displacement of trichomes. The trichomes in a colony remain partially or completely surrounded by a confluent sheath. The sheath is of very firm consistency, tough and very frequently heavily encrusted with lime.

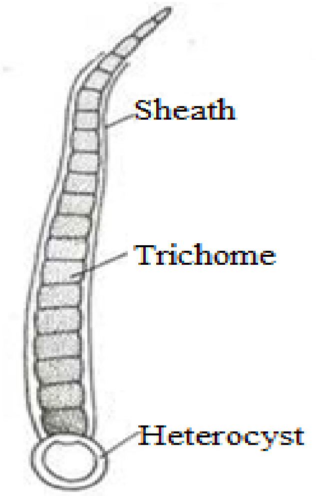

Fig.4.16 *Rivularia sp.*

Cell Structure

The cell exhibits a typical cyanophycen structure. The mucilagenous components of the cell wall contain arabinose and glucose. The protoplast is differentiated into a peripheral pigmentated chromoplasm and a central centroplasm. The chromoplasm contains important phycobilin pigments, c-phycoerythrin and c-phycocyanin. The centroplasm is relatively dense and represents the incipient nucleus of the cell.

Growth

The growth of the trichome in *Rivularia* is trichothallic. It takes place by the activity of meristematic cells in the intercalary meristematic zone located at the base of the terminat hair. The meristematic cells are comparatively small in size and have denser granular contents.

Reproduction

1. *Rivularia* reproduces vegetatively by the formation of hormogonia and rarely by the heterocyst which gives rise to new trichomes on germination. At the time of formation of hormogonia, the trichome usually sheds its hair.

2. Sexual reproduction is not known.

3. The delimitation of hormogonia starts in the meristematic zone and gradually proceeds towards the basal portion of the trichome.

4. Hormogonia are formed either singly or in series. In latter case, they are separated by biconcave separation discs.

5. At the time of germination, on of the two end cells of a harmogonium is modified into a basal hetrocyst, and the other cell divides repeatedly in a single plane to form a long trichome.

6. *Rivularia* can be differentiated from Gloeotrichia in the absence of akinetes.

4.5 SUMMARY

The word alga represents a large group of different organisms from different phylogenetic groups, representing many taxonomic divisions. In general algae can be referred to as plant-like organisms that are usually photosynthetic and aquatic, but do not have true roots, stems, leaves, vascular tissue and have simple reproductive structures.

The algae have chlorophyll and can manufacture their own food through the process of photosynthesis. Recently they are classified in the kingdom of Protista, which comprise a variety of unicellular and some simple multinuclear and multicellular eukaryotic organisms that have cells with a membrane-bound nucleus. The main groups of algae are

Chlorophyta division of the kingdom of Protista consisting of the photosynthetic organisms commonly known as green algae. The various species can be unicellular, multi-cellular, coenocytic (having more than one nucleus in a cell), or colonial.

Phaeophyta phylum of the kingdom Protista consisting of those organisms commonly called brown algae. Many of the world's familiar seaweeds are members of phaeophyta.

Rhodophyta phylum of the kingdom Protista consisting of the photosynthetic organisms commonly known as red algae. Members of the division have a characteristic clear red or purplish color imparted by accessory pigments called phycobilins. The red algae are multicellular and are characterized by a great deal of branching, but without differentiation into complex tissues.

4.6 GLOSSARY

Akinete - a thick-walled, resting, vegetative cell that can withstand environmental stresses such as temperature (asexual reproduction)

Alga(e)- Primitive, often aquatic, plants that carry on photosynthesis but lack the flowers, roots, stems, and leaves of higher plants.

Algal bloom – High concentrations or densities of algae.

Allopathy – The suppression of growth of an organism by another due to the release of a toxic substance.

Autospore - internal spore formed by cell division within a mother cell forming a replica of the mother cell, not flagellated (asexual reproduction)

Autotrophic – Organisms such as plants and some bacteria which produce their own food from inorganic substances such as carbon dioxide and inorganic nitrogen.

Benthic – Pertaining to the sea floor.

Benthos – The floor of a sea or ocean; also includes the bottom-dwelling organisms that live there.

Centric diatom - radially symmetric diatom; compare to pennate diatoms

Chlorophyte – A green alga.

Chloroplast – The structure in a plant or algal cell that contains chlorophyll.

Conjugation - sexual fusion of two ameboid cells (motile is from ameboid movement not flagella). Two types

Cyanobacteria – Blue-green bacteria, sometimes called blue-green algae.

Cytotoxicity – The characteristic of being toxic to living cells.

Diatom – Single-celled algae, mostly photosynthetic, that form silica cell walls, can grow singly, in chains or in simple colonies.

Dinoflagellate: a single-celled organism found in fresh and marine waters with characteristics of both plants (e.g., photosynthesis) and animals (e.g., uses outside organic sources of nutrition). Many harmful algal blooms are caused by dinoflagellates.

Ecosystem – Organisms of a natural community together with the environment.

Eutrophication – The excessive addition of nutrients, which spurs accelerated algal growth, creating more plant biomass than the ecosystem is capable of using.

Flagellate – Flagellates are single-celled Protista with one or more flagella, a whip-like organelle often used for propulsion.

Frustule - cell wall of a diatom

HAB – Harmful Algal Bloom.

Herbivory – The consumption of plant material.

Heterotrophic – Organisms that obtains nourishment from the ingestion and breakdown of organic matter such as plants and animals.

Hydrolysis – Chemical reaction of a compound with water, usually resulting in the formation of one or more new compounds.

Hypotheca - the large or lower valve of a diatom cell wall (frustule)

Light attenuation - The decrease in light intensity as a result of absorption of energy and of scattering due to particles in the water.

Microflagellate - Small protists that can be photosynthetic or heterotrophic.

Micrometer (µm) or micron – One millionth of a meter (1 inch = 25,400 µm). 1 millimeter = 1000 microns.

Micronutrient - Nutrient required in relatively small concentrations such as trace organics, metals and chelators.

Microphytoplankton – Small, plant planktonic organisms in a size range 20 – 200 microns.

Microplankton - Small, single-celled planktonic organisms in a size range 20 – 200 microns.

Photosynthesis - The physicochemical process by which plants, algae and some bacteria can utilize the energy of sunlight to power the biosynthesis of organic molecules, using carbon dioxide as the carbon source.

Phylogeny - The history of the development of a species of related organisms.

Phytoplankton - Microscopic, photosynthetic plants that are suspended in the water column.

Phytosterol or plant sterols – are found in all living plants and are natural constituents of the human diet.

Picoplankton - Very small, single-celled planktonic organisms (plants or animals) in a size range 0.2 - 2.0 microns.

Protista - A group of simple organisms not distinguished as animals or plants, though having some characteristics common to both.
Pseudoraphe - clear line down the middle of a diatom created by the lack or ornamentation
Raphe - linear slit in the valve
Spore - asexual reproductive cell
Tropic level - Any of the feeding levels through which the passage of energy through an ecosystem process.
Zooplankton - Microscopic animals that are suspended in the water column.
Zoospore - a flagellated spore (asexual reproduction)

4.7 SELF ASSESSMENT QUESTION

4.7.1 Multiple Choice Questions:

1-Gametes formed by meiosis are called
(a) Coenogametes (b) Meiogametes
(c) Mitogametes (d) None of these

2- Which one is a parasitic algae?
(a) *Vaucheria* (b) *Polysiphonia*
(c) *Cephaleuros* (d) *Batrachospermum*

3-Algal cell wall is composed of
(a) Chitin (b) Cutin
(c) Cellulose (d) Suberin

4-An example of agarophyte is
(a) *Dictyota* (b) *Fucus*
(c) *Nostoc* (d) *Gelidium*

5-Algae which form motile colony is
(a) *Volvox* (b) *Nostoc*
(c) *Spirogyra* (d) *Chlamydomonas*

6- Sporophytic generation is represented by zygote only in
(a) *Funaria* (b) *Chlamydomonas*
(c) *Pinus* (d) *Selaginella*

7- In biotechnological studies, the alga that is exploited as a rich source of protein is
(a) *Spirogyra* (b) *Spirulina*
(c) *Chlamydomonas* (d) *Scytonema*

8- More than one pyrenoid is present in

(a) *Ulothrix* (b) *Spirogyra*

(c) *Oedogonium* (d) All the above

9- The non-motile, greatly thickened asexual spores are called

(a) Hypnospores (b) Aplanospores

(c) Macrozoospores (d) Microzoospores

10-Which one of the following statements concerning the algae is wrong

(a) Most algae are photosynthetic (b) Algae can be classified according to their pigments

(c) All algae are filamentous (d) Spirogyra does not produce zoospores

11- Which among the following do you consider as the best evidence to show that two species of algae are closely related?

(a) They both respire and release CO2 (b) They both are found in the same habitat

(c) They both reproduce asexually (d) They both have same type of pigments

12- Algae are important, we should study algae because

(a) They are good organisms to experiment with

(b) They can be grown in large tank cultures

(c) They may form important constituent of human food (diet) in future

(d) They produce oxygen and organic acids

4.7.1 Answer Key: 1-(b), 2-(c), 3-(c), 4-(d), 5-(a), 6-(b), 7-(b), 8-(d), 9-(a), 10-(c), 11-(d), 12-(c)

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4.9 TERMINAL QUESTIONS

4.9.1 Long answer type Questions:

1. *Vaucheria* is almost like a phycomycetous fungus but has chromatophores. Why?
2. Discus the important features of sexual and asexual reproduction in *Vaucheria.*
3. Give an illustrated account of life-cycle of *Chara*?
4. Why *Chara* is considered an alga?
5. Give an account of thallus structure and life-cycle of *Batrachospermum*?
6. Give the structure and life history of *Polysiphonia*?

7. Give an illustrated account of the vegetative structure and methods of reproduction in *Volvox*?
8. Describe the vegetative structure and mode of branching in *Cladophora*?
9. Explain the method of growth and movement in *Oscillatoria*?
10. Write a note on economic importance of *Anabaena*?
11. Method of false branching in *Scytonema* with the help of labeled?
12. What is Gaidukov phenomenon?

UNIT-5 MORPHOLOGICAL STUDY OF REPRESENTATIVES OF ALGAE-II

5.1 OBJECTIVE

After reading this unit students will be able-

- To observe two different species of green algae.
- To draw diagram and compare these green algae to each other.
- To observe an example of brown and red algae and compare them to green algae.

5.2 INTRODUCTION

Algae are classified into four major groups (Palmer 1962): Blue-greens, Greens, Diatoms and Flagellates.

Blue Greens (Known as Cyanobacteria)

It comes under the Division Cyanophyta, Kingdom Eubacteria. They are referred to as algae but are actually photosynthetic bacteria that appear like true algae. They are mostly single-celled organisms or aggregations of single-celled organisms (planktonic). Planktonic algae generally do not adhere together in a mass, in that you could not easily grab a handful or mass of these organisms. Some species, such as *Nostoc*, are gelatinous masses that can be picked up. *Anabaena*, *Aphanizomenon, Oscillatoria* and *Mycrocystis* often dominate plankton communities and are notorious for producing potentially toxic blooms in fresh waters (only certain species produce toxins).

Greens include species from the Division Chlorophyta (Green Algae). They are morphologically diverse (micro and macroscopically). Microscopically, they can be uni- or multi-cellular, colonial, have branched or unbranched filaments and vary in size. Macroscopically, they can be planktonic, filamentous or found attached to objects (epiphytic).

Diatoms include species from the Class Bacillariophyta, of the Division Chrysophyta. They are often too small to see with the naked eye. Many are single celled, and less often colonial or filamentous.

Flagellates include species from various Divisions (including Chrysophyta, Euglenophyta, and Pyrrhophyta) that are motile, i.e. they have whip-like tails called flagellae.

5.3 PROCEDURE

Samples are in liquid, use a pipette to remove just a little alga to a slide, and cover with a cover slip. Remove excess liquid with a tissue, so that the cover slip is not floating.

Material's are-

- *Chlorella*
- *Hydrodictyon*
- *Oedogonium*

- *Ulva*
- *Nitella*
- *Botrydium*
- *Ectocarpus*
- *Dictyota*
- *Laminaria*
- *Fucus*
- *Gelidium*
- *Gracillaria*

*Wherever possible, collect specimens from the ocean for use in the lab.

Part A: Green Algae

1. Prepare a wet mount of preserved *Algae* for viewing under the microscope.
2. Observe the algae under both low and high power objective lenses.
3. Draw Diagram of one or two cells of *Algae* in the space provided. Note the shape of its chloroplasts. Use high power to draw the algae.
4. Label these parts on your diagram: cell wall, green chloroplast, nucleus, and single cell unit.
5. Describe the shape of the chloroplast.
6. Describe the colour of its chloroplast.
7. Describe the complete shape of the algae.

Part B: Red and Brown Algae

Most red and brown algae grow in marine habitats. Most red and brown algae are multicellular and all have nuclei within their cells. They are often found clinging to rocks along the ocean shores by a special structure called a holdfast. For this part of the lab you will need to find samples of red and brown algae.

5.3 STUDY OF REPRESENTATIVE MEMBERS OF ALGAE

5.3.1- *Chlorella*

(Chlor, green; ella, diminutive of affection)

Occurrence

Almost all species are fresh water and found in ponds and lakes. Species of *Chlorella* grow in wide variety of habitats.

They occur in fresh water, brackish water and also in terrestrial habitats. Most of the species are free living, but some grow within the cells and tissues of invertebrates, forming symbiotic or parasitic association.

Chlorella parasitica occurs as a parasite in *Spongilla* and *Ophryodium; C. conductrix* forms symbiotic association with invertebrates like *Hydra*, *stentor* and *paramecium* and *C. lichina* is an algal symbiotic partner of a lichen-*Calicium chlorina.*

The genus has about 8 species-*Chlorella parasitica, Chlorella ellipsoidea* and *C. gonglomerata* are common Indian species.

External Features

1. This is a unicellular non- motile alga.
2. The cell is small and globose. The cell wall is made up of cellulose.
3. Each cell is surrounded by three layered cell wall. The outer layer consists of mucilage, the middle layer of pectose and innermost of cellulose.
4. Each cell contains a cup shaped chloroplast usually without pyrenoid.
5. The cup-shaped cavity of chloroplast is filled with colourless cytoplasm.
6. The cytoplasm has single nucleus and other cell organelles like **Endoplasmic reticulum, Mitochondria, Golgi bodies and Vacuoles.**
7. The cell is uninucleate. The contractile vacuoles are not found.
8. The cells lack any type of flagella. Change in environmental condition s like duration, intensity and quality of light, temperature and chemical composition of growth medium greatly influence microbiology of chloroplast.

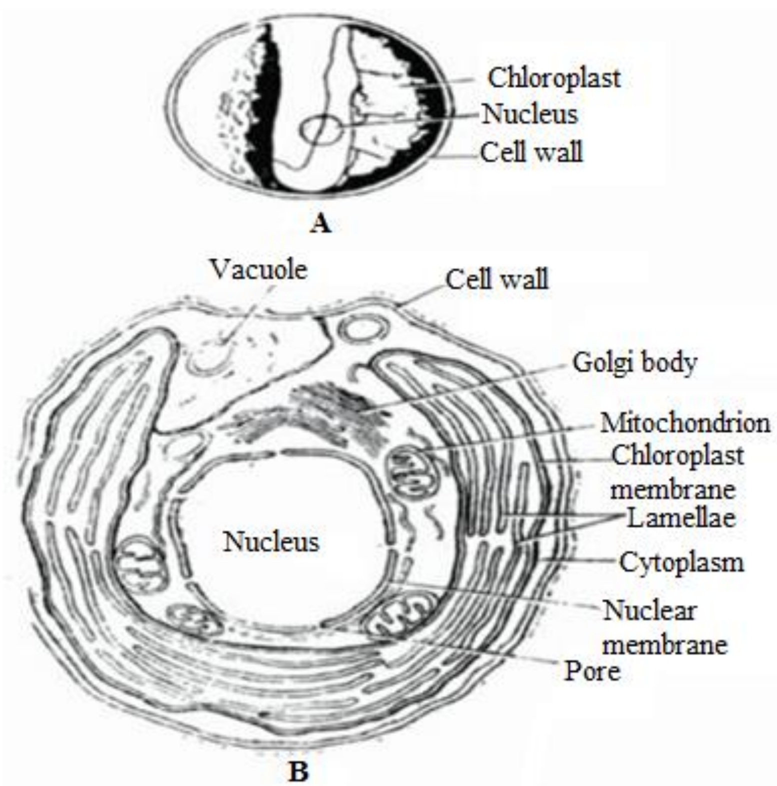

Fig.5.1:- A-B. *Chlorella*: A. Cell structure under light microscope. B. Cell structure under electron microscope.

5.3.2- Hydrodictyon

(*Hydro*, water*: dictyon*, net)

Identification and Systematic Position

Algae

(i) Chlorophyll bearing organisms.
(ii)Unicellular sex organs or multicellular ones in which every cells forms a gamete.
(iii) Autotrophic in nutrition.

Chlorophyceae

(i) Chlorophyll present within chloroplast.
(ii) Photosynthetic food product is starch.
(iii) Both the flagella are equal in length.

Chlorococcales

(i) The forms may be unicellular or coenobial.
(ii) Asexual reproduction takes place by means of zoospores, aplanospores, hypnospores, autospores, palmella stage and resting cells.

Hydrodictyaceae

(i) They form floating coenobia by union of their cells.
(ii) Sexual reproduction is isogamous.

Hydrodictyon

(i) Free floating cylindrical network.
(ii) Meshes of net and hexagonal or pentagonal

Occurrence

Hydrodictyon is commonly known as **water net**. It is free floating fresh water alga. It grows luxuriantly during late summer and spring season and sometimes almost completely covers the pond. The genus is represented by 5 species. *Hydrodictyon indicum* and *H. reticulatum* are common Indian species which occurs in temporary or permanent water reservoirs.

External Features

The coenobium is free floating hollow cylindrical network, closed at either end reaching a length of as much as 20 cm. mature coenobium is **sausage shaped** and hollow in center.
H. indicum Iyenger is larger form with bigger cells and meshes and thicker lamellated walls.

The meshes are pentagonal or more usually hexagonal, the angles being formed by the union of three of the elongate multinucleate cells.

Cell Structure

1. The cell is cylindrical, multinucleate and possesses a large central vacuole.
2. The lining layer of cytoplasm contains a nuclei and complex reticulate chloroplasts with many pyrenoids.
3. The young cells contain a single nucleus but the older cells become coenocytic.

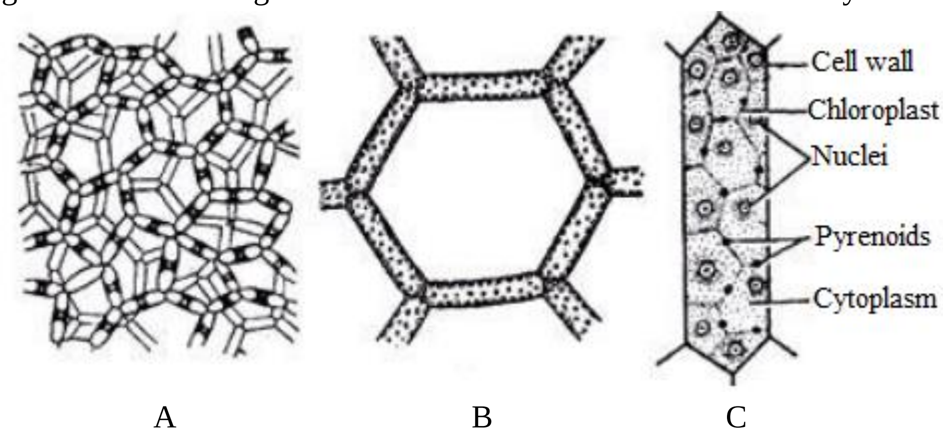

Fig.5.2: *Hydrodictyon*- Vegetative structures, A- A part of net; B. Hexagonal mesh; C. A cell

5.3.3- *Oedogonium*

Identification and systematic position

Algae

(i) Chlorophyll bearing organisms.
(ii) Unicellular sex organs or multicellular ones in which every cell forms gametes.
(iii) Autotrophic in nutrition.
(iv) Cellulose cell wall.

Chlorophyceae

(i) Chlorophyll present within chloroplasts and photosynthetic product is starch.
(ii) Usually pyrenoids present within chloroplasts.
(iii) Both flagella are equal in length.

Oedogoniales

(i) The thallus is filamentous which may be branched (*e.g., Oedocladium* and *Bulbochaete)* or unbranched (*e.g., Oedogonium)*
(ii) The cells are uninucleate, cylindrical and placed end to end.
(iii) There is special type of cell division and 'caps' are formed.

(iv) Stephanokontean type of motile bodies are formed *i.e.*, zoospores and antherozoids bear a circle of flagella.
(v) Sexual reproduction is oogamous.

Oedogoniaceae

Single family. Characteristics of the order

Oedogonium

(i) The filaments are present.
(ii) Special type of cell division present. Caps are present.
(iii) Well developed holdfast.
(iv) Dwarf males present.

Occurrence

It is exclusively fresh water in habit. The young filaments are found to be attached to some substrate. On maturity the filaments become free floating. Sometimes they are epiphytic upon other large size fresh water algae.

External features

1. The filaments are long and unbranched.
2. The basal cells of the young filament is devoid of chlorophyll and attached to some substratum is called the holdfast.
3. The terminal cell of the filament is broadly rounded at its apex.
4. The intercalary cells are cylindrical, uniform in thickness and arranged end to end.
5. The cells possess one or more striations at their apical ends called 'apical caps'.

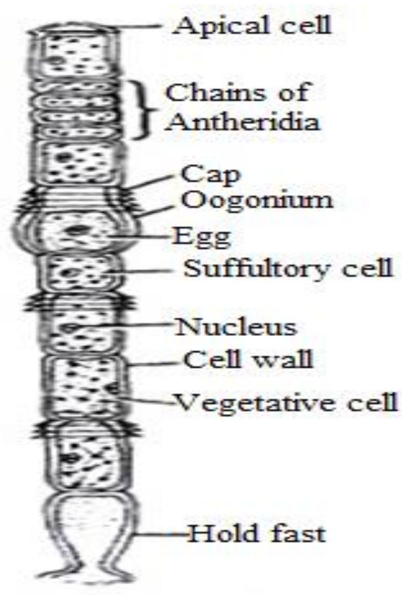

Fig.5.3: *Oedogonium* filament

Cell structure

1. The cells are cylindrical and covered with well defined three layered cell walls.
2. The outer layers consist of chitin, the middle of pectose and the innermost of cellulose.
3. Each cell contains a nucleus situate in the peripheral cytoplasm of the cell.
4. The chloroplast is reticulate and contains pyrenoids at its anastomoses. Each pyrenoid is surrounded by a starch sheath.

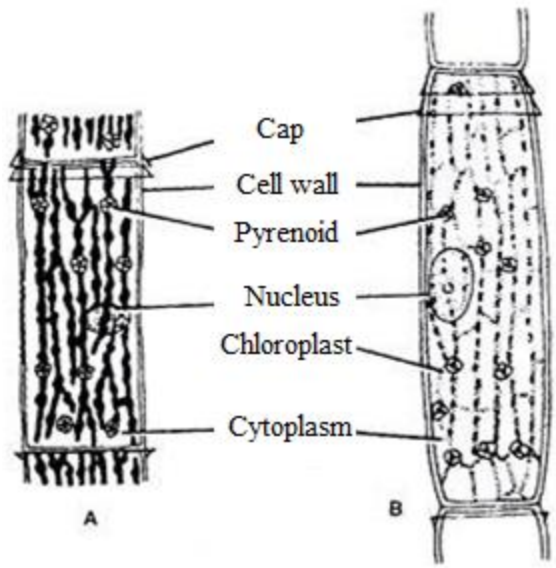

Fig.5.4:- *Oedogonium* A- young cell, B-mature cell

Macrandrous species: In such species the oogonia and anthredia may be developed on the same filament or on two different filaments. The anthredia are either terminal or intercalary. The protoplast of each anthredium metamorphoses in a single antherozoid.

Nannandrous species: The anthredia in such species are produced on special 'dwarf males' or 'nannandria'. Majority of the nannandrous species are heterothallic, *i.e.*, oogonia are produced on the ordinary filaments and anthredia on special filaments called 'dwarf males' or nannandria. The dwarf males are produced by the germination of androspores. Dwarf male is composed of a basal, long and sterile cell, which attaches the whole structure to the cell wall. It had disc or finger like structure at its base.

1. The oogonia of both the species are quite similar in structure. The oogonium is rounded or ovoid in structure.

2. On maturity a hyaline spot develops at the upper end of the oogonium. Each mature oogonium contains a large spherical egg cell in it.

5.3.4- *Ulva*

Identification and Systematic Position

Algae

(i) Chlorophyll bearing organisms.

(ii) Unicellular sex organs or multicellular ones in which every cell forms a gamete.
(iii) Autotrophic in nutrition.
(iv) Cellulose cell wall.

Chlorophyceae

(i) Chlorophyll present within chloroplast and photosynthetic food product is starch.
(ii) Usually pyrenoids present within chloroplasts.
(iii) Both the flagella are of equal length.

Ulotrichales

(i) They may be unbranched filaments (Ulotrichaceae) or thalloid sheet like structures (Ulvaceae)
(ii) Asexual reproduction mainly by zoospores.
(iii) Sexual reproduction ranges from isogamy to oogamy.
(iv) The chloroplasts may be girdle like, ring like, stellate, cuplike or plate like.

Ulvaceae

(i) The thallus is either an expanded sheet one or two cell in thickness (*Ulva)* or a ribbon like structure two or more cells in thickness (*Enteromorpha).*
(ii) The cells are uninucleate and possess a single cup shaped or laminate chloroplast.
(iii) Asexual reproduction by quadriflagellate zoospores and sexual ranges from isogamy to oogamy.

Ulva

(i) The expanded sheet of thallus is composed of two vertical rows of cells.
(ii) The rhizoids emerge from thallus near the point of attachment to the substratum and become closely intermingled to one another forming a pseudoparenchymatous holdfast.

Occurrence

Most of the species are exclusively marine. This is also known as ‘sea lettuce’, commonly found in the mid-tidal zone and frequently grows profusely in waters polluted by sewage.

External Features

1. The thallus consists of a large expanded sheet two cells in thickness and frequently several metres in length.
2. The thallus remains attached to substratum by a holdfast composed of rhizoidal outgrowths from the lower cells.

Cell Structure

1. Cells are isodiametric or vertically elongated to the thallus surface the walls of cells being more or less confluent with one another to form tough gelatinous matrix.

2. Each cell possesses a single cupshaped chloroplast which lies next to the outer face of the cell. Each chloroplast contains one pyrenoid.
3. The cells are uninucleate.
4. In the lower portion of the thallus certain cells send out long colourless rhizoids. The emerging points of rhizoids are green, transversely septate and multinucleate.

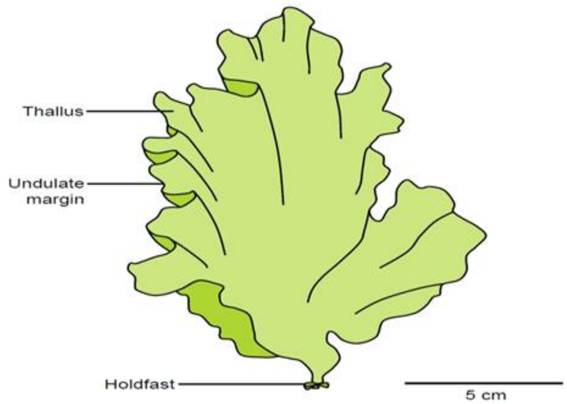

Fig.5.5: Ulva sp.

5.3.5- *Nitella*

Identification and Systematic Position

Algae

(i) Chlorophyll bearing organisms.
(ii) Unicellular sex organs or multicellular ones in which every cell forms a gamete.
(iii) Autotrophic in nutrition. Cell wall made up of cellulose.

Chlorophyceae

(i) Chlorophyll present within chloroplast. Photosynthetic food product is starch.
(ii) Usually pyrenoids present within the chloroplasts.
(iii) Both flagella are of equal length.

Charales

(i) They survive best in hard and clear water.
(ii)The plant body is erect and is differentiated into nodes and internodes.
(iii) The male and female fructifications are known as 'globule' and 'nucule'.

Characeae

Single family, Characteristics of the order.

Nitella

(i) Intermodal cells are without cortex.
(ii) Nucule is present below the globule.

(iii) The nucule bears a ten celled corona at its apex.

Occurrence: The species of *Nitella* are commonly found in clear and fresh waters. They are submerged and found in much deeper water than *Chara.*

External Features

1. The thallus can be easily recognized with unaided eye. It is multicellular and branched.
2. The plants look like the small plant of *Equisetum*, because of the presence of lateral branches at the nodes.
3. The thallus is differentiated into (a) lower rhizoidal portion and (b) the erect and branched main axis.
4. The plants remain attached to the muddy soil by means of rhizoids. The rhizoids are multicellular and branched.
5. The rhizoids are given out from the lower most nodes of the main axis. They possess oblique septa.
6. A quadrant of cells is found at the cross wall of each cell from where the rhizoids are given out. This quadrant is also called rhizoidal plate.
7. The main axis consists of nodes and internodes arranged alternately. The internodes are long and unicellular whereas nodes are short and multicellular.
8. Intermodal cells do not possess cortex.
9. The node of main axis bears branches of limited and unlimited growth in whorls. The branches of limited growth are known as short laterals and the branches of unlimited growth are long laterals.
10. The branches of limited growth bear nodes and internodes, the nodes bearing unicellular branches known as stipules. The tip of short lateral is tapering.
11. The branches of unlimited growth arise from the node of main axis. They are of similar structure as that of main axis. They possess large number of nodes and internodes than found on the short laterals.
12. Two or three long laterals are produced from each node of the main axis.

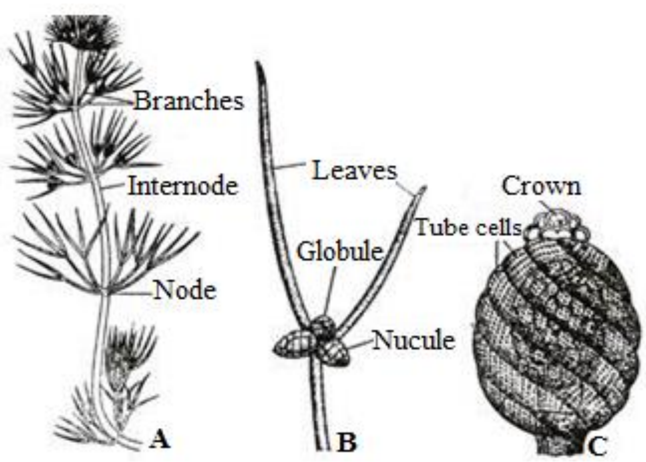

Fig.5.6: *Nitella sp*. A- Habit, B-Arrangment of globule and nucule, C- Nucule

Cell Structure

1. The intermodal cell remains covered by a distinct cellulose cell wall.
2. There is a peripheral cytoplasmic layer and a large central vacuole. A single nucleus remains embedded in the cytoplasm. Numerous discoid chloroplasts are irregularly dispersed in the cytoplasm. The chloroplasts are without pyrenoids.

5.3.6- *Botrydium*

Identification and Systematic Position

Algae

(i) Chlorophyll bearing organisms.
(ii) Unicellular or multicellular sex organs in which every cell forms a gamete.
(iii) Autotrophic in nutrition. Cell wall made up of cellulose.

Xanthophyceae

(i) Yellowish green chromatophores.
(ii) Food reserves-leucosin and oil. Starch absent.
(iii) Flagellation two unequal flagella at the anterior end of motile body.

Heterosiphonales

All members multinucleate, siphonaceous and multicellular.

Botrydiaceae

Characteristic features of the Heterosiphonales.

Botrydium

The thallus remains differentiated into vesicle and rhizoids.

Occurrence: It is terrestrial in form. It grows on damp soils, drying muddy banks of streams, pools, ponds, and rivers.

External Features

1. The plant body is unicellular.
2. It has two different parts-(a) the aerial part is rounded 1 to 2 mm in diameter and contains typical xanthophycean type of chromatophores. (b) The rhizoidal portion found embedded in the mud is colourless and branched.

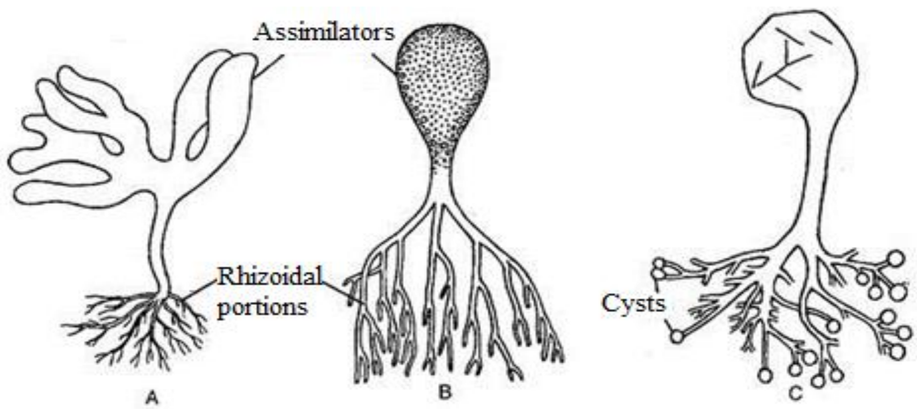

Fig.5.7:- Different species of *Botrydium*: A- divisum B- granulatum C- tuberosum

Cell Structure

1. The outer vesicular portion has a tough wall. Just beneath this wall there is a thin cytoplasmic layer.
2. Several nuclei and chromatophores are embedded in this thin lining of cytoplasm.
3. The chromatophores are discoid and many and remain connected to each other by cytoplasmic strands.
4. Pyrenoids are found in the chromatophores of young plants.
5. The rhizoidal system has no chromatophores but numerous nuclei are found in its cytoplasm.
6. The rhizoids hold the mud or damp soil firmly.

5.3.7- *Ectocarpus*

Identification and Systematic Position

Algae

(i) Chlorophyll bearing organisms.
(ii) Unicellular or multicellular sex organs in which each cell forms gametes.
(iii) Autotrophic in nutrition. Cellulose cell wall.

Phaeophyceae

(i) The chromatophores are yellowish brown in colour.
(ii) The reserve food products are alcohol, mannitol and laminarin.
(iii) The unicellular bodies are unknown.

Ectocarpales

(i) Branched, heterotrichous filamentous thallus with tricothallic growth.
(ii) The reproductive elements may be terminal or intercalary, borne singly or in chains.
(iii) The plant itself is sporophyte bearing unilocular and plurilocular sporangia.
(iv) Isomorphic alternation of generations.

Ectocarpaceae

(i) Plant body branched, branches uniseriate.
(ii) Sporangia terminal or intercalary.
(iii) Sporophytes bear uni or plurilocular sporangia.

Ectocarpus

(i) Chromatophores discoid or band like.
(ii) Naked pyrenoid like bodies present.

Occurrence: They are marine and species are commonly found in colder seas of temperate and polar regions. They are very common along the Atlantic coast. The plants occur attached to the rocks in the littoral and sublittoral zones. Many species are epiphytic on the sea weeds. For example *E.romentosus* grows upon the species of *Fucus.*

External Features

1. The plant body is filamentous and heterotrichous. It is differentiated into prostrate and erect thalli.
2. The prostrate portion is found to be attached to the substratum and remains creeping on it. The branches of erect portion arise from the prostate portion.
3. The prostrate portion of the plant is much branched than of the erect portion.
4. The ultimate branches of erect portion are generally thin and pointed.
5. The cells of branches of erect portion are uniseriately arranged end to end. The branching is always lateral and the branches arise just beneath the septa.

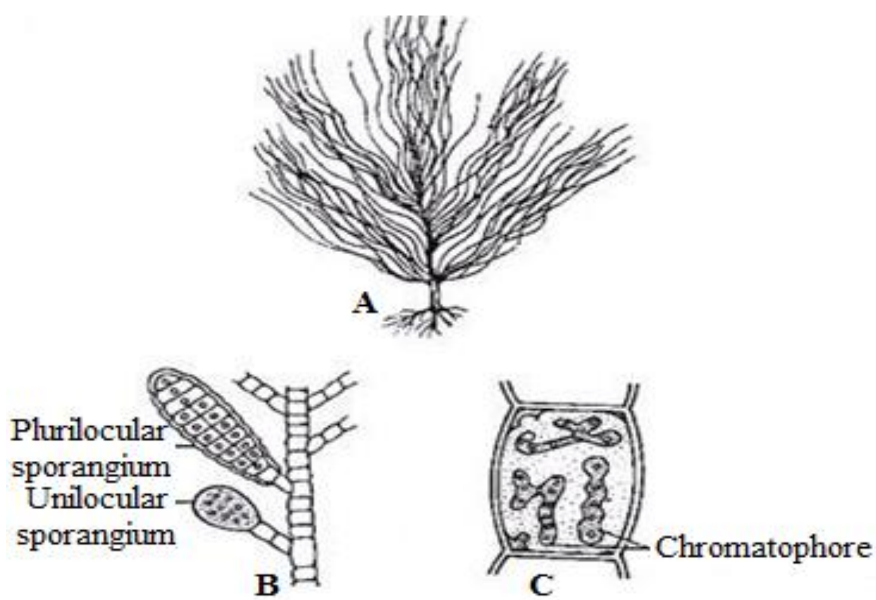

Fig.5.8: *Ectocarpus* thallus A- External features B- Part of thallus C- A cell

Cell structure

1. The cells are small, cylindrical, uninucleate and with a few band shaped chromatophores of irregular shape. Sometimes the cell contains many discoid chromatophores.
2. The protoplast is differentiated into nucleus and cytoplasm.
3. The cell wall is thick and consists of three pectic cellulose layers. The cell wall is mucilaginous.
4. Naked pyrenoid-like structures are present in the golden brown chromatophores.

5.3.8- *Dictyota* (like a mat)

Occurrence

They are widely distributed in warm seas of tropics. Usually the thalli remain attached to rocks in tide pools by a holdfast.

External features

1. The plant body consists of a strap like thallus ten to twenty cm. Long. The thallus is dichotomously branched.
2. The thallus branches repeatedly, each division giving rise to two equal branches.
3. The basal portion of the thallus from a disc like branched holdfast by which the thallus remains attached to the solid substrata.
4. The strap like thallus consists of rectangular cells arranged in a singular layer, with a superficial of smaller cells on each side of thallus.
5. Smaller tufts of hairs develop from scattered group of these surface cells.
6. In transverse section the thallus is seen to be composed of three layers, a central one of large cells and upper and lower epidermis of small assimilatory cells from where groups of mucilage hairs arise

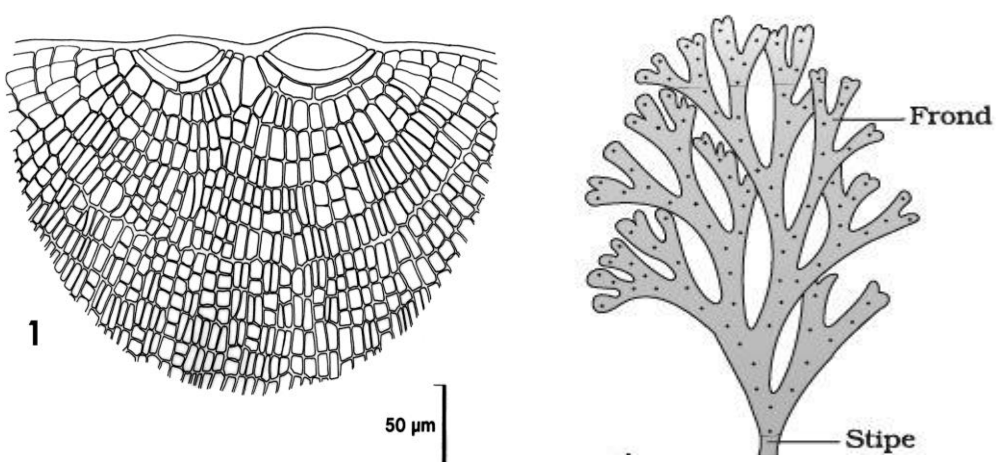

Fig.5.9: *Dictyota.* Surface View of Thallus Apex

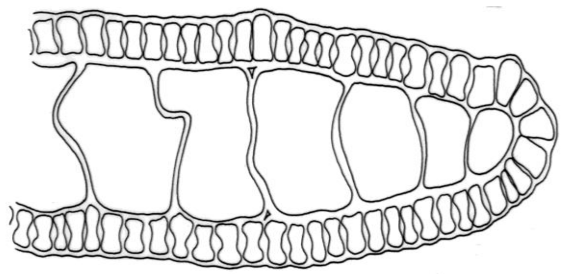

Fig.5.10: ***Dichomotomous*** **Branching in Thallus**

5.3.9- *Laminaria* (a thin plate)

Occurrence: This is exclusively marine and occurs in shallow cold waters along rocky shores but just below the low tide level.

External and internal structure

1. The plant is a sporophyte which remains differentiated into a holdfast, stipe and blade.
2. The holdfast may be a solid disc but it usually consists of forked root like branches known as heptera.
3. The stripe found above holdfast is always unbranched and either cylindrical or somewhat flattened.
4. The stripe terminates into a single blade which maybe entire or vertically incised into a number of segments.
5. Both stipe and lamina in transverse section show a sepration into three distinct zones, although these zones are more clearly marked in the stipe because of its greater thickness.
6. These three zones are epidermis, the cortex and medulla.
7. The epidermis is composed of one or two layers of small cubical cells containing many chromatophores.
8. In many species the cortex may contain mucilage ducts which form an anastamosing system of canals filled with mucilage.

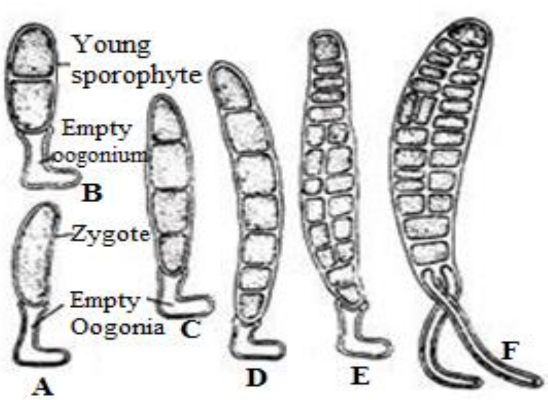

Fig.5.11: ***Laminaria sp.*** **A-F- Stages in development of sporophyte**

5.3.10- *Fucus*

Occurrence: This is a marine alga and occurs in the seas of cold water. They are commonly found in intertidal zones attached to the rocks on the shores.

External features

1. The thallus remains attached to the rock by a well developed holdfast.
2. A dichotomously branched leathery thallus called the frond or lamina is found above holdfast.
3. The dichotomous branches are flat ribbon like a process distinct midrib in them. Certain air bladders are present upon ribbon like branches which give buoyancy to the plants.
4. A cylindrical portion found just above the holdfast is called the 'stipe'.
5. The midribs present right from holdfast to the branches.
6. Each cryptoblast opens outside in a stoma like structure the 'cryptostoma'.
7. The special reproductive branches bear the 'receptacles' at their tips. Several fertile conceptacles are scattered over these receptacles.

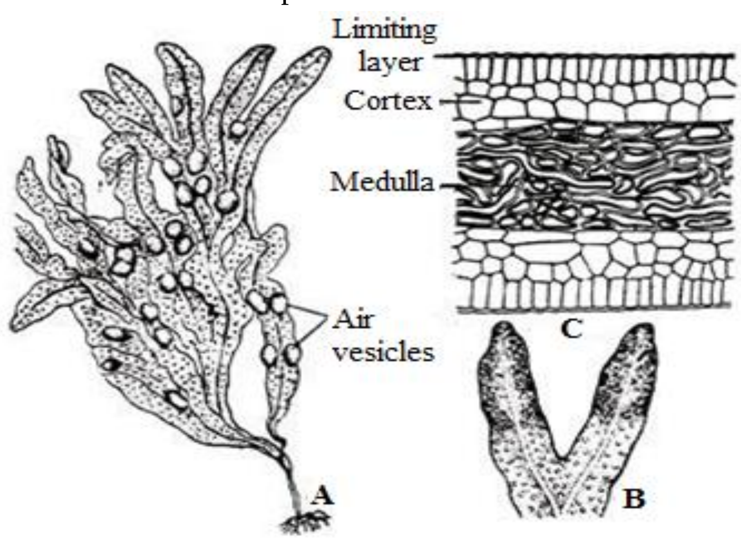

Fig.5.12: ***Fucus sp.*** **A- Habit B- Apex of thallus C- Portion of the thallus in section**

Apical growth

The apical growth of the thallus takes place by a single pyramid- like apical cell situated in the terminal notch of the lamina.

Internal structure: T.S. of lamina

1. It is differentiated into epidermis, cortex and medulla.
2. The outer most layer process thin walled cells.
3. These cells contain numerous chromatophores.
4. The certain region consists of septate loose elongated interwoven filaments. This is medulla.
5. In the T.S. of midrib region the medulla exhibits longitudinal and irregular hyphae that make a thick and compact solid tissue.

5.3.11- *Gelidium*

1. Gelidiales is an order of marine Rhodophyceae in which the carpogonial branch consists of a single cell, the carpogonium. .
2. The plants are commonly used in the production of agar, with almost half of the world supply coming from members of this order (Lewis and Hanisak, 1996).
3. Male plants are similar in morphology to female plants, with the spermatangial areas forming irregular patches on the thalli.
4. Plants has triphasic life cycle of gametophyte, tetra sporophyte, and carposporophyte.
5. The gametophyte and tetra sporophyte of *Gelidium* have a dome-shaped apical cell that cuts off daughter cells basipetally.
6. The daughter cells divide to form a thallus that soon loses its uni axial nature in the mature parts. The carpogonia are usually formed on special **ramuli** (branches) with a deep apical notch, behind which there is a depression on both surfaces.
7. The carpogonia are produce in these depressions.
8. The carpogonium is cut off from a cell beneath the surface of the thallus and has a long trichogyne that reaches to the outside of the thallus.
9. The carpogonial branch thus consists of a single cell.
10. Nutritive filaments are cut off from the cells at the base of each of the laterals in the fertile area.
11. After fertilization, the carpogonium may fuse with the supporting cell and/or nutritive filaments, with the gonimoblast filaments and carposporangia developing from this fusion cell.
12. The cortical cells of a fertile area elongate, fade in color, and become transformed into spermatangial mother cells.
13. The colorless spermatangia are formed by transverse division of the mother cell.

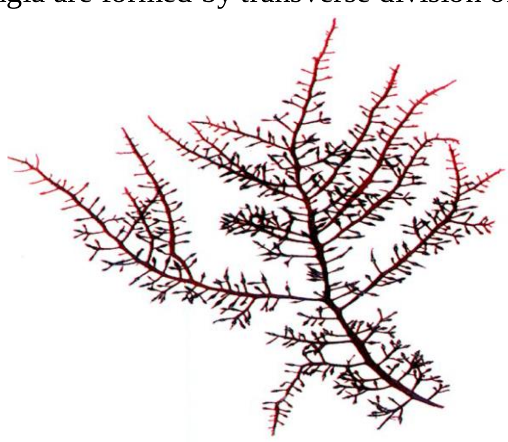

Fig.5.13: *Gelidium*

5.3.12- *Gracillaria*

1. The plants are fleshy, having a tendency to be flattened or foliose with pseudoparenchymatous tissues that lack filamentous cells in the mature vegetative thallus.

2. Intercalary origin that bears a two-celled carpogonial branch flanked by two or more sterile branches.
3. The principal genus in the family is *Gracilaria*, found at low tide level and below, with about 100 species.
4. The dark-red thallus grows by means of a two-sided apical cell and has tapering branches.
5. There are large isodiametric cells in the medulla, with small cortical cells containing a number of ribbon-shaped chloroplasts.
6. Unicellular hairs arise from enlarged peripheral cells that become multi nucleate as they age.
7. The gametophytic plants are either male or female, and equal numbers of each are produced from tetra spores.
8. The male plants produce spermatia in antheridial pits over the surface of the thalli.
9. The female plants form supporting cells from the outer layer of the large cells of the medulla, the supporting cells producing the two-celled carpogonial branch and a number of laterals, a cell of which functions as the auxiliary cell.
10. After fertilization the carpogonium fuses with one of the nutritive cells that is acting as an auxiliary cell.
11. The carposporangia ripen successively from the outside in. In some species, elongate cells radiate from the compact regions of the gonimoblast, penetrating the **pericarp** (cystocarp wall), and become connected with the cells of the pericarp.
12. The carpospores germinate to produce a parenchymatous disc that forms the tetrasporophyte as an erect protuberance.
13. The tetrasporophyte is morphologically similar to the gametophyte and about the same size as the female gametophyte.
14. The tetra spores germinate to form a parenchymatous disc that produces the gametophyte as an erect protuberance.
15. *Gracilaria* is a major agarophyte, currently providing greater than half of the world's supply of agar-agar.
16. The cultivation of *Gracilaria*, both in the sea and in tanks, has been a principal factor in making this genus a source of agar-containing seaweeds.
17. Human consumption of *Gracilaria* has been linked to "**ogonori**" **poisoning** .The symptoms are hypotension, vomiting, nausea, and death resulting from hypotensive shock.

Fig.5.14: *Gracillaria* thallus

5.4 SUMMARY

Within the classification of algae, individual species are divided into three groups, based on characteristics such as type of chlorophyll molecule used in photosynthesis and type of reproductive cycle. The structure of the chloroplast is also used, for a very important reason. The number of membranes surrounding the chloroplast allows us to determine what type of organism the original photoautotroph. On the basis of chlorophyll molecule algae classified into three group namely Green algae (*Chlorophyseae*), Brown algae (*Pheophyceae*) and Red algae (*Rhodophyceae*).

5.5 GLOSSARY

Anisogamy - sexual fusion between flagellated gametes of distinctly different sizes and morphologically different

Anthropogenic (source of nutrients) - Derived from humans (sewage) or human activities (e.g., crop farming, high intensity animal operations, automobile exhaust pipes, and urban runoff).

Aplanospore - non-flagellated spore (asexual reproduction)

Assimilate - Conversion of nutritive materials into a living organism.

Autocolony - a newly produced coenobium with the same form as the parent colony (asexual reproduction)

Binary fission - a single cell doubling it's nuclear material and then dividing into two cells (asexual reproduction)

Biocides - Chemicals used to kill living organisms (e.g, pesticides ,algaecides).

Eukaryotic - A cell with a distinct membrane-bound nucleus.

Eutrophic - High in nutrients (nitrogen, phosphorus) and high in organic (biological) production.

Invertebrates - Animals lacking a backbone and internal skeleton.

Isogamy - sexual fusion between flagellated gametes of same size and similar morphology

Isolates - Single species of algae picked from a natural population and established in culture.

Lateral conjugation - adjacent cells in the same filament conjugate

Microzooplankton - Small animals (or animal plankton) in the size class 20-200 microns that are carried with the motion of the currents.

Niche – A unique ecological role of an organism in a community.

Oogamy/oogamous - sexual fusion between a flagellated gamete (sperm/antherozoid) and a non-flagellated gamete (egg).

Pigments - Large, colored molecules that capture light energy and make it available for photosynthesis.

Plankton - Organisms, both plant and animal that are suspended in the water column and transported by tides and current.

Symbiotic - An interrelationship between two different organisms in which the effects of that relationship are expressed as being harmful or beneficial; intimate associations in which organisms of more than one species live together. The association may be beneficial to both (mutualism), beneficial to one with no effect on the other (commensalism) or beneficial to one with harmful effects on the other (parasitism).

5.6 SELF ASSESSMENT QUESTIONS

5.6.1 Multiple Choice Questions:

1- Who is regarded as the "Father of Indian Phycology"

(a) Prof. M.O.P. Iyenger (b) Prof. J.N. Mishra
(c) Prof. R.R. Mishra (d) Prof. R.N. Singh

2- Phycology is the study of

(a) Algae (b) Fungi
(c) Bacteria (d) All the above

3-Who is popularly known as the "Father of Phycology"

(a) Fritsch (b) Papenfus
(c) Smith (d) Morris

4- The classification of algae is based on

(a) Type of pigment (b) Nature of cell wall material
(c) Nature of reserve food (d) All the above

5- Sexual reproduction and mobile cells are absent in

(a) Chlorophyceae (b) Myxophyceae
(c) Rhodophyceae (d) Phaeophyceae

6- Botanical name of sea palm is

(a) Polysiphonia (b) Postelsia
(c) Ectocarpus (d) Macrocystis

7-Agar-Agar is obtained from

(a) Gigartina (b) Gelidium
(c) Gracillaria (d) All the above

8- Iodine is obtained from the members of

(a) Green algae (b) Brown algae
(c) Red algae (d) Blue green algae

9- Example of coenocytic algae is
(a) Vaucheria (b) Chara
(c) Nostoc (d) Polysiphonia

10- In the life cycle of which group flagellated cells are not formed
(a) Chlorophyceae (b) Phaeophyceae
(c) Rhodophyceae (d) Both (b) and (c)

11- Coenobium means
(a) A hollow spherical colony (b) A group of filaments
(c) Palmelloid form (d) None of these

12- Which one of the following is not a accessory pigment
(a) Chlorophyll 'a' (b) Chlorophyll 'e'
(c) Phycocyanin (d) Xanthophyll

13- In physiological anisogamy
(a) Gametes are morphologically similar but physiologically dissimilar
(b) Gametes are morphologically dissimilar but physiologicaly similar
(c) Gametes are morphologically and physiologically similar
(d) None of the above

14- Fusion of mature individuals which directly act as gametes, is called
(a) Isogamy (b) Anisogamy
(c) Hologamy (d) Autogamy

15-A motile flagellated asexual cell is called
(a) Sperm (b) Zoospore
(c) Oospore (d) Androspore

5.6.1 Answer Key: 1-(a), 2-(a), 3-(a), 4-(d), 5-(b), 6-(b), 7-(d), 8-(b), 9-(a), 10-(c), 11-(a), 12-(a), 13-(a), 14-(c), 15-(b)

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5.9 TERMINAL QUESTIONS

5.9.1 Long answer type Questions:

1. Describe the cell structure, reproduction and economic importance of *Chlorella*?
2. Discuss Autospore formation in *Chlorella*?
3. Give the cell structure and life history of *Hydrodictyon?*
4. Discus the important features of sexual and asexual reproduction in *Oedogonium?*
5. Describe the method of sexual and asexual reproduction in *Ulva*?
6. Give an illustrated account of the thallus organization in *Ulva*?
7. Give an illustrated account of life-cycle of *Nitella?*
8. Describe the cell structure and reproduction of *Ectocarpus?*
9. Silent features of the structure and life cycle of *Dictyota?*
10. Draw transverse section of the stipe part of *Laminaria* thallus?

UNIT-6 MORPHOLOGICAL STUDY OF REPRESENTATIVES OF BRYOPHYTES- I

6.1 OBJECTIVE

After reading this unit students will be able-

- To learn the morphological features of following liverworts: *Sphaerocarpus, Marchantia, Plagiochasma, Conocephalum, Cryptimitrium, Frullaria, Porella, Pellia.*

6.2 INTRODUCTION

Bryophytes are an informal group consisting of three divisions of non-vascular land plants (embryophytes), the liverworts, hornworts and mosses. They are characteristically limited in size and prefer moist habitats although they can survive in drier environments. The bryophytes consist of about 20,000 plant species. These produce enclosed reproductive structures (gametangia and sporangia), but do not produce flowers or seeds and reproduce via spores.

A liverwort is a flowerless, spore-producing plant. The English word "wort" means "small plant." The term liverwort originated from the fact that the early herbalists thought that one of the liverworts had some resemblance to liver - and some use as medicine for liver ailments, hence the word liverwort for a "liver-like small plant". The term hepatics are also used alternatively for liverwort.

Liverworts can vary in size from less than 1 mm to 50 mm or more, and generally lie prostrate on the substrata. In appearance they can look leaf-like (leafy liverworts) or form large flat sheets (thallose liverworts) and are represented by approximately 60 families. Some important liverworts are described below.

6.3 MORPHOLOGICAL STUDY OF REPRESENTATIVES OF BRYOPHYTES

6.3.1 *Sphaerocarpus*

Division: Bryophyta
Class: Hepaticopsida
Order: Spherocarpales
Family: Sphaerocarpaceae
Genus: *Sphaerocarpus*

Habit and Occurrence: The genus *Sphaerocarpus* is not found in India. Mostly it is found in northern as well as southern hemisphere chiefly in Gulf and Pacific coast. The plant prefers to grow on moist and colder places. The morphology of plant varies if the habitat is varies.

External Structure of the Thallus

1. The gametophytic plant body is thalloid and bilaterally symmetrical.
2. Thallus is prostrate, dorsiventrally flattern, dichotomously branched and green in color.
3. Most of the species has notched margin and each margin bears growing points.
4. Thallus has broad midrib which is several cell thick and unistratose wings.
5. Wings are entire or incised into leaf-like lobes, which on detachment serve as vegetative propagules.
6. Rhizoids are present on the ventral surface.
7. All rhizoids are smooth walled and confined to the thickened portion.

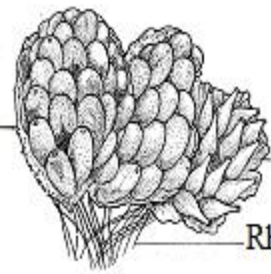

Fig. 6.1: *Sphaerocarpus* Plant

Internal Structure (Anatomy) of the Thallus

1. Internal structure of the thallus is very simple.
2. The photosynthetic zone, air pores and air chambers are also absent.
3. All cells except rhizoids are chlorophyllous.
4. The midrib is made up of multiple layers of cells while the wings are made up of single layer of cells.

Reproduction

1. Reproduction occurs in plant by vegetatively and sexually both.
2. Vegetative reproduction occurs through adventitious and dichotomous branching both.
3. The plant is dioecious and controlled by the sex chromosomes.
4. Annual species are found in the group of four, of these two are male and two are female.

Antheridiophores and Achegoniophores

Antheridia

1. Male plant is smaller in size than the female plant.
2. It is about 2 mm in diameter with their flask shaped involucres and a purple tinge which open outside by a mouth.
3. The involucre is one cell thick and formed by elevation of dorsal surface.
4. Each involucre has a single anthridium, the body of which is large and globose and situated on a short stalk.

5. The body of anthridium is single layered thick with a sterile covering.
6. Sterile cells contain chromatophores which gives it a deep orange red color on maturation.
7. Antherozoids are biflagellate and spindle or coiled shaped.

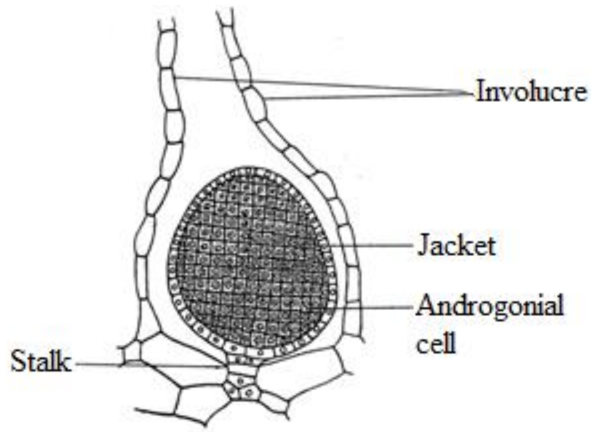

Fig. 6.2: An Antheridium

Archegonia

1. Female plants are bigger in size upto 1 cm in diameter with their archegonia in subspherical to cylindrical involucres.
2. Dorsal surface of female thallus bears numerous oval involucres with wide mouth at its top.
3. The archegonia, on the female thallus, initiates with the capitate enlargement of an archegonial initial with 2-3 cells behind the apical cell.
4. Involucres of female plant are one cell thick and all cells contain chloroplast.
5. Each involucres covers a single sessile and short archegonium.
6. Neck of archegonium has six vertical rows of cells with four neck canal cells.

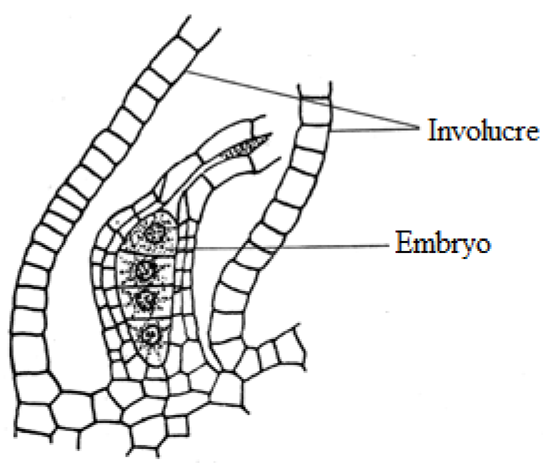

Fig. 6.3: Four Celled Embryo

Sporophyte

1. Sporophyte is differentiated into foot, seta and capsule.
2. In a mature sporophyte the jacket and nurse cells are chlorophyllous.
3. The wall or jacket of a sporophyte is one cell thick and remains intact.

4. Spores are spread out by the death and decay of the jacket and surrounding cells of gametophyte.
5. Half of the spores germinate into male and rests are into female thalli.

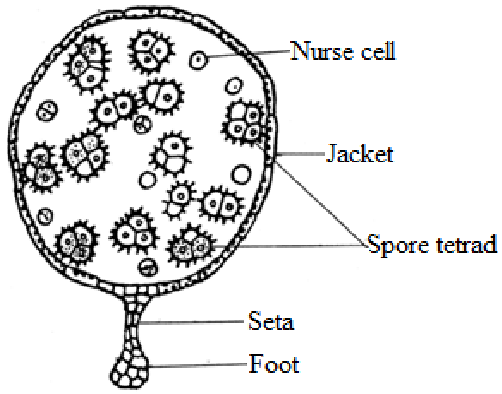

Fig. 6.4: A mature sporophyte

Identification and Systematic Position

Division: Bryophyta

1. Gametophytic plant body
2. Absence of true roots.
3. Absence of vascular strands.
4. They are homosporous.

Class: Hepaticopsida

1. Thalloid plant body.
2. Chloroplasts devoid of pyrenoids.
3. Rhizoids without septa.
4. Capsule lacks columella

Order: Spherocarpales

1. Ventral scales are absent but mucilaginous hairs are found near growing point.
2. Tuberculated rhizoids are absent.
3. Only smooth walled rhizoids are present.
4. All the cells are uniformly green in thallus.

Family: Spherocarpaceae

1. Thalloid plant body is bilaterally symmetrical.
2. Family is represented by two genera: *Sphaerocarpus* and *Geothallus.*

Genus: *Sphaerocarpus*

6.3.2 *Marchantia*

Division: Bryophyta

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

Habit and Occurrence: It is cosmopolitan genus with about 65 species are found worldwide. In India eleven species are reported from the Himalayan region. *Marchantia polymorpha* is a best known and widely distributed species.
They commonly thrive upon moist soil found on the rocks in shady places, in open woodland or near the banks of stream. This genus grows best in the burnt soil.

External Structure of the Thallus

1. The plant body is a prostrate thallus, dorsiventral structure which branches dichotomously and attains a length upto10 cm or more.
2. A distinct midrib is present which is represented by shallow groove on dorsal side and projection on ventral side.
3. The rhomboidal or polygonal small areas are found on the dorsal surface of the thallus which indicates the boundaries of the underlying air chamber.
4. The apex of each branch of the thallus bears a notch in which the growing point is situated.
5. On maturity the margin of the thallus is somewhat wavy.

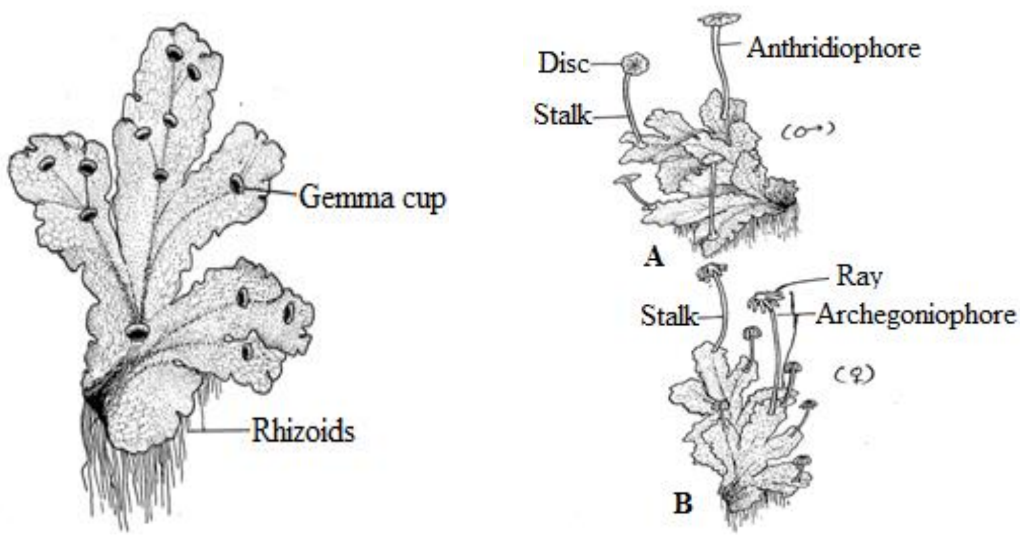

Fig. 6.5: *Marchantia* Thallus, A-Male Plant, B- Female Plant

6. On the ventral surface of the thallus rhizoids and scales are present.
7. Scales are membranous and one cell thick, multicellular structure with mucilage papillae. These are of two types: appendiculate and ligulate.
8. Rhizoids are simple and tuberculated which form dense tuft along the midrib and help in the attachment of thallus to the substratum.

Internal Structure (Anatomy) Of the Thallus

A vertical cross section of the thallus can be differentiated photosynthetic zone and lower storage zone.

(a) Upper Photosynthetic Zone

1. The outermost layer is upper epidermis which is single layered.
2. Its cells are thin walled square, compactly arranged and contain few chloroplasts.
3. Its continuity is broken by the presence of many barrel shaped air pores. Each pore is surrounded by four to eight superimposed tiers of concentric rings with three to four cells in each tier.
4. The lower tier consists of four cells which project in the pore and the opening of the pore looks star like in the surface view. The walls of the air pore lie half below and half above the upper epidermis.
5. Just below the upper epidermis photosynthetic chambers are present in a horizontal layer. Each air pore opens inside the air chamber and helps in exchange of gases during photosynthesis.
6. These are chambers develop schizogenously (Vocalized separation of cells to form a cavity) and are separated from each other by single layered partition walls. The partition walls are two to four cells in height. Cells contain chloroplasts. Many simple or branched photosynthetic filaments arise from the base of the air chambers.

(B) Storage Zone

1. It lies below the air chambers.
2. This region is more thickened in the centre and gradually tapers towards the margins. It consists of several lasers of compactly arranged, thin walled parenchymatous isodiametric cells.
4. Intercellular spaces are absent.
5. The cells of this zone contain starch. Some cells contain a single large oil body or filled with mucilage. The cells of the midrib region possess reticulate thickenings. The lower most cell layer of the zone forms the lower epidermis. Some cells of the middle layer of lower epidermis extend to form both types of scales and rhizoids.

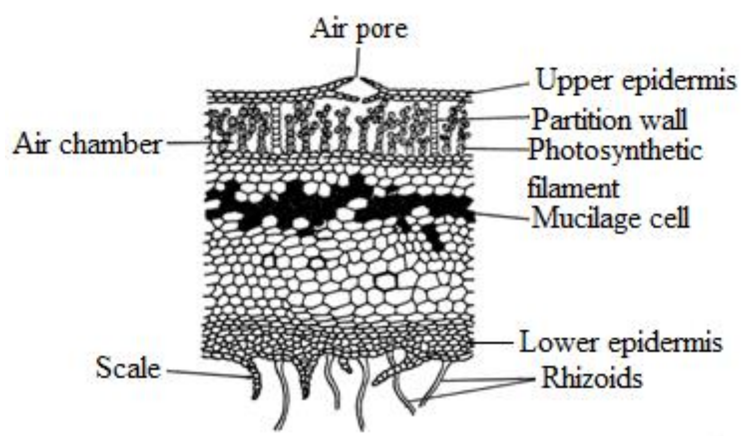

Fig. 6.6: T.S. of Thallus

Reproduction

Gemma Cups

1. The most common of the vegetative reproductive takes place by means of gemmae formed in the gemma cups.
2. Crescent shaped gemma cups are found on the dorsal surface of the gametophytes. These are found usually along the mid ribs.
3. Gemmae are produced in the gemma cups which are found on the dorsal surface of the thallus and 3 m.m. in diameter with smooth, spiny or fimbriate margins.
4. Each gemma cup contains a large number of gemmae.

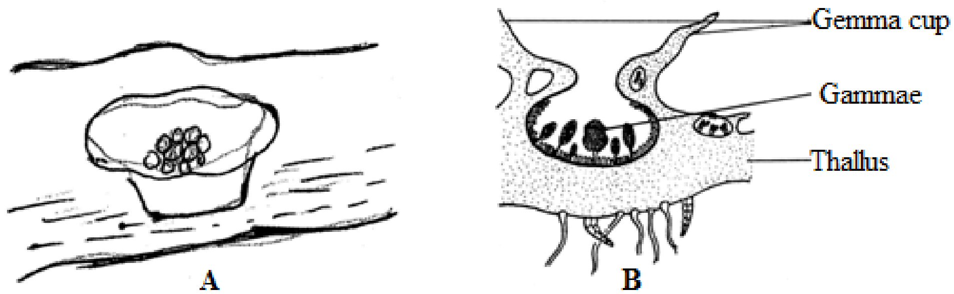

Fig. 6.7: A-Gemma Cup, B- V.S. of Gemma Cup

Gemma

1. Mature gemmae are found to be attached at the base of the gemma cup by a single celled stalk.

2. Each gemma is autotrophic, multicellular, bilaterally symmetrical, thick in the centre and thin at the apex.

3. There are two notches situated on the internal margins opposite to each other.

4. About all the cells of a gemma contain chloroplasts.

5. A few rhiziodal cells are colourless and larger in size.

6. It consists parenchymatous cells, oil cells and rhizoidal cells.

Antheridiophores and Achegoniophores

1. Some thalli produce special, erect, stalked upright branches at their growing apices. They bear the male and female sex organs and are called the antheridiophores and archegoniophores respectively. These are produced on different thalli.
2. Anthridiophore is about 1-3 centimetre long stalk and a lobed disc at the apex. The disc is usually eight lobed but in *M. geminata* it is four lobed. The lobed disc is a result of created dichotomies.
3. A mature archegonium is a flask shaped structure which remains attached to the archegonial disc by a short stalk. It consists upper elongated slender neck and basal globular portion called venter. The neck consists of six vertical rows enclosing eight neck canal cells and large egg. Four cover cells are present at the top of the neck.

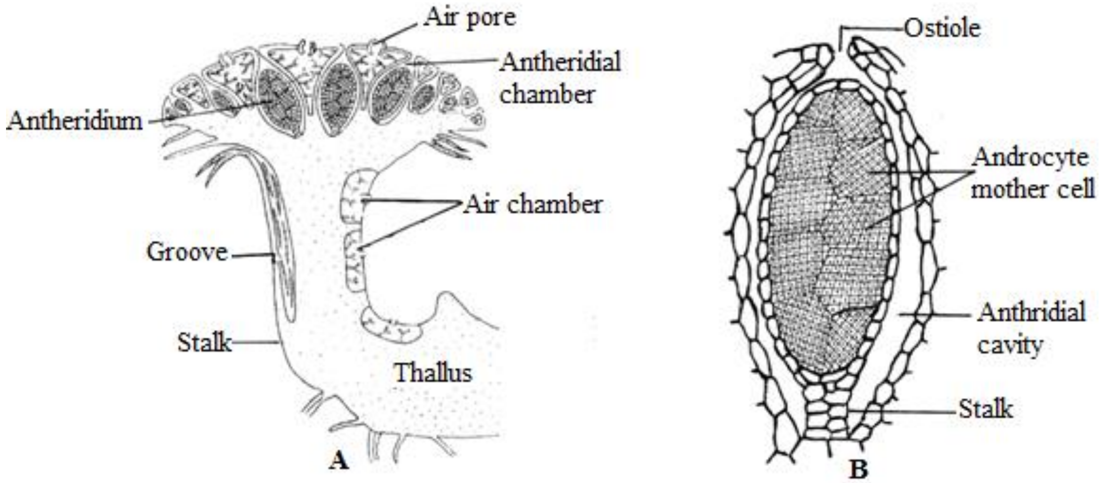

Fig. 6.8: ***Marchantia*****: A-V.S. of Anthridiophore, B-Anthridium**

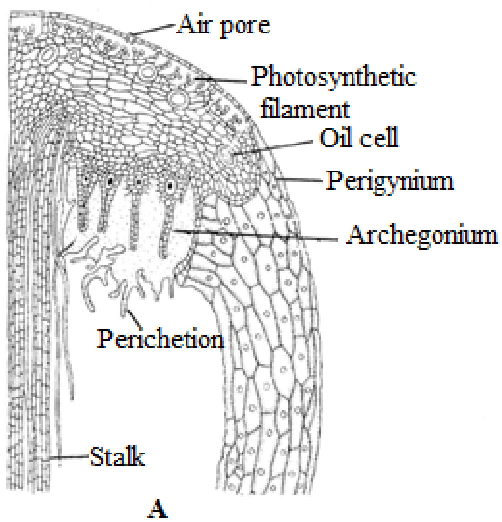

Fig. 6.9: ***Marchantia*****: A-V.S. Archegoniophore, B-Young Archegonia**

Sporophyte-The Sporogonium

1. The mature sporogonium is differentiated into three regions, viz., the foot, seta and capsule.
2. Towards the base of the archegonium, there is a bulbous, absorptive structure, the foot.
3. The seta is somewhat elongated and connects the foot and the capsule.
4. The seta pushes the capsule out of the three layers, the calyptra, perigynium and perichaetium.
5. The capsule is somewhat oval-shaped and remains covered by a single layered jacket layer.
6. Within the jacket layer, there are spores and sterile, hygroscopic, spindle-like elaters.

Spores

1. The spores are small and spherical; they range from 12μ to 13μ in diameter.
2. Each spore is covered by a thin coat, differentiated into two layers.

3. The outer layer is thick exospore and the inner one endospore is thin and smooth.
4. Each spore contains a small amount of granular cytoplasm and a nucleus in it.

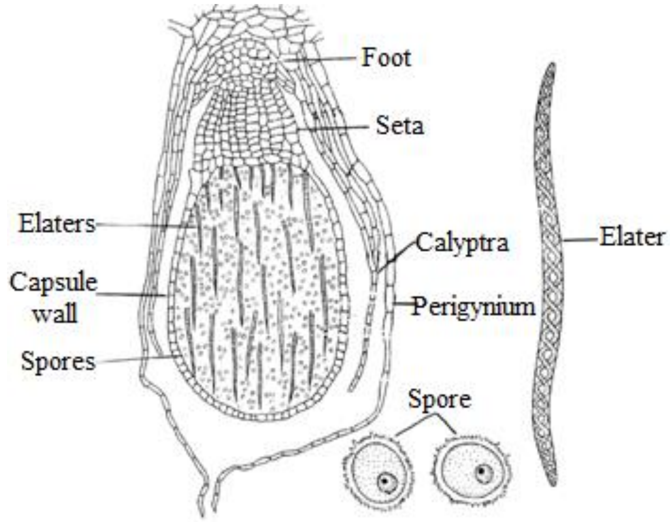

Fig. 6.10: Mature Sporophyte of *Marchantia*

Identification and Systematic Position

Division: Bryophyta

1. Gametophytic plant body
2. Absence of true roots.
3. Absence of vascular strands.
4. They are homosporous.

Class: Hepaticopsida

1. Thalloid plant body.
2. Chloroplasts devoid of pyrenoids.
3. Rhizoids without septa.
4. Capsule lacks columella

Order: Marchantiales

1. Ventral portion of thallus parenchymatous.
2. Scales and rhizoids present on the ventral side of thallus.
3. Air chamber opens out by air pores.

Family: Marchantiaceae

1. Barrel-shaped air pores present.
2. Sex Organs are borne on specialized branches.
3. Air chambers have photosynthetic filaments.

Genus: *Marchantia*

6.3.3 *Plagiochasma*

Division:	Bryophyta
Class:	Hepaticopsida
Order:	Marchantiales
Family:	Marchantiaceae
Genus:	*Plagiochasma*

Habit and Occurrence: It is common genus with about 20 species found worldwide out of which ten species are reported from India. Most of the Indian species are xeromorphic and are more adapted for the drier habitat.

External Structure of the Thallus

1. Thallus is long, lobed, and flat, dorsiventrally differentiated, dichotomously branched and with undulated margins.
2. Apex of the thallus is notched with dark green dorsal surface.
3. Ventral surface is purplish and bears scales and rhizoids.
4. Midrib is inconspicuous and gradually passing into the lamina.

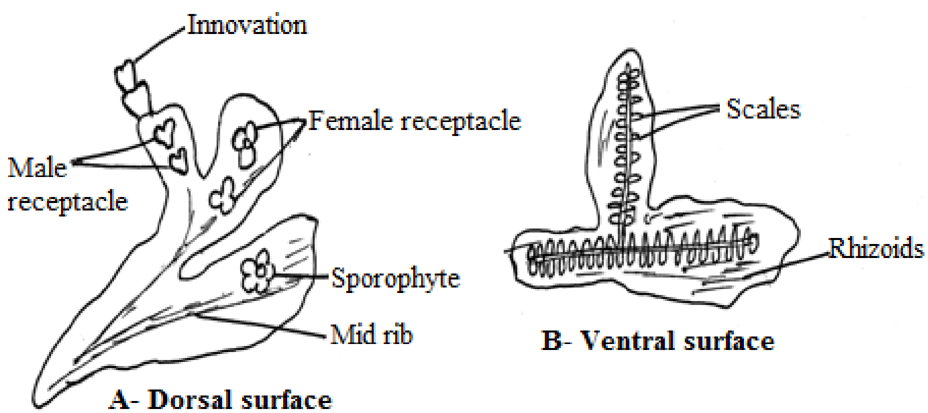

Fig. 6.11: *Plagiochasma* thallus

Internal Structure (Anatomy) of the Thallus

A vertical cross section of the thallus can be differentiated into epidermal region, photosynthetic zone and storage zone.

(a) Epidermal Region

1. It includes both dorsal (upper) and ventral (lower) epidermis.
2. The upper epidermis is interrupted by simple pores that are connected with air chamber.
3. Air pores are slightly raised above the surface of the thallus.
4. The lower epidermis follows the storage region and made up of thin walled cells.
5. Lower epidermis also gives rise to rhizoids and scales.

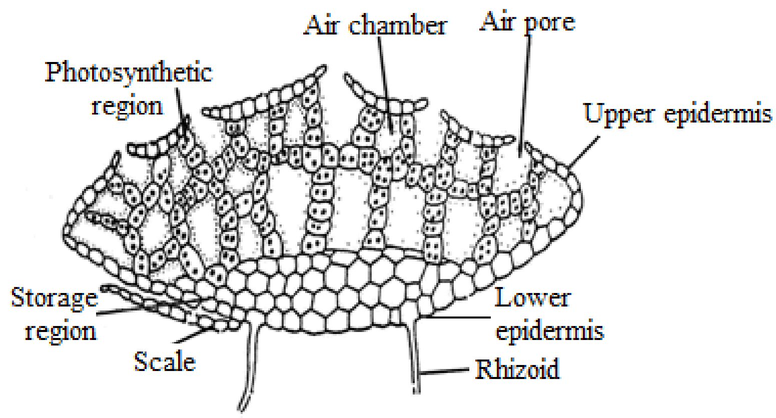

Fig. 6.12: ***Plagiochasma*, VTS of thallus**

(b) Photosynthetic Zone

1. It consists of irregular network of complex air chamber system which are interconnected with each other.
2. These are made up of a single layer of chlorophyllous cells.
3. Air chambers are empty and no photosynthetic filaments are found within it.
4. It also helps in the formation of food and also called assimilatory region.

(c) Storage Zone

1. It lies below the air chambers which made up of parenchymatous cells.
2. Cells contain starch and reserve food material.
4. Occasionally mycorrhizal association is also found in the storage region.

Reproduction

Vegetative

1. It takes place through adventitious branches.
2. These adventitious branches are known as innovations.
3. These branches develop at the apex of the thallus and when detached these grow into new independent thallus.

Sexual Reproduction

1. Plant may be homo thallic or heterothallic.
2. Sex organs develop on specialized structure known as receptacles.
3. In some plants receptacles are dorsal which not hinder the terminal growth while in some species the receptacle growth is terminal.

Antheridiophore

1. These are found on the horse shoe shaped male receptacle and grow on the dorsal surface of the thallus.

2. Mature anthridium is club shaped structure attached to the base of anthridial cavity by stalk.
3. The jacket layer is single celled and isodiametric which encloses a mass of androcyte cells.
4. These androcyte cells later metamorphose into antherozooids.
5. Each antherozooid has two flagella attached to its anterior end.

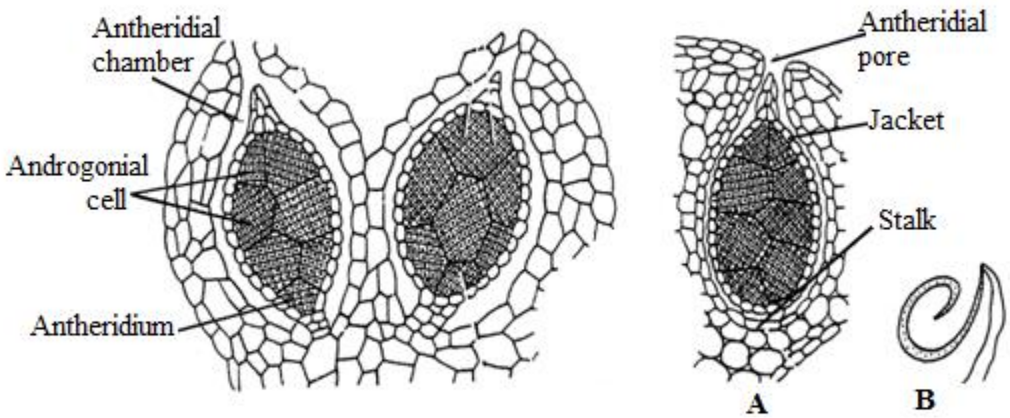

Fig. 6.13: V.S. of male receptacle, A- An antheridium, B- An Antherozoid

Archegoniophore

1. Archegonia are present on the archegoniophore or carpocephalum.
2. The archegoniophore arises on the midrib region which consists of a short stalk and a terminal disc.
3. Disc of receptacle is 2-9 lobed and only one archegonium is present on each lobe.
4. A mature archegonia is flask shaped structure attached to the lobe the disc by a short stalk.
5. It has a broad venter and narrow neck and venter contains a large egg and venter canal cells.
6. The neck of archegonia is composing of six vertical rows of cells and it has 8-9 neck canal cells.
7. Four cover cells are present at the tip of the neck.

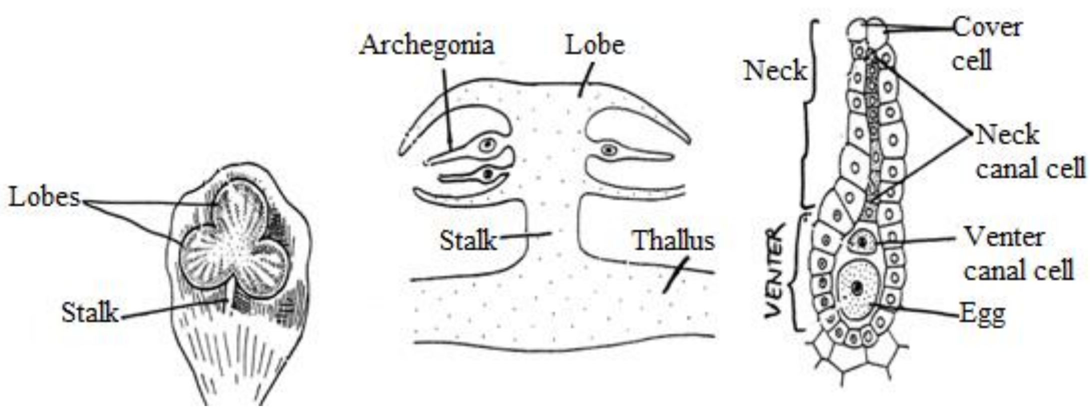

Fig. 6.14: A- Archegoniophore, B- V.S. of Archegoniophore, C- Mature Archegonium

Sporophyte-The Sporogonium

1. With capsule, short seta and a foot capsule is spherical with single-layered jacket.

2. Foot is the basal part of the sporophyte composes of parenchymatous cells and help in the anchorage and absorption of food.
3. Capsule is nearly spherical structure which contains single layered jacket of thin walled cells.
4. The spore wall is composed of three layers and outer perineum is reticulated.
5. Elaters are long, narrow and spindle shaped with 2-4 spiral thickening bands.

Identification and Systematic Position

Division: Bryophyta

1. Gametophytic plant body
2. Absence of true roots.
3. Absence of vascular strands.
4. They are homosporous.

Class: Hepaticopsida

1. Thalloid plant body.
2. Chloroplasts devoid of pyrenoids.
3. Rhizoids without septa.
4. Capsule lacks columella.

Order: Marchantiales

1. Ventral portion of thallus parenchymatous.
2. Scales and rhizoids present on the ventral side of thallus.
3. Air chamber opens out by air pores.

Family: Marchantiaceae

1. Barrel-shaped air pores present.
2. Sex Organs are borne on specialized branches.
3. Air chambers have photosynthetic filaments.

Genus: *Plagiochasma*

6.3.4 *Conocephalum*

Division:	Bryophyta
Class:	Hepaticopsida
Order:	Marchantiales
Family:	Conocephalaceae
Genus:	*Conocephalum*

Habit and Occurrence: *Conocephalum*, commonly known as the snake liverwort, is the largest of the thalloid liverworts. Its pale to dark green thallus can grow up to 20 cm long. The dorsal surface is covered with tiny hexagons, which makes the entire thallus seem snake-like. Mostly the liverwort is found in open areas of woodlands on wet cliffs, behind waterfalls, damp depressions, sandy banks, wet rocks, and moist inorganic soils.

External Structure of the Thallus

1. Plant body is thalloid in nature and the thallus is large, dichotomously branched and dorsiventrally differentiated.
2. The thallus is usually large, light green, and irregularly branched.
3. The dorsal-side of the thallus has hexagonal surfaces that outline the air chambers. In the centre of each hexagon is a white-ringed pore is present.
4. Dorsal surface of the thallus is dark green, but ventral surface is pale green.
5. Midrib is very conspicuous. There are a few scales arranged in two rows on ventral surface by the side of midrib, along with unicellular, smooth-walled and tuberculate rhizoids.
6. White rhizoids and purple scales are located on the ventral central line of the thallus. Here is a photo of a scale.
7. There are two types of rhizoids, pegged and smooth walled.

Internal Structure (Anatomy) of the Thallus

1. Thallus is divided into two different regions. Upper photosynthetic or assimilatory region and lower storage region.
2. Single layered upper epidermis with simple, elevated airpores, visible to the naked eye.
3. Presence of upper dorsal layer with large air-chambers, where filamentous and chlorophyllous cells arise from the floor and formed pointed beaks.
4. Parenchymatous storage tissue and lower epidermis with scales and 2 types of rhizoids are present.
5. Each air chamber has branched or unbranched photosynthetic cells.
6. The pores are simple and occasionally one complex oil body present per cell. In some cells elongate pits are found.
7. The lower region is called storage region which is mainly made up of parenchymatous cells which consists of oil bodies and starch granules.

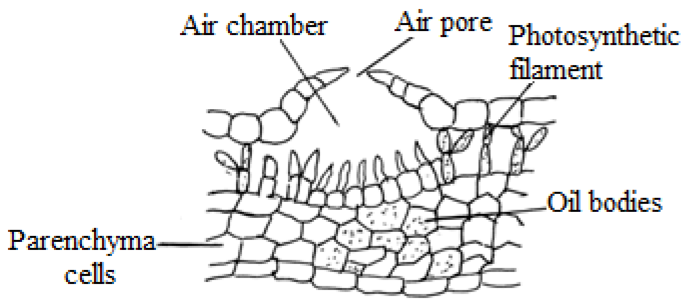

Fig. 6.15: T.S. thallus

Reproduction

1. Plants are dioecious and have the male and female organs in different plants.

2. Vegetative reproduction is takes place by apical innovation.
3. Gemma cups are absent on dorsal surface and gemma are produced on the lateral margin of apex.
4. Male receptacle is disciform, papillose, sessile and situated near the apex of a branch, or sometimes apparently lateral in a cup formed by the growth of the thallus laterally and posteriorly.
5. Female receptacle is nearly terminal, long-stalked and located in a pit.
6. It is obtusely conical, almost entire and composed of 5-8 tubular involucres on the underside, each enclosing a single capsule.
7. Parianth is absent.

Sporogonium

1. It is composed of foot, seta and capsule.
2. Capsule has a rather long pedicel and it is clavate-pyriform in shape.
3. It dehisces at maturity by throwing off an apical cap, and the remaining part of jacket splitting longitudinally by 4 to 8 reflexed valves.
4. Spores are large, papillose and many-celled.
5. Elaters contain 2-4 spiral and bluntly fusiform thickening bands.

Antheridia and Archegonia

1. There is an antheridial pad enclosing antheridia. The antheridial pads are the dark and oval regions on the thallus.
2. The archegonia are elevated by an archegoniophore. The anacrogynous and enclosed archegonia is present.
3. The archegoniophores elevate through the growth of gametophytic stalks.
4. The cells of the stalk of the archegoniophore contain lots of starch grains.

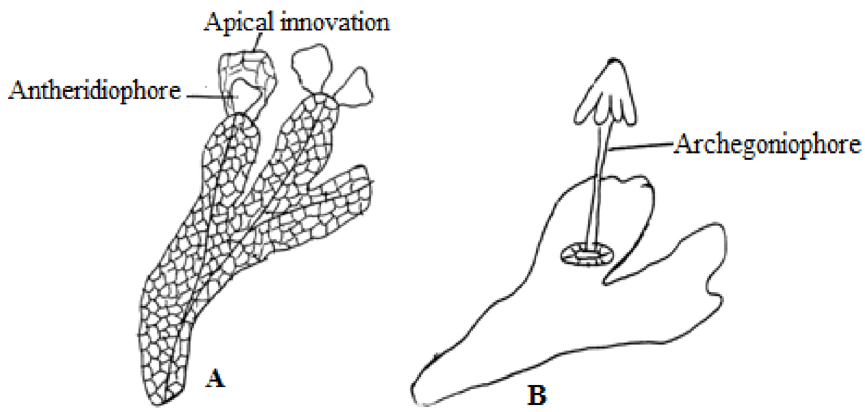

Fig. 6.16: *Conocephalum*, A-Male plant, B- Female plant

Sporophyte

1. Cone-shaped receptacles that bear sporangia (archegoniophore).

2. The sporangial jacket is unistratose. A massive seta extends the sporangium downward, just enough for the sporangium to efficiently disperse spores.
3. Spores are multicellular at maturity and intermixed with elaters.

Identification and Systematic Position

Thallus dorsiventrally flattened and prostrate sporophytic simple and with limited growth, columella absent.

Division: Bryophyta

1. Gametophytic plant body
2. Absence of true roots.
3. Absence of vascular strands.
4. They are homosporous.

Class: Hepaticopsida

1. Plant body prostrate, sex organs on dorsal surface
2. Sporophyte devoid of columella or elaterophores.

Order: Marchantiales

1. Antheridia and archagonia localised on special branches.
2. Sporophyte differentiated into foot, seta and capsule.

Family: Conocephalaceae

1. Gemma cups are absent on dorsal surface.
2. Storage region contains oil bodies and some slime cells.
3. Female receptacle nearly terminal and stalked.
4. Dorsal surface of the thallus with distinct reticulations and pores.

Genus: *Conocephalum*

6.3.5 *Frullania*

Division: Bryophyta
Class: Hepaticopsida
Order: Jungermanniales
Family: Frullaniaceae
Genus: *Frullania*

Habit and Occurrence: It is a large genus with about 700 species, mainly distributed in the tropical part of the world. In India the genus is represented with about 39 species. Most of the species are terrestrial and growing on moist and shady area. A few species are epiphytic which grow on the trunks of the tree in moist wood and swamps.

External Structure of the Thallus

1. The gametophytic plant body is dorsiventral and is differenciated into prostrate stem, axis and leaves.
2. The stem is pinnately or bipinnately branched and about 1-5 cm in length.
3. Leaves are arranged in three rows. Two rows of dorsal leaves are placed laterally and a third row of leaves is arranged on the lower or ventral side of the stem.
4. The leaves of the ventral row, called amphigastria or underleaves and are rounded, cordate or deeply bilobed.
5. Many smooth walled, unicellular and unbranched rhizoids are present in tufts at the base of axisor middle of amphigastria.

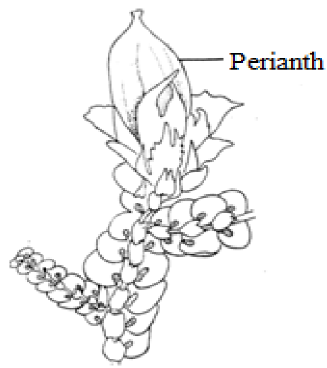

Fig. 6.17: ***Frullania*, whole plant**

Internal Structure (Anatomy) of the Thallus

Stem

1. Stem is differentiated into outer cortical and inner medullary regions.
2. Cortical region is made up of small thick walled cells.
3. Cells in the medullary region are elongated with larger diameter.
4. Conducting tissue and epidermis are not well differentiated.

Leaf

1. Leaf is made up of single layer of cells.
2. Each cell of leaf contains several chloroplast and oil bodies.
3. Oil bodies are spherical, ellipsoidal or long fusiform in shape.
4. Young leaves are colorless while mature leaves are thick and pigmented.

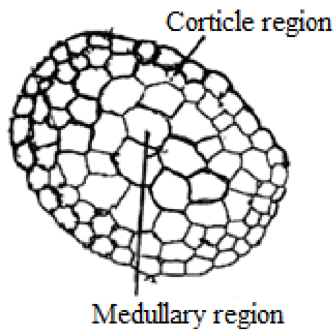

Fig. 6.18: T.S. of Axis

Reproduction

Gemmae

1. Mature gammae are 4-6 celled globose structures.
2. Develop on the margins and leaf surface.
3. These can detach from plant by a slight jerk and when conditions become favourable it gives rise to new plant.

Anthredia

1. The anthredia develop on the special short branches called androecia.
2. The male branch bears 2-5 pairs of perigonial bracts.
3. Each perigonial bract is divided into two lobes of almost equal size which bears two anthredia in each bracts.
4. Each mature antridium has a spherical body with long and slander stalk.
5. It contains a mass of spermatocytes enclosed by a single layered sterile jacket.

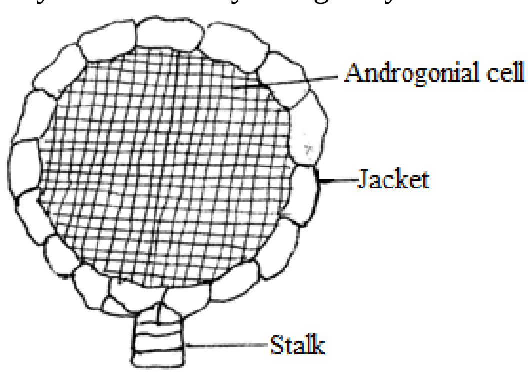

Fig. 6.19: Antheridium (*Frullania*)

Archegonia

1. The archegonia are grown in the group of 2 or 3 at the apex of the short archegonial branch.
2. Each of the branches contains 2-5 pairs of perichetial bracts.
3. Mature archegonia is flask shaped structure differenciated into a constrict neck and swollen venter.
4. 5-8 neck canal cells are present.

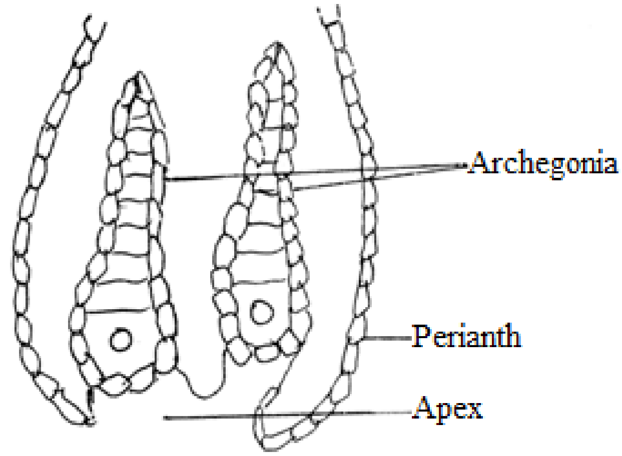

Fig. 6.20: Archegonium (*Frullania*)

Sporophyte

1. The mature sporophyte is differentiated into blunt foot, short seta and globose capsule.
2. Foot remains attached into female branch and help in absorption of food.
3. Globose capsule remains surrounded by two layer sclerified wall.
4. The capsule wall encloses spores and elaters.
5. Elaters are non spiral, flattened and each possess trumpet shaped lower end.
6. The sudden and rapid movement of the contracting elaters produce a sling like action which helps in expelling the spores.

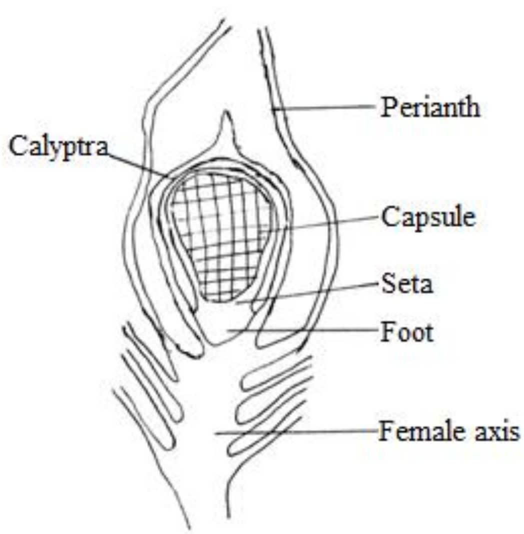

Fig. 6.21: Sporophyte (*Frullania*)

Spores:

1. The spores are long, oblong or spherical and range from 22μ to 55μ in diameter.
2. Each spore is covered by a thick coat, differentiated into two layers.
3. The outer thick and sculptured layer is known as exospore and the inner thin and smooth layer is known as endospore.
4. Each spore is uninucleate and has several chloroplasts.

Identification and Systematic Position

Division: Bryophyta

1. Gametophytic plant body
2. Absence of true roots.
3. Absence of vascular strands.
4. They are homosporous.

Class: Hepaticopsida

1. Thalloid plant body.
2. Chloroplasts devoid of pyrenoids.
3. Rhizoids without septa.
4. Capsule lacks columella

Order: Jungermanniales

1. Plant body is gametophytic and gametophytes are either thallose or foliose.
2. Plant body attached to substratum through rhizoids which are smooth walled.
3. Scales are generally absent.
4. Archegonial neck is almost as broad as venter.
5. Capsule is multistratose.

Family: Frullaniaceae

1. This family includes only three genera *i.e. Frullania, Jubula* and *Neohattoria.*
2. Plants are usually large sized and predominantly reddish brown or deep green in color.
3. Stem is usually prostrately and pinnately or bipinnately branched.
4. Characteristic *Frullania* type branches are present in majority of members. In this type a branch develops from the ventral half of lateral segment replacing the lobule of the leaf. The lateral leaves are complicate-bilobed and each leaf is divided into a flat antical lobe.
5. Archegonia vary from 2 to 12 in a group.

Genus: *Frullania*

6.3.6 *Porella*

Division:	Bryophyta
Class:	Hepaticopsida
Order:	Jungermanniales
Family:	Porellaceae
Genus:	*Porella*

Habit and Occurrence: It is cosmopolitan genus with about 180 species found worldwide. In India about thirty five species are reported mostly from the Himalayan region and few are from south India. Usually the plant grows on moist shady rock, stone and bark of the tree. *Porella densifolia* and *P. boreilli* are the common species reported from the Kumaon.

External Structure of the Thallus

1. Plant body is flat, dorsiventral with a bi- or tripinnately branched leafy axis with no rhizoids in mature plants.
2. There are 3 rows of leaves. Two rows of larger leaves are found on dorsal side while one row of smaller leaves is found on the ventral side.
3. The smaller leaves are generally termed as amphigastria.
4. Larger leaves of dorsal side are unequally bilobed. The upper larger lobe is antical lobe and the lower smaller lobe is the postical lobe or lobule.
5. Leaves are thin without midrib and one cell in thickness.
6. The arrangement of leaves is incubous type. In it the posterior margin of the leaf underlines anterior margin of the anterior leaf.
7. Rhizoids are smooth walled and arises from the lower surface of the stem.

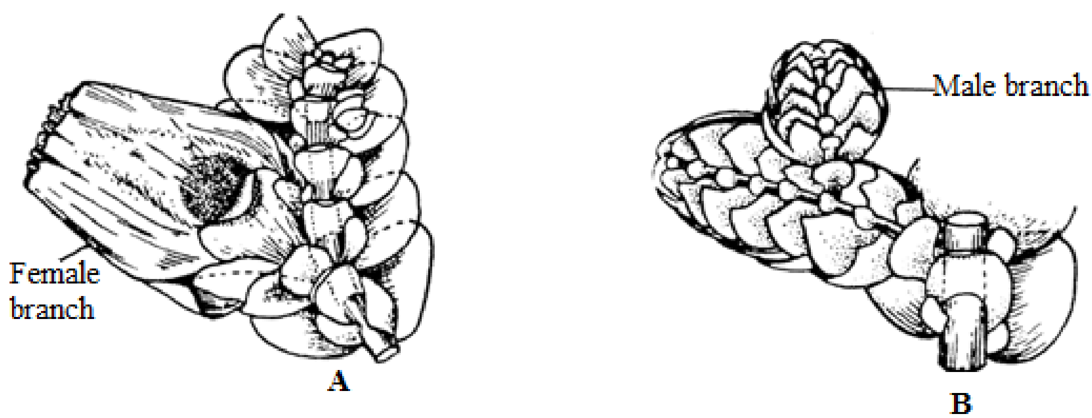

Fig. 6.22: *Porella,* A-Female, B-Male

Internal Structure (Anatomy) of the Thallus

1. The internal structure of the axis is differentiated into 2-5 layered cortex and elongated and thin walled medulla.
2. The peripheral cells of cortex are smaller with slightly thicker walls while the central cells are larger with thinner walls.
3. The leaf is composed of single layered isodiametric, parenchymatous cells with many chloroplast.
4. No midrib and vascular tissue are found on the leaf but oil cells may found in some species.
5. The apical growth is takes place by means of apical cells which are tetrahedral or pyramidal in shape with three cutting faces.

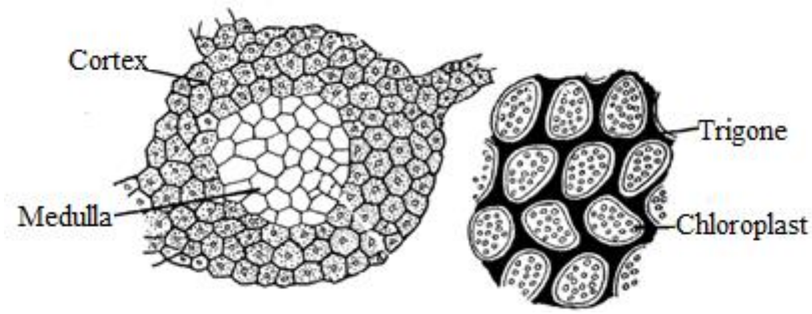

Fig. 6.23: T.S. of Axis and Leaf (*Porella*)

Reproduction

1. *Porella* is reproduces by vegetative and sexual methods.
2. The vegetative reproduction takes place by the gammae and by gradual death and decay of the gametophyte.
3. Gemmae are produced in on the lower surface of the leaf which on germination gives rise to new plant.

Sexual Reproduction

1. Plants are dioecious and male gametophyte is usually smaller than the female gametophyte.
2. The male plant is smaller with the antheridial branches projecting out at right angles from the axis.
3. The male and female sex organs are called antheridia and archegonia respectively.

Antheridia

1. The antheridia develop on the specialized lateral branches, known as antheridial branches.
2. These arise nearly at right angle to the main stem.
3. Leaves on the antheridial branch are closely imbricate and a single antheridium is borne in the axil of each leaf.
4. The mature antheridium is globular with a two-celled stalk.
5. The body of antheridiumis surrounded by single layered jacket, but the proximal part is two to three layered.
6. The jacket encloses the fertile mass known as androcyte.

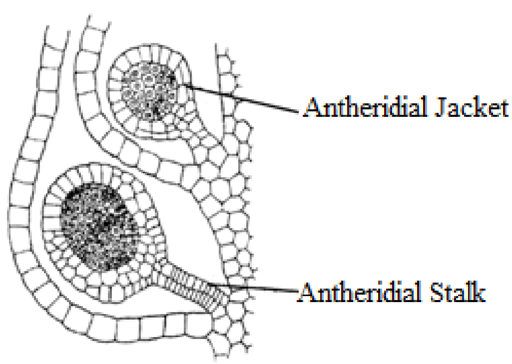

Fig. 6.24: Antheridium (*Porella*)

Archegonia

1. The female plant bears archegonial branches with enlarged perichaetial bracts.
2. The lower bracts form an involucre while the upper two are unite together to form a perianth within which the archegonia develop.
3. A mature archegonium shows a venter with the egg and a neck (Fig 5.12).
4. The neck is composed of five vertical rows of neck cells and encloses with 6-8 neck canal cells.
5. The venter and basal part of the neck has a two layered jacket.

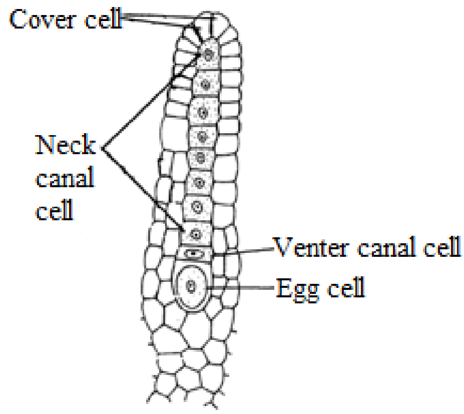

Fig. 6.25: Archegonium (*Porella*)

Sporophyte

1. Sporophyte consists of a spherical capsule, a short seta and a bulbous foot.
2. The capsule wall is 2 to 5 layers thick. Inside the capsule there are a number of spores and elaters.
3. The capsule wall is two or three layered.
4. At the point of dehiscence the capsule wall is thin while rest of the place it is thick walled.
5. Numerous elaters and spores are found within the capsule.
6. The young sporophyte is enclosed by the three protective covering *i.e.* calyptras, perianth and involucres.

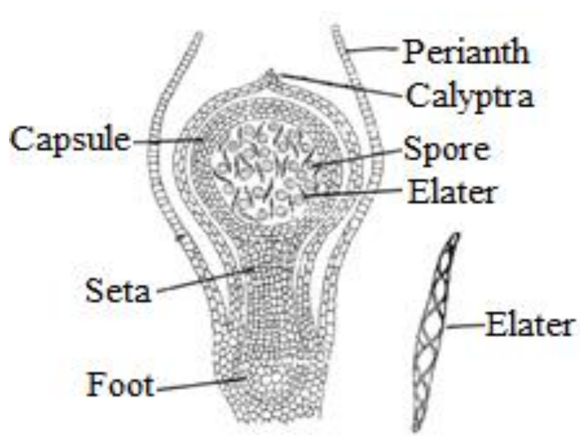

Fig. 6.26: Sporophyte (*Porella*)

Identification and Systematic Position

Division: Bryophyta

1. Gametophytic plant body
2. Absence of true roots.
3. Absence of vascular strands.
4. They are homosporous.

Class: Hepaticopsida

1. Absence of scale, tuberculated rhizoids and air chamber in gametophytic tissue with no differentiation of internal tissue.
2. Anthridia is globose, long-stalked with multilayered capsule wall
3. Foot and seta distinct.

Order: Jungermanniales

1. Plant body is gametophytic and gametophytes are either thalloid or foliose.
2. Thallus is green, flattened and glossy with chlorophyllous and homogenous cells while rhizoids are generally absent.
3. Sporophyte is differentiated into foot, seta and capsule.
4. Capsule is with distinct elaterophores at the basal part.
5. Usually the whole gametophytic body or at least the reproductive part foliaceous and archegonia formed apically.

Family: Porellaceae

1. The family Porellaceae is also known as Madothecaceae.
2. Plant body flat with bi- or tri-pinnately branched leafy axis.
3. Ventral smaller row forming amphigastria and rhizoids arise from it in the form of tuft.
4. The amphigastria is large sized.

Genus: *Porella*

6.3.7 *Pellia*

Division:	Bryophyta
Class:	Hepaticopsida
Order:	Jungermanniales
Family:	Pelliaceae
Genus:	*Pellia*

Habit and Occurrence: The genus *Pellia* is a thalloid liverwort, represented by five species which are widely distributed in north temperate region. Out of five species three species are reported from India (Parihar and Kashyap). They commonly occur along the moist places and tree trunks. Sometime the sterile form is also found submerged in the water. *Pellia endiviaefolia* is common in western and Kumaon Himalaya from 1700 to 2500 meters in height.

External Structure of the Thallus

1. The mature gametophyte is thin, dorsiventral, prostrate, dichotomously branched, with somewhat wavy margin.
2. The dorsal surface is almost smooth and a median midrib is prominent.
3. On the ventral surface numerous smooth, unicellular rhizoids are present which are restricted to the midrib.
4. Thallus lobe are thin, long, narrow and ribbon like in submerge form and thick and robust in the terrestrial form.

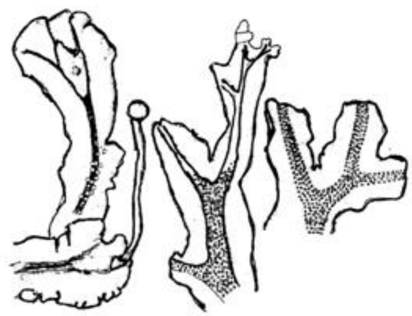

Fig. 6.27: Thallus of *Pellia*

Internal Structure (Anatomy) of the Thallus

1. The internal structure of the plant is uniformly composed of parenchymatous cells.
2. No cellular differentiation is present in thallus. The dorsal epidermis is continuous and air pore and air chambers are absent.
3. Usually the midrib portion is thicker (8 – 16 layers in depth) than margins (2-5 layers in depth).
4. In between the two epidermal layers there are compact parenchymatous, chloroplast containing cells with a few scattered fibrous cells.
5. The lower epidermal cells give rise to unicellular rhizoids in the midrib region.

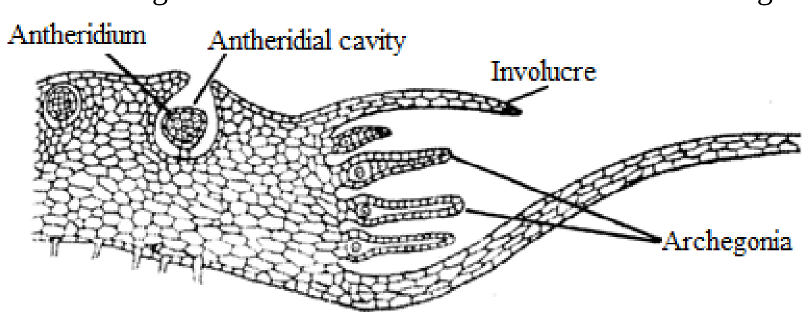

Fig. 6.28: L.S. Thallus

Reproduction

1. The reproduction takes place through vegetative and sexual methods.

2. Vegetative reproduction takes place by fragmentation and breaking of the adventitious branches.

Sexual Reproduction

1. It is of oogamous type and male and female reproductive structures are known as anthredia and archegonia respectively.
2. Some species are monoecoius while others are dioecious.
3. The monoecious specious are protandrous i.e. the antheridia is matures before the archegonia.

Antheridia

1. It is present on the dorsal surface of the thallus in regular row along the midrib as wart like projection.
2. In the dioecious forms, the male plant bears antheridia all along the dorsal surface of the midrib while the archegonia develop in a cluster just behind the growing tip on the dorsal side of the female plant.
3. In monoecious forms, the antheridia are behind the archegonia.
4. The mature antheridium is globose with a jacket one cell in thickness and a multicellular short stalk.
5. It lies at the bottom of the antheridial chamber which is open on the dorsal surface by a pore.
6. The body of antheridium is covered by a single layered jacket of the sterile cell enclosing the multicellular androcyte mther cell.

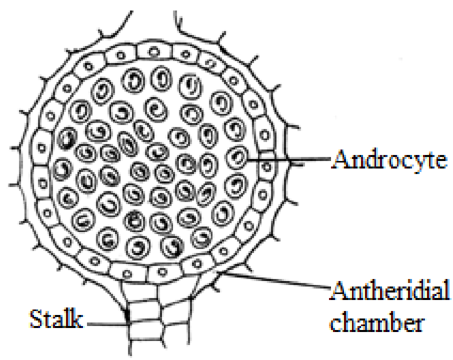

Fig. 6.29: Mature Antheridia (*Pellia*)

Archegonium

1. The mature archegonium shows a venter containing the egg, a ventral canal cell and 4 to 6 neck canal cells.
2. These grow in groups of 4-7, close to the apex of the thallus and each group is protected by a tubular involucre.
3. The archegonia are horizontally placed with their neck directed towards the apex of thallus.
4. These are differentiated into a basal venter and a long neck.
5. Neck is composed of five vertical rows of neck cells which enclose 6-8 neck canal cells.
6. Four cover cells are present at the apex of neck.
7. Venter has venter canal cells and a large egg.

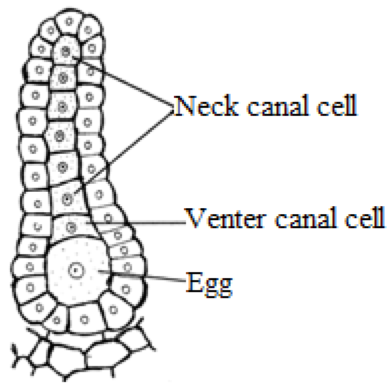

Fig. 6.30: Mature Archegonium

Sporophyte

1. Sporophyte is covered by involucre and calyptra.
2. Each sporophyte has a distinct foot, seta and globose capsule.
3. Capsule has two-layered jacket cells of outer layer larger with radial walls thickened and cells of inner layer with inner tangential wall thickened and numerous spores and elaters.
4. There is a distinct elaterophore (formed by a group of elaters) at the base of each capsule.
5. The characteristic feature of the sporophyte of *Pellia* is the presence of the basal elaterophores.

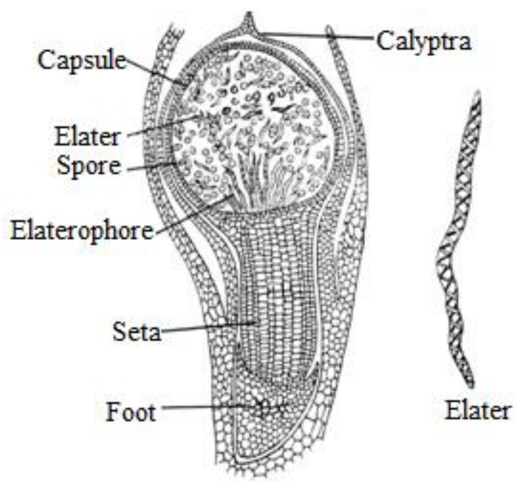

Fig. 6.31: Sporophyte (*Pellia*)

Identification and Systematic Position

Division: Bryophyta

1. Gametophytic plant body
2. Absence of true roots.
3. Absence of vascular strands.
4. They are homosporous.

Class: Hepaticopsida

1. Absence of scale, tuberculated rhizoids and air chamber in gametophytic tissue with no differentiation of internal tissue.
2. Anthridia is globose, long-stalked with multilayered capsule wall
3. Foot and seta distinct.

Order: Jungermanniales

1. Thallus is green, flattened and glossy with chlorophyllous and homogenous cells and scales are generally absent.
2. The antheridia are globose or subglobose and archegonial neck is as almost as broad as venter.
3. Sporophyte is differentiated into foot, seta and capsule.
4. Capsule is with distinct elaterophores at the basal part and generally dehiscence by four valve at maturity.

Family: Pelliaceae

1. Gametophyte usually thallose and prostrate.
2. Archegonia on dorsal surface of the thallus just behind the apical cell.

Genus: *Pellia*

6.4 SUMMARY

The thallus of *Sphaerocarpus* is prostrate, dorsiventrally flatterned, dichotomously branched and green in color. Wings are entire or incised into leaf-like lobes, which on detachment serve as vegetative propagules.

Marchantia belongs to class Hepsticopsida. The plant body is gametophytic, thalloid, flat, prostrate, long and dichotomously branched. Dorsal surface of plant is dark green. The midrib is marked on the dorsal surface by a shallow groove and on the ventral surface by a low ridge. Each polygonal area re-presents the underlying air chamber. The vegetative reproductive structures are gemma cups and develop along the midrib. These are crescent shaped with spiny or fimbriate margins and are about one eighth of an inch in diameter.

The thallus of *Plagiochasma* is long, lobed, flat, dorsiventrally differentiated and dichotomously branched with undulated margins. Apex of the thallus is notched with dark green dorsal surface. Ventral surface is purplish and bears scales and rhizoids. Midrib is inconspicuous and gradually passing into the lamina. Air-chambers with simple pores lie between the antheridia. Female receptacle is also sessile when young, but at maturity is stalked. The stalk arises from the dorsal side of the thallus, and is devoid of rhizoidal furrow, but has scales at base and apex.

In *Conocephalum* the plant body is thalloid in nature and the thallus is large, dichotomously branched and dorsiventrally differentiated. Dorsal surface of the thallus is areolate, and areolae are very distinct and mostly hexagonal. Male receptacle is disciform, papillose, sessile and situated near the apex of a branch, or sometimes apparently lateral in a cup formed by the growth of the thallus laterally and posteriorly. Female receptacle is nearly terminal, long-stalked and located in a pit. It is obtusely conical, almost entire and composed of tubular involucres on the underside, each enclosing a single capsule.

Frullania is a large genus, mainly distributed in the tropical part of the world. Most of the species are terrestrial and grow on moist and shady area. A few species are epiphytic which grow on the trunks of the trees and in moist wood and swamps. The gametophytic plant body is dorsiventral and is differenciated into prostrate stem, axis and leaves. The stem is pinnately or bipinnately branched. Leaves are arranged in three rows. Two rows of dorsal leaves are placed laterally and a third row of leaves is arranged on the lower or ventral side of the stem. Many smooth walled, unicellular and unbranched rhizoids are present in tufts at the base of axisor middle of amphigastria.

The gametophyte of *Pellia* is thin, dorsiventral, prostrate, dichotomously branched, with somewhat wavy margin. The dorsal surface is almost smooth and a median midrib is prominent. On the ventral surface numerous smooth, unicellular rhizoids are borne from under the midrib. Plants are either monoecious or dioecious. In the dioecious forms, the male plant bears antheridia all along the dorsal surface of the midrib while the archegonia develop in a cluster just behind the growing tip on the dorsal side of the female plant. In monoecious forms, the antheridia are behind the archegonia. The mature antheridium is globose with a jacket one cell in thickness and a multicellular short stalk. It lies at the bottom of the antheridial chamber which is open on the dorsal surface by a pore

Porella belongs to class hepaticopsida. The gametophyte is flat, dorsiventral with a bi or tripinnately branched leafy axis with no rhizoids in mature plants. There are three rows of leaves in which two lateral and one smaller row on the ventral side termed as amphigastria. Leaves are one cell thick and no midrib is present. Lateral leaves are two lobed with upper larger lobe is antical lobe and the lower smaller lobe is the postical lobe or lobule. The arrangement of leaves is incubers.

6.5 GLOSSARY

Apospory: The production of gametophyte directly from the unspecialized cells of sporophytes without the formation of spores is termed as apospory e.g., Anthoceros. The new gametophytic plants are diploid because these are formed directly from the diplod cells of sporophyte without undergoing meiosis.

Columella: Central column of sterile cells found inside the capsule of some bryophtes. It is surrounded by sporogenous tissue which consists of spores and elaters.

Dioecious: Having the male and female organs in separate and distinct individuals; having separate sexes.

Multistratose: Composed of multiple layer of cells.

Operculum: It is the cap of capsule in mosses.

Peristome: Peristome is a fringe of teeth around the mouth of capsule in mosses.

Protonema: is a filamentous stage in the development of gametophyte of a moss from the spore.
Secondary protonema: Protonema which is formed by means other by the germination of spores is called secondary protonema.
Unistratose: Composed of a single layer of cells.

6.6 SELF ASSESSMENT QUESTIONS

1. Name one saprophytic member of Bryophyte?
2. Who coined the term Bryophyte?
3. Who is known as father of Indian Bryology?
4. Alternation of generation in Bryophytes is known as........
5. ....is mother cell of sporophytic generation.
6. Gemmae are responsible for..........mode of reproduction.
7. Sporophyte in *Marchantia* is represented by?
8. Specialized branches that bear sex organs in *Marchantia* are named as?
9. What types of scales are found in *Marchantia*?
10. Name any dioecious species of *Marchantia*?
11. Mention the Shape of chloroplast in *Marchantia* thallus?
12. How many layers of protective coverings envelope the sporophyte of *Marchantia*?
13. In *Pellia* the archegonia are borne………….. apex and are placed…………
14. In *Pellia* the neck of archegonium is made up of …………vertical row of cells.
15. In *Frullania* the orientation of elaters is…………………

Answer Key: 1-Buxbaumia, 2- Braun (1864), 3- Prof Shiv Ram Kashyap, 4-Heteromorphic, 5-Zygote, 6-Vegetative, 7-Foot, Seta and Capsule, 8-Gametophores (Antheridiophore and Archegoniophores), 9- Two types of scales are found in *Marchantia* are ligulate scales and appendiculate scale, 10-*Marchantia nepalensis*, 11- Discoid, 12-Three-Calyptra, Perigynium and Perichaetium, 13- Close to the; horizontally, 14-Five, 15-Longitudinal

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6.9 TERMINAL QUESTIONS

1- Write the systematic position of *Marchantia*?
2- Draw the T.S. of thallus of *Porella*?
3- What is elaterophore? Name the bryophytes where you found these.
4-Who is the Father of Indian Bryology?
5- Describe the specialized branches containing male and female sex organs in *Marchantia*?

UNIT-7 MORPHOLOGICAL STUDY OF REPRESENTATIVES OF BRYOPHYTES-II

7.1 OBJECTIVE

After reading this unit students will be able -

- To Study the external features, internal structure and reproductive structures of Bryophytes- *Sewardiella, Calobryum, Anthoceros, Sphagnum, Funaria, Polytrichum, Andreaea, Takakia* with the help of permanent and /or temporary preparations.

7.2 INTRODUCTION

Bryophytes (mosses, hornworts, and liverworts) can be found in all ecosystems of the earth. The diversity of bryophytes increases at tropical and subtropical latitudes. Another term commonly used for this group is nonvascular plants because these lack the conductive tissues xylem and phloem. Bryophytes are also called embryophytes because these plants have an embryonic stage in their life cycle which involves an alternation between sporophytic and gametophytic stage.

Bryophytes have gametophytic stage which is dominant in its life and in most cases it forms the green mats and tufts. The gametophytic stage is composed of either stem or leaves or flattened ribbon-like thallus. The leaves of bryophytes are structurally very different from those of higher plants and generally one cell thick.

Bryophytes, while very simple, exhibit a great diversity in growth form and habitat. There are bryophytes that can withstand extended periods of desiccation and others that are aquatic. You will find them on virtually every substrate: rocks, soil, tree bark, decaying wood, and even cars and other synthetic materials. Due to their diminutive stature and few human applications they have remained a largely overlooked group of organisms. Mosses, liverworts, and hornworts are the most ancient lineages of plants and can offer some clues about early plant evolution.

7.3 MORPHOLOGICAL STUDY OF REPRESENTATIVES OF BRYOPHYTES

7.3.1 *Calobryum*

Division: Bryophyta
Class: Hepaticopsida
Order: Calobryales
Family: Calobryaceae
Genus: *Calobryum*

Habit and Occurrence: The genus *Calobryum* comprises eight species. Out these eight species three species i.e. *C. blumii*, *C. indicum* and *C. denatum* have been reported from India. The plant grows along the wet and dry places.

External Structure of the Thallus

1. The gametophytic plant body consists of branched, creeping rhizome.
2. The subterranean as well as aerial portion of the stem lacks rhizoids.
3. The leaves are simple, entire, dorsiventrally flattened, soft texture and without a midrib.
4. Growth of the stem occurs by a pyramidal apical cell with three cutting faces, one slightly narrower than the other.
5. The aerial shoot is differentiated into a central colorless zone of elongated cells and a peripheral zone of thicker cortical cells containing oil droplets and pale green plastids.
6. The leaves are one layered thick except for the basal part which is two or four cell in thickness.

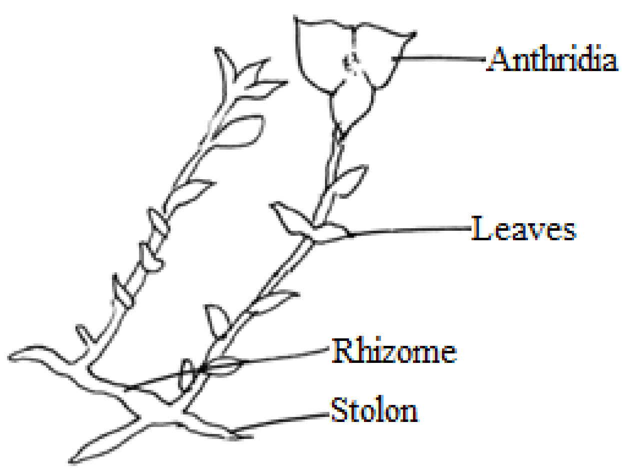

Fig. 7.1: A Young Plant

Internal Structure (Anatomy) of the Plant

Leaf Anatomy

1. The leaves vary in structure in different species.
2. The leaf cells are non-collenchymatous, soft, and large with thin walled internal structure and contain several to many oil bodies chloroplasts.

Stem Anatomy

1. The stem is divided into two distinct regions the outer cortex and inner central strand.
2. The central strand consists of elongated laptodermis cells and is 10-15 cells in diameter.
3. The cells of central strand contain no cell organelles but having lost their protoplasmic content are empty.
4. The central strand is the massive cortex consisting of large parenchymatous cells containing starch grains.
5. The peripheral cortical cells may grow into short 2-3 celled slime papillae of non baked type with a clavate apical cell.

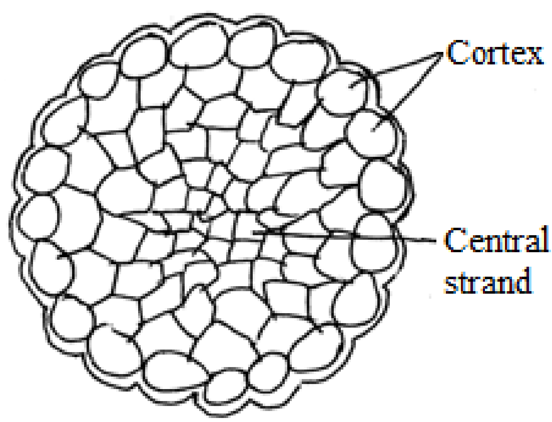

Fig. 7.2: T.S. of Stem

Reproduction

1. Asexual reproduction is unknown in Calobryales. The gametophyte plants are of two kinds, male and female (heterothallic).
2. Antheridia and archegonia are produced on the expanded apex of the erect shoot of different plants.

Antheridiophores and Achegoniophores

Antherdia

1. The antheridia are orange yellow in color and grouped at the apex of a dialated receptacle.
2. The antheridial receptacle is surrounded by an expended perianth like structure formed by the closely set, enlarge young male or perigonial bracts which occur in more than three rows.
3. Male plant looks like moss gametophore. The anthridium consist of an ovoid or rounded body raised on a long stalk composed of several superimposed tier of four cell each.
4. Anthridium has a jacket layer of cells enclosing a central mass of dividing androgonial cells.

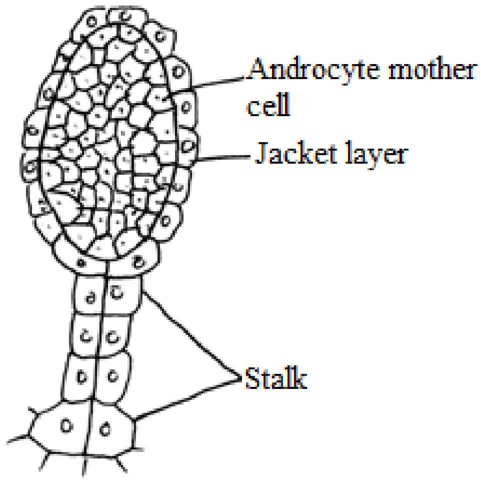

Fig. 7.3: An Anthridium

Archegonia

1. The tip of the female gametphyte is expended to form receptacle.
2. The archegonia are borne singly at the apex of the main shoot and protected by perichetial leaves.
3. Archegonium has a very long, twisted neck which is composed of four neck cells.
4. The Venter is slightly broader than the neck.
5. The ventral cavity contains an egg and a ventral canal cell above it.

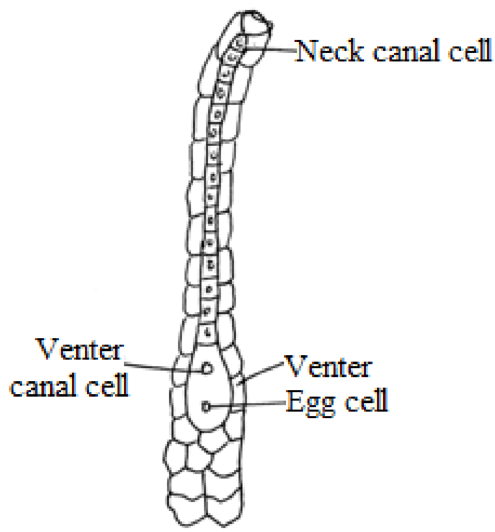

Fig. 7.4: An Archegonium

Sporophyte

1. Sporophyte is terminal and surrounded by the massive shoot calyptras.
2. The mature sporophyte is differentiated into foot, seta and capsule.
3. The capsule is deep brown, ellipsoidal and cylindrical with acuminated foot.
4. The sporogenous tissue is differentiated into spores and elaters and elaterophores are absent.

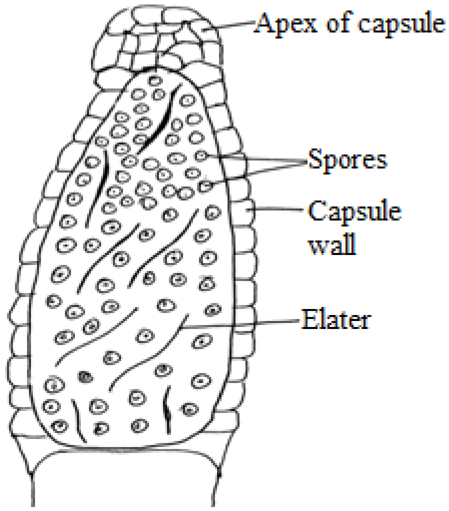

Fig. 7.5: Sporophyte of *Calobryum*

Identification and Systematic Position

Division: Bryophyta

1-Gametophytic plant body
2- Absence of true roots.
3- Absence of vascular strands.
4-They are homosporous.

Class: Hepaticopsida

1- Thalloid plant body.
2- Chloroplasts devoid of pyrenoids.
3- Rhizoids without septa.
4- Capsule lacks columella

Order: Calobryales

1. Leafy shoots are radially organised with three vertical rows of leaves.
2. Ovoid stalked antheridia develop in a distinct manner and archegonia with a neck of four vertical rows of cells.
3. Elongated sporophyte with a unistratose capsule wall which becomes multistratose at the apex.

Family: Calobryaceae

1. The family includes a single genus *Calobryum*.
2. Gametophytes are small, rhizomatous and lack drought resistance.
3. Plant body is differentiated into a basal, branched, creeping rhizome like structure.
4. Sexually dimorphic and heterothallic.
5. All the species are mesophytes.
6. Plants are creeping, leafless basal, branched rhizome.

Genus: *Calobryum*

7.3.2 *Anthoceros*

Division: Bryophyta
Class: Anthocerotopsida
Order: Anthocerotales
Family: Anthocerotaceae
Genus: *Anthoceros*

Habit and Occurrence: *Anthoceros* is the largest genus of the Anthocerotopsida comprising about 200 of the 300 species included within the Class. About 25 species of these are reported from the tropical, subtropical and temperate hilly areas all over India. They grow in very moist, shady places by clay banks and ditches or in the crevices of rocks. Campbell (1939) noted that the species of *Anthoceros* fall into two groups, with black spores and with yellow spores, the two groups also showing other morphological differences. Proskauer (1951) has placed the yellow spored ones into the new genus *Phaeoceros*.

External Structure

1. The gametophytic plant body is thalloid, dorsiventral, prostrate, dark green in colour with dichotomous branching.
2. The thallus is small, prostrate, dark green thin, lobed and dorsiventrally differentiated and midrib is absent.
3. The dorsal surface of thallus is smooth (*A .leavis*), velvet like (in *A.crispus*) or with spines and ridges (in *A.fusiformis*).
4. Smooth-walled, simple rhizoids are found.
5. The ventral surface bears many unicellular, smooth-walled rhizoids and scales.
6. Only tuberculated rhizoids are present and scales or mucilaginous hairs are absent.
7. Many small, opaque, rounded, thickened dark bluish green spots can be seen on the ventral surface. These are the mucilage cavities filled with Nostoc colonies.
8. Each sporogonium is surrounded by a sheath like structure on its base. It is called involucre.

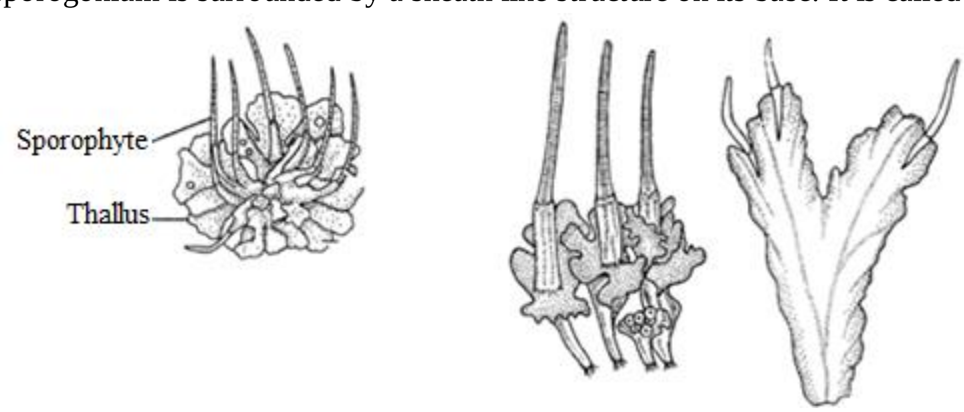

Fig. 7.6: *Anthoceros* Thallus

Internal Structure of Thallus

1. The thallus shows a very simple structure and lacks any zonation.
2. It is uniformly composed of thin walled parenchymatous cells and thickness of the middle region varies in different species.
3. Air chambers and air pores are absent.
4. Internal to the upper and lower epidermis there are simple, parenchymatous cells.
5. The cells of parenchyma are isodiametric and uniform.
6. Each cell contains a big lens-shaped chloroplast which possesses a single pyrenoid in its centre.
7. The nucleus lies in the close vicinity of the chloroplasts, near the pyrenoid.
8. On the ventral side of the thallus several intercellular mucilage cavities are found which open by small openings, the slime pores on the ventral surface of the thallus.
9. The colonies of blue green alga *Nostoc* are found in the mucilage cavities.
10. The thalli are dark green, because of the presence of the *Nostoc* colonies, which may easily be seen with the help of lens from the underside of the thallus.

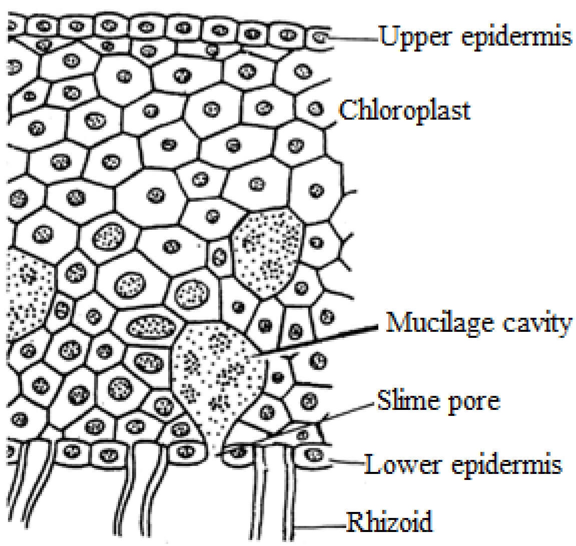

Fig. 7.7: T.S. of Thallus

Reproductive Structure

1-Vegetative reproduction: The vegetative reproduction takes place by tubers, gemmae and apices.

(a) Tubers: The thallus becomes thickened at several places on the margins; these marginal thickenings are called, the tubers; each tuber may develop into a new thallus on return of favourable conditions.

(b) Gemmae: The gemmae have been recorded from the species, *A. glandulosus*, *A. formosae*.
(c) Apices: The apices develop into new thalli.

2-Sexual Reproduction: The species may be homothallic (monoecious) or heterothallic (dioecious). The homothallic species are *A. fusiformis*, *A. punctatus* while the heterothallic species are *A. pearsoni*, *A. halli*, *A .erectus*. The sex organs, antheridia (male) and archegonia (female), are found embedded in the tissues of the dorsal side of the thallus.

The Antheridium

1. The antheridia are produced singly or in group in the antheridium chambers.
2. Each mature antheridium is stalked and club-shaped.
3. The stalk of antheridium consists of the mass of cell, e.g., in *A.laevis* of the four rows of the cells as in *A.erectus* and *A.punctatus*.
4. The antheridium proper is covered by a single layered jacket.
5. Inside the jacket there are numerous androcytes which metamorphose into antherozoids.
6. Each antherozoid is spindle-like and biciliate; the cillia are attached to the anterior end of the body.

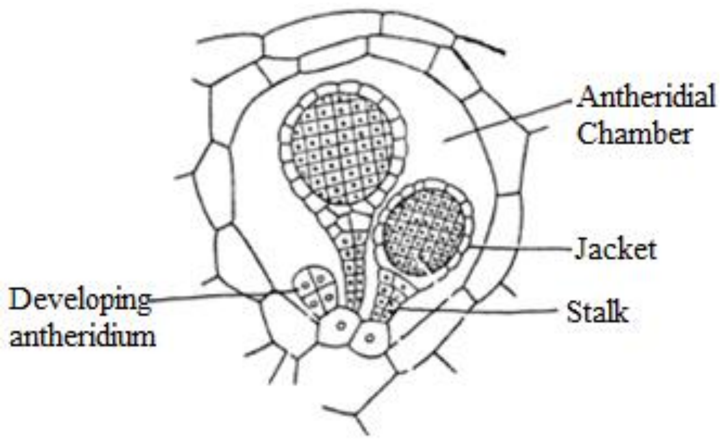

Fig. 7.8: An Antheridium

The Archegonium

1. The archegonium remains embedded in the thallus and only the cover cells project out of the thallus.
2. The nearly mature archegonium is composed of a neck and venter, the neck contains 4-6 neck canal cells; the venter contains a ventral canal and an egg.
3. On the maturity of the archegonium, the ventral canal cell and canal cells are gelatinized.
4. A mature archegonium is flask shaped, without neck canal cells and with an egg (oosphere) in its venter.
5. At the top of the neck of archegonium there are four cover cells.

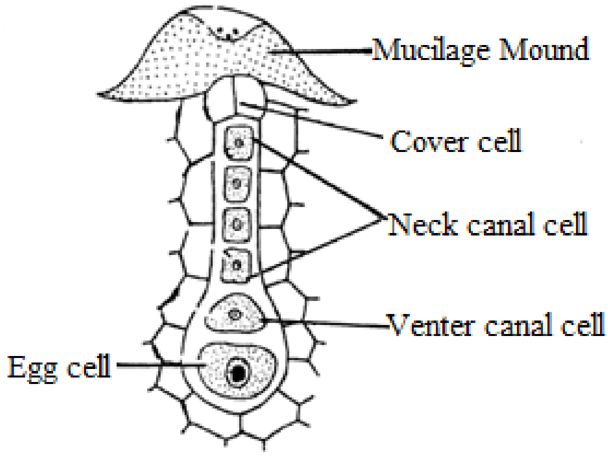

Fig. 7.9: An Archegonium

The Sporophyte

1. The mature sporogonium consists of an erect capsule and bulbous foot which embedded in thallus and act as hustaurium.
2. Capsules arise from the thalli in the form of small horny structures; usually they are 2 to 3 cm long, but some species they range even from 5-15 cm.
3. The cells developing from the meristem become differentiated into jacket layer, columella and archesporium.
4. In the region just above the foot the archesporium is single layered and too young.
5. The tip region of sporogonium possesses mature spores and pseudoelaters.
6. The wall of the capsule consists of the four to six layers of the parenchymatous cells.
7. The outermost layer is epidermis which is interrupted by stomata at several places; the epidermal cells are cutinized; the stomata open in the intercellular spaces of the chlorophyllous cells; usually each cell possesses two chloroplasts.
8. The dehiscence begins from the tip region of capsule which on maturation becomes black or brown in colour. .
9. The pseudoelaters are 2-3 celled structure which lack the characteristic spiral thickenings of true elaters, and therefore, known as pseudoelaters.
10. Each spore is somewhat spherical and possesses two wall layers. The outer wall layer is exine and the inner wall layer is intine; the intine is smooth and thin while the exine is thick and ornamental.
11. Each spore possesses a single nucleus, a colourless plastid, few oil droplets and food material within it.

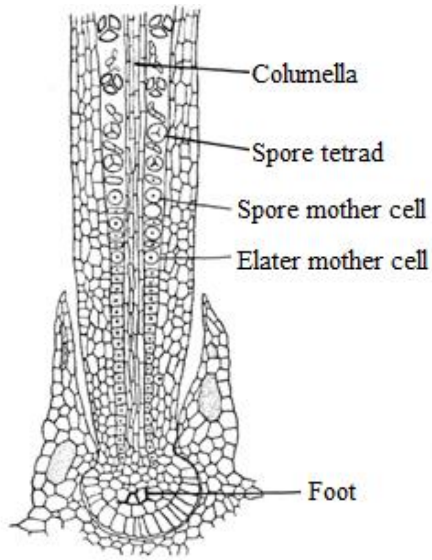

Fig. 7.10: Sporophyte of *Anthoceros*

Identification and Systematic Position

Division: Bryophyta

1. Gametophytic plant body
2. Absence of true roots.
3. Absence of vascular strands.
4. They are homosporous.

Class: Anthocerotopsida

1. Gametophytic plant body thalloid.
2. Rhizoids simple and smooth walled.
3. Tuberculate rhizoids and scales absent.
4. Thallus homogenous not differentiated; air chambers and air pores are absent.
5. Each cell of thallus possesses a large chloroplast and pyrenoid within it.
6. Capsule with central sterile columella.

Order: Anthocerotales

1. The gametophyte is thalloid and dorsiventral, bearing simple and smooth-walled rhizoids; tuberculate rhizoids and ventral scales are altogether absent.
2. The tissues of the thallus are undifferentiated; air chambers and air pores are absent; each cell bears a large chloroplast and a conspicusous pyrenoid within it.
3. The sex organs are found to be embedded in the gametophytic tissue.
4. The antheridia arise from the hypodermal cells of the thallus on the dorsal side of it; they develop within the antheridial chambers, singly or in groups on the dorsal side of the thallus.
5. The archegonia are found in sunken conditions on the dorsal side of the thallus, they develop from superficial cells.
6. The elongated and cylindrical sporogonium arises from the dorsal side of the thallus.

7. The sporogonium consists of foot, meristematic region and capsule; the meristem is intercalary and continues its growth thoughout the growing season.
8. The wall of sporogonium contains chlorophyll.

Family: Anthocerotaceae

1. The capsule is erect and cylindrical.
2. The capsule wall has stomata.
3. Elaters are without thickening bands.
4. The archesporium develops from amphithecium.

Genus: *Anthoceros*

7.3.3 *Sphagnum*

Division: Bryophyta
Class: Bryopsida
Order: Sphagnales
Family: Sphagnaceae
Genus: *Sphagnum*

Habit and Occurrence: The genus *Sphagnum* is represented by about 336 species which are cosmopolitan in distribution. In India, it is represented by about 20 species. The moss grows along the bank of lakes and gradually encroach more and more of the water as creeping bogs and with of time they completely cover up the lake transforming it into a bog. Hence *Sphagnum* is known as bog moss. These species are aquatic or semiaquatic and grow in dense masses or cushions in swamps, ponds and lake margins, moist heaths and wet hill sides.

External Structure

1. The gametophyte phase of *Sphagnum* consists of two distinct stages namely: (1) juvenile Protonema, and (2) mature leafy or gametophore stage.
2. The mature plants grow in dense clumps and their shoots are of whitish or brownish green in colour.
3. The moss accumulates water and often grows with bright colour (deep red, rose pink, etc.) due to the presence of water-soluble pigments, anthocyanin.
4. They are perennial showing unlimited growth by means of an apical cell with three cutting faces.
5. Very young gametophyte bears multicellular rhizoids with oblique septa while rhizoids are absent in mature gametophytes.

Main Axis and Branches

1. The main axis is soft and weak at young stage, but becomes erect and stout at maturity. It is much longer in aquatic species, but is relatively short in terrestrial forms due to the progressive death of the older basal parts.

2. The axis branches profusely on the lateral sides. A group of three to four tuft branches or single branch arises from the axils of every fourth leaf of the main axis. At the apex of the main stem, many small branches of limited growth are densely crowded forming a compact head called coma.
3. The coma is formed near the apex due to the condensed growth of apical internodes. As the stem grows in length these short branches elongate and become normal branches.
4. In submerged species (*S. obesum*, *S. cuspidatum*) all the branches are similar in form and structure, but in terrestrial species the branches are of two types, (i) pendent branches, and (ii) upwardly divergent branches.

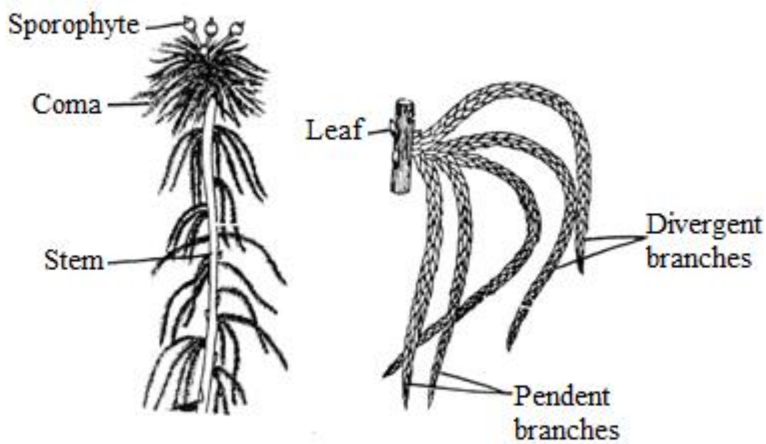

Fig. 7.11: *Sphagnum:* A Plant

Pendent Branches

1. These are long slender loosely arranged, turn downwards and then grow parallel to the main axis. They are also termed flagelliform or decurrent branches.

Divergent Branches

1. These are short and stout branches which grow outwards and upwards and are also termed as excurrent branches.
2. Sometimes, one divergent branch in each node develops strongly than others and gives rise to a new plant when it becomes detached from the mother plant.

Leaves

1. The leaves occur both on the main axis as well as on the branches in spiral phyllotaxy.
2. On the branches, the leaves are closely set and overlapped which are placed apart on the main axis.
3. Moreover, the leaves on the main axis differ from those on the branches in size, shape and details of cell structure.
4. The leaves are small, sessile, entire, thin and scale like with acute apex and without a midrib.

Internal Structure (Anatomy) of Plant

Stem: Internally, the stem shows distinct differentiation of tissues into three zones viz., outer cortex or the hyalodermis, prosenchymatous region (hydrom) and the central cylinder or medulla.

Outer Cortex

1. The cortex forms the outermost region of the main axis and lateral branches.
2. The cortex remains two to four layered in the main axis, but it is single layered in lateral branches. The mature cortical cell is devoid of protoplasm.
3. On the basis of the nature of hyaline cells, the genus *Sphagnum* has often been divided into two subgenera: *Inophloea* and *Lithoploea*.

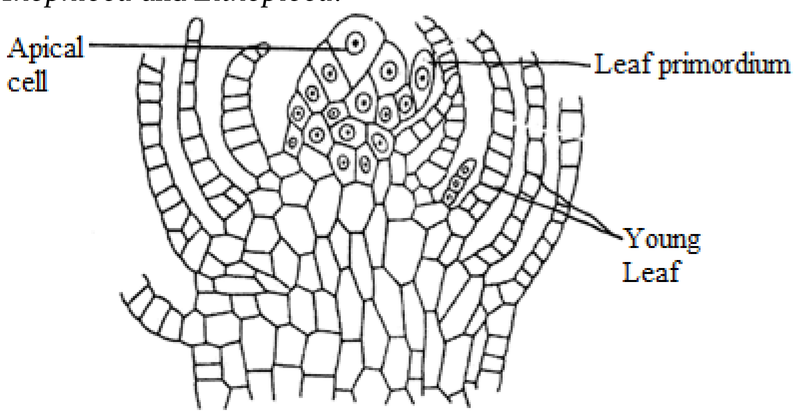

Fig. 7.12: T.S. of Stem

4. In the sub genus *Inophloea*, cortical hyaline cells are fibrose and porose, and in sub genera *Lithoploea* these are without pores or spiral thickening.
5. In some species (*S. tenellum*, *S. molluscum*), some outer cortical cells enlarge peculiarly and become bottle or retort shaped.
6. The neck of each cell is turned outward away from the axis and has a pore at the distal end. These are called retort cells.
7. They accumulate water and inhabited by small microscopic animals.

Prosenchymatous Region

1. It lies next to the cortex and consists of 4-6 layers of small thick-walled, prosenchymatous cells.
2. This part is called hydrom which gives mechanical support to the stem.

Central Cylinder or Medulla

1. It is the innermost region of the stem comprised of small, vertically elongated, thin-walled parenchymatous cells.
2. In some species it is composed of prosenchymatous medulla.
3. It also functions as storage region.

Leaf

1. In *Sphagnum*, the cross-section of leaf shows only one cell in thickness and composed of much elongated cells.
2. A young leaf is com-prised of square or rectangular cells of uniform size, while a mature leaf is characterised by two types of cells: the ordinary type hyaline cells and green chlorophyllous cells or assimilatory cells.
3. The hyaline cells are large polygonal and become colourless or hyaline by losing their protoplasts.
4. Their walls are provided with pores and become spirally thickened.
5. The hyaline cells have a remarkable capacity of absorption and retention of water (hence called capillary cells), thus rhizoids are not necessary in the mature plants.
6. The chlorophyllous cells are small triangular or biconvex living cells with many discoid chloroplasts and have their photosynthetic ability.
7. The chlorophyllous and the hyaline cells are arranged in an alternate sequence to form a regular reticulate pattern.

Reproduction

In *Sphagnum*, reproduction takes place both by vegetative and sexual methods, however, the vegetative propagation is more common.

Vegetative Reproduction

1. Sometime, one of the divergent branches grows upwards and becomes as strong as the main stem. Such apical branch is known as innovation.
2. Due to the progressive death of the lower basal part of the main axis, the innovation gets detached from the mother plant and ultimately gives rise to a new plant.

Sexual Reproduction

1. *Sphagnum* may be monoecious or dioecious, but the antheridia and archegonia are always borne on the special separate antheridial and archegonial branches of the same plant.
2. These branches are much smaller than the vegetative branches. In monoecious plants, the antheridial branches develop first.

The Antheridia

Antheridial Branch

1. The antheridial branches first appear near the apex of the main shoot but eventually carried downwards due to the growth of the apical region.
2. These branches are usually shorter but stouter than the vegetative branches.
3. They are spindle shaped and densely covered with yellow, red or dark green leaves generally smaller than the foliage leaves.

Anthridium

1. The antheridia develop singly and acropetally below the leaves.
2. Each antheridium develops from a superficial antheridial initial of the stem which develops a small filamentous structure.
3. The terminal cell of this filament grows by two cutting faces to form an apical cell.
4. Each distal cell gives rise to an outer jacket initial and an inner primary androgonial cell. The primary androgonial cell, by further divisions in all possible planes, forms the antheridium.

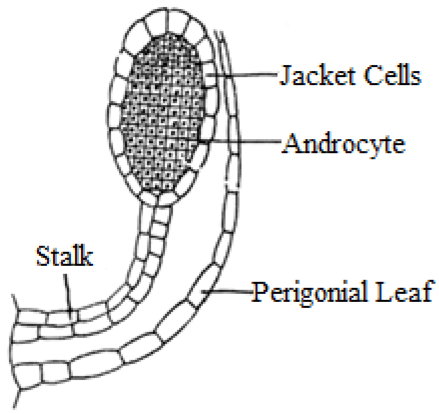

Fig. 7.13: Antheridia of *Sphagnum*

5. A single-layered jacket is formed from jacket initials.
6. The mature antheridium has a long stalk of two to four rows of cells and a globose or ovoid body.
7. The body has a jacket of one layer of cells enclosing a mass of androcytes formed from the sperm mother cells.
8. Each androcyte cell metamorphoses into a spirally coiled biflagellate antherozoid or sperm.

Dehiscence of the Antheridium

1. The apical cells of the jacket of a mature antheridium swell through the absorption of water as a result of turgor pressure thus generated the wall of the swollen antheridium breaks into a number of irregular lobes at the apex that eventually turns backwards.
2. The mass of androcytes comes out and the antherozoids are liberated immediately and swim freely in water.

The Archegonia

Archegonial Branches

1. Archegonia are borne at the apices of the archegonial branches which develop at the apex, or laterally.
2. The archegonial branches are very short and more or less ovoid in shape.
3. The leaves on these branches are larger than those present on the foliage leaves.
4. The upper leaves of these branches constitute the perichaetium enclosing the archegonia and thus protect archegonia from injury.

Archegonium

1. The archegonia develop on the apex of the archegonial branches either singly or in groups.
2. The apical cell of this branch forms the primary archegonium. Two to five secondary archegonia develop from derivatives of the apical cell.

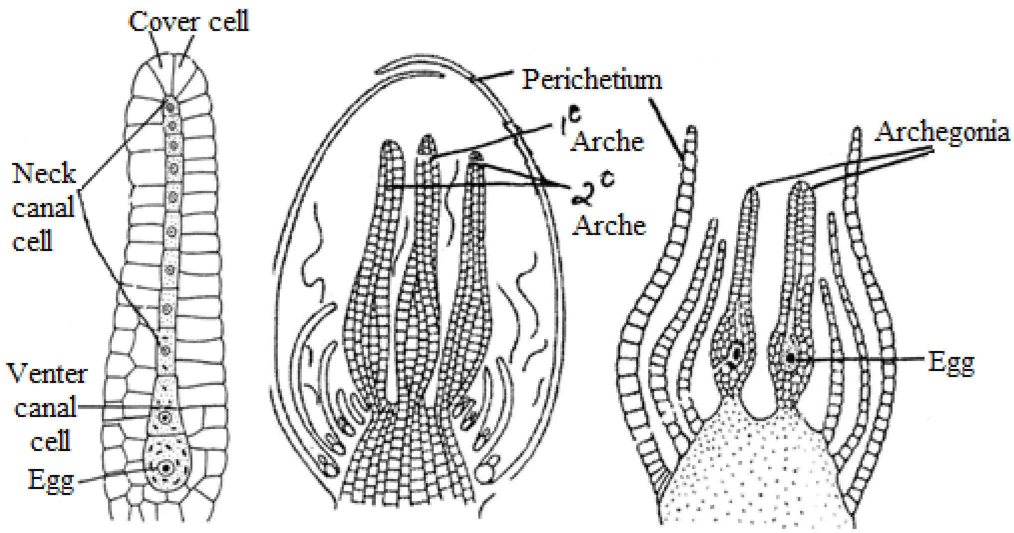

Fig. 7.14: Archegonia of *Sphagnum*

3. Usually, there are three archegonia in a group i.e., one primary archegonium at the apex and two secondary archegonia emerge from the base of primary archegonium.
4. The developments of both the primary and secondary archegonia are similar.
5. The archegonial initial divides transversely to form a four- to six-celled filament.
6. The terminal cell, by three intersecting vertical walls, cuts off three periclinal jacket initial cells and an primary axial cell.
7. The primary axial cell divides transversely to form an upper cover initial and lower central cell. The central cell divides transversely to form an upper primary neck canal cell and lower primary ventral cell.
8. The primary neck canal cell, by repeated trans-verse divisions, forms a row of eight to ten neck canal cells, while the primary venter cell, by a single transverse division, forms a ventral canal cell and an egg.
9. The cover initial divides vertically to form a group of eight or more cover cells that form the upper portion of the archegonial jacket.
10. The jacket initial, by anticlinal and periclinal divisions, subsequently forms the neck and the middle and basal portion of the archegonial jacket.

Mature Archegonium

1. The mature archegonium is a relatively large structure with a long stalk, a long twisted neck with eight or nine neck canal cells.
2. A massive multilayered venter contains a ventral canal cell, and an egg.

Fertilisation of Archegonium

1. The process of fertilisation takes place only in the presence of water.
2. The antherozoids swim freely in water and reach the archegonia.
3. At maturity, the neck canal cells and the ventral canal cell disorganise and form a passage for the antherozoids.
4. The antherozoids reach near the archegonia attracted chemotactically and pass into the passage to reach the egg. Ultimately, only one antherozoid fuses with the egg and forms a zygote.

The Sporophyte

1. The diploid zygote is the first cell of the sporophytic generation. Among the few archegonia only one is developed to form embryo in an archegonial branch.
2. The zygote enlarges, invests itself with a cell wall and then divides transversely to form an upper epibasal cell and a lower hypobasal cell.
3. Transverse divisions in both the cells continue until a six or seven celled filament is formed. The lower half of the filament undergoes irregular divisions forming a parenchymatous bulbous foot which also acts as haustorium.
4. The upper cells of the filament divide by two vertical divisions at right angle to each other and form a quadrant.
5. The cells of the quadrant divide periclinally to form an inner endothecium and an outer amphithecium. The cells of the endothecium repeatedly divide and form a central sterile part, columella.
6. The amphithecium divides periclinally to differentiate an inner two to four layered archesporium and the outer three to seven layered capsule wall.
7. The archesporium forms a dome shaped arch over the columella. The cells of the archesporium later develop into 2-4 layered sporogenous tissue.
8. All sporogenous cells function as spore mother cells that divide meiotically and form haploid spores.
9. The spores are enclosed within a spore sac developed from the surroun-ding sterile tissue. There is only a short neck like inconspicuous seta connecting the upper capsule and the lower bulbous foot.

Structure of the Mature Sporophyte

1. The mature sporophyte consists of a bulbous foot, a neck-like inconspicuous seta and an almost spherical black to dark-brown capsule.
2. The whole sporophyte is covered by the calyptra. The lowest part of the calyptra that covers the foot is called the vaginula. The perichaetial leaves are present below the sporophyte.

3. The elongated archegonial branch at the base of the sporogonium is called pseudopodium. It increases in length and pushes out the capsule above the perichaetial leaves to facilitate the spreading of spores.
4. The capsule in longitudinal section shows an outer jacket and middle spore-sac with spores which overarches the dome-shaped inner columella.

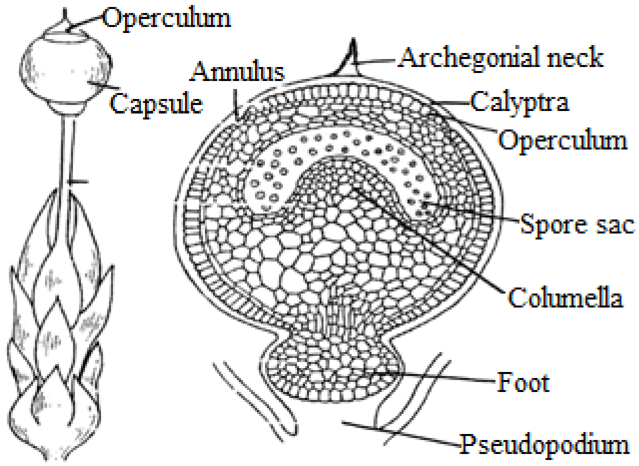

Fig. 7.15: A mature Sporophyte

5. The capsule wall or jacket is several layers thick. The outermost layer of the bears several rudimentary non-functional stomata.
6. The circular biconvex disc-shaped lid, called operculum, is present at the top of the jacket. The operculum is delimited from the rest of the jacket by a groove of thin-alled cells, called the annulus.
7. The capsule dehisces on a bright sunny day by an explosive mechanism.
8. The capsule wall and columella become dry and shrivel due to heat which results in the formation of a large air space below the spore sac.

Identification and Systematic Position

Division: Bryophyta

1. The true roots are always absent.
2. They lack typical vascular tissues.
3. They are homosporous.

Class: Bropsida (Musci)

1. Two stages of gametophyte—(a) prostrate, thalloid branched protonema, and (b) erect leafy gametophore.
2. Rhizoids multicellular, branched and obliquely septate.
3. Tissue of stem differentiated into (a) outer thin walled cortex, and (b) central thicl walled conducting tissue.
4. The sporogonium is differentiated into food, seta and capsule; capsule wall interruped by stomata.

5. Elaters absent.

Order: Sphagnales

1. Thallose protonema produces one gametophyte.
2. Leaves are without midrib and compose of two types of cells.
3. Axillary anthridia, that is with a distinctive differentiation of fertile portion.
4. Archegonia are acrogynous.

Family: Sphagnaceae

1. Contains only one genus *Sphagnum*.
2. The plant forms clusters of short branches (heads or coma) above, and below the heads, elongated spaced out tufts (fascicles) of branches are formed along the stem.
3. Each tuft is often made up of three to eight branches. The plant is pale green with shades of pink, red, yellow or brown.
4. The stems are erect and individually weak and gain support by aggregation and growing in dense masses or cushions.
5. The length of the stem is practically indefinite

Genus*: Sphagnum*

7.3.4 *Funaria*

Division: Bryophyta
Class: Bryopsida
Order: Funariales
Family: Funariaceae
Genus: *Funaria*

Habit and Occurrence: It is a cosmopolitan moss with around 117 species in this genus. About 18 species have been recorded from India. Most of the species grow as close tufts on damp and shady walls in the form of velvety mat but some species are epiphytic and grow upon the tree trunk.

The species *Funaria hygrometrica* is best known among the mosses. They grow luxuriantly in alkline soil and on soils burnts by fire.

External Structure

1. The plant is small about 1-3 cm long, erect, green and branched.
2. Gametophytic plant arises from a prostrate alga like filament the protonema.
3. The gametophytic plant body is differentiated into rhizoids, leaves and axis.
4. The rhizoids are present at the base of gametophytic plant and they are branched, multicellular obliquely septate and thread like,
5. Rhizoids usually contain oil, but if exposed to light they develop chorophyll.
6. The leaves are sessile, small, ovate, bright green and spirally arranged on the stem and possess a distinct mid rib.

7. The upper leaves are somewhat larger in size and crowded at the apex of the plant whereas the lower leaves are smaller and scattered on the stem.

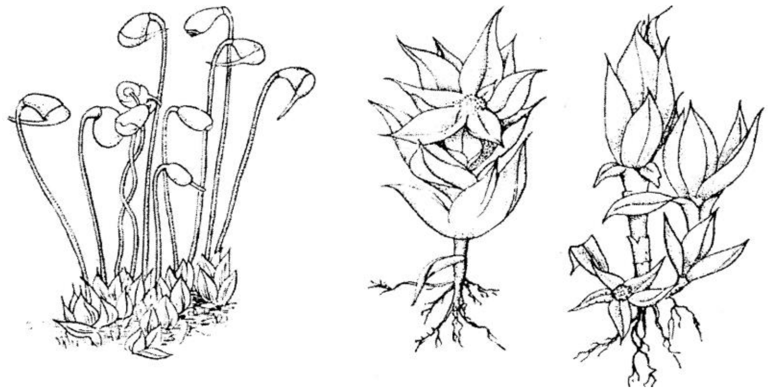

Fig. 7.16: *Funaria* Plant

Internal Structure (Anatomy) of Plant

Anatomy of Leaf

1. A transverse section of the leaf shows a well defined central midrib and the one- celled thick lamina.
2. The mid rib is several-celled in thickness whereas the wing on either strand in the centre of the midrib. It helps in the conduction of the food and water.
3. Lamina cells are elongated, thin-walled and rich in chloroplasts.
4. There is a central stand in the centre of the midrib.
5. The leaves are devoid of stomata or hairs.

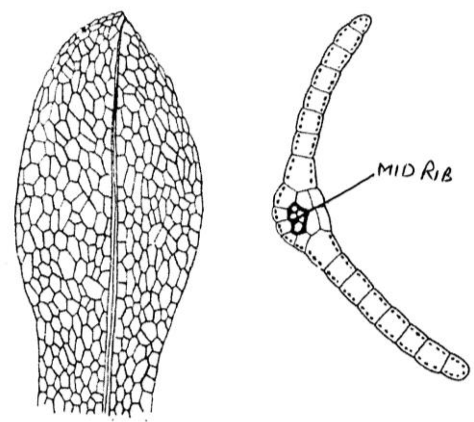

Fig. 7.17: *Funaria*: A Leaf and T. S. of Leaf

Anatomy of Stem

The internal structure of stem consists of three parts: epidermis, the cortex and the central cylinder.

Epidermis

1. The epidermis is a single-layered, devoid of cuticle and stomata.
2. It consists of thin-walled compactly arranged cells with chloroplast

Cortex

1. The cortex is multilayered and consists of thin walled parenchymatous cells.

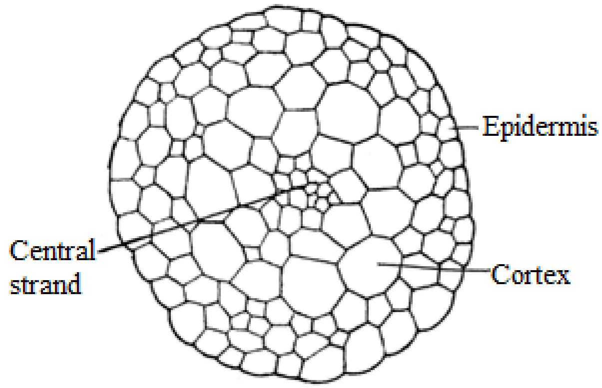

Fig. 7.18: *Funaria*: T.S. of Stem

Central Cylinder

1. The central cylinder of the stem consists of somewhat thick-walled, compactly arranged cells. The central cylinder acts as conducting tissue.
2. The cells of this region are vertically elongated and of smaller diameter than those of cortical cells.

Reproduction: The reproduction in *Funaria* is mainly through vegetative and sexual method.

(a) Vegetative reproduction

1. Many mosses produce small, multicellular gemmae, in groups at the apices of the leaves; sometimes solitary gemmae may be produced on the rhizoids.
2. Subterranean gemmae, produced on the rhizoids are called the bulbils.
3. Each such gemmae or bulbils develop into a new moss plant.

(b) Sexual reproduction

1. *Funaria hygrometrica* is strictly monoecious and autoecious species.
2. The term autoecious means that the male (antheridia) and female (archegonia) sex organs develop on the two separate branches of the same plant.
3. The main shoot of the gametophyte bears the male the sex organs whole the lateral branch bears the female sex organs.
4. On maturity the male branches become brownish in colour whereas the female branches remain green.

The Antheridium

1. The antheridium consists of two parts: a short massive stalk and the main body.
2. The main body remains surrounded by a single layered outer jacket; the jacket cells contain chloroplasts, they turn red or brown on maturity.
3. The jacket layer surrounds the central dense mass of androcytes.

4. At the apical end of the male branch of gametophore the antheridia intermingle with several sterile paraphysis.
5. The paraphyses are hair like in structure and each paraphysis is multicellular and consists of four or five cells which arranged in a uniseriate row.
6. The lower cells of the paraphysis are elongated and termainal cells are globular.

The Archegonium

1. The stalk of archegonium is longer than that of antheridium and flask shaped.

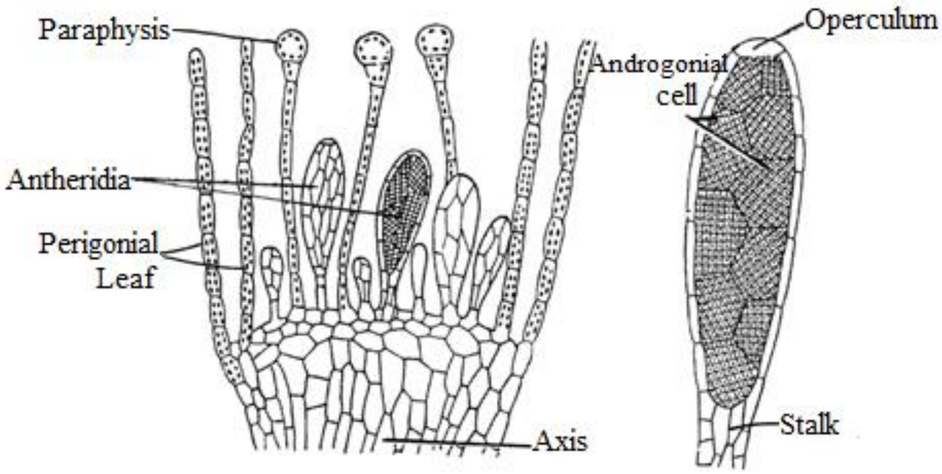

Fig. 7.19: *Funaria*: Anthridium

2. It possesses a massive stalk, venter and neck.
3. The bulbous venter possesses a two layered jacket, whereas the jacket of neck is single layered.
4. The venter contains the egg (oosphere) and the venter canal cell.
5. The elongated neck contains six or more neck canal cells.
6. On maturity of the archegonium, the neck canal cells and the ventral canal cell disintegrate forming a mucilaginous substance.

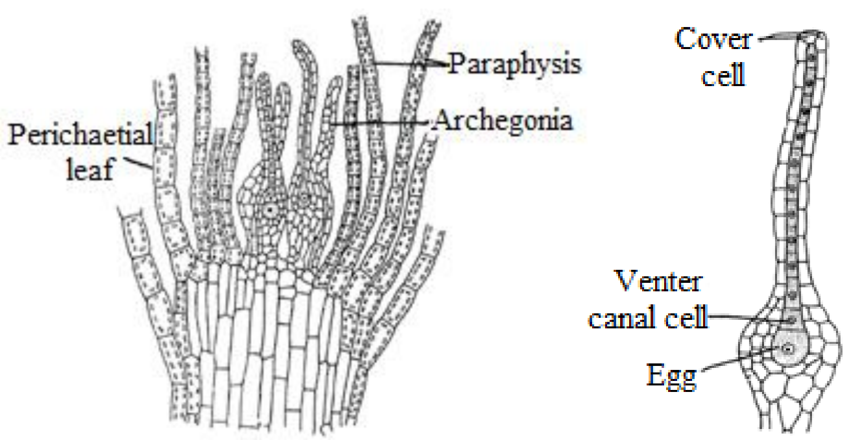

Fig. 7.20: *Funaria*: Archegonia

The Sporophyte (Sporogonium)

1. The sporophyte consists of a foot, seta and capsule.
2. The foot is a small, conical structure embedded in the apical portion of the female branch of gametophore.
3. The seta is an elongated slender and thread-like structure which bears the capsule at its apical end.
4. The outline of a mature capsule is pear shaped in the beginning an irregular calyptra is found as a cup-like structure at the apical end of the capsule, but very soon this is blown off.

Capsule

L.S. of capsule shows following three regions namely apophysis, theca and upper region.

Apophysis

1. The elongated seta expands at its apical end to form the apophysis.
2. This is assimilatory region.
3. The stomata may be seemed here and there in the epidermis.
4. The cells with chloroplasts possess intercellular spaces among them.
5. The central conducting strand consists of colourless cells.
6. This strand is conducting with the conducting strand of seta.

Theca

1. The central fertile region of the capsule is known as the theca proper.
2. This region consists of many layers of cells.
3. The outermost layer is the epidermis, which lies in continuation of the epidermis, of the apophysis of the capsule.
4. Just beneath the epidermis, there is one to two layered hypodermis; the cells of hypodermal regions are colourless.
5. Next to the hypodermis there is one or two layered chlorenchyma tissue; the cells of this layer contain choroplasts and act as assimilatory tissue.
6. Just beneath the chlorenchmatous layer there is a big air space, traversed by several trabeculae and each trabecula consists of 3 or 4 green cells.
7. These filiform structures act as connections between chlorenchymatous layer and the outer spore sac of the capsule.
8. The columella remains surrounded by the spore sac.
9. In between these inner and outer spore sacs there are spore mother cells; each spore mother cell develops into a spore tetrad of four spores after meiosis.
10. The central region of the theca is occupied by a pith-like solid cylinder of parenchyma, called the columella; the columella is narrow at its base and broad at its apical end; it is connected to the conducting strand of the apophysis of the capusle at its base.

11. The spore sac is barrel shaped; the spore sac has an inner single layered wall called the inner spore sac; the outer wall of the spore sac is three of four layered and known as the outer spore sac.

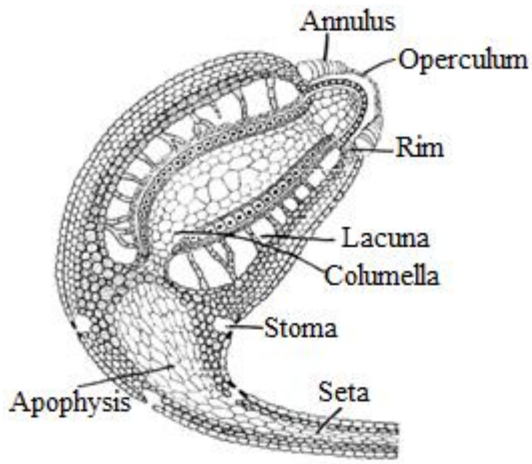

Fig. 7.21: *Funaria*: L.S. Capsule

Spore Germination and Protonema

1. The rim stretches inward from the epidermis and connects the peristome to the epidermis of the capsule.
2. The peristome lies just beneath the operculum; it consists of two sets of incurved teeth known as inner and outer peristome.
3. Each set of peristomial teeth consists of sixteen incurved triangular teeth; the teeth are spirally twisted towards left.

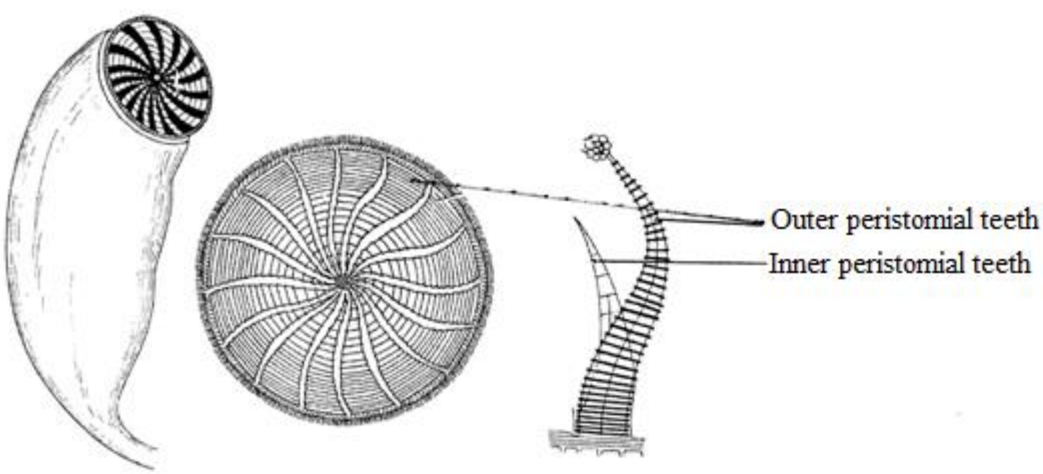

Fig. 7.22: *Funaria*: Persistomial teeth

4. The teeth of outer peristome are red and of inner peristome are colourless; the inner teeth are shorter than the outer ones.
5. The annulus is found just above the rim; it consists of 5 or 6 layers of epidermal cells.
6. The mouth of the capsule remains closed by means of lid or operculum.

7. The spores are more, less spherical; each spore possesses a covering wall of two layers; the outer layer is somewhat coloured, smooth and known as exosporium; the inner layer is colourless; smooth and known as endosporium; the spore contains within it, a nucleus, oil globules and chloroplasts.

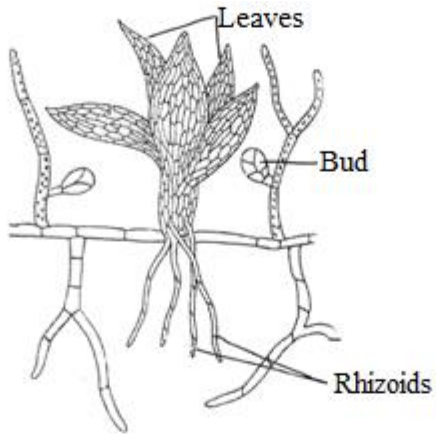

Fig.7.23: *Funaria*: Protonema

8. On germination the spore gives rise to a multi-cellular filament called the primary protonema.
9. The primary protonema further differentiates into prostrate chloronemal branches and the obliquely septate rhizoidal branches penetrating the substratum.

Identification and Systematic Position

Division: Bryophyta

1. The true roots are always absent.
2. They lack typical vascular tissues.
3. They are homosporus.

Class: Bryopsida

1. Two stages of gametophyte: prostrate, thalloid, branched protonema, and erect leafy gametophore.
2. Rhizoids multicellular, branched and obliquely septate.
3. Tissues of stem differentiated into outer cortex, and central conducting tissue.
4. The sporogonium is differentiated into foot, seta and capsule.
5. Capsule wall interrupted by stomata.
6. Elaters absent.

Order: Funariales

1. Terrestrial plants.
2. Leaves with midribs arranged in rosettes at the apex of gametophyte.
3. Capsules wide; provided with unbeaked operculum.
4. Peristome double.

Family: Funariaceae

1. Leaves one cell in thickness except at midrib region.
2. Small mosses.

3. Calyptra soon detached from operculum; calyptra with long beaks.
4. Capsules pyriform.
5. Seta long.

Genus: *Funaria*

7.3.5 *Polytrichum*

Division: Bryophyta
Class: Bryopsida
Sub class: Andreaeidae
Order: Polytrichales
Family: Polytrichaceae
Genus: *Polytrichum*

Habit and Occurrence: The genus *Polytrichum* with around 100 species is widely distributed genus in tropical and temperate regions of the world. The plants are mostly found in cool and shady places while these may also be found growing in bogs and marshes, on soil of firm or loose texture, on rocks and cliffs and as epiphytes on trunks of trees. In India the genus is mostly distributed in the Himalayan region. The common species recorded from India are *Polytrichum densifolium*, *P. juniperunum* and *P. xanthopitum.*

External Structure

1. The gametophyte remains differentiated into two parts: the underground rhizome and the erect stem and leaves.
2. The rhizoids present on rhizome are long and thick walled with oblique septa.
3. The rhizoids give mechanical support to the plant and also helps in vegetative reproduction.
4. The leaves are small, scale like and usually brown, colorless with midrib and becomes narrow upwards.
5. Each leaf possesses a broad colourless membranous sheath at its base.
6. The midrib remains covered on its upper surface by means of longitudinal cell plates which contain chlorophyll and are known as lamellae.
7. At the apex of a stem, young leaves are spirally arranged in three vertical rows.

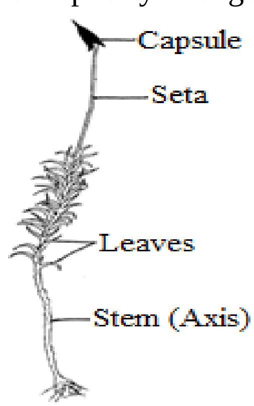

Fig. 7.24: *Polytrichum* Plant

Internal Structure (Anatomy) of Plant

T.S. of Rhizome

1. The rhizome is roughly triangular in shape with rounded corner.
2. The transverse section of rhizome shows different zonations, the epidermis, cortex, pericycle, leptoids, amylom and central cylinder.
3. The cortex is divided by three radial strands which penetrate into the central cylinder to give it a three lobed outline.
4. Cortex consists of 3 to 4 layers of cells. The outermost layer is strongly suberized while the innermost layer of the cortex consists of very large cells with thin suberized walls, the endodermis.
5. Two or three layered, primitive pericycle is found just beneath the endodermis; this surrounds the central cylinder but does not form a continuous band.
6. The greater part of the central cylinder is made up of the thick-walled, somewhat elongated cells, which form the ‘sterome’ among which there are scattered groups of empty, elongated cells the ‘hydroids’.
7. The three radial strands start from groups of thick walled cortical cells, with their inward ends remain embedded in the central cylinder, consists of thin walled leptoids.
8. Internal to the lepton mantle there is hydrom sheath which is also known as amlylom layer. It consists of one or two layers of cells.
9. Inside the amylom layer there is the hydrom mantle which consists of thin walled cells in the centre of the stem.

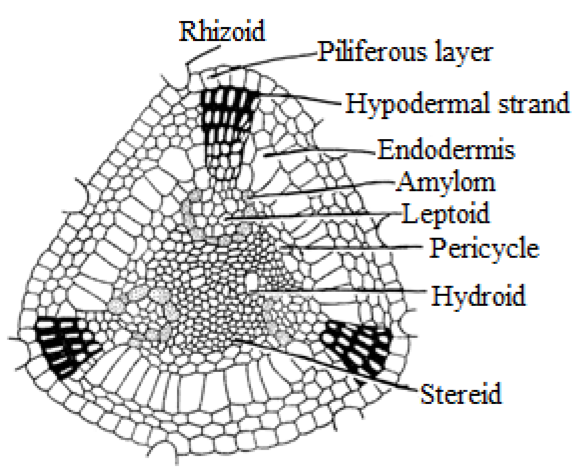

Fig.7.25: *Polytrichum*: T.S. of Rhizome

V.T.S. Of Leaf

1. The broad midrib is several cells thick in the centre and gradually merges into the so called lamina at the margins.
2. On the lower surface there is well marked epidermis composed of large cells whose outer walls are thickened.
3. Inside the epidermis there are one or two layers of very small cells with very thick walls.

4. The central tissue of the leaf is composed of thin-walled parenchymatous cells; among which are scattered small groups of small thick-walled cells.
5. The upper (adaxial) surface is composed of a layer cells high, containing chloroplasts; these plates are knows as lamellae.

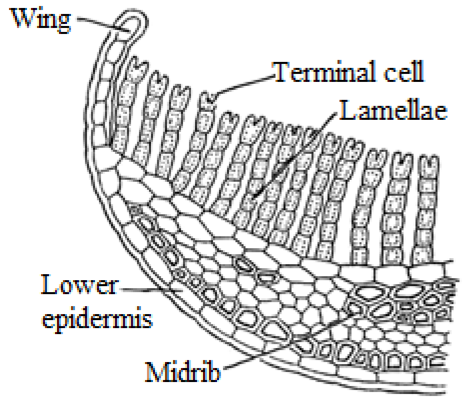

Fig. 7.26: *Polytrichum*: V.T.S. of Leaf

Reproduction

Usually the plants are diocecious and the antheridia (male) and archegonia (female) are borne in terminal clusters at the apex of separate gametophores.

Sexual Reproduction

The Antheridia

1. The antheridia arise at the top of the leafy stems within an involucre of bright red or orange color leaves.
2. The involucral leaves on the male head are arranged spirally from the vegetative apex outwards.
3. Each mature antheridium of a stalk and a clavate body and the club-shaped body remain surrounded by a single-layered jacket.
4. The antheridia are produced in groups in the axils of these perichaetial leaves so that the whole head becomes compound and contains a variable number of these closely set antheridial groups.
5. Inside the jacket there are androcytes within the antheridum.
6. The antheridia are intermingled with paraphyes; some paraphyses are simple and filament like while the others are broadened at their tips.

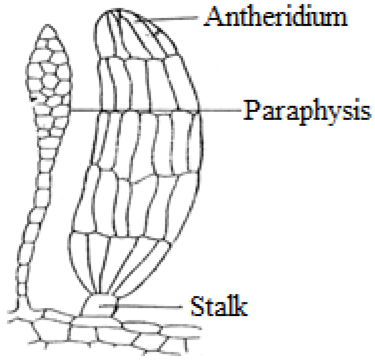

Fig. 7.27: *Polytrichum*: An Anthridia

The Archegonia

1. The archegonia arise at the top of the leafy stems within an involucre of leaves.
2. Usually three archegonia are found in an archegonial head.
3. Each stalked archegonium consists of a venter and a long neck.
4. The neck contains 6-9 neck canal cells.
5. The venter contains a ventral canal cell and an egg.

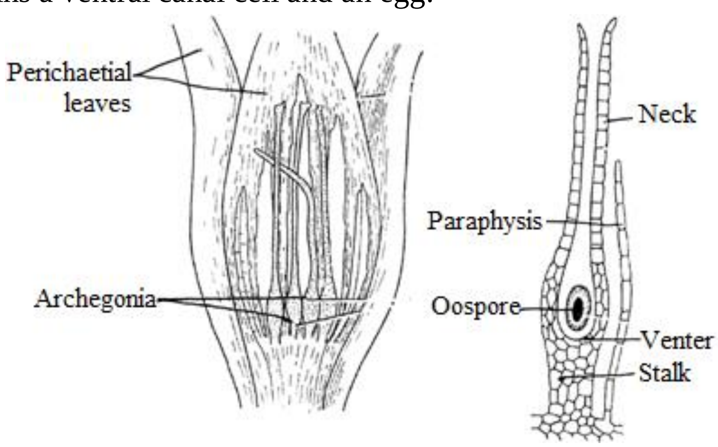

Fig. 7.28: *Polytrichum*: An Archegonium

The Sporophyte (Sporogonium)

1. The mature sporogonium consists of a foot, seta and a capusle.
2. The foot remains embedded in the tissue of an archegonium.
3. Just above the foot and continuous with it there is a long slender seta which supports the capsule at its terminal end.
4. The seta may reach a length of several inches. The seta and apophysis are considerably larger in size.
5. In T.S. the capsule is angular as well as square in outline. The wall of capsule consists of several layers of cholorophyllous cells; the outermost layer represents the epidermis.
6. In the mature capsule the sporogenous tissue forms a tube around columelle and is sperarated from it by air spaces which are traversed by filaments of assimilatory cells.
7. A similar assimilatory tissue is also developed between the spore mass and the wall of the capsule.

8. At the apex of the capusle, the calyptra remains attached for a long time.
9. The calyptra develops a brown colour, and grows after its separation from the basal part of the archegonium, forming a shaggy, hairy cup which covers the whole capsule and because of this feature it is known as 'hair moss.
10. At the top of the capsule there is an operculum which appears as a lid which is conical with a long beak or rostrum. Annulus is not well marked though the thickened diaphragm is present.
11. The peristome teeth are short and stout, formed of a group of sclerotic cells.
12. At maturity the peristome consists of 32 or 64 teeth.
13. The openings between the teeth form a ring of pores and the spores are dispersed through these pores by the force of the wind shaking the sporogonium.

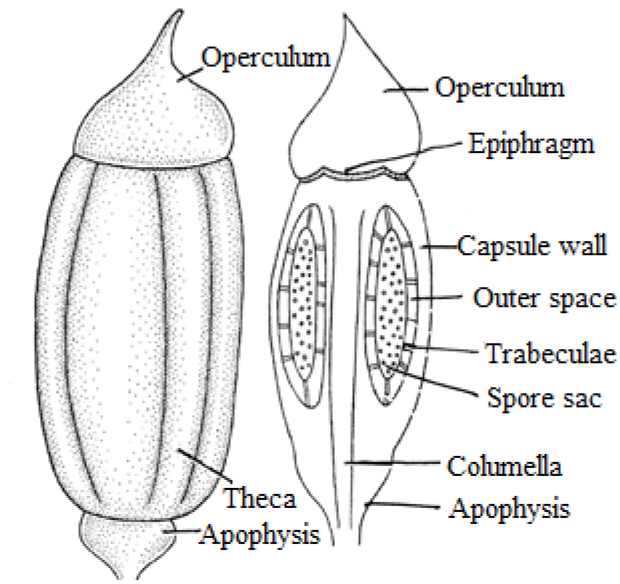

Fig. 7.29: *Polytrichum*: A Capsule

Spores and Protonema

1. The spores are uninucleate and two walled; the outer wall is exine while the inner one is intine.
2. The buds develop near the base of upright filaments. The older filaments of the protonema sometimes become twisted together into cable like strands.
3. On germination, the spore gives rise to septate branched filament, the protonema; some filaments grows upwards and turn green while some grow downwards to the substratum and remain colourless.

Identification and Systematic Position

Division: Bryophyta

1. The true roots are always absent.
2. They lack typical vascular tissues.

3. They are homosporous.

Class: Bropsida (musci)

1. Two stages of gametophyte—(a) prostrate, thalloid branched protonema, and (b) erect leafy gametophore.
2. Rhizoids multicellular, branched and obliquely septate.
3. Tissue of stem differentiated into (a) outer thin walled cortex, and (b) central thicl walled conducting tissue.
4. The sporogonium is differentiated into food, seta and capsule; capsule wall interruped by stomata.
5. Elaters absent.

Order: Polytrichales

1. Gametophyte perennial and tall.
2. Leaves quite narrow and possess longtiudinal lamellae on upper surface of midrib.
3. Capsule terminal.
4. 32-64 pyramidal teeth in peristome.
5. Epiphragm covers the mouth of capsule.

Family: Polytrichaceae

1. Single family; characters as of order.

Genus: *Polytrichum*

7.3.6 *Andreaea*

Division:	Bryophyta
Class:	Bryopsida
Order:	Andreaeales
Family:	Andreaeaceae
Genus:	*Andreaea*

Habit and Occurrence: The moss genus *Andreaea* is cosmopolitan in distribution. Mostly the plants are found in cold regions. With few exceptions, the moss grow in extremely exposed situations especially on non calcareous granite or other siliceous rocks, that is why the common name “granite moss” is given to genus.

External Structure

1. The gametophyte has two phases typical of a moss: the juvenile protonemal phase which gives rise to persistent leafy plant and the gametophores.
2. The gametophores are small, dark, and brown to blakish in color and occur in dense tufts or cushions.
3. The general structure of the gametophore is like the bryidae.

4. The stem grows prostrate along the rock surface with a sympodial branching in which one branch grows more strongly than other.

Fig. 7.30: *Andreaea*: Plant with Capsule

5. The stem bears numerous rhizoids from the basel creeping structure of the stem.
6. Terminal growth of the stem occurs by means of an apical cell with three cutting face of the apical cell.
7. The leaves are small, papilose and of variable shape ranging from ovate to subulate in outline.
8. In some species the leaves are one cell in thickness and without a midrib while in other species the median longitudinal axis is differentiated into a midrib more than one cell in thickness.

Internal Structure

1. The stem shows no internal differentiation into cortex and central conducting strand.
2. Superficial cells may be somewhat thicker walled and darker in color than the deep lying cells and cells contains large oil globule.

Reproduction

Usually the plants are monoecious and have the antherida (male) and archegonia (female) borne in terminal groups on separate branches. A few species such as *A. blyttii* and *A. nivalis* are dioecious.

Sexual Reproduction

The Antheridium

1. The antheridium consists of two parts: a long uniseriate or biseriate stalk and the main ellipsoid body.
2. Anthridia is surrounded by a number of perigonial bracts.
3. Interspersed with numerous filamentous paraphyses.

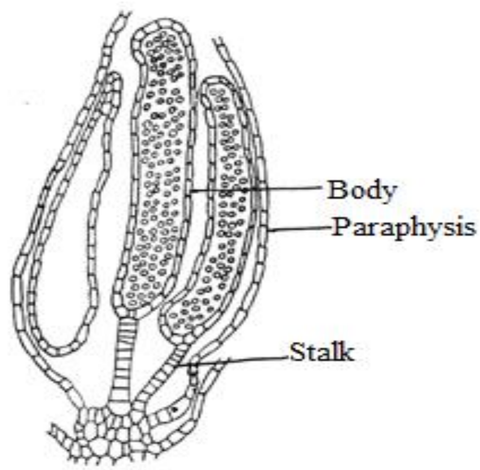

Fig. 7.31: *Andreaea*: An Anthridia

The Archegonium

1. The archegonium consists of a short stalk and a long neck.
2. Anthridia is surrounded by a number of perichetial bracts.
3. Interspersed with numerous filamentous paraphyses.

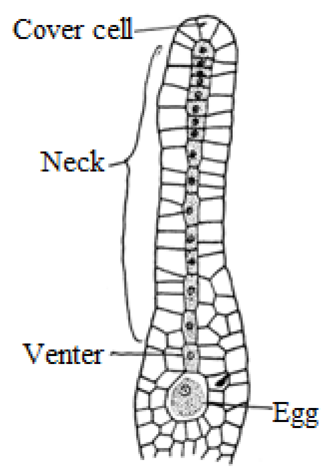

Fig. 7.32: *Andreaea*: An Archegonia

The Sporophyte (Sporogonium)

1. After fertilization the venter of the archegonium increases somewhat in thickness and develops into a calyptra which surrounds the sporophyte until the maturity.
2. The mature sporogonium is differentiated into a swollen foot or haustorium and a minute ovoid capsule tapering a little at base and apex.
3. The foot and the capsule are connected by a very short seta or neck.
4. The capsule has a jacket of about six layer of cells athe outermost of it is epidermis.
5. The central of capsule is occupied by a club shaped columella.
6. Pseudopodium is present which acts as seta and helps in the dehiscence of the capsule.

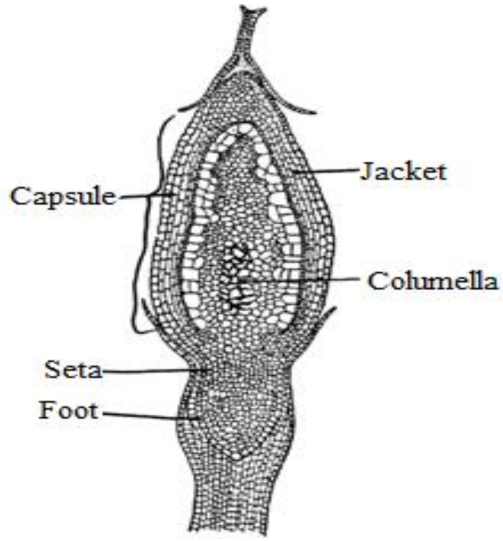

Fig. 7.33: *Andreaea*: L.S. Sporophyte

Spores and Protonema

1. The spores are double walled; the outer wall is exine while the inner one is intine.
2. The spores contains chloroplast and oil globule.
3. The protonemata of *Andreaea* are unusual in being able to undergo a dormant stage if conditions for growth become unfavourable.

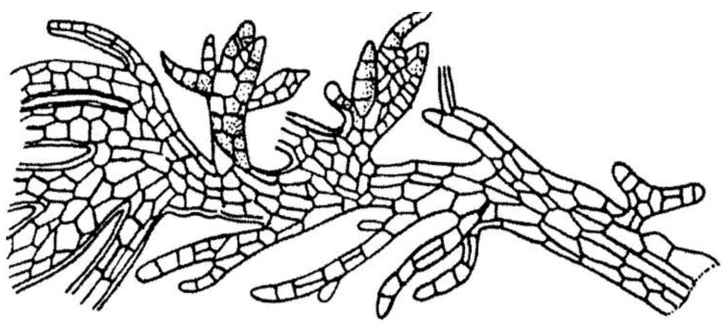

Fig. 7.34: *Andreaea*: Protonema

Identification and Systematic Position

Division: Bryophyta

1. The true roots are always absent.
2. They lack typical vascular tissues.
3. They are homosporous.

Class: Bropsida (Musci)

1. Two stages of gametophyte—(a) prostrate, thalloid branched protonema, and (b) erect leafy gametophore.
2. Rhizoids multicellular, branched and obliquely septate.
3. Tissue of stem differentiated into (a) outer thin walled cortex, and (b) central thicl walled conducting tissue.

4. The sporogonium is differentiated into food, seta and capsule; capsule wall interruped by stomata.
5. Elaters absent.

Sub class: Andreaeidae

1. Lack of internal differentiation in the stem of gametophore.
2. Neck like seta is replaced functionally by an elongated pseudopodium.

Order: Andreaeales

1. Single order of the sub class andreaeidae.
2. Capsule raised on a pseudopodium.
3. Capsule opens along several vertical dehiscence lines.

Family: Andreaeaceae

Genus: *Andreaea*

7.3.7 *Takakia*

Division: Bryophyta
Class: Hepaticopsida
Order: Takakiales
Family: Takakiaceae
Genus: *Takakia*

Habit and Occurrence: The monogeneric order Takakiales includes the genus *Takakia* consisting of two species *T. lapidozioides* and *T. ceratophylla*. These are hygrophytes and grow in cool, moist or wet shady places at higher altitudes.

External Structure

1. The plant body is differentiated into an erect, radial leafy shoot and a branched subterranean, cylindrical rhizome.
2. The rhizome and leafy axis are covered with copious mucilage hairs.
3. The gametophyte bears geotropic organs which grow downwards towards soil.
4. The aerial gametophores are isophyllous and bear deep green cylindrical structure or leaves.
5. Growth of the stem is due to an apical cell with three cutting faces.

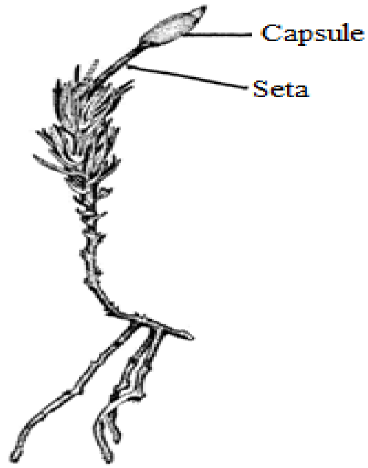

Fig. 7.35: *Takakia*: Plant with Capsule

Internal Structure

Leaf Anatomy

1. Except the tip the rest is three to five cells thick and it gradually tapers towards the apex ending in a blunt conical cell.
2. The cells are parenchymatous and contain chloroplast.
3. Only one medullary cell is present which is much larger than the surrounding cortical cells.
4. The central strand of medullary cell is always surrounded by a single layer cortex in size.

Stem Anatomy

1. The cross section of the stem shows two distinct region outer cortical and inner medullary region.
2. The cortical region is chlorophyllous and one to two cell thick.
3. Cortical wall is thick and brown in color.
4. The medullary region shows differentiation into a small central core of small walled cell.
5. The cells of central strand are colorless and lose their protoplasmic content.
6. These are elongated with dedicated walls interconnected with plasmodesmata.

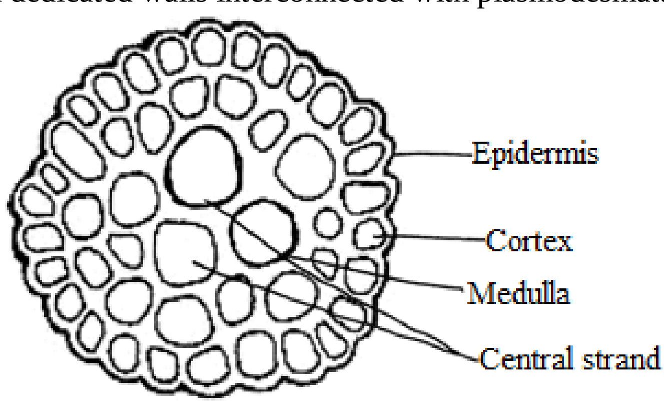

Fig. 7.36: *Takakia*: T.S. of stem

Reproduction: The reproduction in *Takakia* is mainly through vegetative and sexual method. Usually the plants are dioecious and heterothallic. Externally there is no differentiation in male, female and sterile plant.

Vegetative reproduction

1. Occurs mainly through the breaking of plant parts.

Sexual reproduction

The Antheridium

1. The antheridium is obovate to ellipsoidal in shape with bright orange in color.
2. The stalk of anthridium is ill demarked and is made up of 3-4 tier of four cell each.
3. The dehiscence of anthridium is via a ill defined cap or lid.

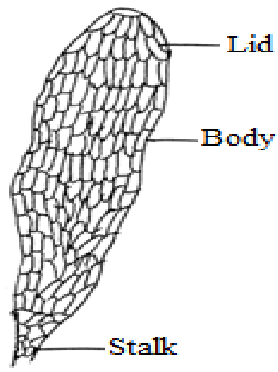

Fig. 7.37: *Takakia*: L.S. of Anthridium

The Archegonium

1. The female plant produces single archegonium normally but sometimes scattered 2-3 irregularly scattered archegonia are present.
2. The archegonium is without any special protective structure and is plump, large, green and stalked when young.
3. The archegonial neck is not long and with six neck cells.
4. The venter is fleshy and becomes two stratose prior to fertilization.

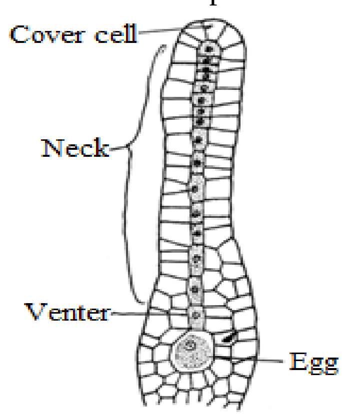

Fig. 7.38: *Takakia*: L.S. of Archegonia

The Sporophyte (Sporogonium)

1. The sporophyte has three distinct parts: the foot, seta and capsule and covered by two protective covering the vaginula and calyptra.
2. The foot and major portion of seta is protected by vaginula while the capsule and rest portion of seta is protected by calyptra.
3. The pseudopodia are absent in *Takakia*.
4. Foot is well developed, tapers into apex while seta is erect and stout, well developed and becoming slightly twisted at maturity.
5. Capsule is erect, elliptical, and green in early stage of development due to presence of chlorophyll in surface wall.
6. Operculum, theca and apophysis and peristome teeth are absent.

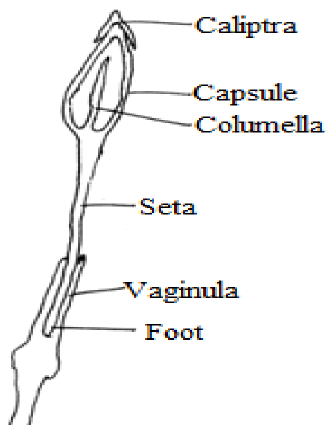

Fig. 7.39: *Takakia*: L.S. of Sporophyte

Identification and Systematic Position

Division: Bryophyta

1. The true roots are always absent.
2. They lack typical vascular tissues.
3. They are homosporous.

Class: Bropsida (Musci)

1. Two stages of gametophyte—(a) prostrate, thalloid branched protonema, and (b) erect leafy gametophore.
2. Rhizoids multicellular, branched and obliquely septate.
3. Tissue of stem differentiated into (a) outer thin walled cortex, and (b) central thick walled conducting tissue.
4. The sporogonium is differentiated into foot, seta and capsule; capsule wall interruped by stomata and elaters are absent.

Order: Takakiales

Family: Takakiaceae

Genus*: Takakia*

7.4 SUMMARY

The *Calobryum* grows along the wet and dry places. The gametophytic plant body consists of branched, creeping rhizome. The subterranean as well as aerial portion of the stem lacks rhizoids. The leaves are simple, entire, dorsiventrally flattened, soft texture and without a midrib. Growth of the stem occurs by a pyramidal apical cell with three cutting faces, one slightly narrower than the other. The aerial shoot is differentiated into a central colorless zone of elongated cells and a peripheral zone of thicker cortical cells containing oil droplets and pale green plastids.

Genus *Anthoceros* belongs to family Anthocerotaceae of class Anthocerotopsida. It is found in the hollows of moist rock in the dense patches. The thallus is small, prostrate, dark green thin and dorsiventrally differentiated. The midrib is absent. The ventral scales and tuberculate rhizoids are also absent. The anatomy of the thallus is quite simple and not differentiated. Each cell contains a big chloroplast which possesses a single pyrenoid in its centre. On the ventral side of the thallus certain intercellular mucilage cavities containing nostoc colonies are found which open by small openings, the slime pores on the ventral surface of the thallus. The tip region of sporogonium possesses mature spores and pseudoelaters.

The genus *Sphagnum* is represented by about 336 species which are cosmopolitan in distribution. In India, it is represented by about 20 species. The moss grows along the bank of lakes and gradually encroach more and more of the water as creeping bogs and with of time they completely cover up the lake transforming it into a bog. Hence *Sphagnum* is known as bog moss. These species are aquatic or semiaquatic and grow in dense masses or cushions in swamps, ponds and lake margins, moist heaths and wet hill sides.

Genus *Funaria* belongs to class Bryopsida and grows luxuriantly in humic soil and on soils burnts by fire. The small erect, green gametophytic plant arises from a prostrate alga-like filament the protonema. The gametophytic plant body is differentiated into rhizoids, leaves and stem. The rhizoids are branched, multicellular obliquely septate and thread like, stem is upright erect. green and monopodial branched; leaves are sessile, small, ovate, bright green and spirally arranged on the stem; *Funaria hygrometrica* is strictly monoecious and autoecious species.

Genus *Polytrichum* belongs to class Bryopsida. They grow luxuriantly in bogs and marshes, on soil of firm or loose texture, on rocks and cliffs and as epiphytes on trunks of trees. In India, they are commonly found in hills. The gametophyte remains differentiated into rhizoids, the underground rhizome, the erect stem and leaves. The plants are diocecious and the antherida (male) and archegonia (female) are borne in terminal clusters at the apex of separate gametophores. At the apex of the capusle, the calyptra remains attached for a long time. All cells of sporogeonus tissue give rise to spores.

The monogeneric order Takakiales includes the genus *Takakia* consisting of two species *T. lapidozioides* and *T. ceratophylla*. These are hygrophytes and grow in cool, moist or wet shady places at higher altitudes. The plant body is differentiated into an erect, radial leafy shoot and a branched subterranean, cylindrical rhizome. The gametophyte bears geotropic organs which grow downwards towards soil.

The moss genus *Andreaea* is cosmopolitan in distribution. Mostly the plants are found in cold regions. With few exceptions, the moss grow in extremely exposed situations especially on non-calcareous granite or other siliceous rocks, that is why the common name “granite moss” is given to genus. The gametophyte has two phases typical of a moss: the juvenile protonemal phase which gives rise to persistent leafy plant and the gametophores.

7.5 GLOSSARY

Apospory: The production of gametophyte directly from the unspecialized cells of sporophytes without the formation of spores is termed as apospory. e.g. anthoceros. The new gametophytic plants are diploid because these are formed directly from the diplod cells of sporophyte without undergoing meiosis.

Columella: Central column of sterile cells found inside the capsule of some bryophtes. It is surrounded by sporogenous tissue which consists of spores and elaters.

Elaterophore: Coherent mass of sterile tissue that helps in spore dispersal. The elaterophore occupy an axial position in the capsule.

Elaters: These are elongated, spindle shaped sterile, hygroscopic cells with spiral thickenings in the sporogonium of some bryophytes. These help in spore dispersal.

Gemma: Special reproductive bodies produced in large numbers in small gemmae cups. Each gemmae is small stalked discoid body with two notches on the lateral sides. Most of gemmae contain chloroplast, oil cells and rhizoidal cells.

Hornworts: Refer to members of Anthocerotopsida. Sporophyte of Anthoceros appears like a horn.

Operculum: It is the cap of capsule in mosses.

Perichaetium: An envelope surrounding many archegonia.

Peristome: Peristome is a fringe of teeth around the mouth of capsule in mosses.

Protonema: is a filamentous stage in the development of gametophyte of a moss from the spore.

Pseudoelaters: These are found in *Anthoceros* and are sterile cells that help in spore dispersal. These lack spiral thickenings characteristics of elaters.

Rhizoid: Nonvascular filamentous structure that helps in anchorage and absorption like roots.

Scales: Multicellular, one celled thick membranous structures found on the ventral surface of thallus. These are violet colured due to presence of the anthocyanin pigments.

Secondary protonema: Protonema which is formed by means other by the germination of spores is called secondary protonema.

Tuberculate rhizoids: The inner walls of these rhizoids develop into peg like projections.

Venter: It is the enlarged basal portion of sterile cells found in an archegonium in which an egg is present.

7.6 SELF ASSESSMENT QUESTIONS

7.6.1 One word Questions:

1. The pigment present in the *Sphagnum* which gives it bright colour is…………..
2. *Funaria* is also known as.............
3. Which is the chief assimilatory part of *Funaria* capsule?
4. At what region, the cells of *Funaria* capsule break to liberate operculum?
5. What is mode of nutrition in sporophyte of *Funaria*?
6. Name the early filamentous structure produced by spores cheifly in Moss?
7. Moss rhizoids are characterized by having?
8. In *Polytrichum* leaves are arranged in how many rows?
9. How many pyramidal teeth are present in peristome of *Polytrichum*?
10. Which organ in *Polytrichum* sporogonium controls the spore liberation?
11. Name one saprophytic member of bryophyte?
12. Who coined the term bryophyte?
13. Who is known as father of Indian Bryology?
14. Which type of cells conduct water in Mosses?
15. Moss sporophyte is............dependent on sporophyte?
16. Columella in the moss sporophte is situated in.......
17. ....is mother cell of sporophytic generation.
18. Gemmae are responsible for..........mode of reproduction.
19. In *Anthoceros* spores develop from………..
20. What kinds of rhizoids are found in *Anthoceros*?
21. Name two bryophytes having columella?
22. From which part of sporogonium, does the sporogenous tissues originate in *Anthoceros*?
23. Bryological flora of India has been written by...

7.6.1 ANSWER

1-Anthocyanin, 2-Cord Moss, 3-Apophysis, 4- Annulus, 5-Autotrophic, 6-Protonema, 7-Oblique septa, 8- 3 rows, 9-32, 10-Peristome, 11- Buxbaumia., 12-Braun (1864), 13-Prof Shiv Ram Kashyap, 14-Hyaline cells, 15-Partially, 16-Theca, 17-Zygote, 18-Vegetative, 19-Endothecium, 20 -Only smooth walled, 21- *Anthoceros* and *Funaria*, 22- From amphithecium, 23-W. Milten (1859)

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7.9 TERMINAL QUESTIONS

1. Write the systematic position of *Polytrichum*?
2. Which generation is well developed in Moss plant?
3. Name the two growth stages of the gametophyte in life-cycle of *Funaria*?
4. What term is used for mosses bearing antheridia and archegonia on different branches of same plant?
5. How can we distinguish the protonema of moss from filamentous green alga?

UNIT-8 MORPHOLOGICAL STUDY OF REPRESENTATIVES OF PTERIDOPHYTES-I

8.1 OBJECTIVES

After reading this unit students will be able to study plant morphology of pteridophytes i.e- *Rhynia, Psilotum, Lycopodium, Lepidodendron, Selaginella, Isoetes, Sphenophyllum.*

8.2 INTRODUCTION

Pteridophytes are ferns and maidenhair, from the Filicinae (Filicopsida) group, and selaginellas, moss-like plants from the Lycopodinae group (Lycopsida). Pteridophytes are cryptogamic plants, they are flowerless and seedless. They are tracheophyte (vascular) plants, and have tissues specialized in the transmission of water and nutrients.On the back side of each leaf of the plant, there are small dust-like dots called sori (singular, "sorus", also known as "seeds").

8.3 MORPHOLOGICAL STUDY SUCH AS EXTERNAL STRUCTURE, LEAVES, STEM, ROOT AND REPRODUCTIVE STRUCTURE OF REPRESENTATIVE PTERIDOPHYTES

8.3.1 *Rhynia*

Rhynia was a vascular plant, and grew in association with other vascular plants such as *Asteroxylon mackei*, which is considered as ancestor of modern clubmosses (Lycopsida), and with pre-vascular plants such as *Aglaophyton major*. It is supposed to have deciduous lateral branches, which it used to disperse laterally over the substrate.

Scientific Classification

Kingdom: Plantae
Subdivision: Rhyniophytina
Class: Rhyniopsida
Order: Rhyniales
Family: Rhyniaceae
Genus: *Rhynia*

Habit and Habitat: Two main species named as *R. major* and *R. gwynne-vaughani* have been found in Scotland. These specimens are well-preserved and provide detailed information about the form and structure of this very primitive vascular plant. There are some evidences which suggest that they grew in swampy marshes near the volcanoes.

External Structure of *Rhynia*

1. The Plant body is mainly sporophytic.
2. Height of Rhynia ranges from 50 cm and its diameter varies from 1.5 to 6 mm whereas *R.gwynne-vaughani* height is 20 cm and its diameter is 1 to 3 mm.
3. Plants had dichotomously branched rhizome.
4. Many dichotomously branched erect aerial shoots emerged from rhizome towards the upper side while many rhizoids are arising towards the lower side.
5. No leaves and roots are present in the plants.
6. Aerial shoots of *Rhynia major* were Smooth and devoid of leaf or any other outgrowth, while many adventitious branches were present on the aerial shoots of *R.gwynne-vaughani*.
7. Aerial shoots either had simple vegetative tips or having terminal sporangia.
8. The plant body was differentiated into a subterranean rhizome which gives rise to upright photosynthetic aerial shoots.
9. Tufts of unicellular rhizoids are arose from rhizome.
10. Aerial shoots were cylindrical and leafless as no leaves are present and a tapering dichotomously branched system is seen in them.
11. The branches might help in vegetative propagation of *Rhynia*.
12. A solitary terminal sporangium is beared on the tip of the aerial branch of *Rhynia* which is 12 mm in length and about 4 mm in diameter.

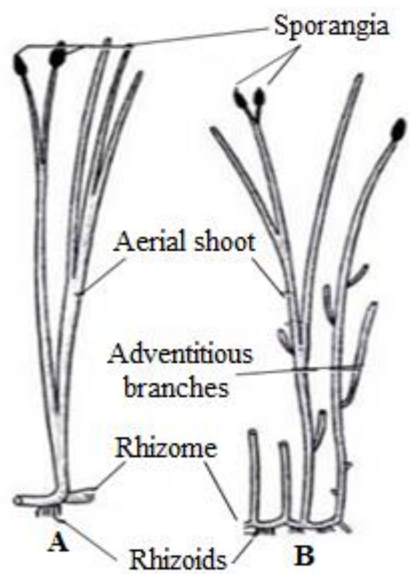


Fig. 8.1: Plant structure of (A) *R. major* (B) *R. gwynne-vaughani*

Reproductive Structures of *Rhynia*

1. The single sporangia were present on the apices of some aerial branches.
2. Each sporangium has oval or slightly cylindrical structure developed on the aerial branch.
3. They were 12 mm long and 4 mm in broad in *R. major* whereas 4 mm long and 1 mm broad in *R. gwynne-vaughani*.
4. A Sporangium had a five cells thick wall, whose outermost layer was 1 cell thick cuticularized epidermis which was followed by 3 cells thick middle layers of thin walled cells.

5. The inner-most layer was 1 cell thick tapetum.

6. A spacious sporangial cavity surrounds the wall, which was without columella and contained large number of spores.

7. The jacket layer of the sporangium is several celled thick.

8. The spores were of same size with 60 µ in diameter i.e. they are homosporus which are distributed in sporangium as tetrahedral tetrads of spores.

9. The disintegration of the sporangial wall results in liberation of spores.

10. Little knowledge about the gametophyte of *Rhynia* is known.

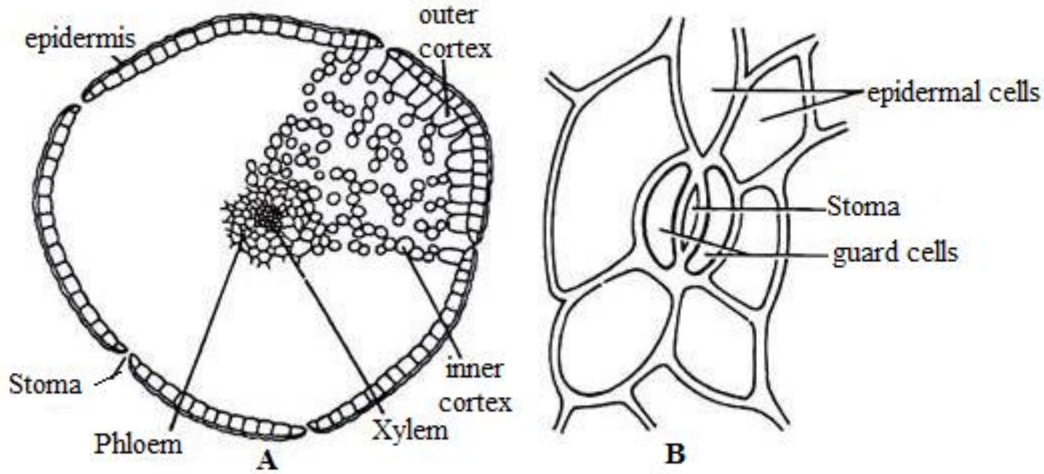


Fig. 8.2: A- T.S. of aerial Shoot, B- A stome

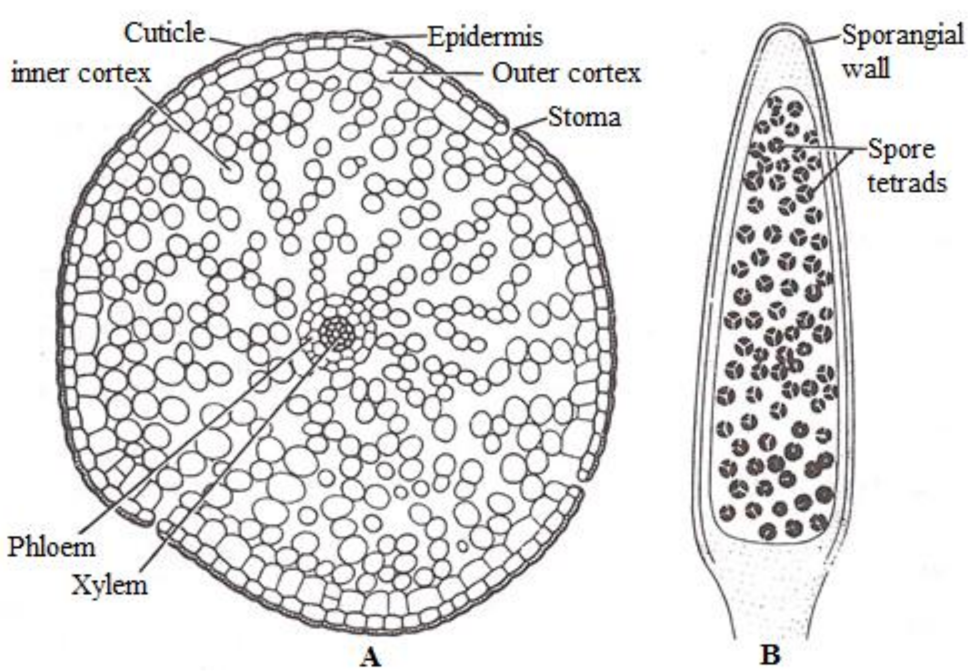


Fig. 8.3: A-T.S. of rhizome, B-L.S. Sporangium

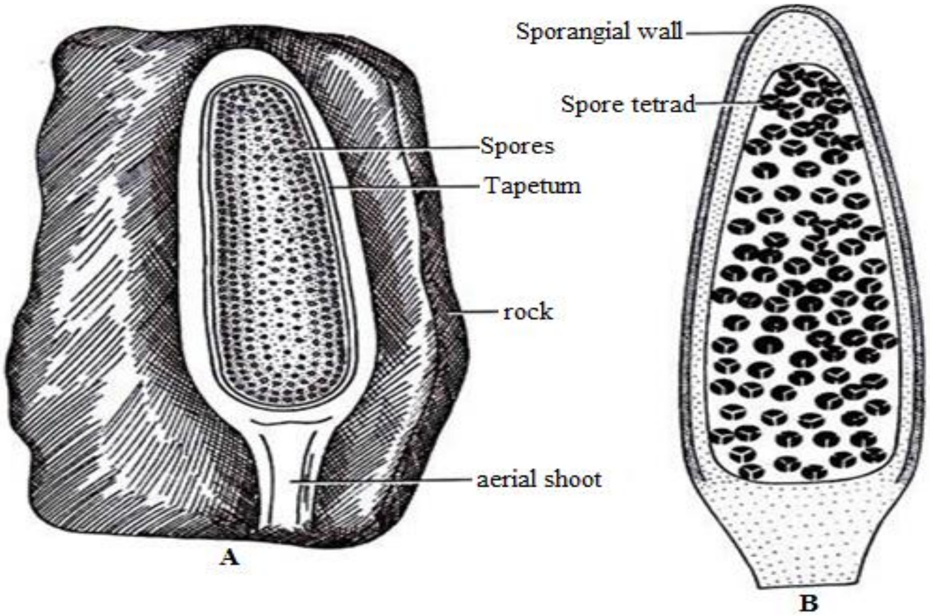


Fig. 8.4: A-L.S. of sporangium of *R. major,* B-L.S. of sporangium of *R. gwynne-vaughani*

8.3.2 *Psilotum*

Psilotum, also known as whisk ferns, is a vascular plants genus.

Scientific Classification

Kingdom: Plantae
Division: Pteridophyta
Class: Psilotopsida
Order: Psilotales
Family: Psilotaceae
Genus: *Psilotum*

Habitat and Occurrence: It is the genus in which some species are commonly found e.g. *P. nudum* but some species are rare and found in the tropical islands e.g. *P. flaccidum*. They usually grow upon tress and hence called epiphytes but they may also grow in soil or humus or in the crevices of the rocks.

External Structure

1. Plant body is green, dichotomously branched stems, slender and shrubby.
2. Leafless upright branches are present.
3. The Stem structure is perennial and xerophytic.
4. Tiny green flattened protuberances with no veins are present.
5. No roots are present.

6. The development of gametophyte is exosporic and forms monoecious subterranian gametophyte.

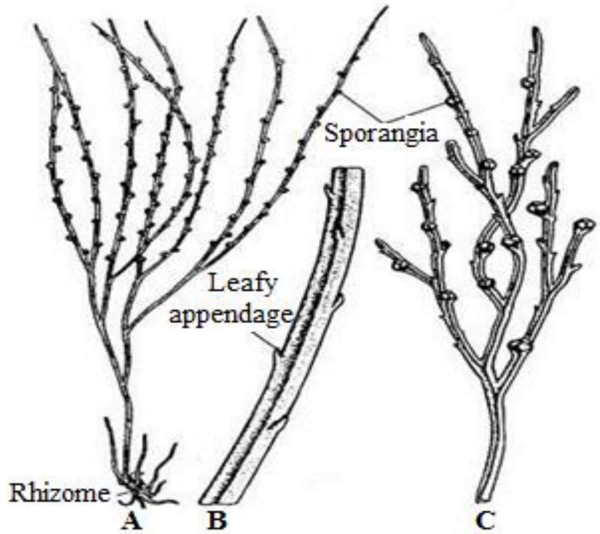


Fig. 8.5: A-Complete Sporophytic Plant, B-Stem showing scaly appendage, C- fertile twig of *Psilotum*

Stem

1. Aerial shoots are 20-75 cm long and are usually ribbed and multi-angular in structure.
2. The base of the aerial shoot is triquetrous whereas the flattened tips are present in them.
3. A number of scales or appendages which are often called leaves are present on aerial shoots.
4. Aerial shoots can be sterile or fertile.
5. Sterile shoots are found all along the length of the aerial shoot while the fertile shoots are only found on the upper portions.
6. A Synangium, trilobed spore bearing structure is present in the axils of fertile shoots.
7. Aerial shoot has many dichotomous branching.
8. Shoot basal part is cylindrical in shape.

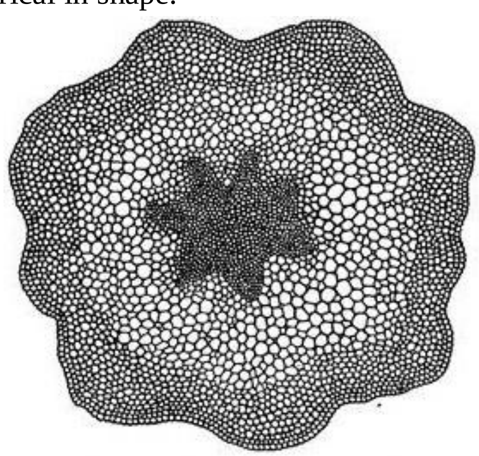


Fig. 8.6: T.S. of stem *Psilotum nudum*

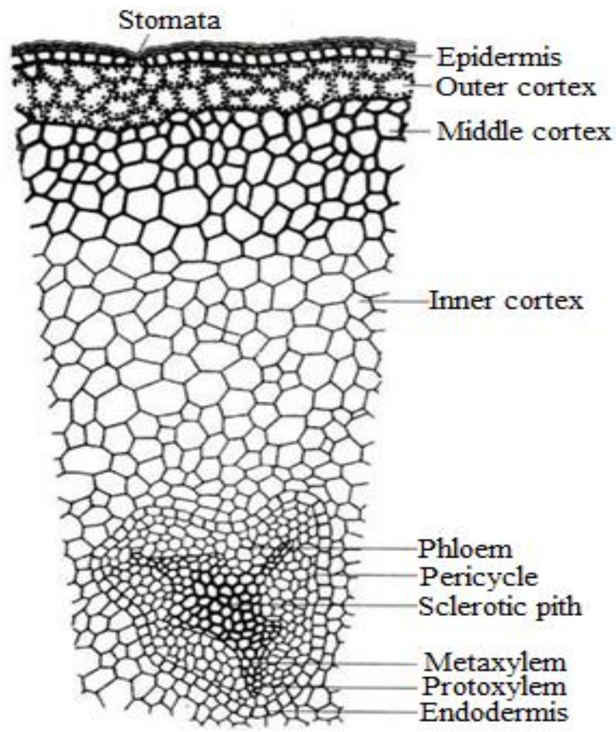


Fig. 8.7: Enlarged view of a segment of T.S. of *Psilotum nudum* stem

Leaves

1. Scales or appendages are present on aerial shoots which are considered as leaves.
2. Leaves can be sterile or fertile.
3. Leaves are devoid of any vasculature.
4. No veins are present in the leaves.
5. They are not found on the rhizomes and extreme base of the aerial shoot.

Rhizome

1. Any dichotomy of rhizome is capable of developing into aerial shoot.
2. Mycorrhizal fungus is present in rhizome.
3. Rhizome is brownish in color and dichotomously branched.
4. Rhizome contains hair-like structure called rhizoids which perform the function of absorption.
5. Some branches of rhizome may give rise to erect (*P. nudum*) or pendulous (*P. flaccidum*) shoot system.

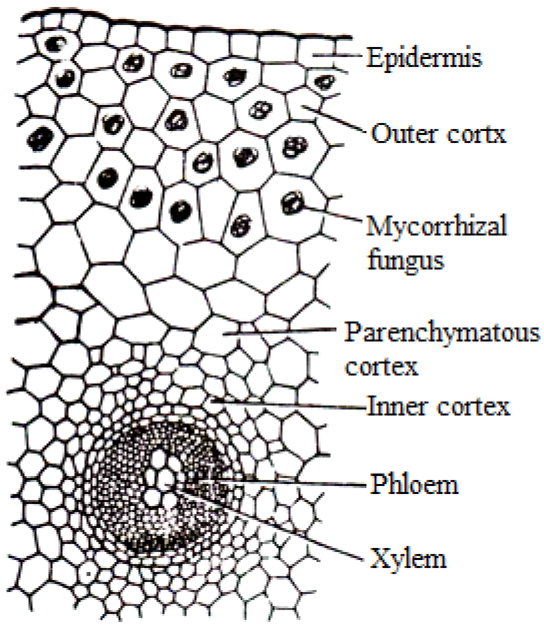


Fig. 8.8: T.S. of Rhizome

Reproductive Structures

Spore producing organ

The Synanagium

1. Sporangia are borne in triads on minute appendages.
2. Sporangia are present in fused group and hence are called Synangium.
3. The wall of the trilobed synangium is made up of 4-5 layers of cells.
4. The outermost layer of the wall is prismatic.
5. Three chambers of spore cavities containing spores are present in synangium.
6. All the spores are of the same type.

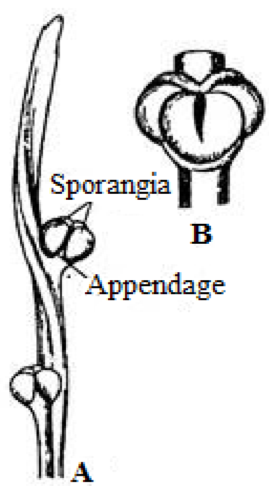


Fig. 8.9: A- Fertile axis bearing sporangia, B- Trilocular synangia showing dehiscence

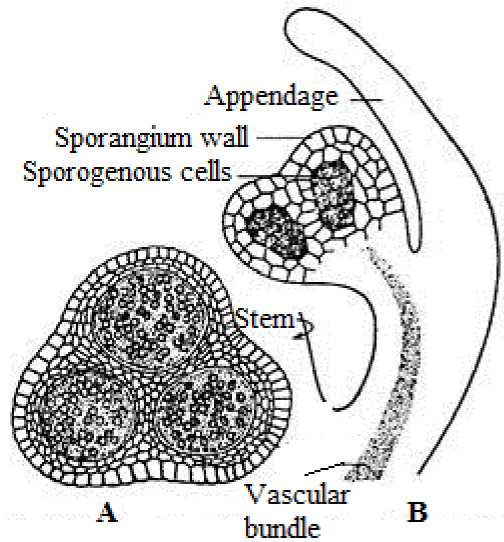


Fig. 8.10: A- T.S. synangium, B- V.S. of fertile axis through a synangium

Antheridia

1. Antheridium develops from a superficial cell called and antheridial initial.
2. A mature antheridium is small and spherical in shape and projects out of the gametophyte as a hemispherical protuberance.
3. The jacket is made up of about 12 cells and has a special cell called the opercula cell which degenerates at maturity and thus liberates the antherozoids.
4. Approximately about 250 antherozoids are found inside the antheridium.

Archegonia

1. Archegonia develop superficially on the surface of the gametophyte.
2. It has flask-like structure which is consisted of a bulbous venter and a long neck.
3. Neck region of archegonium is composed of 4 vertical rows of cells of 4 to 5 cells.
4. Venter contains an egg and a venter canal cell.

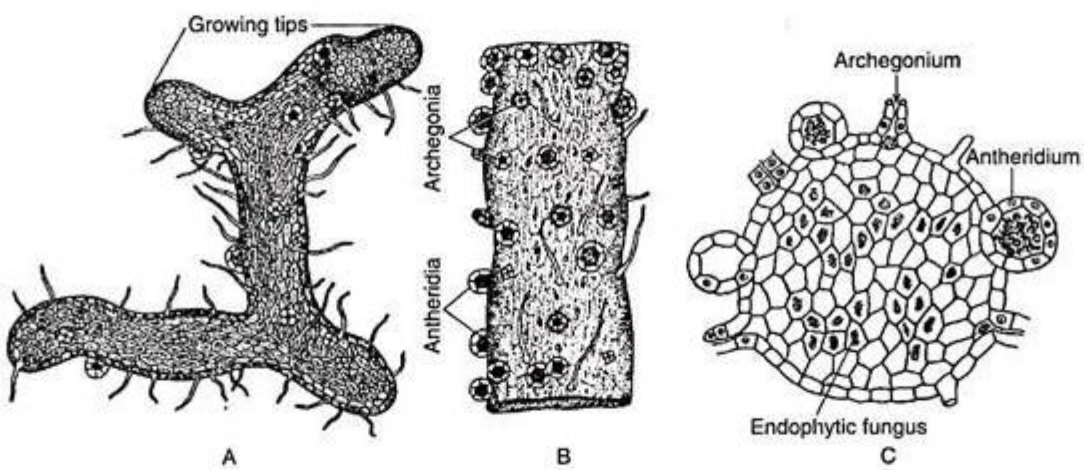


Fig. 8.11: A- gametophyte, B- An enlarged portion of the gametophyte showing sex organs and rhizoids, C- T.S. of gametophyte

8.3.3 *Lycopodium*

Lycopodium is a genus of clubmosses, also known as ground pines or creeping cedar. They reproduce by spores through asexual means. The plants can also produce gametes, and thus alternates their lifecycle to the spore-producing plant.

Scientific Classification

Kingdom: Plantae
Division: Lycopodiophyta
Class: Lycopodiopsida
Order: Lycopodiales
Family: Lycopodiaceae
Subfamily: Lycopodioideae
Genus: *Lycopodium*

Habit and Habitat: It has about 400 species and they are nearly found everywhere hence considered as cosmopolitan in distribution. They are found in both colder arctic region and temperate, tropical and sub-tropical regions but they are mostly abundant in tropical zones. Thirty three species of *Lycopodium* are found in India. Mostly, it grows in moist and shady places which are rich in humus and other organic matters. Some of the common species are *L. clavatum*, *L. phlegmaria, L. cernuum*, etc.

External Features

1. They are flowerless, vascular, terrestrial or epiphytic plants.
2. They have widely branched, erect, prostrate or creeping stems, with small, simple, needle-like or scale-like leaves that cover the stem and branches thickly.
3. The leaves contain a single, unbranched vascular strand and are called microphylls.
4. The kidney-shaped or reniform spore-cases (sporangia) contain spores of one kind only (isosporous, homosporous) are present on the upper surface of the leaf blade of specialized leaves called sporophylls.
5. The club-shaped fertile stems are the reason for name “the clubmosses’’.

Roots

1. The primary root or first formed root, present in young sporophyte is ephemeral, short-lived.
2. Dichotomously branched adventitious roots are present in older plants.
3. The basal part of the stem in species like *Lycopodium selago* and *Lycopodium compactum* is prostrate.
4. Some of the species have prostrate creeping stem e.g., *Lycopodium clavatum* and *Lycopodium cernuum* which bear roots all along its length.

Leaves

1. The leaves are simple, eligulate, sessile and small with a single unbranched mid-vein called microphyIIs.
2. They are generally lanceolate in shape with a narrow apex and slightly broad base.
3. The margins on the leaves are generally entire but may be serrated sometimes e.g., *L. serratum.*
4. Phyllotaxy is helical as in *L. clavatum* but the arrangement of leaves can appear opposite decussate as found in *L. complanatum*, *L. alpinum* or whorled e.g. *L. cernuum.*
5. The leaves can also be decurrent i.e. the leaf base is fused with and extends down the stem to varying degree).
6. The leaves can be Isophyllous or Homophyllous.
7. The leaves can show dimorphism e.g. Anisophylly or Heterophylly.

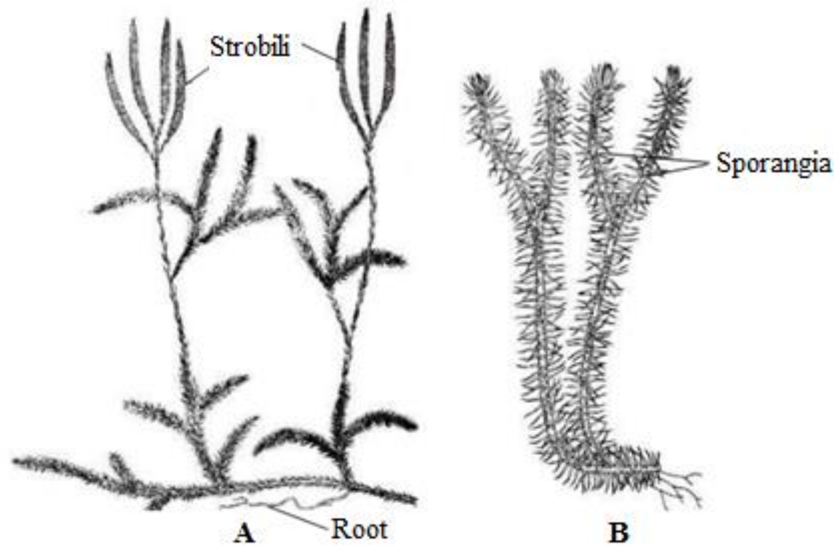


Fig. 8.12: Complete plant of (A) *L. clavatum* (B) *L. selago*

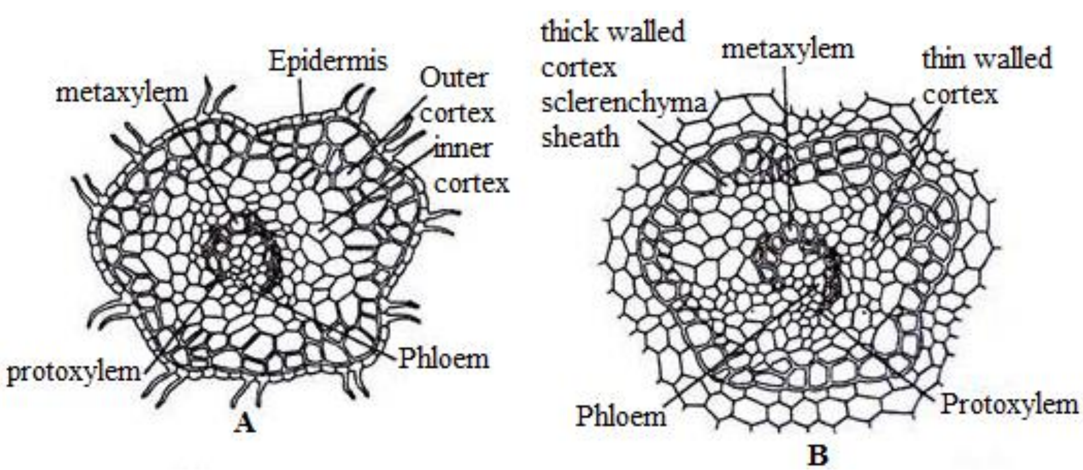


Fig. 8.13: A-Aerial root, B- Cortical root

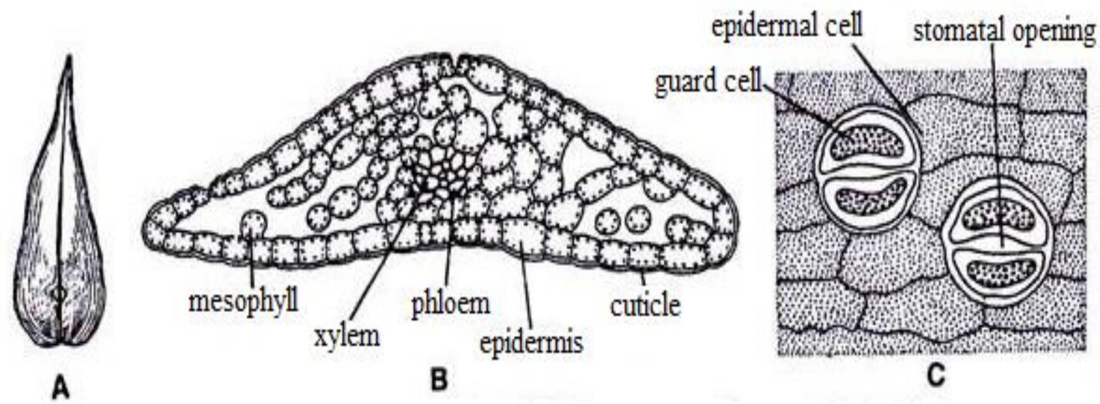


Fig. 8.14: A- leaf, B- T.S. of leaf, C- Stomata on leaf surface

Stems

1. Stems are weak, slender and rhizomatous.
2. They can be erect e.g., *L. selage* or pendent e.g., *L. phlegmaria*.
3. They can have prostrated creeping which can be sparsely e.g., *L. annotinum* or profusely branched e.g., *L. obscures*.
4. The branching is typically dichotomous in the members of the sub-genus Urostachya, but it is first dichotomous and later becomes monopodia in case of Rhopalostachya.
5. The stem and branches are covered with small leaves which are known as microphylls.

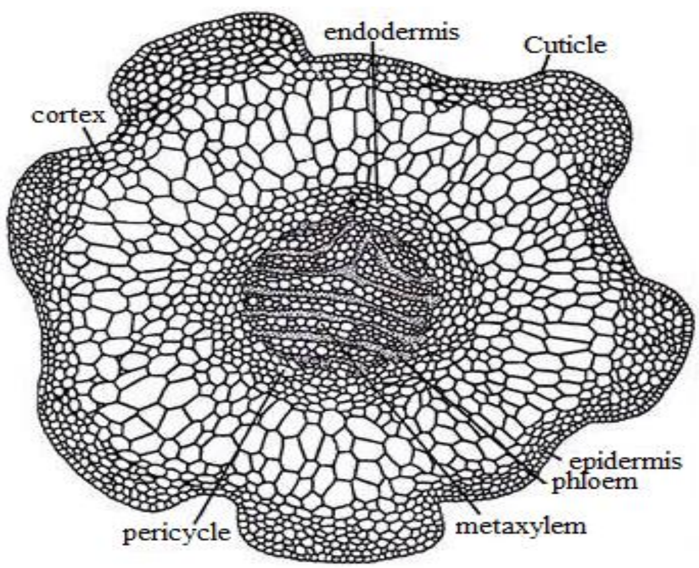


Fig. 8.15: T.S. of Stem *L. clavatum*

Reproductive Structures

Spore bearing organs

1. Sporangia are sac-like structures but generally are kidney shaped in appearance.
2. They may be sub-spherical in appearance.
3. Their colour varies from orange to yellow.

4. Each sporangium consists of a basal short massive stalk which is sub-sessile and an upper globular unilocular body containing numerous spores.
5. The body of the sporangium consists of 3 or more layers of wall surrounding a cavity.
6. The inner most layer of the wall of sporangium is called tapetum which provides nutrition to sporangia and persists till maturity.
7. The wall of the sporangium is made up of transverse strip of cells known as stomium.
8. The sporangium at maturity splits into 2 valves resulting in spores dispersal through wind.
9. The spores produced by a sporangium are homosporous and are small, rounded or even spherical structures.
10. The surface of the spores is usually rough due to the presence of reticulate ridges or knob like protrusions.
11. Each spore is provided with a triradiate ridge and is nearly yellow in colour.
12. A small amount of chlorophyll may or may not be present in spores.
13. Oil is stored as a Reserve food.

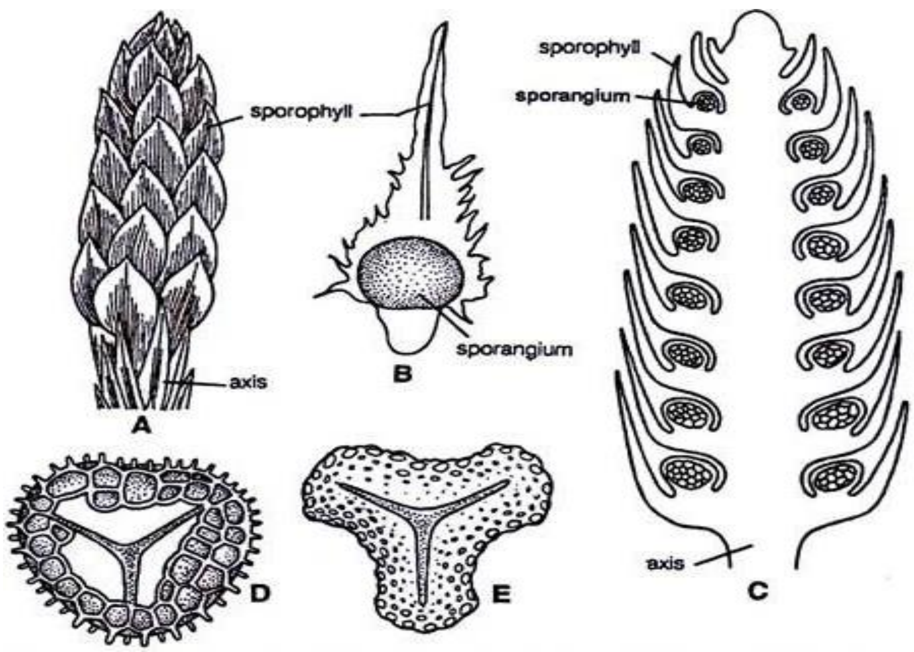


Fig. 8.16: (A-E)- *Lycopodium*: Structure of strobilus; A- A strobilus, B- Longitudinal section of strobilus, C- A sporophyll showing sporangia on the adaxial surface, D-E- Spores

Gametophyte

1. Prothallus can be sub-aerial or subterranean.
2. Sub-aerial prothallus is inconspicuous having height of 2-3 mm and 1-2 mm diameter.
3. Subterranean type prothallus is non-green and 1-5 mm long.
4. Prothalli are monoecious and embedded sex organs are present with the tissue.

Antheridium

1. A single superficial cell situated just away from the meristematic cells is responsible for giving rise to an antheridium which is known as antheridial initial.

2. The jacket initial divides only anticlinal by several divisions resulting in the formation of single layered covering known as jacket layer.
3. In the middle of the jacket layer, a triangular cell known as opercula cell is differentiated.
4. The primary androgonial cell is divided by various divisions which results in the formation of a mass of cells embedded in the prothallus, known as androgonial cells which is responsible for giving rise to androcytes.
5. The number of androcytes per antheridium varies in different species.
6. Each androcyte later on by metamorphosis develops into a biflagellate antherozoid.
7. Each antherozoid is a haploid, uninucleate, fusiform structure with broad rounded posterior end and an upper pointed biflagellated anterior end.

Archegonium

1. Archegonium arises from a single superficial cell called archegonial initial which is situated at the apex, away from the meristematic cells.
2. A variable number of neck canal cells are present in different species such as one in *L. cernuum*; seven in, *L. selago* and 14-16 in *L. complanatum*.
3. The primary ventral cell may act as an egg or may divide transversely to form an upper ventral canal cell and a lower egg.
4. The egg is broader than the rest part of archegonium.
5. The archegonial jacket is absent.
6. The archegonium has a sunken flask shaped structure with neck projecting out of the prothallus.

8.3.4 *Lepidodendron*

Lepidodendron or scale tree, sometimes erroneously called "giant club moss", is an extinct genus of primitive, vascular, arborescent (tree-like) plant related to the lycopsids (club mosses). They were part of the coal forest flora. They were present the Carboniferous Period before going extinct and were actually more closely related to quillworts rather than modern club mosses.

Scientific Classification

Kingdom:	Plantae
Division:	Lycopodiophyta
Class:	Isoetopsida
Order:	Lepidodendrales
Family:	Lepidodendraceae
Genus:	*Lepidodendron*

Habit and Habitat: These arborescent plants were used to form extensive coal measures swamp forest of the Northern Hemisphere Euramerican province during the Carboniferous period. They are now extinct and hence only traces for once existence are found.

External Structures

1. The *Lepidodendron* was a large tree of height up to 50-60 m tall with a prominent trunk up to 35 m in height.
2. The ultimate dichotomies formed the leaves.
3. A crown bearing cones at their tips are formed from the branched and leaves.
4. The plant had bipolar growth because of which main axis developed branches at both ends.
5. The aerial branches bear branches and foliages which are similar to the basal branches formed which bears stigmarian root system.

Stem

1. The trunk of the stem attained a height up to 30-35 m.
2. The first branching at a distal end appeared up to 30-35 m in height.
3. The trunk’s diameter at the base is 3.3 ft (1 m).
4. Many spirally arranged leaves are present on the stem surface.

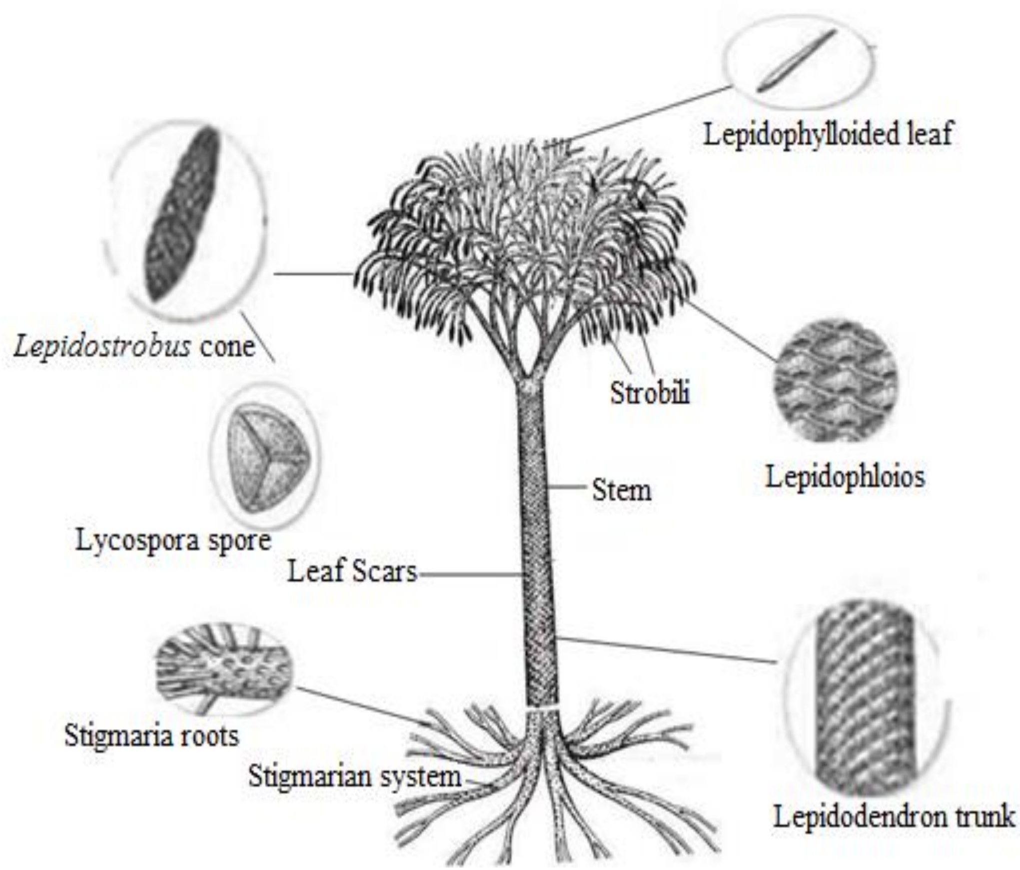
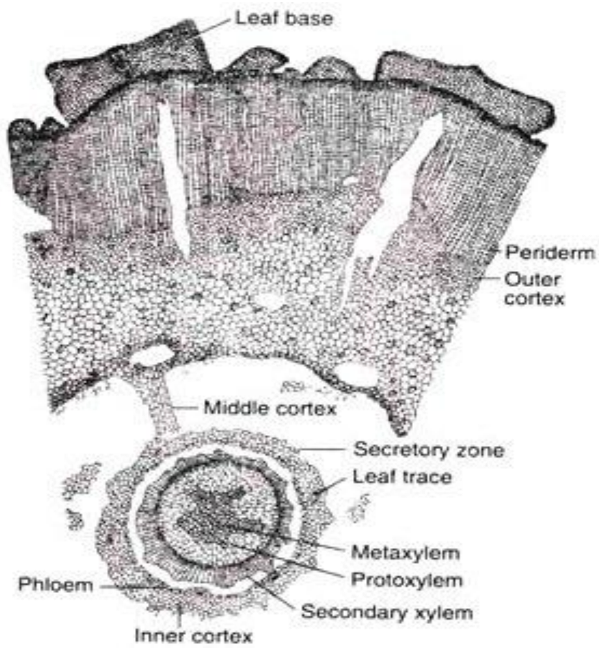
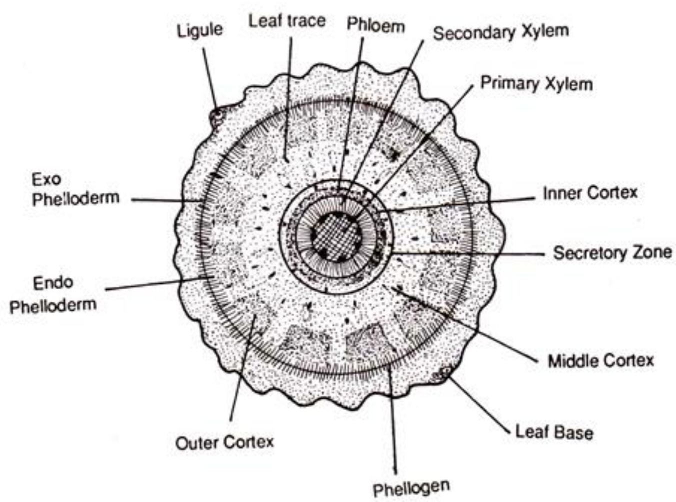


Fig. 8.17: Morphological Structure of *Lepidodendron*



A



B

Fig. 8.18: (A-B)- T.S. stem of *Lepidodendron*

Leaves

1. The leaves were microphyllous ligulate, generally linear, acicular or awl-shaped.
2. They are grown on the small penultimate or ultimate branches.
3. The leaves were deciduous and had swollen photosynthetic bases (leaf cushion) that attached to the base even after the shedding of laminae.
4. The size of the leaf cushion was dependent upon diameter of the shoots.
5. The smallest twigs have smallest leaf cushions.

Rhizomorph

1. Root-bearing underground axes are called rhizomorph.
2. The detached rhizomorph and their roots are called Sigmaria which are mostly found as siliceous casts or molds.
3. The younger portions of the Stigmaria had spirally arranged roots which are known as Stigmarian rootlets.
4. The older portions of the Stigmaria had spirally arranged root scars that might have abscissed.

Reproductive Structures

1. The strobili of *Lepidodendron* are called Lepidostrobus.
2. They had a central axis bearing spirally arranged or whorled sporophylls.
3. The sporophylls were ligulate and may be peltate which bears a single, sessile, elongate sporangium on their adaxial face.
4. It is supposed that some sporangia were trabeculate which are concerned with nutrition.
5. The strobili were heterosporous with the megasporophylls present in the form of aggregate towards the base.

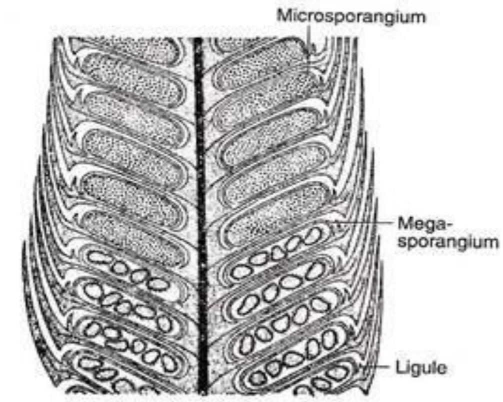


Fig. 8.19: L.S. of *Flemingites* cone

8.3.5 *Selaginella*

Selaginella is the only genus of primitive vascular plants in the family Selaginellaceae. They are also called the spikemosses or lesser clubmosses.

Scientific Classification

Kingdom: Plantae
Division: Lycopodiophyta
Class: Isoetopsida
Order: Selaginellales
Family: Selaginellaceae
Genus: *Selaginella*

Habit and Occurrence: This genus comprises about 700 species and about 58 species have been found in different parts of India. Majority of species are tropical and grow in rain forests. Some species are grown upon bare rocks and dry soils and are considered as xerophytic plants e.g. *S. rupestries* and *S. lepidophylla* and are called as 'resurrection plants' whereas some species are moist loving and found in the shady places of hills. In India, majority of species are commonly found in the Himalayas and hills of south India. Species like *S. oregano* grows as an epiphyte upon the trunks of trees covered with moss plants. Some species are quite small and moss like e.g. *S. spinulosa* but some attain the length of even twenty metres as in *S. willdenovii*. Some species are prostrate and creeping as in *S. kraussiand*, some are sub- erect e.g., *S. erythropus*. Some species are climbing and climb with the help of rhizopores as present in *S. alligans*.

External Structure

1. On the basis of general structure of stems, plant can be Homeophyllum and Heterophyllum
2. The examples of sub-genus Homoephyllum are – *S. pygmaea, S. spinulosa, S. rupestris,* etc, which possess erect stem and the same sized spirally arranged leaves covering the stems.
3. The sub–genus Heterophyllum comprises of species such as *S.kraussiana, S. lepidophylla, S. martenssi*, etc which possess prostrate stem, short erect branches and dimorphic leaves.

Stems and leaves

1. The stem is covered over with four rows of leaves in sub-genus Heterophyllum.
2. Prostrate stem, short erect branches and the different sized (dimorphic) leaves are the characteristics of sub-genus Heterophyllum.
3. The prostrate stem is dorsiventral.
4. The leaves are arranged in pairs; each pair consists of two different sized leaves.
5. The large leaf of each pair is inserted on the ventral side of the axis.
6. The pairs of leaves are arranged in such a way, that small leaf alternates with large leaf.
7. The leaves are quite small in size, triangular or lanceolate in structure.
8. The leaves may be moist and thin but thick in xerophytic species.

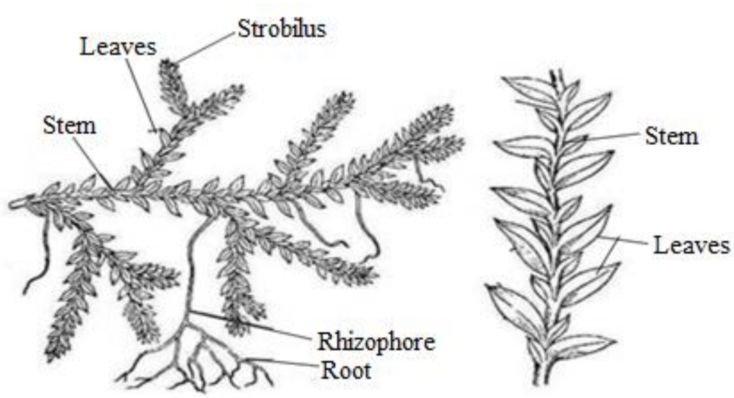


Fig. 8.20: *Selaginella Kraussiana* (A) Sporophyte portion, (B) Part of stem and leaf

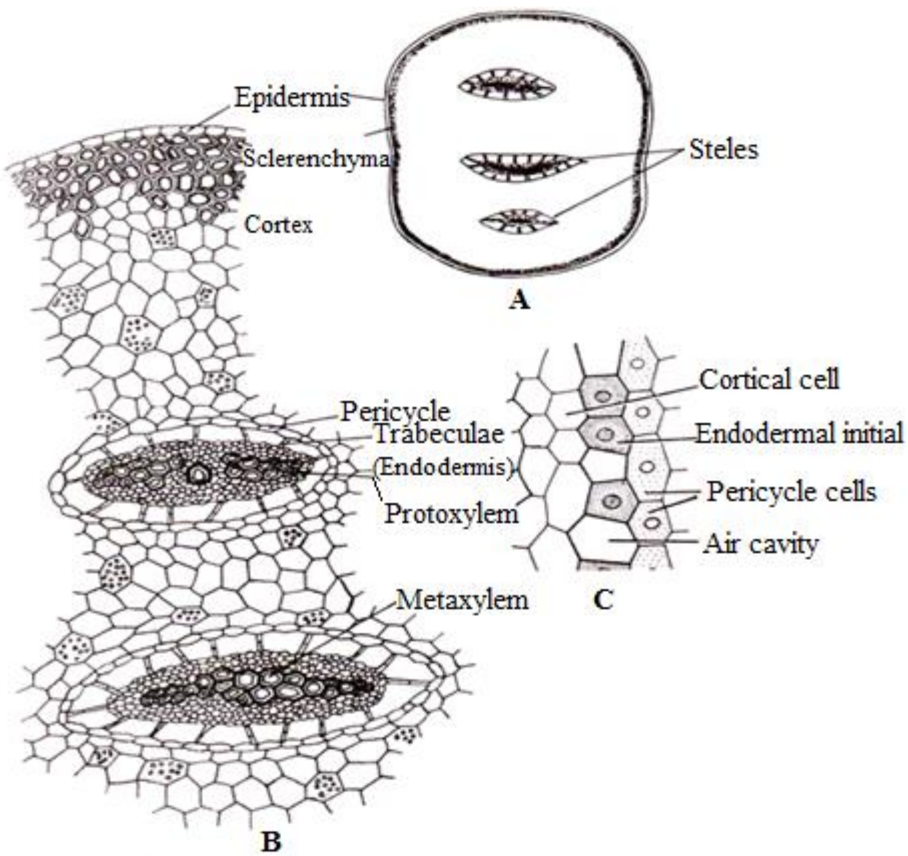


Fig. 8.21: A- Ground plan, B- A sector enlarged, C- Development of trabeculae

Ligule

1. The leaves are ligulate; each leaf bears a thin membranous thin ligule at its base; the ligule is found in upper or ventral surface.
2. The mature ligule has thin, membranous like shape.
3. Hemispherical mass of thin-walled cells known as glossopodium is presented adjacent to the sheath.

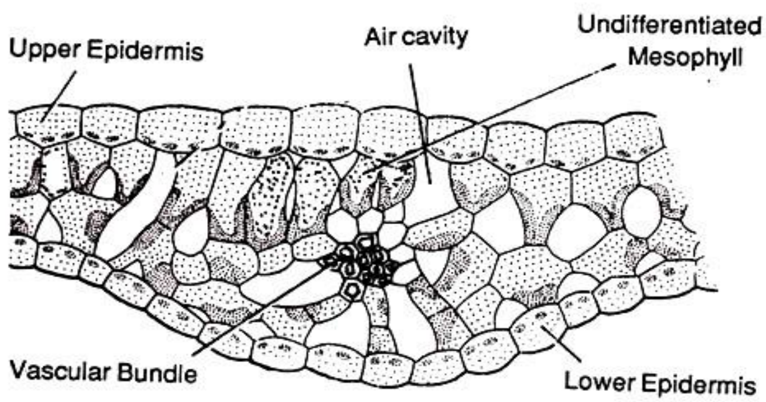


Fig. 8.22: T.S. of Leaf

Rhizopores or roots

1. The prostrate axis bears an elongate, colourless, leafless, cylindrical, downwardly growing structure called the rhizopore which arise from the axis ramifications.
2. At the terminal end of rhizopore, a tuft of adventitious roots develops at the terminal end of rhizopore e.g., in *S. kraussiana*.
3. The adventitious roots are thin, slender, delicate, and dichotomously branched.

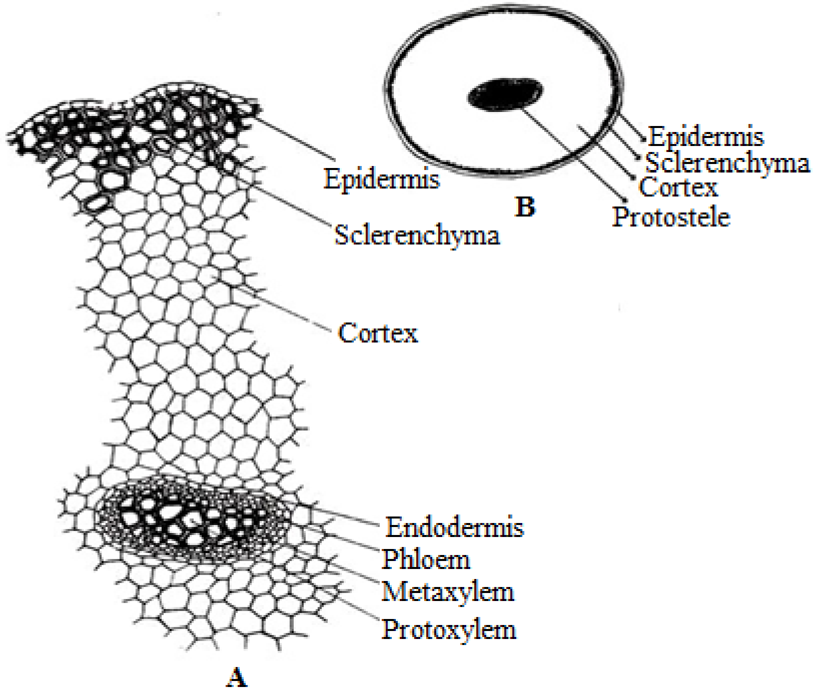


Fig. 8.23: Internal structure of Rhizophore, A- Ground Plan, B- A sector enlarged

Reproductive Structures – Spore Producing Organs

Strobilus or Spike:

1. The Strobilli or spikes are the spore producing structures which develop at the apices of the branches.

2. The strobilus is compact structure of sporophylls.

3. The structure of sporophylls is similar to that of ordinary vegetative leaves.

4. Each sporophyll bears a ligule at its base.

5. Each sporophyll bears a single stalked sporangium which is situated in the axil on the adaxail side between ligule and its base.

6. The sporangia are of two types i.e., microsporangia and megasporangia.

7. The sporophyll that bears microsporangium is microsporophyll and the one that bears megasporangium is megasporophyll.

8. Both micro and megasporophyll may be found in same strobilus e.g., in *S. kraussiana* or in different strobili e.g. *S. gracillis* and *S. atroviridis.*

9. The strobilius which bears both kinds of sporophylls, in which the megasporophylls are found in lower portion of strobilus and microsporophylls are present in the upper portion of strobilus axis e.g., in *S. spinulosa* and *S. rupesris*.

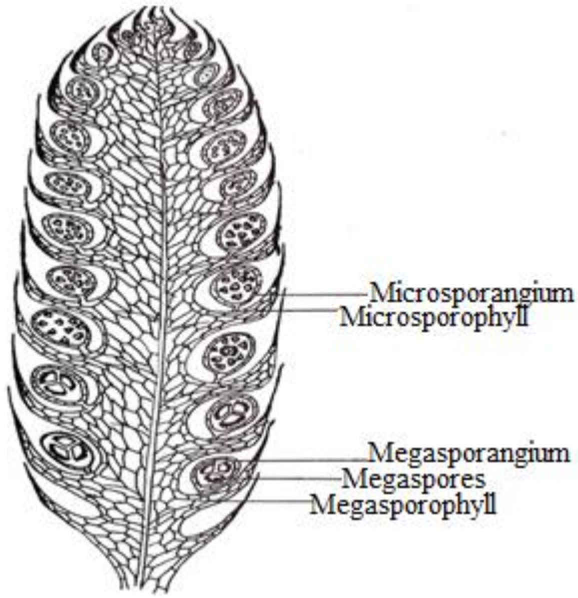


Fig. 8.24: L.S. of strobilus

The Sporangia

1. The sporangia with megaspores are called megasporangia whereas sporangia with microspores are called microsporangia.
2. Both mega and microsporangia are stalked.
3. Two layered thick sporangium is present in which the outer layer of the wall is composed of thick- walled, columnar cells having chloroplast in them and the inner layer of the wall is composed of thin walled cells.
4. The tapetum as a nutritional wall is presents beneath the two layered sporangial wall.
5. The mature microsporangium is red yellow or brown in color.
6. Each microsporangium contains numerous microspores.
7. The mega sporangia are pale or whitish in color and the megaspores found within the megasporangium are either pale or yellow.
8. The mature megasporangium is four lobed and each lobe bears a single megaspore.
9. The microspores are quite small with diameter ranging from 0.015 to 0.06mm and have Spherico-tetrahedral shape but spherical at the distal face of the spore.
10. Each microspore is covered by spore coats which is thick on outer side and ornamented, known as exine or exospores whereas the inner coat is devoid of endospore.
11. The microspores contain oil droplets and are devoid of chlorophyll.
12. The megaspors are quite big in size with diameter ranging from 1.5 to 5 mm.
13. The shape of each megaspore is tetrahedral.
14. A triradiate ridge is found on each spore.

15. Each megaspore is surrounded by two spore coats i.e. the exposure which is thick and ornamented (tuberculate, Spinose or reticulate) while the endospore which is quite thin.

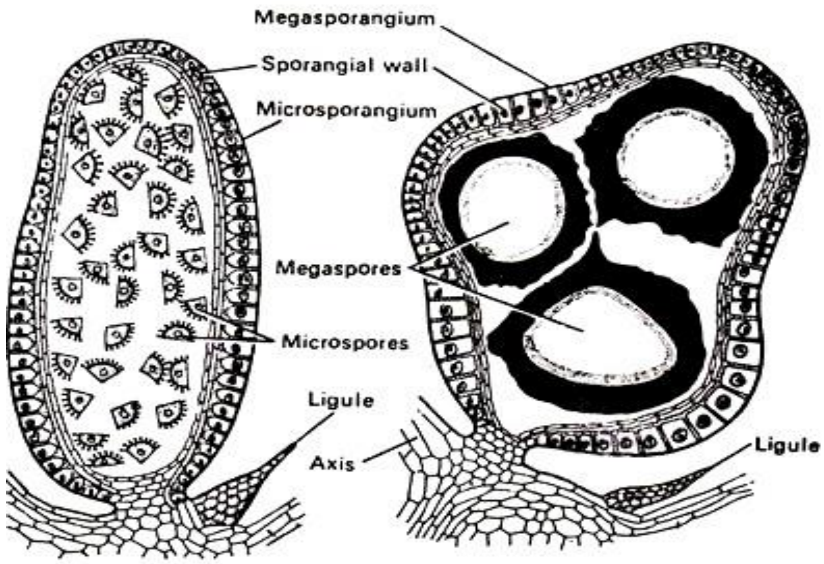


Fig. 8.25: A- Structure of mature microsporangium, B- megasporangium

8.3.6 *Isoetes*

This plant's characteristics are similar to a monocot garlic plant and they are commonly called 'Quill wort' due to the quill like structure of the leaves i.e. a large feather like structure.

Scientific Classification

Kingdom: Plantae
Division: Lycopodiophyta
Class: Isoetopsida
Order: Isoetales
Family: Isoetaceae Rchb.
Genus: *Isoetes* L.

Habit and Habitat: This genus contains nearly 100 species, among which 5 species are reported in India which are *I. coromandelina, I. sahayadrii, I, Dixitii, I.Sampatkumarinii and I. panchananii*. *I. coromandelina* is the most common species and hence is widespread in occurrence. Most of the species are aquatic and grow immersed in water whereas other species are commonly found in swampy or marshy place.

External Structure of Sporophyte

1. The plant body is differentiated into three parts roots, leaves and stem.
2. The plant body is composed of a condensed, lobed corm or axis.
3. Corm possesses a tuft of roots at the base and long feathery leaves on the top.

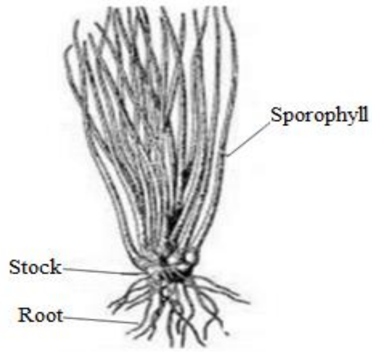


Fig. 8.26: *Isoetes coromandelina* Sporophytic plant

Corm or Axis

1. Commonly stem is known as 'corn' which bear roots on the lower surface and leaves on the upper surface.
2. The corm or axis is a condensed structure which acts as an erect rhizome, stock, corm or stem.
3. The stem is differentiated into an axis (upper leaf bearing part) and rhizomorph (grooves bearing).
4. The upper erect portion is the stem axis from which leaf traces are arising.
5. The rhizomorph is the lower horizontal part bearing root traces.
6. The axis of the stem is covered with dried leaf bases and roots of the previous year.
7. The lower part of the axis is divided through a broad basal groove into 2-3 or rarely 4 lobes and the roots develop from them in definite rows radiating across each lobe.
8. The younger roots are borne nearer the groove, while the older ones are away from it.
9. The spirally arranged leaves cover the apical meristem and can be seen after pulling out all the leaves.
10. The stem is quite short and the upper part covered with the broad bases of the leaves in overlapped fashion.
11. The old stem possesses two or three vertical grooves which unite on the below part of the stem whereas in its upper part, the stem bears many densely crowded long, stiff, rush-like leaves.

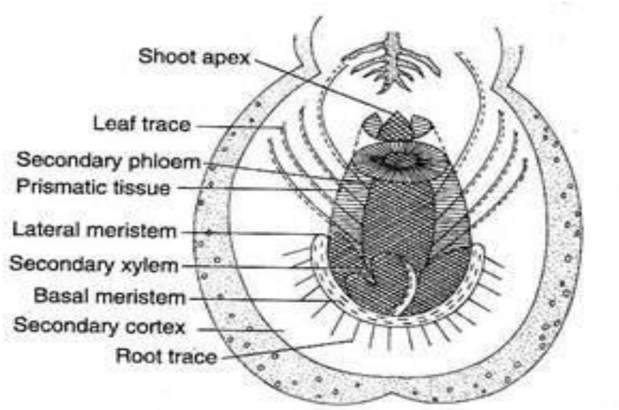


Fig. 8.27: L.S. of the Axis of *Isoetes*

Leaf

1. The leaves are quill-like, develop from the apical meristem.

2. The leaves are borne in acropetal order which overlap with one another in a close spiral arrangement i.e. phyllotaxy.
3. The leaves are microphyllous, ligulate, sessile with expanded base and an abruptly tapering apex.
4. All the leaves are potentially fertile and thus are called sporophylls.
5. Each leaf has a characteristic triangular cordate base and colourless ligule on adaxial surface, and a small flap-like velum in-between sporangium and ligule.
6. They are heterosporous which means micro and megasporophylls are either distributed irregularly on the axis or they are arranged successively from periphery to centre.
7. Each leaf bears an expanded broad sheath with membranous edge.
8. The lowest leaves found on the stem are sterile.
9. Towards the upper side of the stem, the macrosporophyllus, microsporophyllus and imperfectly developed leaves are present.

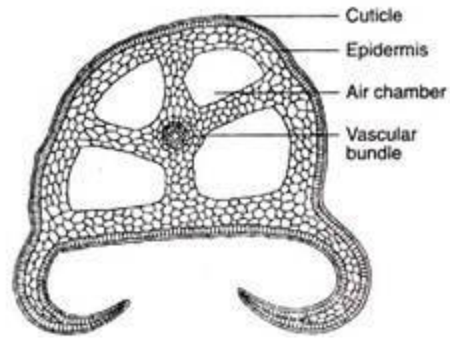


Fig. 8.28: T.S. of Leaf of *Isoetes*

Root

1. Numerous adventitious roots are developed from the basal part of the stele.
2. The roots are dichotomously branched, bearing numerous root hairs.
3. The roots arise from the lower surface of the stem.
4. The roots are dichotomously branched.
5. Roots mostly cover the complete lower surface of plant.

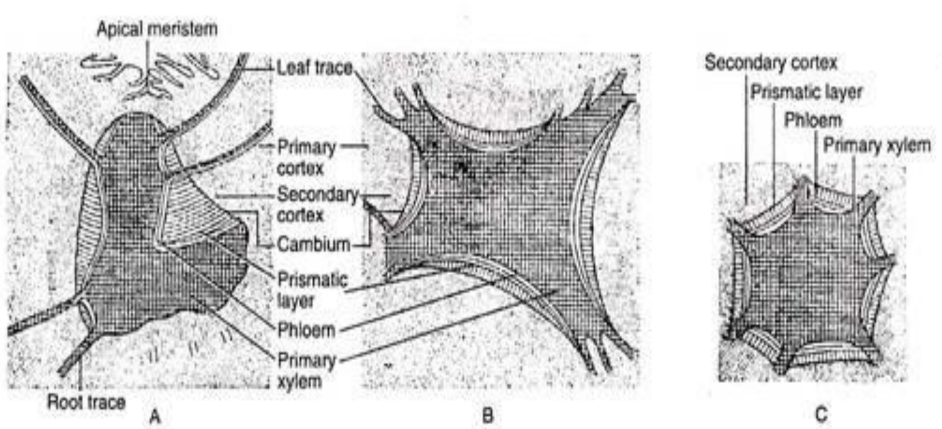


Fig. 8.29: A- V.S. of stock showing one rhizomorph, B- T.S. of stem axis, C- T.S. through rhizomorph part

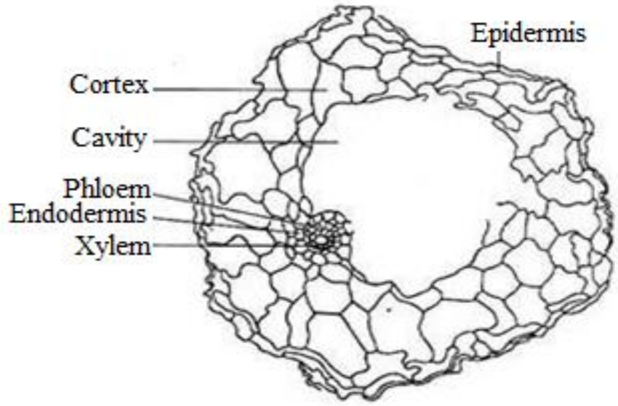


Fig. 8.30: T.S. root of *Isoetes coromandelina*

Reproductive structure

Spore Producing Organs

Sporangia

1. Isoetes is a heterosporous lycopod which produces both the microspores and megaspores.
2. Microspores are produced in microsporangia and megaspores are produced in megasporangia.
3. Two types of sporophylls callled microsporophyll-bearing microsporangia and megasporophyll-bearing megasporangia are present.
4. The plant bears both the sporophylls in which it produces megasporangia first and then followed by microsporangia production and, finally, abortive sporangia.
5. Isoetes produces 50 to 300 megaspores per megasporangium and about 150,000 to 1,000,000 microspores per microsporangium.
6. The sporangium is partially or completely divided by plate-like trabeculae from the internal region.

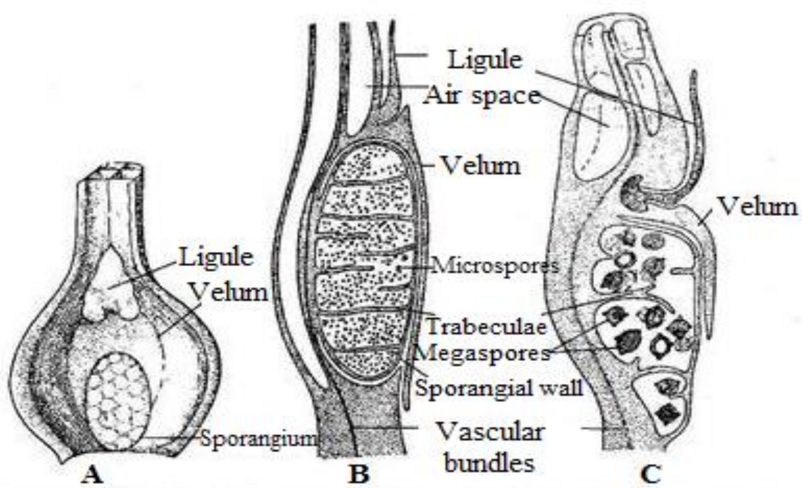


Fig. 8.31: A- Basal Part of Sporophyll, B- Median L.S. of Microsporophyll base, C- Median L.S. of megasporophyll base

Gametophytes

The microspores and megaspores germinate endosporically, producing male and female gametophytes, respectively.

Male Gametophyte

1. Microspores are small with 30-40 µm diameters and have triangular shape with trilete apertures.
2. Microspores germinate immediately after falling upon a suitable substratum and hence a male gametophyte is formed within a few days.
3. The primary androgonial cell forms four androcytes.
4. A mature male gametophyte is consisted of nine cells: one prothallial cell, four jacket cells and 4 androcytes.
5. Each androcyte metamorphoses into a corkscrew-shaped, multiflagellated (about 15 flagella) antherozoid with a terminal vesicle.

Female Gametophyte

1. The megaspores are comparatively larger and have 250-900 µm diameters than microspores.
2. They are triangular in shape with trilete aperture.
3. The exine is provided with large spinulate projections.
4. A mature archegonium has a neck which is composed of four vertical rows of neck cells (4 cells in each row), one neck canal cell, one ventral canal cell and an egg.

8.3.7 Sphenophylum

Sphenophyllum is a genus present in the order Sphenophyllales. This genus includes species of leaves, stems, roots, and even whole plants.

Scientific Classification

Kingdom:	Plantae
Division:	Pteridophyta
Class:	Equisetopsida
Order:	Sphenophyllales
Family:	Sphenophyllaceae
Genus:	*Sphenophyllum*

Habit and Habitat: Sphenophyllales represent a small and compact group of sphenopsida which do not have any surviving member. They existed in carboniferous period. Some of the genera like Sphenophyllum appeared during Devonian period but reached maximum development during carboniferous period. A few members of Sphenophyllales survived upto Triassic period.

External Structures

1. The plant body of *Sphenophyllum* was small and herbaceous.
2. The plant might have a climbing habit.
3. Some morphological features prove that they might have an aquatic habitat, whereas some anatomical features suggest that they had a terrestrial habitat.
4. The plant body consisted of slender and jointed main stem, which is 5 mm in diameter.
5. The stem was ribbed which did not alternate at nodes.
6. Leaves were present in clusters at the nodal regions and they ranged from 6 to 9 at each whorl but the number might go up to 18.
7. The leaves were cuneate and the apex variously modified.
8. In *S. emarginatum*, the leaf apex had rounded teeth, while in *S. cunifolium* and *S. majus* the leaf had pointed teeth.
9. The leaves had veins with dichotomous branching, each branch terminating in an apical tooth.

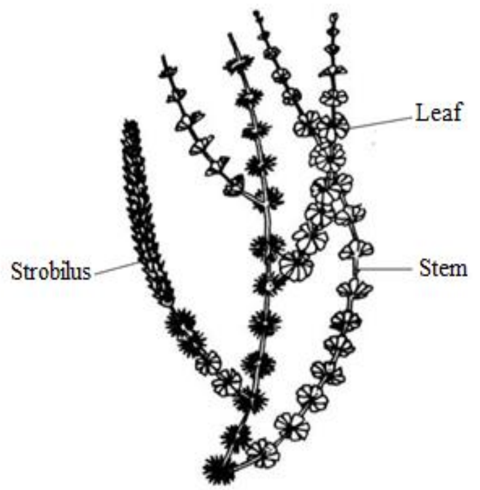


Fig. 8.32: Plant Structure of *Sphenophyllum cuneifolium*

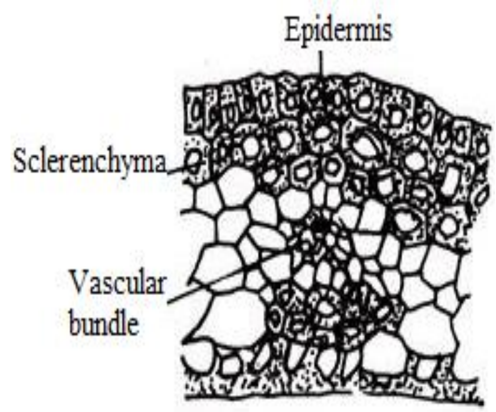


Fig. 8.33: T.S. of Leaf

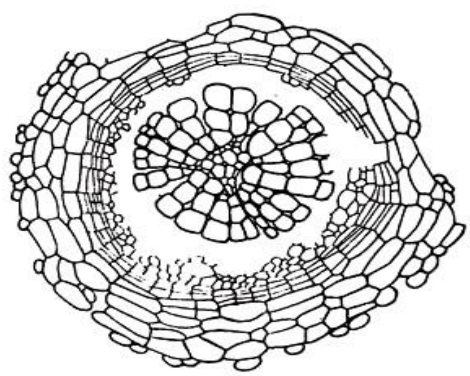


Fig. 8.34: T.S. of root of *Sphenophyllum*

Reproduction Structure

1. Sphenophyllum reproduced through sporangia which were present on sporophylls.
2. The sporophylls aggregated to form long and slender cones terminating the stem apex.

3. The cones which are also known as Bowmanites, had a central axis on which many whorls of sporophylls are arranged.
4. A saucer like structure was formed by the fusion of sporophylls of each whorl at their base.
5. The sporophylls were divided in two parts which are named as an adaxial fertile part and an abaxial sterile part.
6. The sporangia were borne on the fertile part which can be either singly or in pairs but in some cases the fertile lobe might had two or three branches each having one to two sporangia.
7. In *Sphenophylum*, the sporophyll is divided into sterile and fertile appendages.

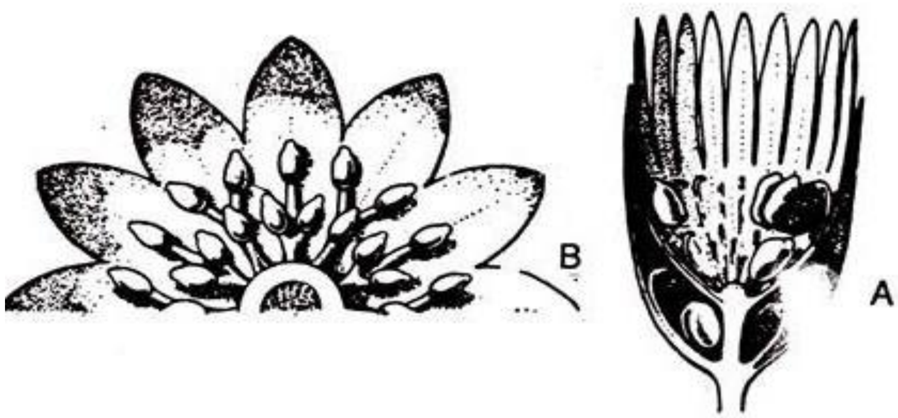


Fig. 8.35: A- L.S. of Strobilus, B- Top view of Strobilus of *S. dawsonii*

8.4 SUMMARY

Rhynia is rootless, leafless, spore-bearing plant. It is about 18 cm (about 7 inches) tall and possessed water-conducting cells in its stem called tracheids, much like those of most living plants. Its stems were photosynthetic, branched evenly many times, and produced elliptical sporangia at the tip of every branch. Another genus, *Horneophyton*, resembles *Rhynia*, but its sporangia were cylindrical and formed in pairs at the branch tips.
Psilotum is a genus of fern-like vascular plants, commonly known as whisk ferns. It is one of two genera in the family *Psilotaceae* and other being *Tmesipteris*. Basically the plant lacks true roots and leaves, the stems being the organs containing conducting tissue. They differ from those in *Tmesipteris* in having stems with many branches and a synangium with three lobes rather than two.
Lycopodium is a genus of clubmosses, also known as ground pines or creeping cedar, in the family Lycopodiaceae. They are flowerless, vascular, terrestrial or epiphytic plants, with widely branched, erect, prostrate or creeping stems, with small, simple, needle-like or scale-like leaves that cover the stem and branches thickly. Its leaves contain a single, unbranched vascular strand and are microphylls by definition. The kidney-shaped or reniform spore-cases (sporangia) contain spores and are borne on the upper surface of the leaf blade of specialized leaves (sporophylls) arranged in a cone-like strobilus at the end of upright stems.

Lycophyte belongs to the division Lycopodiophyta or Lycophyta. They are spore-bearing vascular plants. It is one of the club mosses and their allies, living and fossil. lycophytes are grouped in 6 genera *Huperzia*, *Lycopodiella*, and *Lycopodium*, the club mosses or "ground pines"; *Selaginella*, the spike mosses; the unique tuberous plant *Phylloglossum*; and *Isoetes*, the quillworts. Lycophytes are also known from rocks of the Devonian. The remains of *Lepidodendron* and other extinct lycophytes form most of the great coalbeds of the world. Many of the ancient lycophytes, such as *Lepidodendron*, were trees that often exceeded 30 metres (100 feet) in height. The living genera are all small plants, some erect and others low creepers. Regardless of their size or geologic age, all share certain group features. Branching is usually dichotomous; that is, the shoot tip forks repeatedly. The two branches that result may be equal in length or may be of different lengths. The leaves are generally small, although they sometimes achieved a length of one metre (three feet) in the gigantic *Lepidodendron*. Generally each leaf, or microphyll, is narrow and has an unbranched midvein, in contrast to the leaves of the ferns and seed plants, which generally have branched venation. The sporangia (spore cases) occur singly on the adaxial side (the upper side facing the stem) of the leaf.

Selaginella species are commonly known as spike moss or small club moss. Mostly the species inhabit damp and shaded forests of tropics, but some species (e.g., *S. densa, S. rupestris, S. lepidophylla*) grow in xerophytic habitats, such as exposed rock surfaces. *S. oregano* is an epiphyte that grows on tree trunks in tropical rain forests. Some researcher also reported that several species of *Selaginella* are grown in gardens as ornamentals. Some xerophytic species of Selaginella (e.g., *S. lepidophylla, S. pilifefra*) show caespitose habit; they curl and become ball like during dry season and again become green and fresh when moisture is available. The genus is represented in India by more than 70 species. Among these species, *Selaginella kraussiana, S. monospora, S. biformes, S. rupestris, S. megaphylla, S. bryopteris, S. ciliaris, S. chrysorhizos* and *S. pentagona* are common.

Isoetes, commonly known as the quillworts, belongs to class Isoetopsida and order Isoetales. They are lycopods and the only genus in Isoetaceae. They are one of the most primitive groups of vascular plants that currently exist on Earth. They form a unique class of lycophytes, although many species are now endangered. The quillworts are spore producing plants that rely heavily on water. They do not produce flowers, fruits, seeds or wood and have only a single vein that runs through their leaves.

Sphenophyllum is a genus in the order Sphenophyllales. The genus includes species of leaves, stems, roots, as well as whole plants. They existed in carboniferous period. Some of the genera like Sphenophyllum appeared during Devonian period but reached maximum development during carboniferous period. A few members of Sphenophyllales survived upto Triassic period.

8.5 GLOSSARY

Anisophylly or Heterophylly- It is the state of having dissimilar leaves on one plant.

Appendages- It is a projecting part of an invertebrate or other living organism, with a distinct appearance or function.
Arborescent- It is defined as tree-like in growth or appearance.
Columella- Columella (in plants) is an axis of sterile tissue which passes through the center of the spore-case of mosses.
Decussate- (of two or more things) cross or intersect each other to form an X.
Dichotomous- It is defined as in which the axis is divided into two branches.
Eligulate- Without ligules or not ligulate
Ephemeral- Lasting for a very short time.
Exosporic- Gametophyte develops outside the spore wall e.g.: free living multicellular gametophyte.
Isophylly or Homophylly- The state of having leaves all of the same morphology on 1 plant.
Lanceolate- Shaped like a lance head; of a narrow oval shape tapering to a point at each end.
Metamorphosis- Metamorphosis is a biological process by which an animal physically develops after birth or hatching, involving a conspicuous and relatively abrupt change in the animal's body structure through cell growth and differentiation; or a plant changes its morphology.
Mycorrhiza- It is a symbiotic association between a fungus and the roots of a vascular host plant.
Opercula- A part or organ serving as a lid or cover, as a covering flap on a seed vessel.
Phyllotaxy- It is the arrangement of leaves on an axis or stem.
Prismatic- It is relating to or having the form of a prism or prisms.
Protuberances- It is anything that protrudes from something else.
Pteridophytes- A pteridophyte is a vascular plant (with xylem and phloem) that disperses spores (and lacks seeds).
Sporangia- It is (in ferns and lower plants) a receptacle in which asexual spores are formed.
Sporophytic- A sporophyte is the diploid multicellular stage in the life cycle of a plant or alga.
Stigmarian- Belonging to, resembling, or containing fossils of the genus Sigillaria.
Subterranean- Existing, occurring, or done under the earth's surface.
Synangium- It is a sorus (as in ferns of the family Marattiaceae) made up of sporangia variously united or cohered into a compound structure.
Trabecula- A trabeculum is a small, often microscopic, tissue element in the form of a small beam, strut or rod that supports or anchors a framework of parts within a body or organ.
Triquetrous- It means triangular; especially having a triangular cross-section.
Vascular plants- Any of various plants that have the vascular tissues xylem and phloem, also known as tracheophytes.
Vasculature- It is the vascular system of a part of the body and its arrangement.

8.6 SELF ASSESSMENT QUESTIONS

8.6.1: Fill in the Blanks:

1. Which vascular plant has deciduous lateral branches, which it used to disperse laterally over the substrate?
2. ________can be sub-aerial or subterranean in Lycopodium.
3. Which vascular plant is also known as Whisk Fern?
4. The cones of the *Sphenophyllum* are known as________
5. What are the spore producing organs for Selaginella?
6. The club-shaped fertile stems are the reason for name for plant _________?
7. The strobili of Lepidodendron are called ____________.
8. *Selaginella* is more commonly called the ________ then _________.
9. The detached rhizomorph and their roots are called ________ in Lepidodendron.
10. The wall of the sporangium of ____is made up of transverse strip of cells known as stomium.
11. Three chambers of spore cavities containing spores are present in synangium in which vascular plant?
12. In Lycopodium, leaves contain a single, unbranched vascular strand and are called ________.

8.6.1 Answer Key: 1-Rhynia, 2-Prothallus, 3-Psilotum, 4- Bowmanites, 5- Strobilli or spikes, 6- Lepidostrobus, 7- The Clubmosses, Lycopodium, 8- Spikemosses, clubmosses, 9- Sigmaria, 10- Lycopodium, 11- Psilotum, 12- Microphylls

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8.9 TERMINAL QUESTIONS

1. What is the systematic position of *Selaginella*?
2. What are the major distinguishable characteristics of *Lycopodium*?
3. What were the characteristic features of *Rhynia*?
4. Give some detail about the reproductive structures of *Lycopodium*?
5. What kind of habitat does *Psilotum* have?

UNIT-9 MORPHOLOGICAL STUDY OF REPRESENTATIVES OF PTERIDOPHYTES-II

9.1 OBJECTIVES

After reading this unit students will be able to study the plant morphology of pteridophytes i.e. - *Equisetum, Osmunda, Hymenophyllum, Dryopteris, Adiantum, Marsilea, Salvinia, Azolla.*

9.2 INTRODUCTION

Pteridophytes consist of both living and extinct genus and species. They are also known as Cryptogams because of the lack of presence of flowers and seeds. They are vascular plants which reproduce through spores. The pteridophytes include the ferns, horsetails, and the lycophytes which are clubmosses, spikemosses, and quillworts. Their life cycle shows alternation of generations in which a diploid generation (the sporophyte, which produces spores) is followed by a haploid generation (the gametophyte or prothallus, which produces gametes). Pteridophytes are independent and free-living, although their sporophytic structure is generally much larger and more conspicuous.

9.3 MORPHOLOGICAL STUDY SUCH AS EXTERNAL STRUCTURE, LEAVES, STEM, ROOT AND REPRODUCTIVE STRUCTURE OF REPRESENTATIVE PTERIDOPHYTES

9.3.1 *Equisetum*

Equisetum is the only living genus in family Equisetaceae and hence considered as "living fossil", also known as horsetail, snake grass, puzzle grass.

Scientific Classification

Kingdom:	Plantae
Division:	Pteridophyta
Class:	Equisetopsida
Order:	Equisetales
Family:	Equisetaceae
Genus:	*Equisetum*

Habit and Habitat: *Equisetum* is cosmopolitan in distribution but majorly is present in the non-tropical northern hemisphere. They are most common in northern North America i.e. in Canada and the northernmost United States. They are perennial plants, herbaceous and dying back in winter as most temperate species, or they may be evergreen as most tropical species and the temperate species rough horsetail (*E. hyemale*), branched horsetail (*E. ramosissimum*), dwarf horsetail (*E. scirpoides*) and variegated horsetail (*E. variegatum*).

External Structure

1. The plant body of this genus has an aerial part which is herbaceous and usually annual and an underground rhizome part.
2. The rhizome nature is perennial, horizontal, branched and creeping.
3. Its species are smaller in size ranging from 15 to 60 cm in height and 2.0 cm in diameter.
4. Some species may grow up to varying heights such as *E. giganteum* (13 m), *E. telmateia* (2 m), *E.ramosissimum* (4 m), though their stems are relatively thin (0.5-2.0 cm in diameter).
5. It has sporophytic plant body which is a well-branched perennial herb.

Stem

1. Aerial shoots are articulated (i.e., jointed).
2. Two types of branches in whorls arise from the nodes of aerial sterile shoots.
3. Monopodial branching stem and shoots are differentiated into nodes and internodes.
4. Some shoots are long, unlimited in growth, well-branched similar to the main axis of aerial sterile shoot.
5. Some shoots are short which bear nodes and inter- nodes and are unbranched, hence, limited in growth.
6. Fertile shoots are unbranched, colourless or pale-yellow colour branches, bearing a strobilus at the tip.
7. The stem of *Equisetum* is perennial, underground, much-branched rhizome and erect.
8. In most of the species shoots are alike and chlorophyllous.
9. In some species strobili is beared at their apices as present in *E. ramosissimum*, and *E. debile*.
10. Shoot may shows dimorphism (two types of shoots i.e., vegetative and fertile) e.g., *E. arvense*.
11. Some shoots are profusely branched, green (chlorophyllous) and purely vegetative.
12. Some shoots are fertile, unbranched, and brownish in colour (achlorophyllous) and have terminal strobili.

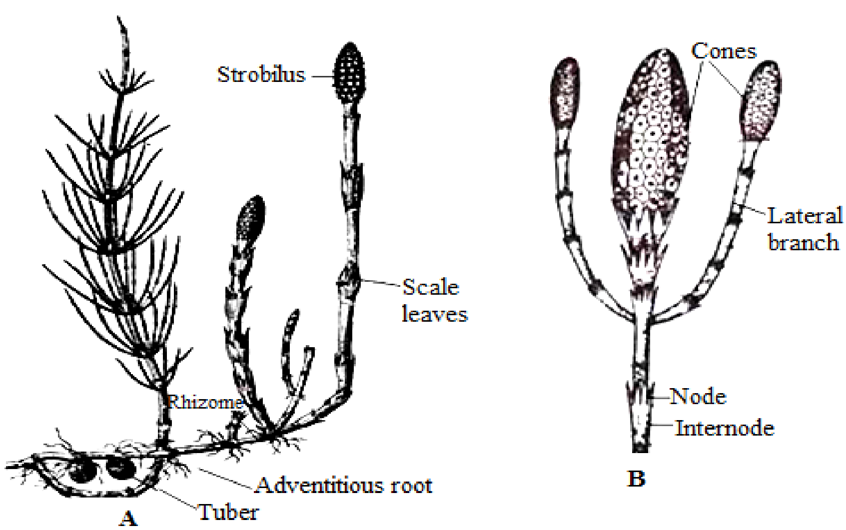

Fig. 9.1: (A) *Equisetum arvense* (B) *Equisetum* branched bearing cones

Leaves

1. The leaves of Equisetum are small, simple, scale-like and isophyllous.
2. Minute, thin and unnerved scaly leaves are present in the form of a whorl which varies in number from 3 to 40 in different species.
3. Young leaves are green but at maturity they become yellow or red-coloured.
4. The pointed leaves unite below at the base to form a sheath on the node.
5. The number of ridges on the internode indicates the number of leaves present.
6. The species with narrow stems have few leaves like 2-3 as in *E. scirpoides* and those with thick stem may have many leaves i.e. up to 40 leaves as in *E. schaffneri*.

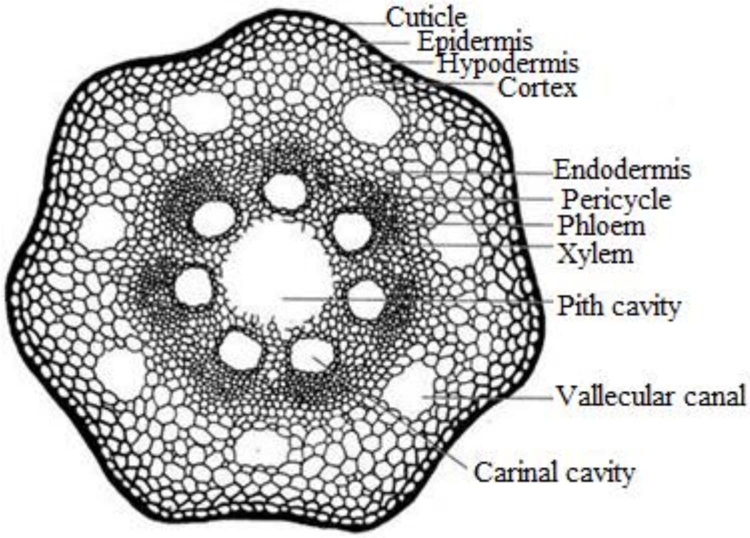

Fig. 9.2: *Equisetum* -T.S. of Stem (Rhizome)

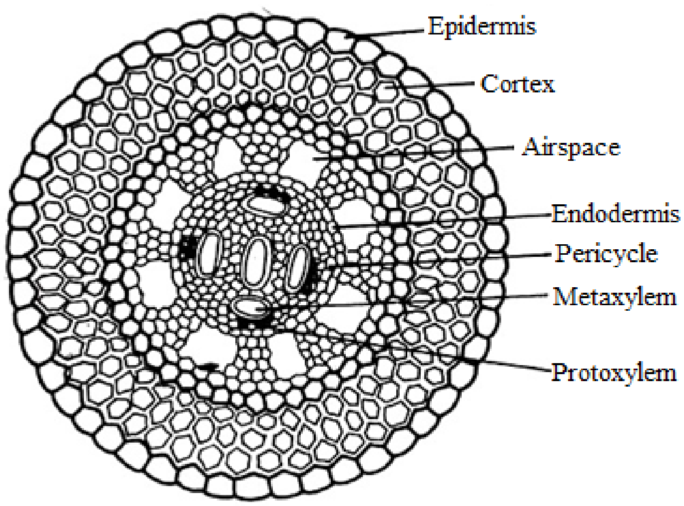

Fig. 9.3: *Equisetum* -T.S. of Root

Rhizophores or Roots

1. The primary root is ephemeral.
2. The slender adventitious roots arise endogenously at the nodes of the stems.

3. Roots, developing from the node of rhizome, are long, slender, well-branched and adventitious.
4. Rhizome gives rise to aerial shoots towards upper side, which are of two types sterile or vegetative shoots and fertile or reproductive shoots.
5. Rhizome are articulated (i.e., jointed).
6. Round or irregular bodies are present on the rhizomes which are called tubers.

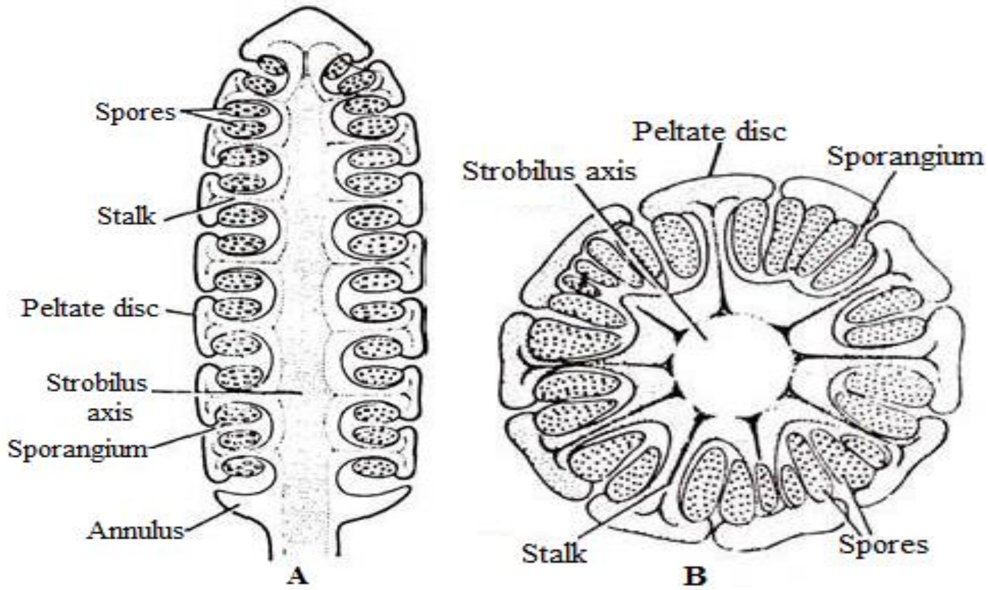

Fig. 9.4: A- L.S. of Cone, B- T.S. of Cone

Reproductive Structures– Spore Producing Organs

Cone

1. Fertile aerial, unbranched shoots bear at the apices of Equisetum are the spore-bearing compact organs known as strobili (sing, strobilus) or cones. Branched fertile axis is also present in some exceptional cases.
2. A thick central axis known as strobilus axis or cone axis is present in each cone or strobilus.
3. Strobilus axis is attached with many umbrellas like sporangiophores in whorl.
4. Each sporangiophore is a stalked structure and the free end has becomes flattened to form a peltate disc.
5. The disc is a hexagonal structure and present at right angle to the stalk.
6. On the undersurface of disc are present many sporangia, horizontally towards the axis of strobilus.
7. Each sporangium is elongated and pendant, and contains a rounded apex.
8. The sporangium is surrounded by jacket and tapetal layers, enclosing many spores.
9. Equisetum is homosporous.
10. A ring-like outgrowth called annulus is present below each strobilus. It is considered as the uppermost whorl of sterile leaves by some people while others consider it as the lowermost sterile sporangiophore.

9.3.2 *Osmunda*

Osmunda is a genus of primarily temperate-zone ferns of family Osmundaceae. Because of the large mass of sporangia that ripen uniformly at the same time to a showy golden colour, the fern look as if they are in flower, and hence is sometimes called the "flowering ferns".

Scientific Classification

Kingdom: Plantae
Division: Pteridophyta
Class: Pteropsida
Order: Osmundales
Family: Osmundaceae
Genus: *Osmunda*

Habit and Habitat: *Osmunda* is widely distributed in the temperate and tropical regions of the southern and northern hemispheres. The various species of *Osmunda* usually grow in cool, moist and shaded places such as the banks of streams, lakes, ponds, and in the forests.

External Features

All the species of *Osmunda* have moderate size but some like *O. cinnamomea* may reach a height of 2-3 metres.

Rhizome

1. The plant body consists of an upright rhizome which is subterranean.
2. The rhizome is studded with a number of persistent, sclerotic leaf bases which are arranged in a rough spiral and bears a crown of leaves.
3. The rhizome is generally un-branched but a dichotomy may also be present.
4. A number of brownish, adventitious roots arise at the base of each leaf.

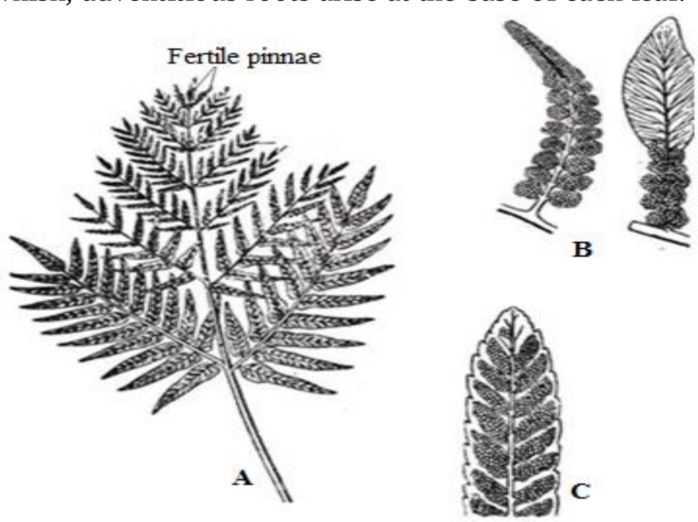

Fig. 9.5: *Osmunda regalis* (A) Leaf (B) Fertile Pinnae (C) Sporangium

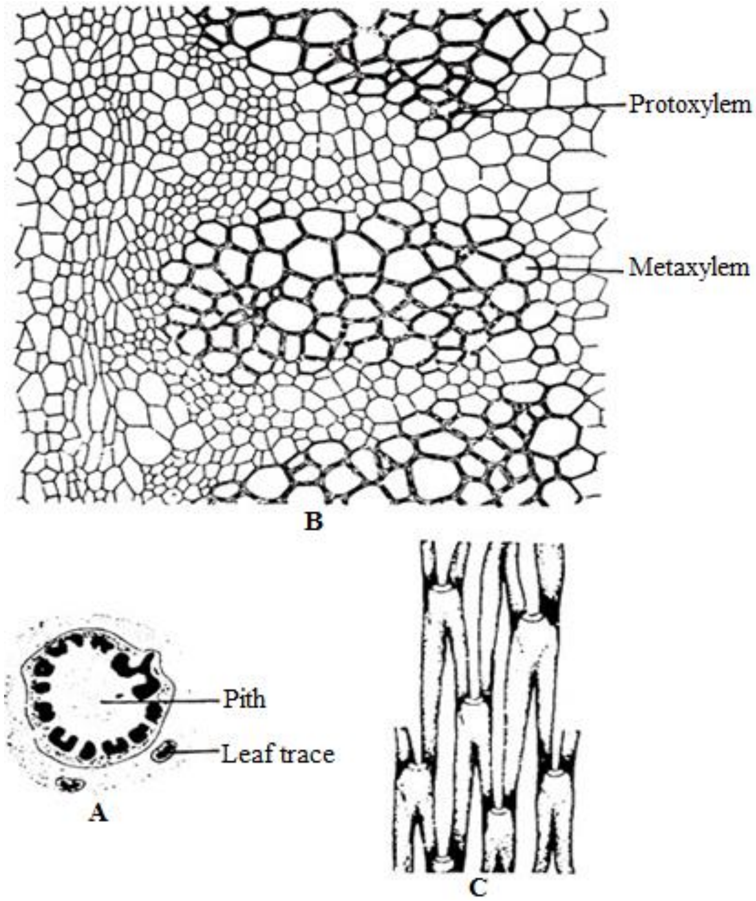

Fig. 9.6: Anatomy of rhizome: A- Ground Plan of T.S. B- A sector enlarged to show steles. C-Stereo Diagram of a part of the stele

Leaves

1. The leaves may be monomorphic as in *O. regalis* and *O. claytoniana* which means there is no distinction into sterile and fertile leaves.
2. Leaves can be dimorphic as present in *O. cinnamomea* and *O. japanica* i.e. fertile and sterile leaves are different.
3. Fertile leaves appear before the sterile ones in dimorphic species when a new crown of leaves is to be unfolded.
4. The chlorophyllous lamina is absent in the fertile leaves.
5. Lamina bears clusters of sporangia.
6. In monomorphic leaves, dimorphic, fertile and sterile pinnae are variously distributed.
7. Pinnae may be present at the base as in *O.vahellii,* lip and *O.regalis* or present in the middle such as in *O. claytoniana* and *O. japanica*.
8. The leaves are arranged spirally at the apex of the rhizome and they are uni-pinnately or bi-pinnately compound e.g. *O. regalis*.

9. Each leaf has a stout rachis with a wing like expansion (stipule) at the base covered with glandular hairs.
10. The leaves are deciduous and every year a fresh crown of leaves is produced.
11. The lamina has a leathery texture and is covered with brown hairs.
12. The venation is of the open dichotomous type.
13. The leaves exhibit circinate vernation characteristic of true ferns.

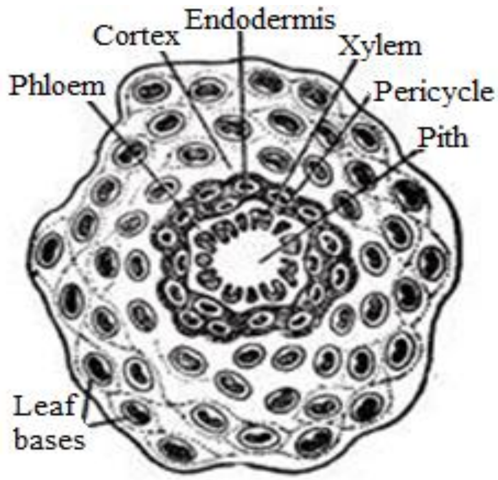

Fig. 9.7: T.S. of Stem of *Osmunda regalis*

Reproductive Structures

Spores

1. The spores are minute in size ranging from 0.054-0.072 mm.
2. They have a three layered wall viz., endospore, perispore and an outermost exospore.
3. The exospore is ornamented with spines or protuberances.
4. Spores are cholorophyllous.
5. The pro-thallus may be filamentous or plate like.
6. The derivatives of apical cell soon form a spatulate pro-thallus, which on further growth becomes cordate.
7. The single apical cell is replaced by a series of marginal cells that cut off segments on three sides.
8. The pro-thallus becomes broader by the activity of this marginal meristem.

Mature Pro-thallus

1. The pro-thallus is cordate but somewhat elongated.
2. It is dorsiventrally flattened and fleshy with a dark green colour.
3. It grows on the surface of the soil. There is a mid rib represented by a groove on the dorsal surface.
4. The prothalli are capable of indefinite growth and may reach upto size of 2.3 cm.
5. The pro-thallus is made of parenchymatous cells.

6. The margin of the pro-thallus is thin, but towards the centre it may be 16-18 cells in thickness.
7. They take up nutrition by autotrophic means.

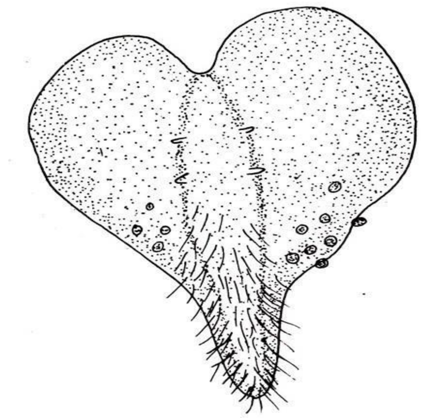

Fig. 9.8: Osmunda gametophyte

9.3.3. *Hymenophyllum*

Hymenophyllum is a genus of ferns in the family Hymenophyllaceae. Its name means "membranous leaf", referring to the very thin translucent tissue of the fronds, which gives rise to the common name “filmy fern” for this and other thin-leaved ferns. The leaves are generally only one cell thick and lack stomata, making them vulnerable to desiccation. Consequently, they are found only in very humid areas, such as in moist forests and among sheltered rocks. They are small and easy to overlook.

Scientific Classification

Kingdom: Plantae
Division: Pteridophyta
Class: Pteropsida
Order: Hymenophyllales
Family: Hymenophyllaceae
Subfamily: Hymenophylloideae
Genus: *Hymenophyllum*

Habit and Habitat: *Hymenophyllum* is distributed in humid, tropical and warm temperate regions of the world. It is found in tropical rain forests and it is especially abundant in the west land forests of New Zealand. It usually grows on forest soil floor or as epiphytes on the wet branches of trees.

External features

1. The plant body size does not exceed 8-10 cm.

2. In *H.pulcherrimum*, the pendant fronds may be 0.5-1 meter in length.

Rhizome

1. Rhizome is very slender and extensive.
2. Branching of the rhizome is axillary.
3. The root-like rhizomes possess a combination of characters of the rhizome (i.e. shoot) and root.

Fig. 9.9: Complete plant of *H. pulcherrimum*

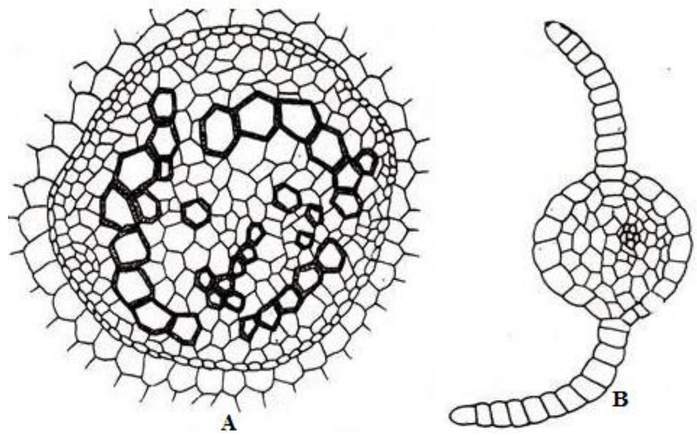

Fig. 9.10: *Hymenophyllum*, A- T.S. of stele of stem, B- T.S. of Leaf

Roots

1. Roots are adventitious and are produced in pairs at the base of each leaf.
2. Sometime roots may be seen between the leaves due to the failure of leaf primordium to develop above the region where the roots are produced.
3. Root-like rhizomes do not completely resemble with the classical root-shoot model of vascular plants and are often called misfits in terms of fuzzy morphology and/or process morphology.
4. Adhesive hairs are modified hairs to root hairs and rhizoids of gametophytes.

Leaves

1. The leaves of *Hymenophyllum* are very characteristic and are the objects of beauty.
2. The transluscent leaves when growing in close mats may easily be mistaken for bryophytic thalli.
3. Leaves are produced in acropetalous succession and show circinate vernation.
4. Many leaf primordia may remain dormant and may resume growth at a later stage.
5. The leaves have a flattened petiole.
6. The lamina may be simple (*H.cruenta*) or dissected into unequal dichotomies as in the majority of species.
7. It is mostly one celled thick and has an open dichatomous venation.

8. The leaves are pale green in colour and together with the roots they take part in the function of absorption.

Reproductive Structures

Spore Producing Organs:

1. In a dissected leaf blade, sori are terminal and in an ensure blade they are marginal in position.
2. Sporangia are produced from the fertile tissue called ‘receptacle’.
3. Receptacle development on the lamina is achieved by the development of two flaps of tissue from the axial and abaxial surface of the leaf.
4. The indusium overarches the sorus, offers protection to the sorus.
5. The sporangia develop in a basipetalous succession.

Development of Sporangia

1. Sporangial initials are first differentiated towards the apex of the receptacle and the succeeding ones appear in basipetalous fashion.
2. A sporangial initial is leptosporangiate type which functions like an apical cell.
3. Apical cell cuts off one or two stalk cells and divides periclinally to form an inner primary archesporial cell and an outer primary wall.
4. The outer primary cell wall undergoes anticlinal divisions and builds up the single layered wall
5. The primary archesporial cell produces the archesporium, which forms the spore mother cells.
6. Meiotic division produces 256-512 haploid spores per sporangium and all spores are of the same type.
7. The dehiscence of the sporangium is brought about by an obliquely vertical annulus.
8. Splitting of the sporangium is transverse and spores are wind dispersed.

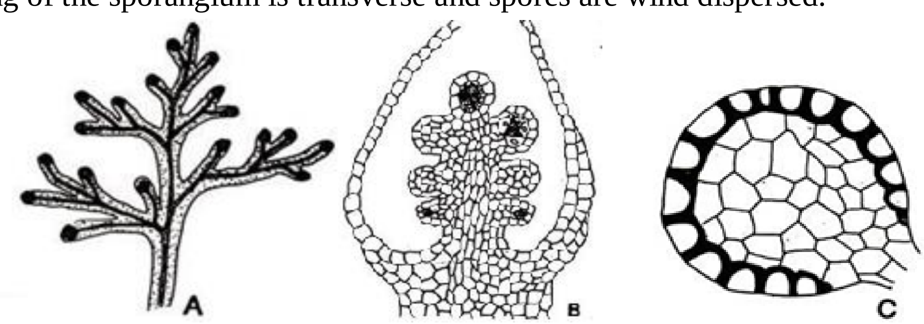

Fig. 9.11: Spore bearing organ, A- Tip of fertile leaf, B-Long section of Receptacle, C- A mature sporangium enlarge

9.3.4 *Dryopteris*

Dryopteris belongs to the division Pteridophyta. It is known by many names such as wood fern, male fern or buckler fern.

Scientific Classification

Kingdom: Plantae
Division: Pteridophyta
Class: Pteropsida
Order: Polypodiales
Family: Dryopteridaceae
Subfamily: Dryopteridoideae
Genus: *Dryopteris*

Habit and Habitat: This genus includes about 250 species of ferns which are distributed in Eastern Asia, the Americas, Europe, Africa, and the Pacific islands. Dryopteris has the highest species diversity in eastern Asia.

External Feature

1. The structure of *Dryopteris* is divided into sporophyte and gametophyte.
2. The sporophyte is further differentiated into root, rhizome and leaves.
3. Some special features are the presence of rounded sori, along with a peltate indusium and also the stipes contains prominent scales.
4. There are some specific characteristics found in many of the species like the presence of stout (slowly creeping rootstocks).

Root

1. The root is primary and lasts for a very short time i.e. it is ephemeral, and is hence replaced by a large number of small fibrils which are branched and grows from the leaf bases (called the adventitious roots).
2. If the T.S. of root is considered, it shows an outer piliferous layer, a cortex and a central stele.
3. An outer parenchymatous zone and an inner sclerenchymatous zone combine to form the cortex region.
4. The xylem is exarch and diarch with protostelic stele.

Rhizome

1. The stem is partly horizontal and partly erect with the apex rising just above the soil surface i.e. rhizomatous.
2. Scales and adventitious roots cover the rhizome.

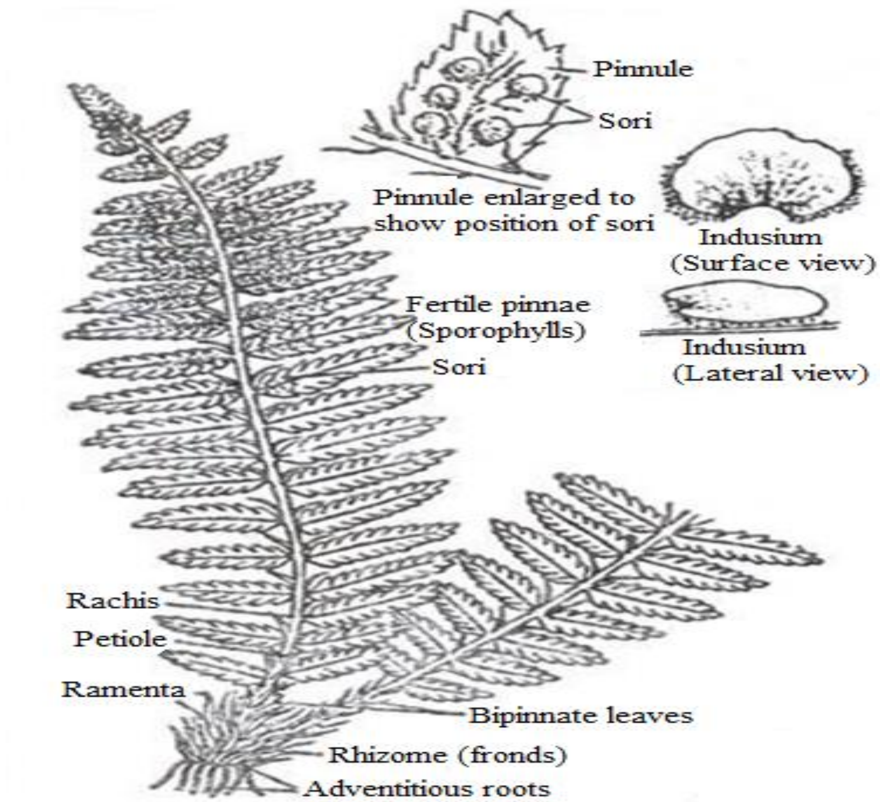

Fig. 9.12: Morphological Structure of *Dryopteris* Plant

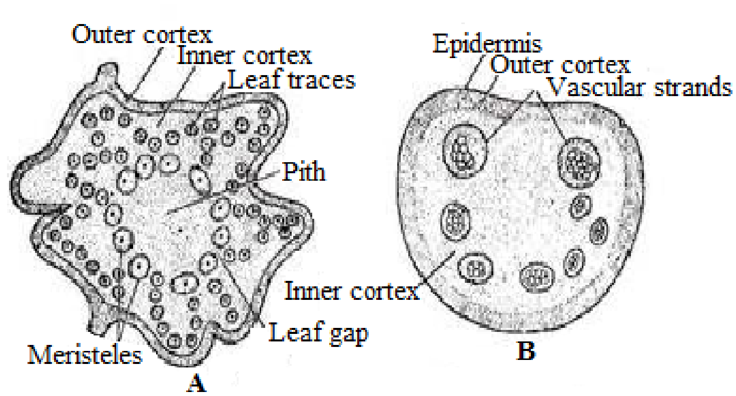

Fig. 9.13: A- T.S. of rhizome, B- T.S. of Rachis

Leaf

1. The succession of leaves is acropetal i.e. they are present at the apex of the rhizome.
2. The typical feature of true ferns is the presence of circinate vernation i.e. the spiral coiling of leaves in young stage.
3. The rachis is long containing uni-pinnately compound leaves.
4. Even after the old leaves perish, sometimes the leaf bases remains persistant.
5. All leaves bear sori on the ventral (abaxial) surface of pinna which is the indication of fertility.

6. Numerous brown scales (calledramenta) cover the base of rachis, the term given to such condition is paleaceous.
7. Isobilateral and amphistomatic lamina is present.

Reproducing Structures

In *Dryopteris*, reproduction takes place by means of spores.

Spore-Producing Organ

1. *Dryopteris* produces same type of spores which means it is a homosporous fern.
2. The median vein of a pinnule contains sori on the two sides, in-between the margin and the midrib.
3. A kidney-shaped indusium covers each sorus.
4. The central placental tissue gives rise to a no. of stalked sporangia.
5. Sporangium arises without any order of development which indicates that the sori are of mixed type.

Development of Sporangium

1. The development of sporangium in *Dryopteris* is similar to that of *Pteris* i.e. leptosporangiate type.

Structure of a Mature Sporangium

1. *Dryopteris* comprises of a long stalk and a terminal capsule as in case of *Pteris*.
2. The jacket of the capsule is single-layered and is differentiated into a thick-walled vertical annulus, a thin-walled radially arranged stomium and large parenchymatous cells with undulated walls.
3. The capsule contains isospores which are structurally and functionally alike indicating the homosporous nature of *Dryopteris.*
4. The shape of spores is triangular with trilete aperture. Exine is the outer spore wall which is either smooth or variously ornamented.
5. The shrinkage of annular cells leads to the dehiscence of the sporangium transversely along the stomium.
6. Air helps in dispersing the spores to a moderate distance.

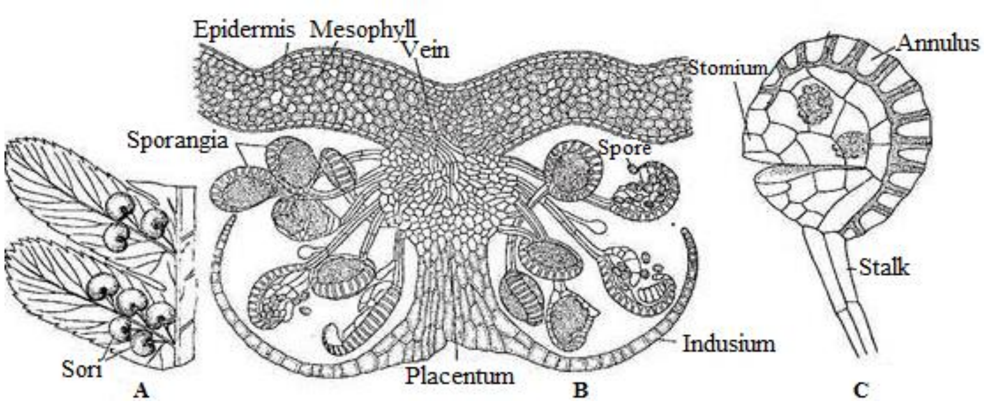

Fig. 9.14: A- Fertile pinnules with sori covered by indusium, B- V.T.S of Pinnule through a sorus, C- A mature sporangium

Gametophyte

1. The spores germinate after falling on a suitable substratum and may remain viable for a long period of time.
2. The formation of germ tube occurs initially by the bursting of exine and the intine.
3. As soon as the exine and intine burst, the inner content comes out in the form of a germ tube and the formation of germ tube thus occurs subsequently by a transverse division.
4. Further *Dryopteris* shows the development of gametophyte similar to that of *Pteris*.
5. *Dryopteris* contains heart-shaped prothallus.
6. Both the male and female gametes are present on the same body i.e. the prothallus is monoecious.
7. Anthredia are confined to the basal central region of the rhizoids and appears first.
8. The development of archegonia occurs near the apical notch.

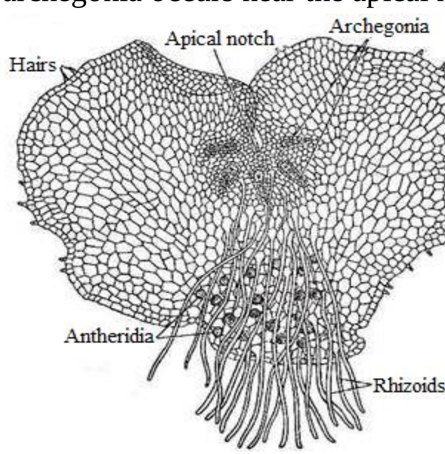

Fig. 9.15: A mature Prothallus

Antheridium

1. The antheridium is similar to that of *Pteris.*
2. The antherozoids are also similar to that of *Pteris* and has multiflagellated and coiled structure.

Archegonium

1. The archegonium develops similar to that of *Ophioglossum*.
2. A 5-7 celled projecting curved neck; a binucleate neck canal cell, a ventral canal cell and an egg constitute a mature archegonium of this plant.

9.3.5 *Adiantum*

Adiantum also called the walking fern or maiden hair fern is a genus comprising of 250 species of ferns in the Vittarioideae subfamily of the family Pteridaceae but some researchers consider it to be placed in Adiantaceae. It is a Greek word which means "not wetting".

Biological Classification

Kingdom:	Plantae
Division:	Pteridophyta
Class:	Pteropsida
Order:	Polypodiales
Family:	Pteridaceae
Subfamily:	Vittarioideae
Genus:	*Adiantum* L.

Habit and Habitat

It is one of the most widely distributed genera (Other genera are Cheilanthes, Pellaea, Ceratopieris and Anogramma) of the family growing luxuriantly in both tropical and sub topical regions of the world. It grows ubiqui-tously wherever nature offers a moist, shaded locality. There are nearly 200 species. Nayar (1961) has investigated the morphology of 24 Indian species of *Adiantum*. Some of the common Indian species are – *A. capillus-veneris, A.pedatum, A. incisum, A. caudatum, A. venustum, A. lunulatum, A. edgowrthii* etc. Species of *Adiantum* are commonly cultivated in green houses because of their attractive foliage.

External Features

1. The plant body of *Adiantum* is sporophytic which consists of an underground rhizome from which leaves and roots are produced.
2. The chaffy scales cover the rhizome called Paleae.
3. It may be of different types, erect in case of *A. caudatum*, semi erect in case of *A. pedatum* and creeping in case of *A.capillus-veneris*.

Stem

1. Rhizome is present which may be branched occasionally.
2. The rhizome may be hard or soft and brown in colour.
3. The transformation of erect rhizome of the young sporophyte of *Adiantum trapeziforme* quickly into creeping is observed.

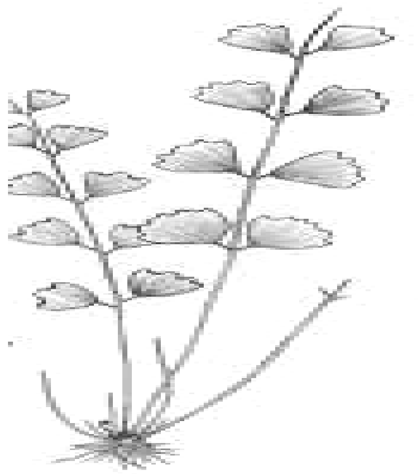

Fig. 9.16: Complete plant of *Adiantum*

Leaves

1. There is no distinction into fertile and sterile leaves.
2. The leaves are present acropetally on the creeping rhizome.
3. The typical feature of the ferns is also shown by the leaves i.e. coiling pattern of young leaves, the circinate vernation.
4. The name maiden hair fern is given due to the presence of hard, wiry, shiny and black or dark brown colored rachis of leaves.
5. A medium dorsal groove is present on the rachis along with paleae at the basal region.
6. There may also be the presence of glandular hairs.
7. The leaves are also of different arrangements. They may be unipinnately compound as in case of *A. caudatum* or bi or tri-pinnately compound as in *A. capillus – veneris*
8. The pinnae have a dichotomous venation and they are stalked.
9. The termination of rachis may be into a pinna or it may bear a bud.
10. The rachis divides pinnately and the ultimate branches bear pinnae in an alternate fashion in *A. capillus veneris.*
11. In *Adiantum,* there is no distinction between fertile and sterile leaves.
12. The ventral surface of the pinnae gives rise to the sori.
13. The whole leaf may be sporangiferous or only certain pinnae which may bear sporangia.

Root

1. The roots are stiff and black in colour.
2. A number of adventitious roots arise from the undersurface of the rhizome.

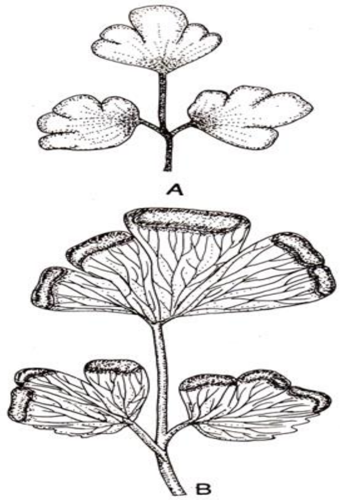

Fig. 9.17: ***Adiantum:*** **(A) Sterile, (B) Fertile Leaflets of** ***A.capillus-veneris***

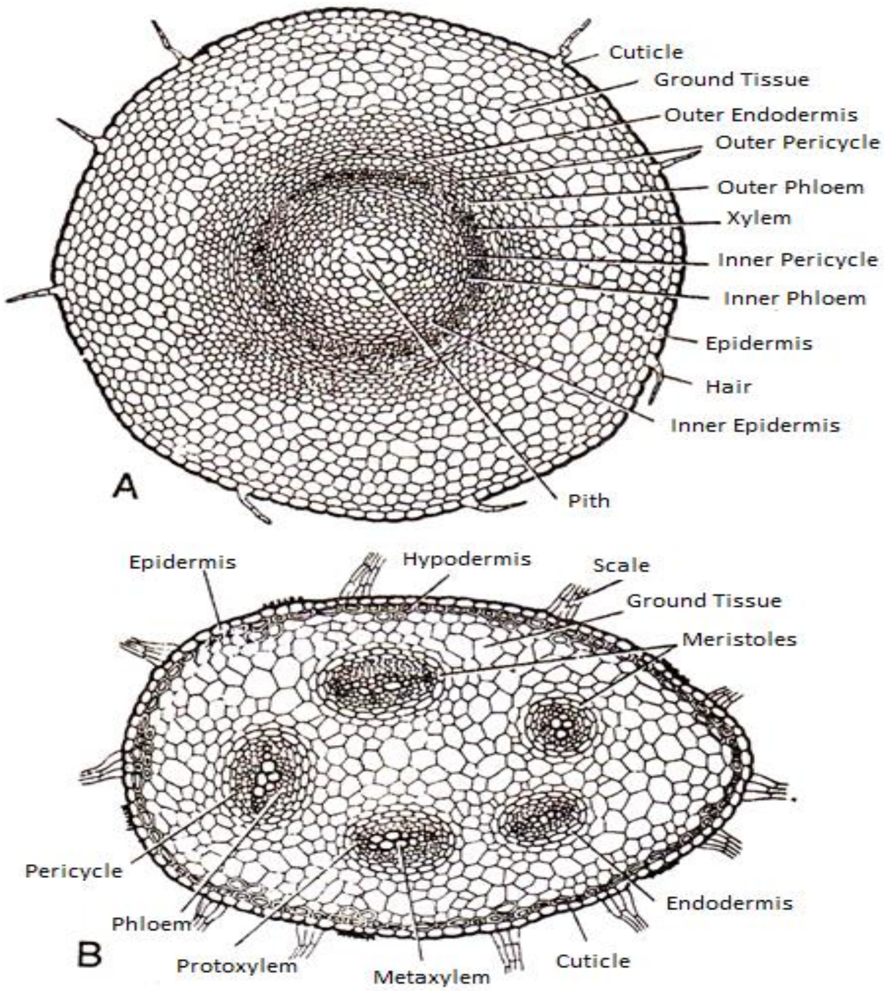

Fig. 9.18: Anatomy of Rhizome, A- Amphiphloic siphonostele in ***A. rubellum,*** **B- Dictyostele in** ***A. capillus-veneris***

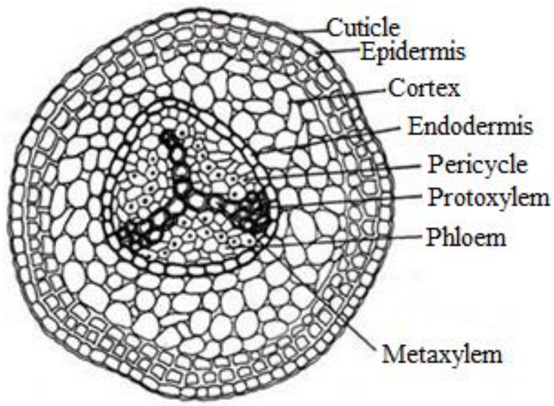

Fig. 9.19: T.S. of Petiole

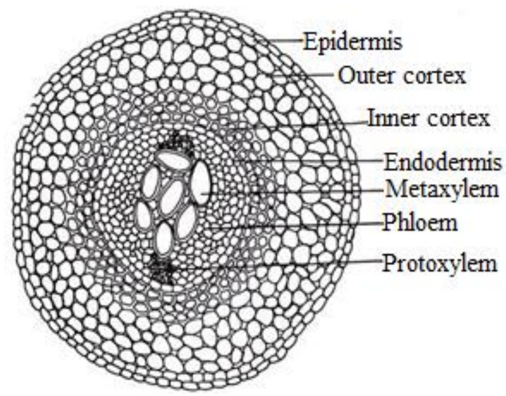

Fig. 9.20: T.S. of Root

Reproductive Structures: Spore Producing Organs

1. The spores are born at the distal end of the pinnae.
2. The sori are not marginal and are borne a little behind the tip of the veins.
3. The false indusium is formed by the curling of sorus bearing margin of the leaf.
4. In some species like *A. phillippense,* sporangia may develop at the distal ends of the veins.
5. In the sori, paraphyses may be present in between the sporangia as in *A. rubellum, A. tenerum,* etc. i.e. The sorus is of the mixed type.

Development and Structure of the Sporangium

1. A mature sporangiuim has a stalk made up of three rows of cells.
2. The stalk terminates in a globose or biconvex capsule.
3. The sporangium wall is made of single layer.
4. An obliquely vertical annulus of 12-24 cells long is present in them.
5. About two or three cells separate annulus from the stalk. The stomium is also separated from both the stalk and the annulus.
6. The rest of the sporangial wall is made up of few large cells.
7. The sporangium dehisces transversely and liberates the spores.
8. All the spores are of the same type hence called homosporous.

Gametophyte of *Adiantum*

Structure of the spores

1. The shape of spores is tetrahedral.
2. The wall is made of two layers i.e. exine and intine.
3. Exine is thick, smooth and has a brownish tinge.
4. The germ tube undergoes several transverse divisions to form a short filament.
5. A lateral rhizoid is formed by the lowest cell.
6. The terminal cell becomes an apical cell with three cutting faces.
7. Through apical cell division, a spatulate pro-thallus is formed initially.

8. The mature pro-thallus is cordate, photosynthetic, dorsiventrally flattened and aerial. All the cells in the pro-thallus are made up of parenchyma.
9. The pro-thallus is one-celled thick towards the margins but many-celled thick towards the centre.
10. In some species, corners are composed of collenchyma.
11. Rhizoids are produced from the ventral surface.

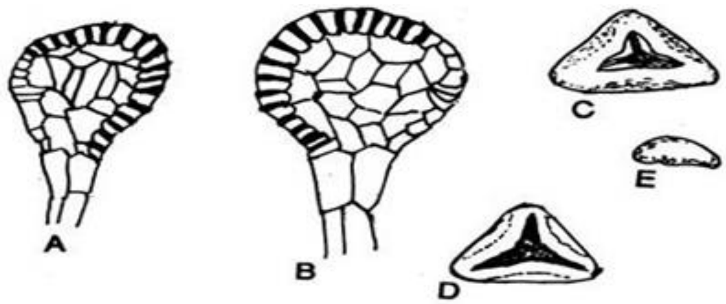

Fig. 9.21: Sporangia and Spores of *A. capillus-veneris,* A-B- Sporangia, C-E- Spores

Reproductive Structures

1. The prothalli are monoecious.
2. Antheridia are found in between the rhizoids towards the ventral surface.
3. Arehegonia is found near the growing point towards the ventral surface.

9.3.6 *Marsilea*

They are a small family of heterosporous, aquatic and semi-aquatic ferns which are commonly known as the "pepperwort family" or the "water-clover family" due to the resemblance of leaves to the superficial four-leaf clover which is a flowering plant.

Biological Classification

Kingdom: Plantae
Division: Pteridophyta
Class: Pteropsida
Order: Salviniales
Family: Marsileaceae
Genus: *Marsilea*

Habit and Habitat: It is world-wide in distribution.It is rich in the warmer parts of the world like tropical Africa and Australia.About 9 living species have been recorded to be found all over India but most common in Punjab after the rain such as *M. brachypus*, *M.quadrifolia*, *M.rajasthanensis* and *M. aegyptiaca*. They are grown submerged or partially out of the water whereas some species are amphibious and some are even xerophytic such as *M. condensata*, *M. rajasthanensis*. They can grow after the rain in temporary shallow ponds and puddles.

External Features

1. The plant body is sporophytic.
2. It has appearance resembling to that of looks like a four- leaves clover plant.
3. The plant body is divided into stem, root and leaves.
4. The multicellular and unbranched dense hairs covered the younger parts of the plant.

Stem

1. The stem is long and slender which creeps either on the surface such as in stolon or slightly below the surface of the soil as in rhizome.
2. Its growth is indefinite and is branched.
3. The branches arise at the bases of leaves and are extra-axillary in position which arises from the lateral or oblique position.
4. Single plant may cover an area about 20 meters in diameter or even more.
5. The stem is divided into distinct nodes and internodes.
6. The long internodes are found in the hydrophytic plant whereas the short ones are found in the sub-terrestrial or xerophytic species.

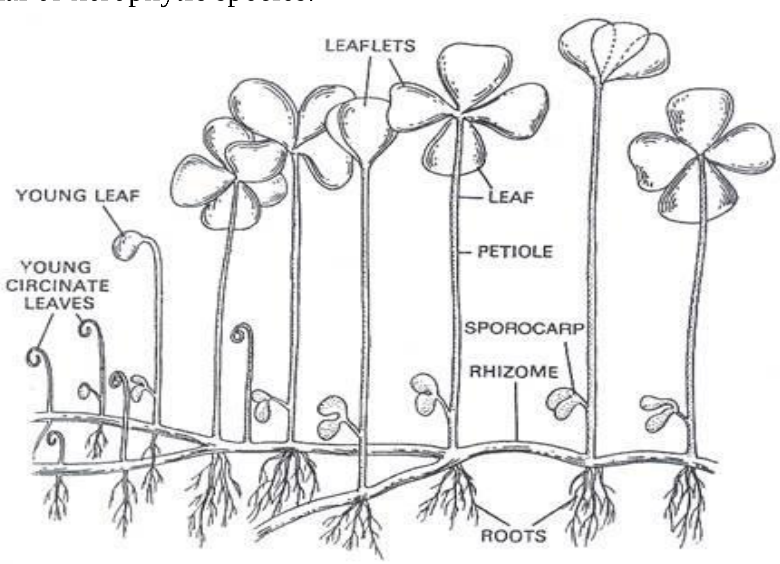

Fig.9.22: *Marsilea quadrifolia*: A sporocarps, rhizome, leaves and roots

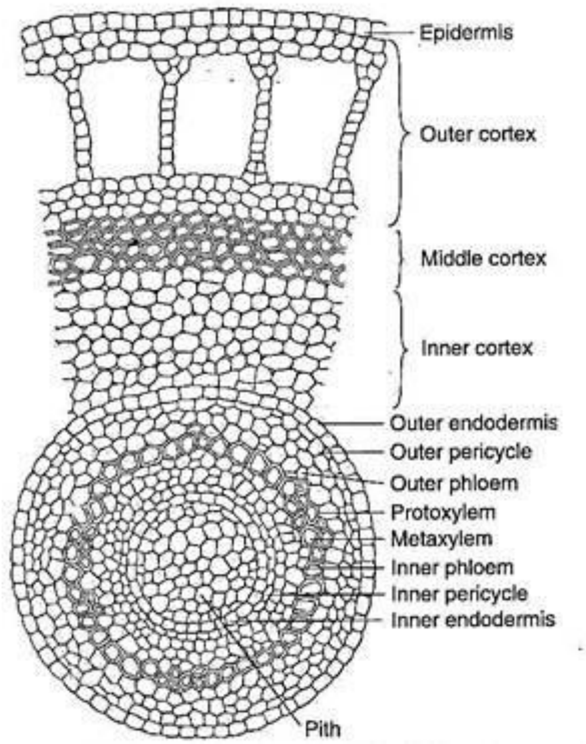

Fig. 9.23: T.S. of rhizome

Roots

1. The primary root is short-lived.
2. The adventitious roots arise at the nodes on the underside of the stem but they may also be able to arise from the internodal region.
3. They are thin and may be branched or unbranched.
4. Their number at each node may be one or more.
5. The branching is monopodial.
6. The branch root is arranged in two rows, developing in an acropetalous succession.

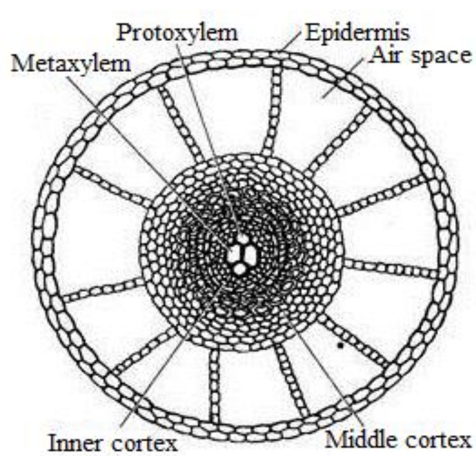

Fig. 9.24: T.S. of Root

Leaves

1. The leaves arising from the upper side of the stem alternatively, are arranged in two rows.
2. They are petiolate and compound.
3. The petioles of the submerged plants are long, thin and flexible with the lamina floating on the surface of water.
4. The leaves of plants growing on mud or land have upright short petioles with lamina held in a spreading position.
5. The compound lamina is divided into four leaflets of the same size.
6. The leaf looks like quadrijugate as the four leaflets are arranged in a pinnate manner. Two of which form the distal pair and the other two form the proximal pair.
7. The leaflets of the proximal pair are arranged in alternate fashion.
8. The number of leaflets varies from 5 or 6 or even 8 instead of the usual number 4.
9. The leaflets can be obovate or obcuneate to wedge-shaped.
10. The margin is variable or entire
11. In *M. minuta* and other hydrophytic species the outer margin of the leaflet can also be crenate or toothed, whereas in the terrestrial species such as in *M. aegyptiaca* and *M. rajasthanensis*) margin can be crenate to slightly deeply lobed.
12. The venation is reticulate and multicostate.
13. The veins of the leaflets divide repeatedly in a dichotomous manner.
14. The young leaves have circinate ptyxis in the bud.

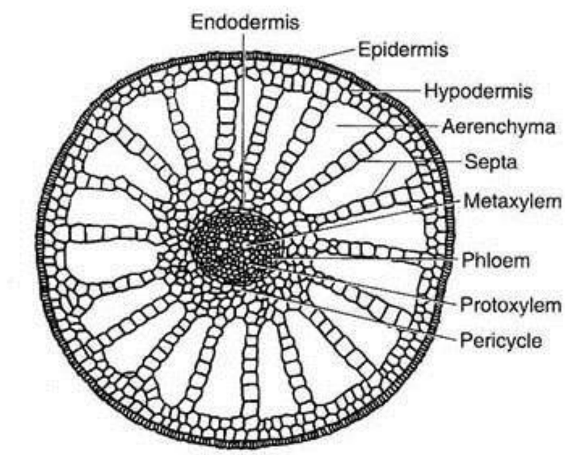

Fig. 9.25: T.S. of petiole

Reproductive Structures

Sporocarps

1. A bean-shaped reproductive body is called the sporocarps.
2. The sporocarps are soft, green and covered with hairs at young stage.
3. The sporocarps are stalked and bisporangiate.
4. The stalk may be long or short and is called the peduncle or pedicel.
5. The shape, size and content of the sporocarp vary considerably with the attachment of its pedicel to the petiole.

6. The pedicle or peduncle of the sporocarp is attached to the petiole.
7. At maturity, Sporocarp becomes brown to dark brown, hard and nut-like.
8. The shape of the sporocarps is either oval or bean shaped as in *M. minuta* and other hydrophytic species, but squarish or rectangular as in *M. aegyptiaca*, *M. rajasthanensis* or other xerophytic species.
9. One or two teeth like protuberances are present at the back in the median plane of the Sporocarp which is known as the horns or teeth.
10. In *M. minuta* both the teeth are prominent but in *M. quadrifolia*, the lower tooth is conspicuous and the upper tooth is blunt whereas in *M. aegyptiaca*, the upper tooth is blunt and prominent.
11. In *M. uncinata*, the teeth look like spine-like projections, with the upper one more conspicuous than the lower.
12. There are some species in which sporocarp lacks teeth.

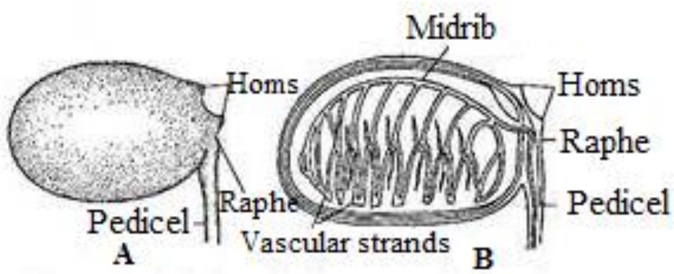

Fig. 9.26: A- Sporocarp, B- L.S. of Sporocarp showing vascular strand on one valve

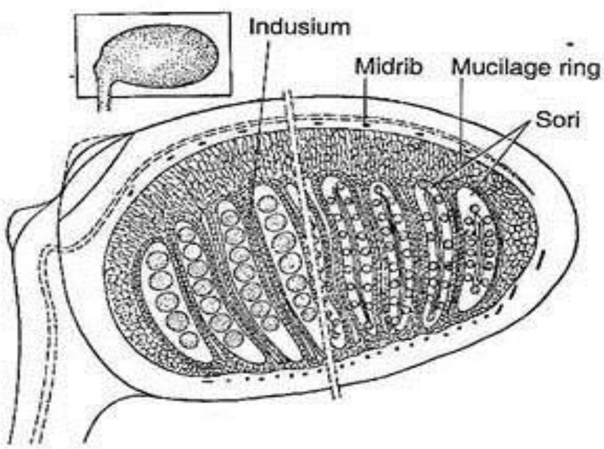

Fig. 9.27: L.S. of Sporocarp (vertical)

Tubers

1. The tubers are the resting propagator bodies found in the stem towards the end of growing season for example in *M. hissuta, M. minuta* which has a function as perennating structures sprouting on the advent of the season favorable for growth.

Spore

1. The plant is heterosporous.

2. The special bean shaped bodies called the sporocarps bears the micro and megasporangia.

9.3.7 *Salvinia*

Salvinia is a free-floating aquatic fern and it lacks roots. They form thick mats which quickly cover water bodies. Infestations reduce water flow, degrade water quality, and affect native animals, stock, and recreational users.

Biological Classification

Kingdom: Plantae
Division: Pteridophyta
Class: Pteropsida
Order: Salviniales
Family: Salviniaceae
Genus: *Salvinia*

Habit and Habitat: Several species of *Salvinia* are found naturally in America, Europe and Asia and also in New South Wales and the Northern Territory. It prefers slow-moving streams or still-water ponds with high nutrient levels and water temperatures 20-30^{o}C.

External Features

1. They are free-floating aquatic fern.
2. The small green leaves are positioned in pairs throughout a common stem.
3. The sporophytic plant body consists of a long slender horizontally growing floating rhizome.
4. The rhizome is completely covered by whorls of leaves.

Leaves

1. Two small, simple lobes are present in this plant.
2. Whorls are distributed opposite to each other.
3. Two types of leaves, emergent and submerged can be seen in this plant.
4. The emergent leaves are green and have obovate shapes which are measured 2.2 cm long and 1.3 cm wide on full maturity.
5. Many hairs are present on the surface of leaves which act as water repellent.
6. The submerged leaves are highly dissected, long and filiform, brown and feather-like in appearance, and hence sometimes are mistaken for roots.
7. Leaves become thick and fold at mid-rib at maturity.
8. Young leaves are oval which resemble duckweed and lie flat on water.

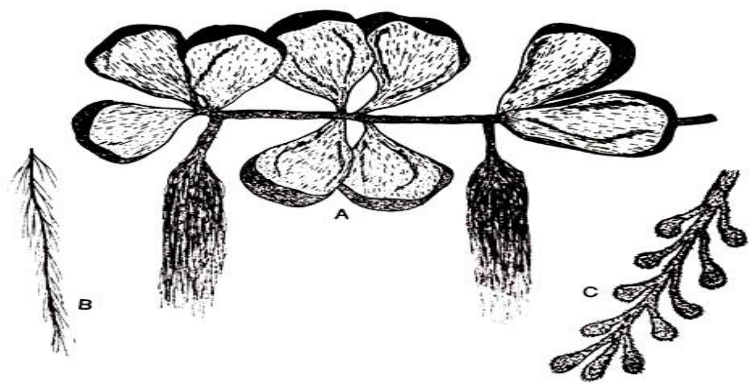

Fig. 9.28 :*Salvinia*:(A) Plant body portion (B) Sumerged leaf (C) Submerged leaf with sporocarp

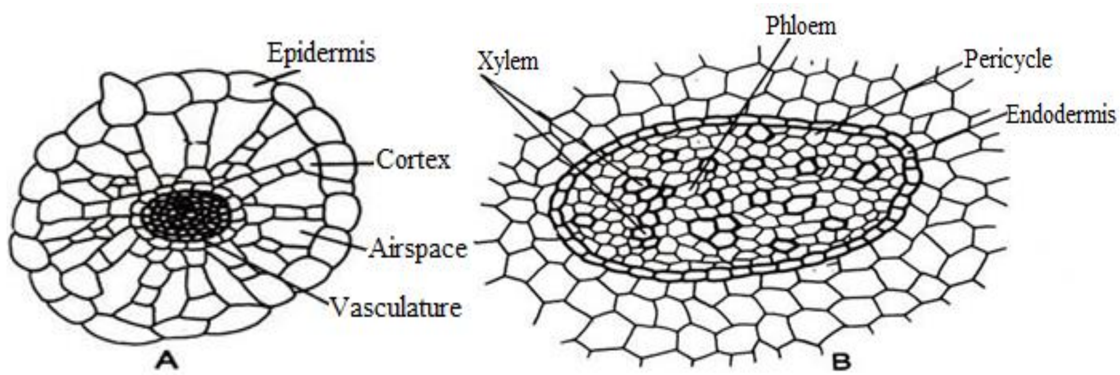

Fig. 9.29: A- T.S. of stem (entire), B- T.S. of stem (stellar portion enlarge)

Stem

1. It is stem less i.e. actual stem is not present, with some leaves as roots.
2. The stem is divided into nodes and internodes with a branch initial produced at every node.
3. The stem is sparsely branched because of the non-functioning of many of the branch initials.

Roots

1. Root is horizontally branched bearing simple roots.
2. No roots are present in the sporophyte thus absorption takes place by the general surface.
3. Multicellular hair like structures found on the submerged filiform leaves may also help in the absorption of water and nutrients.
4. The plant body exhibits radial symmetry whereas the stem exhibits bilateral symmetry at intermodal region, while it is radial at the nodal region.

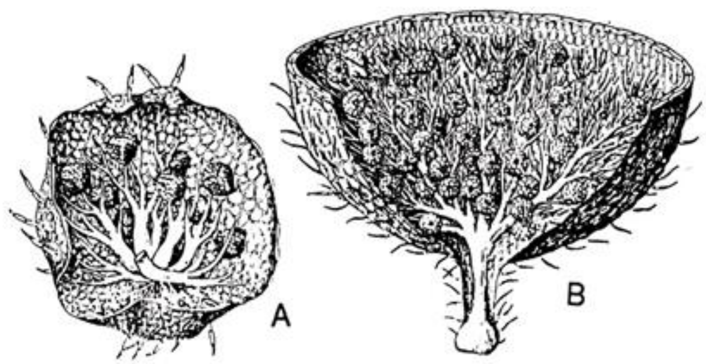

Fig. 9.30: Reproductive structure of *Salvinia*: (A)Sporocarp with Megasporangia (B) Sporocarp with Microsporangia

Reproductive Structures

1. The sporophyte reproduces through sporangia.
2. The sporangia are aggregated to form sporocarps as in *Marselia.*

Sporocarp

1. The sporocraps may range in number from 4 to 20.
2. The sporocarps are usually borne on the inner segments of submerged leaves and they are sympodial in arrangement.
3. Their shape varies from globose to ovoid and can be flattened with ridged surfaces.
4. The wall is two cells layered and the outermost layer is clad with hairs before maturity or at young stage.
5. Externally all sporocarps are alike.
6. The sporocarps are mono-sporangiate as in *Marselia*.
7. The first one or two sporocarps in each cluster are megasporangiate while those formed later are microsporangiate.
8. The sporocarp at its base has a stout columnar receptacle which is unbranched and carries the vascular supply into the sporocarp e.g. *S. natans*.

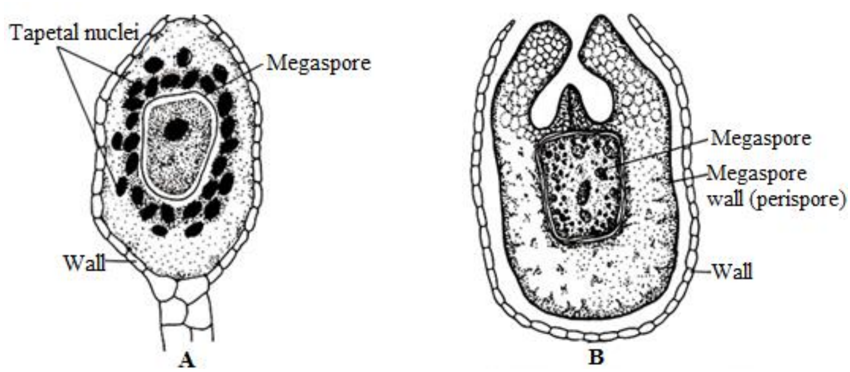

Fig. 9.31: *S. natans*: A- Megasporangium, B- Megaspore

Sporangia

1. The sporangium initials arise on the distal end of the soral primordium and its development is of the leptosporangiate type.
2. The mega-sporangium consists of a short stalk and a generally ovoid capsule.
3. The capsule is single cell layered and tapetum is present to the internal wall of the capsule in which 8 megasporocytes are enclosed.
4. The ‘perispore’ or ‘epispore’ is formed by the hardening of tapetum which surround the functional megaspores in the form of a thick layer.
5. 16 microspore mother cells are enclosed in sporangium and consequently 64 microspores are formed.
6. All the spores after attaining maturity survive.
7. The microspores are embedded in the cytoplasmic fluid derived from the tapetum.
8. The microspores are extremely small, triradiate in appearance and have two wall layers with a single nucleus in each microspore.

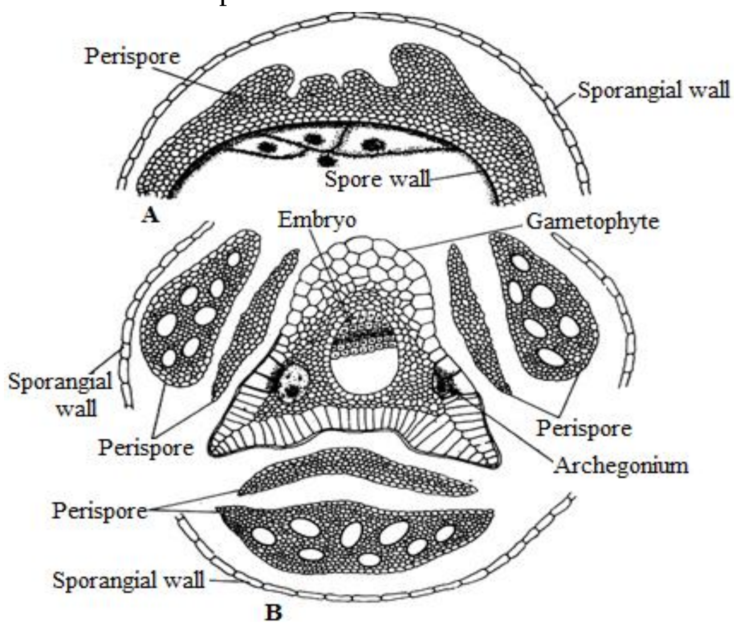

Fig. 9.32: *Salvinia*: A- Median L.S. through apex of Megaspore, B- T.S. of Apical Region of germinated Megaspore

9.3.8 *Azolla*

Azolla is a small aquatic fern with a branched stem and bilobed leaves with roots emerging from the stem which helps in the floating of plant on stagnant water. It houses nearly 80,000 blue green algae which have the capacity to fix atmospheric nitrogen which is utilized by *Azolla*, in return of which, the blue green algae gets shelter and food from *Azolla*, which reaches the soil and plants when it dies.

Biological Classification

Kingdom: Plantae

Division: Pteridophyta

Class: Pteropsida
Order: Salviniales
Family: Salviniaceae
Genus: *Azolla*

Habit and Habitat: *Azolla* is found in ponds, ditches and rice fields of warm-temperate and tropical regions all around the world. Each species occurs in a specific native range such as *Azolla caroliniana* found in Eastern North America and the Caribbean; *Azolla filiculoides* is found in Southern South America through Western North America including Alaska; *Azolla microphylla* is found in tropical and subtropical America; *Azolla mexicana* occurs in Northern South America through Western North America; *Azolla nilotica* can be seen in upper reaches of the Nile to Sudan; whereas *Azolla pinnata* is seen in most of Asia and the coast of tropical Africa regions. Nowadays due to dispersion by the man, these species are found everywhere. They can survive within a pH range of 3.5 to 10, but their range for optimum growth is observed in the range of 4.5 to 7. Optimum temperature is usually in the 20-30°C range, though *Azolla mexicana* can tolerate temperatures over 30°C.

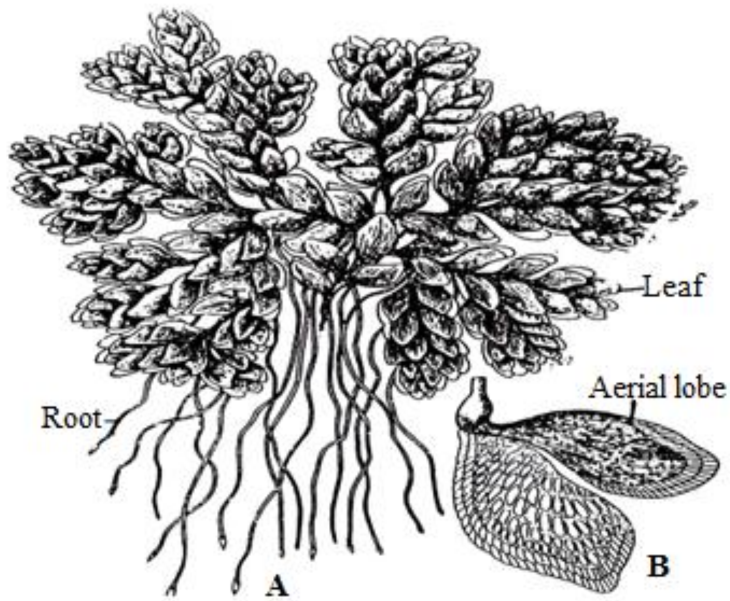

Fig. 9.33: (A) *Azolla microphylla* (B) Enlarged leaf of *Azolla*

External Features

The sporophyte is extremely small in comparison with *Marsilea* and *Salvinia*.

1. It can be divided into stem, leaves and roots.

Stem

1. The stem is generally called the rhizome.
2. It is profusely branched and is covered with dense leaves on upper surface.

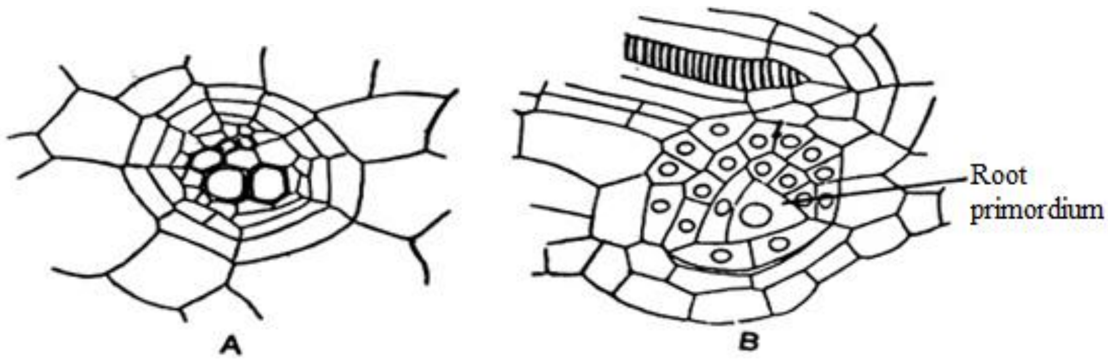

Fig. 9.34: A-T.S. of Stele, B- L.S. of stem with a root primordium

Leaves

1. The leaves are arranged in alternate fashion and are arranged in two rows.
2. Each leaf has two lobes, the upper lobe being aerial and green in color.
3. The thin and colorless lower lobe is completely submerged in water.
4. The dorsal lobe encloses large mucilage filled cavities in which Cyanophycean alga- *Anabaena azollae* are inhabited.

Roots

1. Simple single roots or in clusters are produced on the lower surface of rhizome.
2. These roots help in stably floating the plants in water.

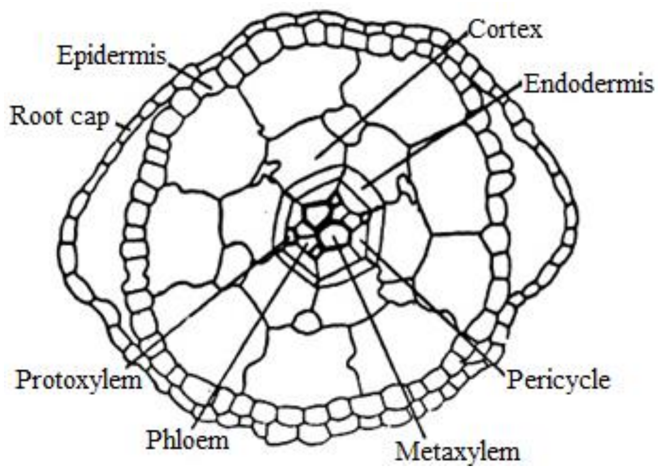

Fig. 9.35: Anatomy of root of *A. filiculoides*

Reproductive Structures

1. The spores in *Azolla* are produced in sporangia which are enclosed in sporocarps such as in *Marsilea* and *Salvinia*.
2. The sporocarps are generally borne on the first leaf of the lateral branch.
3. A Sporocarp is produced terminally in fertile leaves and the upper lobe of the leaf forms a marginal flap which covers the sporocarp.
4. The sporocarps are mono-sporangiate which can either have microsporangia or megasporangia.

5. The megasporocarps are smaller in size and bear only one mega-sporangium, whereas the microsporocarps are large in size and bear large number of microsporangia.
6. The sporocarp wall is two layered.
7. The megasporangium arises at a base on a small receptacle at the base in a megasporocarp.
8. The sporangium is covered by a two layered indusium.
9. In a microsporocarp, a number of microsporangia arise by a central cushion like receptacle.
10. In a megasporagium, eight megasporocytes are surrounded by a layer of tapetum which break down and form a Plasmodium within which sporocytes are enclosed.

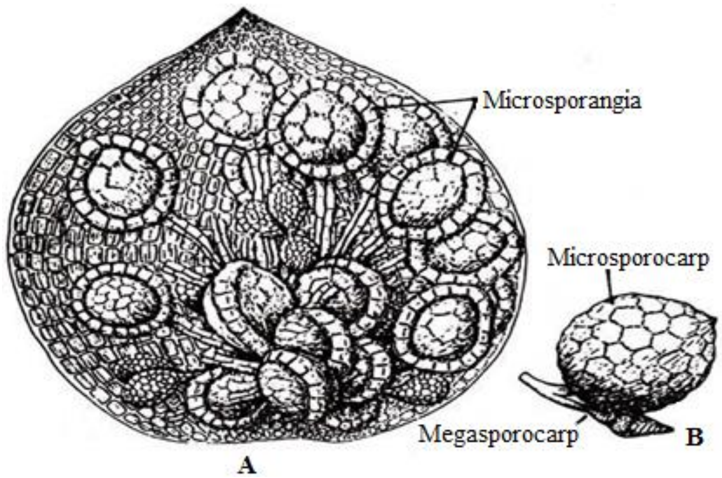

Fig. 9.36: A- Sporocarp split open to show Microsporangia, B- Leaf segment with Macro and Microsporocarps

9.4 SUMMARY

Equisetum, a pteridophytic genus, commonly known as the Horse-tail or Scouring rush, grows in marshy places, ponds, or along the sandy river banks. It is distributed all over the world, except Australia and New Zealand. The genus is represented world over by 30 species; in India, there occur 8 species. Of these, *E. arvense*, *E. debile*, *E. diffusum* and *E. elongatum* are the most common and widely distributed. *Equisetum* plant is a sporophyte, differentiated into stem, leaves and roots. The stem is underground, creeping and perennial rhizome. The rhizome bears two types of aerial shoots first is vegetative shoots and second one fertile shoots. Both are differentiated into distinct nodes and internodes. The leaves are small, scaly and form a whorl around each node. They arise in whorls at the nodes of both the underground rhizome and aerial shoots. The leaves of *Equisetum* are nonphotosynthetic and their main function is to protect the branch bud at the node.

Osmunda is a genus of primarily temperate-zone ferns of family Osmundaceae. Completely dimorphic fronds or pinnae (hemidimorphic), green photosynthetic sterile fronds, and non-photosynthetic spore-bearing fertile pinnae, with large, naked sporangia. Because of the large mass of sporangia that ripen uniformly at the same time to a showy golden color, the ferns look as if they are in flower, and so this genus is sometimes called the "flowering ferns".

Hymenophyllum is a genus of ferns in the family Hymenophyllaceae. Its name means "membranous leaf", referring to the very thin translucent tissue of the fronds, which gives rise to the common name filmy fern for this and other thin leaved ferns. The leaves are generally only one cell thick and lack stomata, making them vulnerable to desiccation. Consequently, they are found only in very humid areas, such as in moist forests and among sheltered rocks. They are small and easy to overlook.

Dryopteris commonly called wood fern, male fern or buckler fern, is a genus of about 250 species of ferns. Many of the species have stout, slowly creeping root stocks that form a crown, with a vase-like ring of fronds. The sori are round, with a peltate indusium. The stipes have prominent scales.

Adiantum the walking fern or maidenhair fern, is a genus of about 250 species of ferns in the Vittarioideae subfamily of the family Pteridaceae, though some researchers place it in its own family, *Adiantaceae*. The genus name comes from Greek, meaning "not wetting", referring to the fronds' ability to shed water without becoming wet.

Marsilea is a fern of the family Marsileaceae. The name honours Italian naturalist Luigi Ferdinando Marsili (1656–1730).These small plants are of unusual appearance and do not resemble common ferns. Common names include water clover and four-leaf clover because the long-stalked leaves have four clover-like lobes and are either held above water or submerged. On wetting, the gelatinous interior of the sporocarp swells, splitting it and releasing a worm-like mass that carries sori, eventually leading to germination of spores and fertilization.

Salvinia, a genus in the family Salviniaceae, Watermoss is a common name for *Salvinia*. *Salvinia* is related to the other water ferns, including the mosquito fern *Azolla*. Recent sources include both *Azolla* and *Salvinia* in Salviniaceae, although each genus was formerly given its own family. *Salvinia*, like the other ferns in order Salviniales, are heterosporous, producing spores of differing sizes. However, leaf development in *Salvinia* is unique. The upper side of the floating leaf, which appears to face the stem axis, is morphologically abaxial. *Salvinia molesta*, commonly known as giant *Salvinia*. It is a free floating plant that does not attach to the soil, but instead remains buoyant on the surface of a body of water. The fronds are 0.5–4 cm long and broad, with a bristly surface caused by the hair-like strands that join at the end to form eggbeater shapes. They are used to provide a waterproof covering. These fronds are produced in pairs also with a third modified root-like frond that hangs in the water.

Azolla is commonly known as mosquito fern, duckweed fern, fairy moss, water fern, is a genus of seven species of aquatic ferns in the family Salviniaceae. They are extremely reduced in form and specialized, looking nothing like other typical ferns but more resembling duckweed or some mosses. *Azolla filiculoides* is one of just two fern species for which a reference genome has been published. *A. pinnata* can spread very quickly forming dense vegetative masses on areas of still water.

9.5 GLOSSARY

Acropetal- Produced in order from the base upwards so that the youngest are at the apex.

Annulus- A ring-shaped object, structure, or region
Basipetalsuccession- of leaves or flowers; developing or opening in succession from apex to base.
Chlorophyllous- Any of a group of green pigments that capture light energy used as the energy source in photosynthesis and that are found in the chloroplasts of plants and other photosynthetic organisms.
Circinate Vernation- Circinate vernation is the manner in which a fern frond emerges. As the fern frond is formed, it is tightly curled so that the tender growing tip of the frond (and each subdivision of the frond) is protected within a coil.
Cordate- heart-shaped
Indusium- Any of several structures having a netlike or skirtlike shape, as the membranous overgrowth covering the sori in ferns.
Leptosporangiate- Having each sporangium formed from a single epidermal cell.
Monopodial branching- Monopodial branching occurs when the terminal bud continues to grow as a central leader shoot and the lateral branches remain subordinate.
Multicostate venation-When a leaf has more than one mid rib, then it is multicostate venation.
Paleae- The upper bract of the floret of a grass.
Peltate- Having the stalk or support attached to the lower surface at a distance from the margin, as a leaf; shield-shaped.
Perennial- Living for several years.
Piliferouslayer- The part of the root epidermis that bears root hairs.
Reticulate venation-Veins run parallel to one another from the base to the tip of the leaf.
Sclerotic- becoming rigid and unresponsive; losing the ability to adapt.
Spatulate- It means broad at the apex and tapered to the base.

9.6 SELF ASSESSMENT QUESTIONS

9.6.1 Fill in the blanks:

1. *Osmunda* is a genus of primarily __________ zone ferns of family Osmundaceae.
2. The Hymenophyllum have _________ kind of venation.
3. The false ________ is formed by the curling of sorus bearing margin of the leaf in *Adiantum.*
4. Which plant is also known as flowering fern?
5. The sporangia are aggregated to form _________ in *Marselia.*
6. ____________ also called the walking fern or maiden hair fern which is a Greek word which means "not wetting"
7. *Marsilea* are found in the warmer parts of the world like ___________.
8. Which aquatic fern lack roots and form thick mats which quickly cover water bodies?
9. The development of *Marselia* sporangium is of which type?
10. The stomium is also separated from both the __________ and the ________ in *Adiantum*.

11. *Dryopteris* has the highest species diversity in ____________.
12. The primary root is ___________ in *Equisetum.*

9.6.1. Answer Key: 1- Temperate, 2-Circinate, 3-Indusium, 4-*Osmunda*, 5-Sporocarps, 6-*Adiantum*, 7-Tropical Africa and Australia, 8-*Salvinia*, 9- Leptosporangiate type, 10-Stalk, annulus, 11-Eastern Asia, 12-Ephemeral

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9.9 TERMINAL QUESTIONS

1. Give detailed information about the leaves of various species of *Osmunda*.
2. What is the habit and habitat of genus *Hymenophyllum*?
3. What is the structure of spore and sporangium in *Adiantum*?
4. What are the characteristic features of root, stem and leaves of the genus *Salvinia*?
5. Provide with detail information about the sporocarp of *Marselia*.

UNIT-10 STUDY ON MORPHOLOGY AND OTHER FEATURES OF IMPORTANT FOSSILS OF INDIA

10.1 OBJECTIVES

After reading this unit students will be able -

- To know the technique for studying the fossils
- To determine the major floral distribution in India
- To know the morphological, anatomical and reproductive features of fossil plants

10.2 INTRODUCTION

The word fossil is derived from the Latin verb 'fodere' which means to dig up. Thus, a fossil refers to anything that is excavated from the earth and not fashioned by man. Actually, the fossil refers to organic remains taken from the earth. So in common sense, fossils are the traces of the past life forms in the womb of the earth. According to Arnold, the fossils are **"the relic of some former living things, plants or animals, embedded in or dug out of the superficial deposits in past geological periods."**

The studies of fossils help us to understand the past vegetation, climate and palaeoecology including the history of plant evolution, biostratigraphy, etc. Now we know some of the important basic aspects of such application, which are as follows:

(a) To Decipher Palaeovegetation and Palaeoclimate
(b) Provide Evidence for Origin and Evolution of Plants
(c) To Ascertain Palaeophytogeography
(d) To Make Biostratigraphic Correlation
(e) Calculation of Age of the Rocks
(f) To provide useful information in the exploration of fossil fuel like coal and oil.

Fossils may be of different types such as Chemical Fossils, Trace Fossils or Ichnofossils, Microfossils, Megafossils, Pseudofossils, Derived Fossils, Coal Balls, Amber etc. Among all of these fossils, mega fossils are very useful for various studies as large parts of plants like leaf, stem, root, flower, seed, etc. and animal remains as whole organism or in parts, preserved in the sedimentary deposits. These are visible to naked eyes and are the better source of morphological as well as anatomical studies. The megafossils may be categorised into the following five types on the basis of the nature of fossilisation**:**

(A) Compressions: These are plant parts, compressed by the vertical pressure of the sediments. The plant fragments like leaves, stem, seeds get flattened and are retained as thin carbonaceous films with outline of external features. Generally, internal structure is not preserved, however, in rare instances cuticles, stomata, etc. are retained.

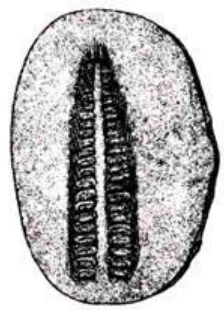


Fig. 10.1: Compression of *Lepidostrobus* cone

(B) Impressions: Impression may be defined as the negative of a compression. These are just impression of plant parts which do not contain organic matters as in compression. The sediments containing the flattened plant parts become hardened and when split open shows the negative imprint i.e. impression.

Fig. 10.2: Impression of *Neuropteris* leaf

(C) Petrifactions: These are the best, but rarest types of fossils which preserve the external form as well as the internal structures. The cellular details are preserved due to the infiltration of minerals like SiO_2, $CaCO_3$, $MgCO_3$, FeS, etc. into the tissue. The petrified fossils can be cut into small pieces and series of section can be made for anatomical studies.

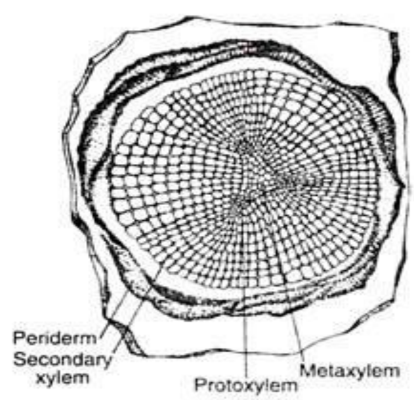


Fig. 10.3: T.S. of a petrified *Sphenophyllum* stem

(D) Casts or Incrustations and Molds: In these types, the deposition of iron and carbonate minerals occurs in the form of a hard cast around the plant parts. The internal structure is degraded to form a cavity which is completely filled up by the surrounding sediments. Thus, the external preserved surface of the plant part is called a mold, while the replaced internal structure of the plant part is called a cast. Stigmarian root system is an example of mold, while the pith cast of a Catamites stem is a common example of incrustation. In these types, only external forms are preserved, while internal cellular details are not preserved.

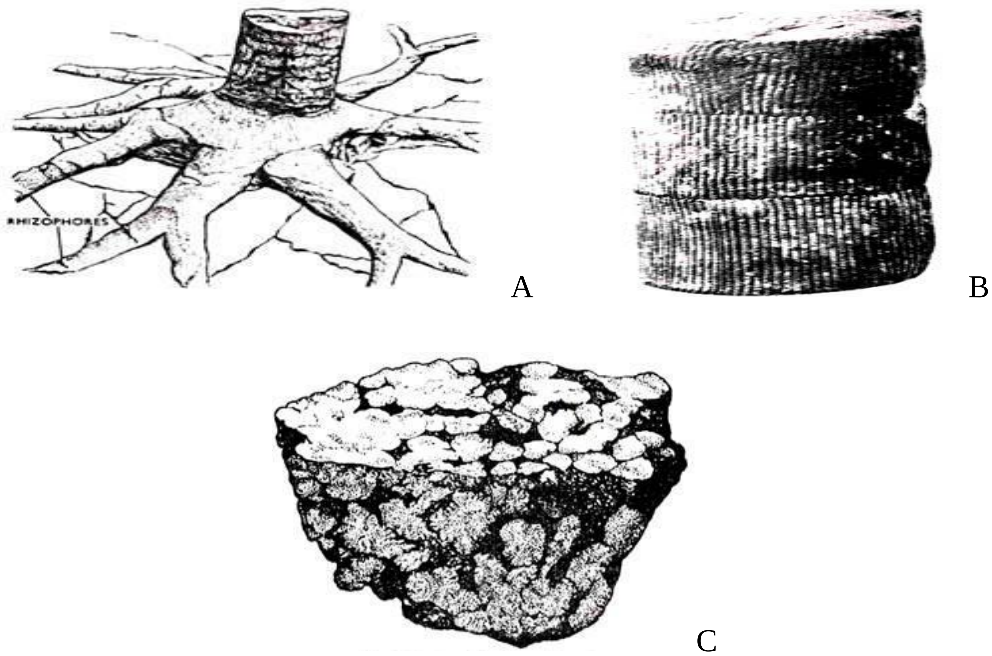


Fig. 10.4: A- A mold of stigmaria, B- A pith cast of calamites, C- A coal ball (sectioned)

10.3 TECHNIQUES FOR STUDYING THE FOSSILS

For studying the fossils, the students should be aware of four different techniques. The techniques are:

1. Ground Thin Section
2. Film or Peel Technique
3. Transfer Technique
4. Maceration Technique.

1. Ground Thin Section: This technique is suitable for the study of petrified fossils which preserve cellular details.

(i) To begin with, the specimen is cut to a convenient size with a lapidiary’s saw or similar instrument and is smoothened on one surface with abrasive (300 or 400 carborundum). The smooth surface is attached to a glass slide with melted resin. Then, the specimen is cut as close to the glass as possible, thus a moderately thin section is obtained.

(ii) The thin section fixed to the glass slide is further ground on a revolving lap with 100 carborundum till sufficiently translucent, so that the section can be viewed under the microscope. Finally, the slice is mounted with a cover glass using suitable mounting media.

Advantage: A thin section of petrified wood can be made that preserves the cellular structure in an unchanged condition.

Disadvantages:

(a) The technique needs extensive labour and is time-consuming,

(b) A small number of sections can be made from a given specimen, thus a lot of material is wasted.

2. Film or Peel Technique: This is a conventional and most suitable technique for study of well-preserved petrifactions with considerable organic materials.

(i) The specimen to be studied is ground and smoothened and is etched with 5% hydrochloric acid (if the material has calcium carbonate) and 10% hydrofluoric acid (if the material has silica) for 5 and 10 mns respectively. The etched surface is gently washed in running water for the removal of acid and is air-dried and then covered with a solution or a thin film of nitrocellulose.

(ii) The specimen is air-dried for at least 6 hours. Then the film is carefully peeled by loosening one edge and is permanently mounted on a slide with a cover- glass using suitable mounting media. An improvement in the peel technique has been made that makes possible rapid preparation of serial sections.

Advantages:

(a) A series of sections can be made from a single specimen.

(b) It is less expensive and quicker to prepare.

(c) The sections (peels) obtained are translucent, thinner and durable.

3. Transfer Technique: This technique is most suitable for the study of coalified compression which reveals additional details of venation, epidermal pattern and hairs.

(i) The face of the specimen adjoining the rock surface is cleaned either mechanically or by washing in an acid for removal of rock particles. The prepared surface of the rock is coated with a solution of nitrocellulose or with a cellulose acetate film. When the film is dried, it is loosened from the rock surface.

(ii) Sometimes coalified materials are adhered to the film. Occasionally the film is treated with strong oxidising agent to make the film more transparent. Finally, the film is dried and permanently mounted on the slide with a coverglass using a suitable mounting medium.

Advantage: This technique is very useful for study of coalified compression. It helps to learn about leaf form, venation pattern, stomata and epidermal characteristics which are important features used in establishing systematics and phylogeny of extinct plants.

4. Maceration Technique: This technique is most suitable for study of peat, lignite and coal. It is very useful for pollen and spore analysis:

(A) PEAT ANALYSIS (ACETOLYSIS TECHNIQUE):

Sample meterial

↓

Cleaning, disaggregation and weighing

↓

Treatment with 10% KOH for removal of humic substances

↓

Wash and centrifuge

↓

The residue is treated with 40% Hydrofluoric acid for digestion of silica

↓

Wash and centrifuge

↓

The residue is treated with Acetolysis mixture (Acetic anhydride : Conc. H_2SO_4 = 9:1) for removal of unwanted materials and also for colouration of spore/pollen wall

↓

Wash and centrifuge

↓

Samples containing pollen/spores are kept in 50% glycerine

↓

A drop of sample is mounted on a slide and observe under microscope

(B) LIGNITE AND COAL ANALYSIS:

Sample meterial

↓

Cleaning, disaggregation and weighing

↓

2-3 gm of coal/lignite pulverised and decalcified

↓

Treatment with 10% HCl

↓

Oxidation with Schulze's solution

↓

Treatment with 5% HCl/dilute NH_4OH/20% K_2CO_3/acetone for removal of humic acid

↓

Stain with Safranin-O

↓

Sample containing pollen/spores are stored in 50% glycerine

↓

A drop of sample is mounted on a slide and observe under microscope

Advantages:

1. A small portion of sediment is enough to get considerable amount of pollen and spores.
2. Due to the presence of resistant chemical sporopollenin in exine, pollen and spores are considerably preserved in deposits like peat/ coal/lignite, etc.

3. The maceration process is very simple and reliable.

10.4 DISTRIBUTION OF FOSSILS

The distribution of the different groups in the different ages is shown more elaborately in Table-1:

Table-1

GEOLOGICAL PERIODS

GEOLOGICAL PERIODS IN THE NORTHERN HEMISPHERE

Era	Period	Age in million years	Types of vegetation
CENOZOIC	Quaternary	1	Modern
	Upper Tertiary, Pliocene Miocene	10 20	Modern
MESOZOIC	Lower Tertiary, Oligocene Eocene Upper Cretaceous Lower Cretaceous Upper Jurassic Lower Jurassic (Liassic) Upper Triassic (Rhaetic)	35 50 75 100 130 140 160	Modern, with tropical plants in Europe Gymnosperms dominant (Conifers and Bennettitales) Luxuriant forests of Gymnosperms and Ferns
	Lower Triassic (Bunter) Upper Permian	180 190	Sparse desert flora with Gymnosperms (Conifers and Bennettitales)
PALAEOZOIC	Lower Permian Upper Carboniferous (Coal Measures)	200	Tall swamp forests with early Gymnosperms, Tree Lycopods *Calamites* and Ferns.
	Lower Carboniferous Upper Devonian	250 260	Early Gymnosperms, large tree Lycopods and Ferns
	Middle Devonian	275	*Rhynia* vegetation in marshy localities.
	Lower Devonian Upper Silurain	300	Herbaceous marsh plants (*Psilophyton* and *Zosterophyllum*) and some small shrubs.
	Silurian	350	Marine algae
	Ordovician	425	Marine algae
	Cambrian	500	Marine algae, but some evidence of land plants too.
PRECAMBRIAN		4500 ?	Fungi and bacteria reported to have occurred 2,000 million years ago.

The Indian Gondwana Flora:

The most important fossil flora of India is known as the Gondwana Flora which covers the period Upper Carboniferous to Jurassic. Indian plant fossils are known before (a few) and after (quite a large number) this period but no flora is as interesting as the Gondwana Flora. Towards the end of the Palaeozoic were the great Hercynian mountain building waves. This was followed in the Upper Carboniferous and the Permian by severe glaciation and the Permian in India is the greatest coal- forming age. The geography of the Earth at that time was quite different from what it is today.

There were three continents—the Eur-American Continent (modern Europe and North America) to the North-West, Angaraland (Siberia and North China) to the North-East and a vast Gondwana land on the South which combined the land masses of India, Africa, Australia, South America and Antarctica. In between the continents was the great Sea of Tethys.

Fig. 10.5: The continents during Upper Carboniferous to lower cretaceous period, shown by thick lines

The Gondwana land has been named after the Gond tribe of Madhya Pradesh ruled by the famous Rani Durgabati during the reign of Akbar. The name was coined by H. B. Medlicott in 1872 but actually published by O. Feistmantel in 1876. The Gondwana land began to split in the Jurassic as shown by the intensive lava injections at that age.

There was drifting apart of the continents in the Cretaceous, gradually bringing them to their present positions. Another series of great mountain building waves built the present dominant Mountains (Himalayas, Alps, etc.) on the location of the Sea of Tethys.

The whole Gondwana land (now distributed over five continents) shows a uniformity of the Flora (and also the Fauna). In Indian Geology the Gondwana rocks are considered to form a Group which is almost equivalent to an Era like Palaeozoic. Feistmantel (1882) divided the Gondwana into Lowor Gondwana (Permo-Carboni- ferous with Glossopteris Flora), Middle Gondwana (Triassic with Glossopteris-Thiimfeldia (Dicroidium Flora) and Upper Gondwana (Jurassic with Ptilophyllum Flora).

This three-fold division has been followed by many authorities like Wadia and Lele. But many other authorities prefer a two-fold division into Lower Gondwana (Upper Carboniferous to Lower Triassic) and Upper Gondwana (Lower Triassic to Jurassic, probably reaching Cretaceous).

The two-fold division is supported by the two (Glossopteris Flora and Thinnfeldia (Dicroidium)—Ptilophyllum Flora) distinct floras (and faunas) in the two divisions.

There is a sudden break between the two floras as during the Upper Permian and Triassic intensive glaciation and drought killed most of the previous early Gymnosperms and arborescent Pteridophytes giving place to the more modern Gymnosperms and herbaceous Pteridophytes (mainly ferns).

Gondwana rocks occur mainly in the Damodar, Sone, Narbada, Godavari and Mahanadi Valleys. There are also some exposure along the Himalayan foothills of Nepal, Bhutan and Arunachal and also in the Punjab, Himachal, Kashmir and Baluchistan. Upper Gondwana rocks are more detached occurring in patches along Rajmahal-Cuttack to Kanya Kumari, in Madhya Pradesh, Rewa, Saurashtra, Kutch and in Ceylon. It should be noted against that the Triassic beds (Maleri, Mahadeva, Pachmarhi, Parsora, Panchet) spreading from Sone to Godavari Valleys are placed by some in Middle Gondwana.

The Gondwana system is comprised of continental deposits of conglomerates, sandstones, shales and coal measures of mainly fluviatile (river) and lacustrine (lake) origin. Recent works also indicate the presence of some marine intercalations in the Gondwana sediments of central and east coastal India. The sediments were deposited in trough-like basins, bounded on either side by older Archaean rocks which endured faulting. Archaean rocks protected the Gondwana deposits from denudation and thus preserved the sediments in their original horizontal stratification. There is a striking homogeneity of Gondwana sediments with a uniform alteration of sandstones and shales bearing coal seams.

According to the period of dominance of the principal genus of the floral assemblage, the Gondwana can be classified into three divisions (Fig.10.6):

1. Lower Gondwana: This division shows predominance of the Glossopteris flora, during Permian period, in which the Talchir, Karkarbari, Barakar, Barren measures Raniganj, Motur, Hingir and Bijori formations are included. Some elements of this division continues till the Middle Triassic.

2. Middle Gondwana: This is characterised by the accession of Dicroidium and declining of Glossopteris flora (mixed flora) at the beginning of Triassic which extends up to the Upper Triassic with dominance of Dicroidium flora. In this division, Panchet, Kamthi, Pachmari, Maleri, Parsora, Bagra, Tiki, etc. formations have been included.

3. Upper Gondwana: This is characterised by the arrival of Ptilophyllum flora till the end of Gondwana era, ranging from Jurassic to Lower Cretaceous, in which Dubrajpur, Rajmahal, Kota, Jabalpur, Gangapur, Shivganga, Bhuj, Pariwar, etc., formations are conveniently included.

There is overlapping of the three distinct floras where the elements of the dying flora crawl for some time amongst the evolving flora, thus, showing the floral continuity throughout the Gondwana period.

So, there is a gradual decline of one flora with the simultaneous evolution of the other, both in number of individuals and species. Even in a single flora, there is specific delimitation where certain species characterise the smaller units of bigger sub-divisions. Thus, the larger sub-divisions can further be divided into smaller units.

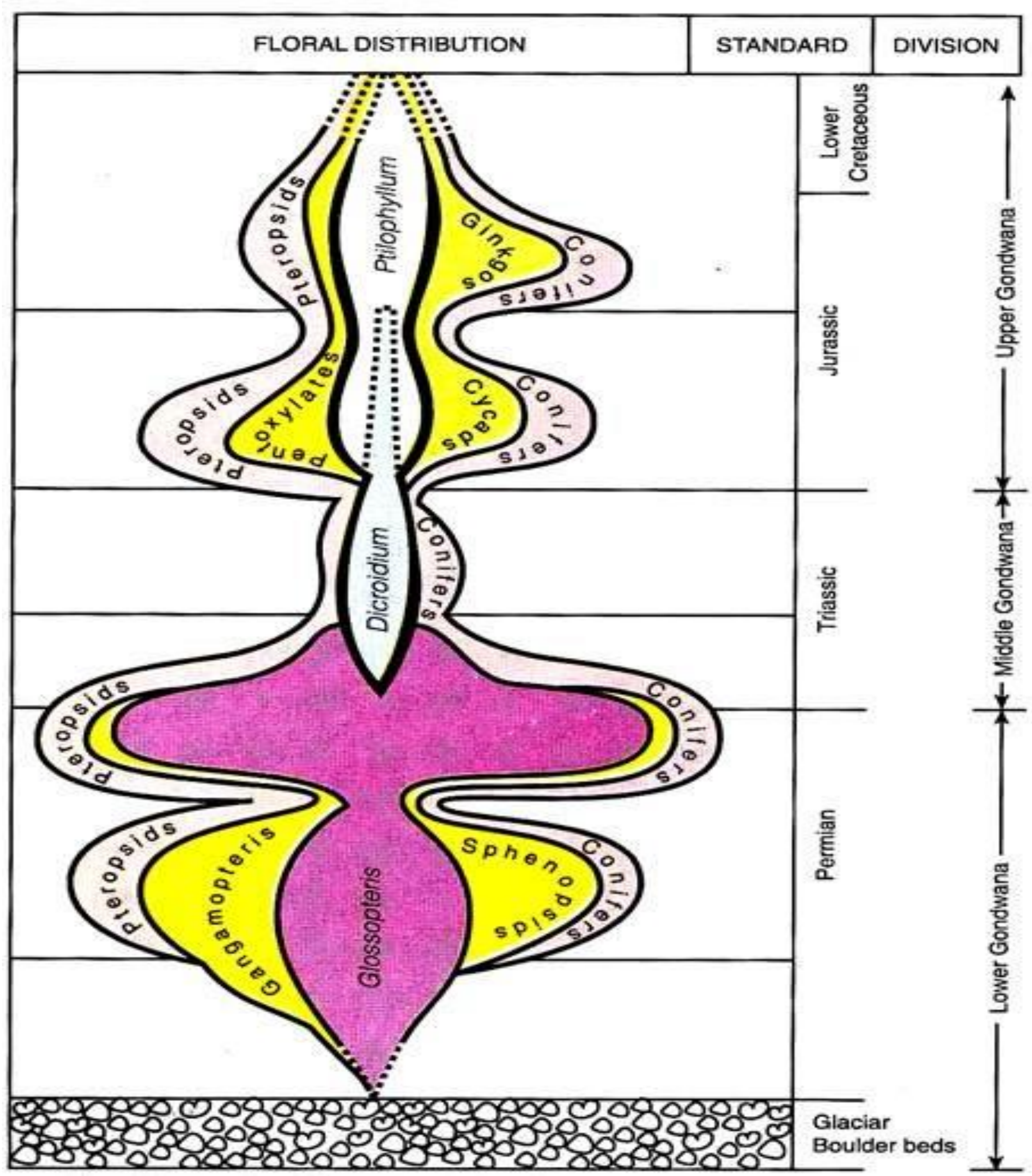


Fig. 10.6: The three fold division of Indian Gondwana showing floral succession

Major Floral Distribution of Gondwanas:

The students now know the floral distribution of Indian Gondwana land.

A- Lower Gondwana Flora:

The different plants recovered from the various stages of the Lower Gandwara are listed:

1. Pteridophytes:

(i) Equisetales: *Schizoneura, Phyllotheca, Stellotheca*.

(ii) Sphenophyllales: *Sphenophyllum, Raniganjia, Trizygia*.

(iii) Lycopodiales: *Cydodendron*.

(iv) Filicales: *Gondwanidium, Pecopteris, Sphenopteris, Angiopteridium*, etc.

2. Gymnosperms:

(i) Glossopteridales: *Gangamopteris, Glossopteris, Rubidgea, Rhabdotaenia, Vertebraria, Scutum, Ottokaria, Glossotheca*, etc.

(ii) Cycadales: *Pseudoctenis, Taeniopteris*.

(iii) Cordaitales: *Noeggerathiopsis, Euryphyllum, Cardiocarpus, Samaropsis*.

(iv) Ginkgoales: *Psygmophyllum, Ginkgophyton*.

(v) Coniferales: *Buriadia, Barakaria, Dadoxylon, Araucareoxylon, Agathoxylon, Damudoxylon* etc.

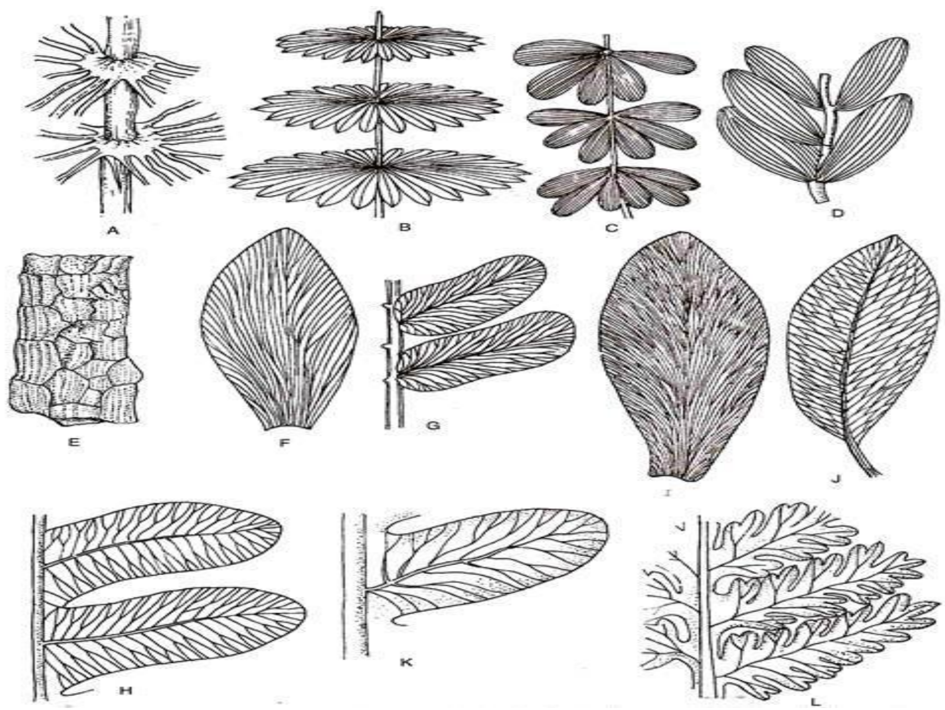


Fig. 10.7: Paleozoic Gondwana flora: A: *Phyllotheca indica*, B: *Raniganjia rayneri*, C: *Sphenophyllum speciosum*, D: *Schizoneura gondwanensis*, E: *Vertebraria indica*, F: *Euryphyllum*, G: *Neuropteris*, H: *Alethopteris*, I: *Gangamopteris*, J: *Glossopteris*, K: *Pecopteris*, L: *Sphenopteris*

Middle Gondwana Flora:

The different plants recovered from the Middle Gondwana are listed as follows:

1. Pteridophytes:

(i) Equisetales: *Schizoneura*

(ii) Calamitales: *Neocalamites*.

(iii) Filicales: *Pecopteris, Sphenopteris, Marianopteris Cladophlebis*.

2. Gymnosperms:

(i) Glossopteridales: *Glossopteris, Macrotaeniopteris, Vertebraria, Dictyopteridium*.
(ii) Corystospermales: *Dicroidium*.
(iii) Cycadales: *Pseudoctenis, Taeniopteris*.
(iv) Cycadeoidales: *Pterophyllum, Zamites, Podozamites*.
(v) Cordaitales: *Neoggerathiopsis, Cardio- carpus, Samaropsis*.
(vi) Coniferales: *Araucarites.*

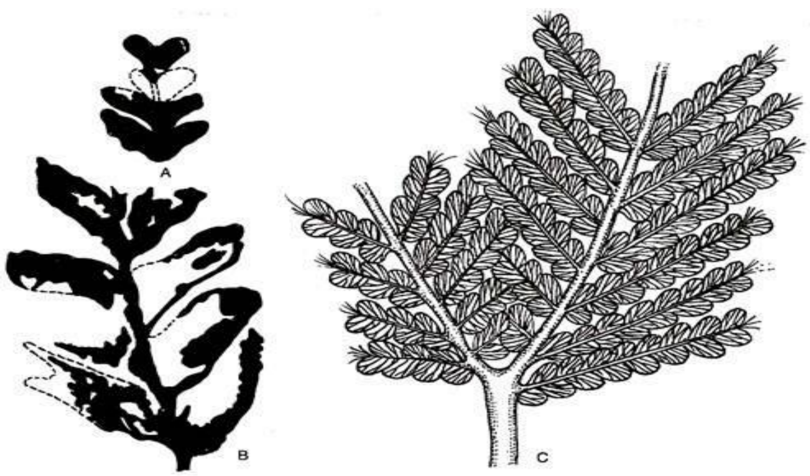


Fig. 10.8: *Dicroidium*: A-B. Leaves preserved as compression, C. Reconstructed plant

Upper Gondwana Flora:

The major floral distribution of the Upper Gondwana is listed:

1. Pteridophytes:
(i) Lycopodiales: *Lycopodites*.
(ii) Isoetates: *Isoetites*.
(iii) Equisetales: *Equisetites*.
(iv) Filicales: *Phlebopteris, Marattiopsis, Gleichenites, Sphenopteris, Osmundites, Cladophlebis, Cyclopteris*.

2. Gymnosperms:

(i) Corystospermales: *Dicroidium, Pachypteris, Cycadopteris*.
(ii) Cycadales: *Niissonia, Taeniopteris, Macrotaeniopteris, Pseudoctenis*.
(iii)Cycadeoidales: *Pterophyllum, Ptilophyllum, Bucklandia Weltrichia, Zamites, Podozamites, Otozamites, Williamsonia, Cycadeoidea, Anomozamites, Sahnioxylon*.
(iv) Caytoniales: *Sagenopteris, Caytonia, Caytonanthus*.
(v) Pentoxylales: *Nipaniophyllum, Carnoconites, Pentoxylon*.
(vi) Cordaitales: *Neoggerathiopsis, Cardiocarpus, Samaropsis*.

(vii) Coniferales: *Dadoxylon, Stachyotaxus, Elatochadus, Nipaniostrobus, Sitholeya, Indophyllum, Pagiophyllum, Brachyophyllum, Araucarites*.

(viii) Ginkgoales: *Baiera, Ginkgoites.*

(ix) Taxales: *Taxaceoxylon, Torreyites, Taxites.*

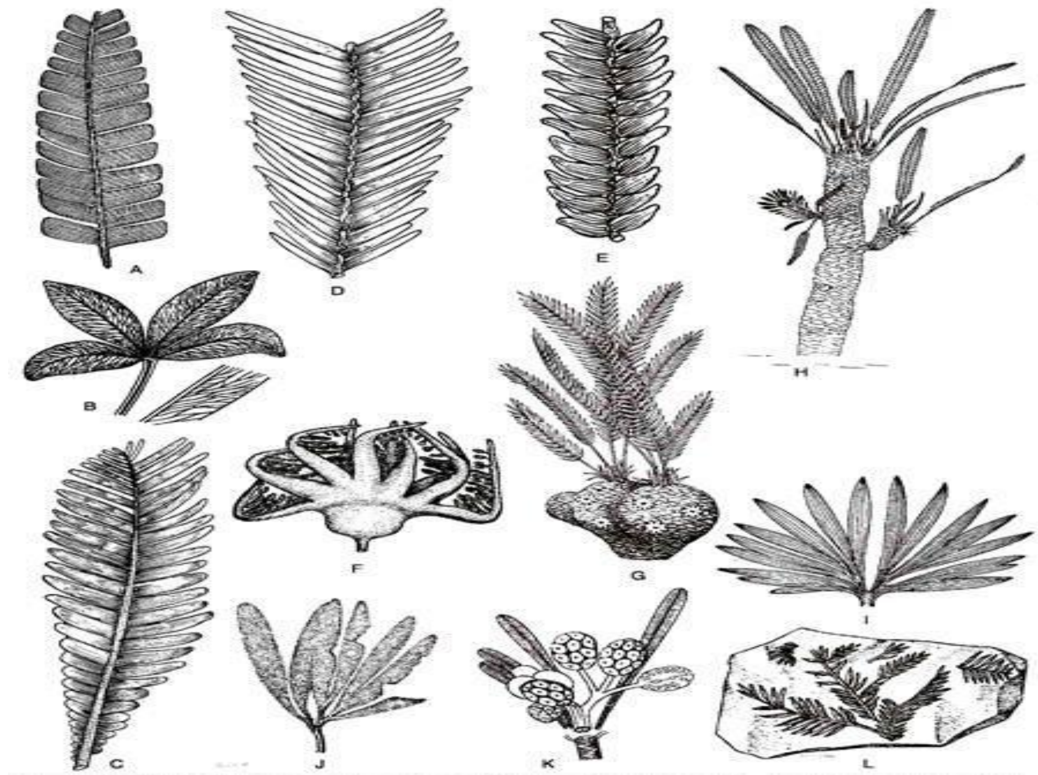


Fig. 10.9: Mesozoic gondwana flora: A. *Nissonia compta*, B. *Sagenopteris*, C. *Pterophullum*, D. *Ptiophullum*, E. *Otozamites*, F. *Weltrichia spectabilis*, G. *Cycadeoidea*, H. *Williamsonia sewardiana*, I. *Baiera gracilis*, J. *Ginkgoites hermelini*, K. Shoot of *Pentoxylon* with *Nipaniophyllum* leaves and *Carnoconites* fructification, L. *Elatocladus*

10.5 LIST OF IMPORTANT FOSSILS PLANTS OF INDIA

The students now aware of morphological, anatomical and reproductive characters of important Fossil Genera Plants which are listed as follows:

1. *Rhynia:*

Systematic position:

Division: Pteridophyta

Class: Psilophyta

Order: Psilophytales

Family: Rhyniaceae

Genus: *Rhynia*

Age: Middle Devonian.
Locality: Rhynie chart bed in Scotland.

Morphological features:

1. Plant body was sporophytic.
2. *Rhynia* major was bigger and attained a height of 50 cm. with a diameter of 1.5 to 6 mm., while *R.gwynne-vaughani* had a height of 20 cm. and a diameter of 1 to 3 mm.
3. Plants had a rhizome which was dichotomously branched.
4. From rhizome developed many dichotomously branched erect aerial shoots towards the upper side while many rhizoids towards the lower side.
5. There were no roots on the plants.
6. Aerial shoot of *Rhynia major* were smooth and devoid of leaf or any other outgrowth, while in case of *R. gwynne-vaughani* many adventitious branches were present on the aerial shoot.
7. Aerial shoot were either ending into simple vegetative tips or having terminal sporangia.

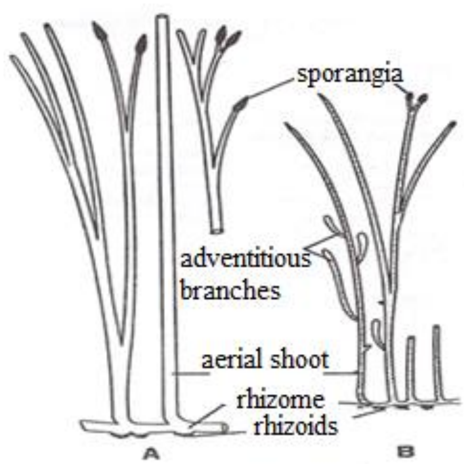


Fig. 10.10: *Rhynia* external features A: *R. major,* B: *R. gwynne-vaughanii*

Anatomy of *Rhynia*:

1. Rhizome and aerial shoots of the plant were internally differentiated into epidermis, cortex and stele
2. Stele was of a simple protostele type, (i.e., central column of xylem was surrounded by phloem).
3. Xylem was made up of only tracheids.
4. Phloem was 4 to 5-cells in thickness.
5. There was no endodermis in between cortex and stele.
6. Cortex was differentiated into outer and inner cortex, and was about 10 times more in thickness than stele.
7. The inner cortex was made up of many spherical cells having large intercellular spaces.

T.S. of Stem of *Rhynia*:

(i) The stem surface is covered by cuticularised epidermis with compactly arranged cells.
(ii) Conspicuous stomata arc present.
(iii) Next to the epidermis, there is a massive cortical zone formed by compactly arranged parenchymatous cells.
(iv) There is no endodermis or pericycle.
(v) At the centre, there is a slender, hadrocentric protostele with a small central xylem core. This is surrounded by 4 – 5 layers of elongated cells with oblique ends which represent the phloem although sieve plates have not been observed.

L.S. Through The Sporangium Of Rhynia Shows The Following Features:

(i) The sporangia arc oval or cylindrical structures with pointed ends.
(ii) The sporangium wall is thick and multilayered with the outer cells thick-walled and inner thinner cells represent the tape-turn.
(iii) The whole interior is filled with spore tetrads or free spores.

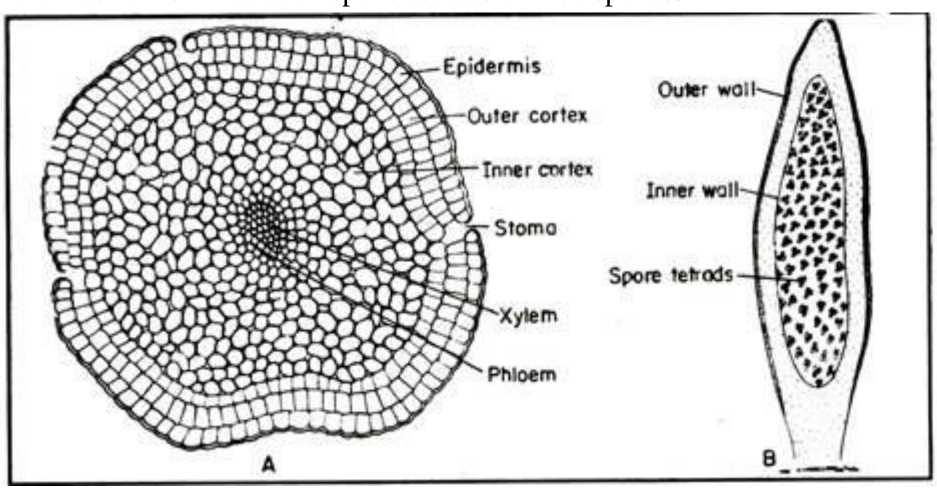


Fig. 10.11 A: T.S. of stem of *Rhynia* sp., B: L.S. through sporangium

2. *Sphenophyllum*

Systematic position:

Division: Pteridophytes
Class: Coniferopsida
Order: Sphenophyllales
Family: Sphenophyllaceae
Genus: *Sphenophyllum*

Age: Upper Devonian to lower Jurassic.
Locality: Europe and also in Indian lower Gondwana.

Identifying Features:

T.S. Through Sphenophyllm (Stem) Shows the Following Features:

(i) There is a conspicuous periderm at the outer-most surface.
(ii) Next to this layer, there is a patch of cortical zone of parenchymatous cells.
(iii) At the middle of the stem, there is a solid strand of protostele.
(iv) The primary xylem of the stele is triangular, exarch and actinostelic.
(v) There is a massive secondary xylem which is arranged in a multiseriate pattern.

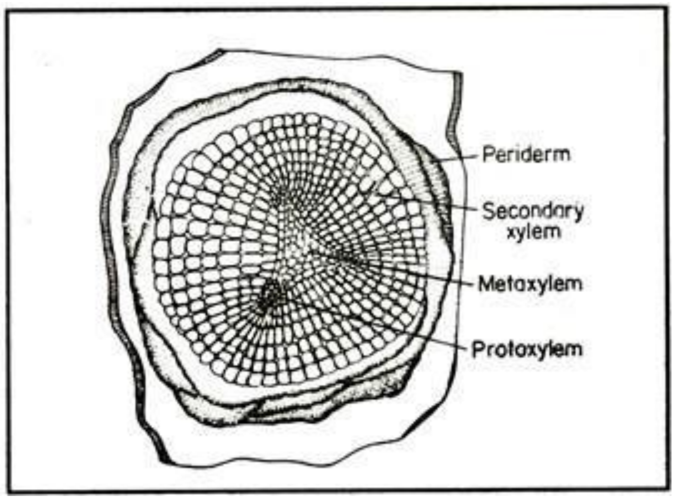


Fig. 10.12: T.S. through stem of *Sphenophyllum* sp.

3. *Medullosa*

Systematic position:

Division: Cycadophyta
Class: Progymnospermopsida
Order: Pteridospermales
Family: Medullosaceae
Genus: *Medullosa*

Age: Permo Carboniferous.
Locality: Indian Gondwana (Lower)

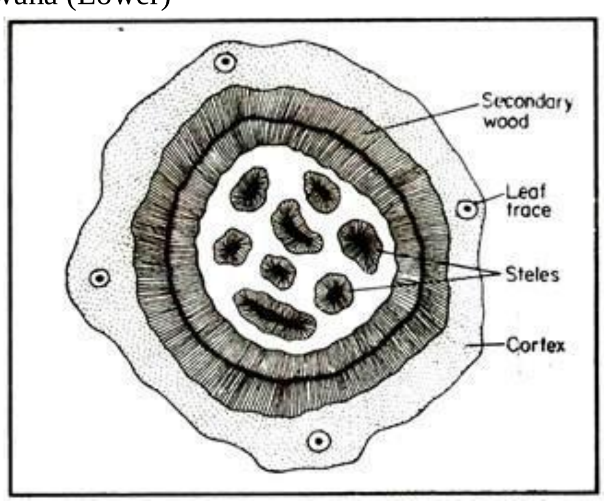


Fig. 10.13: T.S. through stem of *Medullosa* sp.

Identifying Features:

T. S. Through *Medullosa* (Stem) Shows the Following Features:

(i) There is a thick parenchymatous cortex with scattered leaf trace bundles just outside the stelar zone.

(ii) There is a ring of conspicuous secondary wood zone just beneath the cortical layer.

(iii) At the central core primary vascular bundles are scattered in the parenchymatous tissues. Each bundle has distinct xylem and phloem.

4. *Glossopteris*

Systematic position:

Division: Gymnospermae
Class: Cycadopsida
Order: Pteridospermales
Family: Glossopteridaceae
Genus: *Glossopteris*

Age: Parmo – Carboniferous.
Locality: Lower Gondwana (India).

Identifying Features:

The Impression Fossil of *Glossopteris* (Leaf) Shows The Following Features:

(i) Leaves are simple, entire, sessile to short petiolate, linear, lanceolate to ovate and with a very strong midrib from which numerous small fine veins pass out to the margin forming a network.

(ii) Midrib of the leaf is prominent, particularly at the base of the leaf.

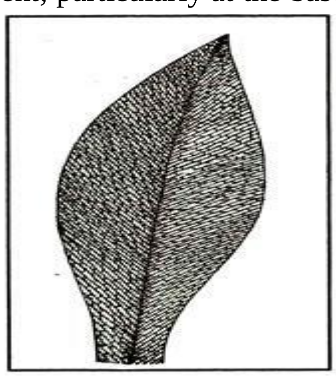


Fig. 10.14: Whole mount of leaf *Glossopteris* sp.

5. Vertebraria

Systematic position:

Division: Gymnospermae
Class: Cycadopsida
Order: Glossopteridales
Family: Glossopteridaceae
Genus: *Vertebraria*

Age: Permo – Carboniferous.
Locality: Lower Gondwana (India).

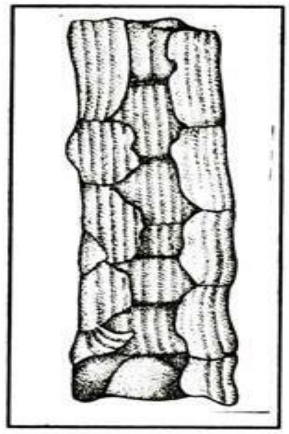


Fig. 10.15: Whole mount of *Vertebraria* sp.

Identifying Features:

The Petrified Fossil Of *Vertebraria* (Stem) Shows The Following Features:

(i) The stem axis is flattened and grooved.

(ii) The axis shows 2-3 series of rectangular blocks of alternate ridges and furrows.

6. *Gangamopteris*

Systematic position:

Division: Gymnospermae
Class: Cycadopsida
Order: Glossopteridales
Family: Glossopteridaceae
Genus: *Gangamopteris*

Age: Permo – Carboniferous.
Locality: Lower Gondwana (India).

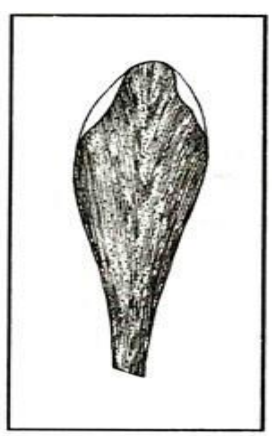


Fig. 10.16: Whole Mount Of Leaf of *Gangamopteris* Sp

Identifying Features:

The Impression Fossil Of *Gangamopteris* (Leaf), Showing The Following Features:

(i) The leaves are simple and ovate to lanceolate in shape.

(ii) There is absence of distinct midrib.

(iii) Lateral veins show parallel anatomising features and thus forming a reticulate network.

7. *Pentoxylon*

Systematic position:

Division: Gymnospermae
Class: Cycadopsida
Order: Pentoxylales
Family: Pentoxylaceae
Genus: *Pentoxylon*

Age: Lower Jurassic.

Locality: Upper Gondwana (India).

Identifying Features (Fig-10.17-A):

T. S. Through *Pentoxylon* (Stem) Shows the Following Features:

(i) There are two rings of steles – inner ring is formed of 5 – 6 larger steles in each of which there is conspicuous endocentric secondary wood, i.e., a greater part of the wood is formed towards the pith.

(ii) Alternating with these inner rings of larger steles there is one outer ring of smaller steles. These steles are formed of secondary wood.

(iii) There are distinct growth rings in each larger stele.

8. Nipanioxylon

Age: Lower Jurassic.

Locality: Upper Gondwana (India).

Identifying Features (Fig.10.17-B):

The Impression Fossil of *Nipanioxylon* (Leaf) Shows The Following Features:

(i) The leaf is strap shaped with a distinct midrib which is formed by several strong parallel veins.

(ii) Each parallel vein is branched and runs parallel to the margin. These branch veins may show forking at the ends.

9. Sahnia

Age: Lower Jurassic.

Locality: Upper Gondwana (India).

Identifying Features (Fig.10.17-C):

Vertical Section Through *Sahnia* (Male Flower) Shows The Following Features:

(i) Micro-sporophylls are branched and fused at the base to form a tubular disc.

(ii) The final branches bear unilocular Microsporangia at the tips.

10. Carnoconites

Age: Lower Jurassic.

Locality: Upper Gondwana (India).

Identifying Features (Fig.10.17-D):

L. S. Through *Carnoconites* (Female Cone) Showing the Following Features:

(i) The cone is pedunculate and each branch bears a female cone.

(ii) Each cone has an axis bearing spirally arranged sessile ovules directly on it.

(iii) There is no scale, bract or megasporophyll which is associated with it.

(iv) The seed shows thick, fleshy integument and protruding micropyle.

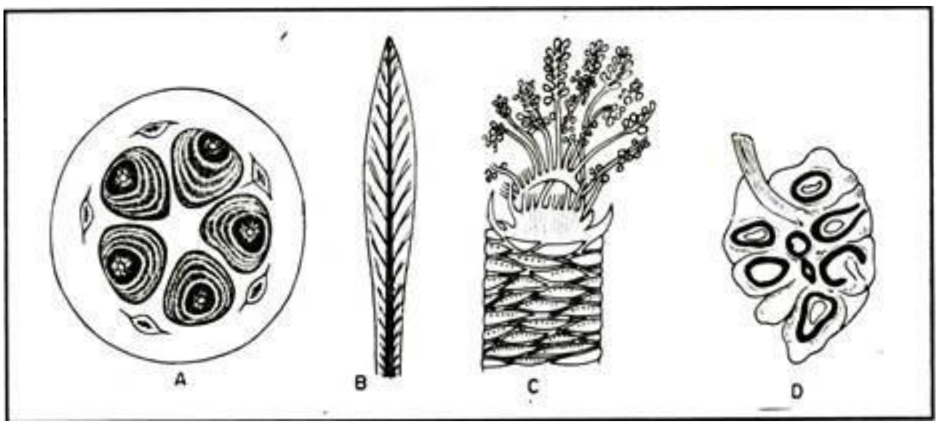


Fig. 10.17 A: T.S. Through stem of *Pentoxylon* sp., B: whole mount of leaf, C: Microsporophyll, D: V.S. through ovules

11. *Cordaites*

Systematic position:

Division: Gymnospermae
Class: Coniferopsida
Order: Cordaitales
Family: Cordaitaceae
Genus: *Cordaites*

Age: Upper Carboniferous.

Locality: Lower Gondwana (India),

Identifying Features

Morphological Features:

i) The plant was tall and slender.

ii) It had a crown of branches near the top, leaves were large simple and pendulate and not found on any living gymnosperm.

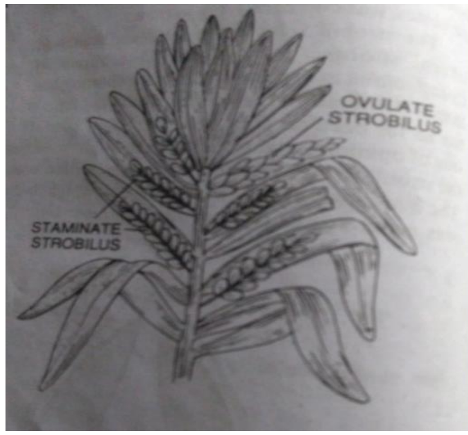


Fig. 10.18: *Cordaites*. Apical portion of the stem with leaves and male and female strobili

Anatomical Features:

T. S. Through *Cordaites* (Stem) Shows the Following Features:

(i) There is a distinct periderm which forms the outermost covering of the stem.

(ii) There is a massive cortex which is parenchymatous with gum canals.

(iii) There are a few leaf trace bundles in the innermost layer of cortex.

(iv) There is a large parenchymatous pith found at the centre of the stem. (v) In between pith and cortex, there is secondary wood which often cracked transversely giving the appearance of a pile of concave discs.

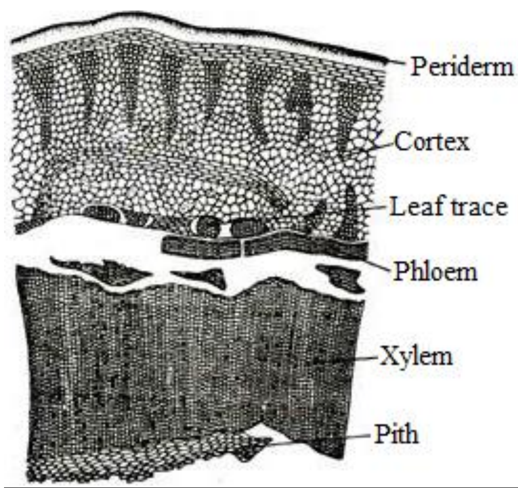


Fig. 10.19: T.S. through stem of *Cordaites* sp.

T. S. Through *Cordaites* Leaf Shows the Following Features:

(i) There are two distinct cutinised, thick walled epidermal layers.

(ii) There is also a thick walled hypodermis just beneath the epidermis which extends up to the bundle sheath.

(iii) Stomata are present in the lower epidermis.

(iv) Mesophyll cells are distinct and lie in between two epidermal and hypodermal zones.

(v) There are conjoint, collateral, closed vascular bundles surrounded by bundle sheath of 1 – 2 layers of thick cells.

(vi) Transfusion tissue is present in between two bundles.

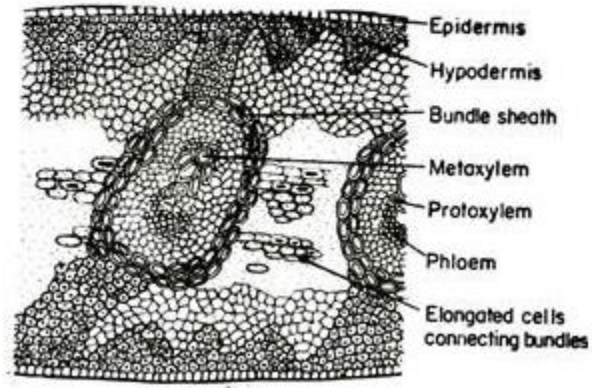


Fig. 10.20: T.S. through leaf of *Cordaites* sp.

12. *Amyelon*

Systematic position:

Division: Gymnospermae
Class: Coniferopsida
Order: Cordaitales
Family: Cordaitaceae
Genus: *Amylon*

Age: Upper Carboniferous.

Locality: Lower Gondwana (India).

Identifying Features:

T. S. Through *Amyelon* (Root) Shows the Following Features:

(i) There is a uniformly thick periderm as outer covering of the axis.

(ii) There is also a parenchymatous cortex just below the periderm layer.

(iii) There is a central triangular protostele which is often triarch (rarely diarch or tetrarch).

(iv) In between primary xylem and cortex, there is a very thick secondary wood zone.

(v) Pith is absent.

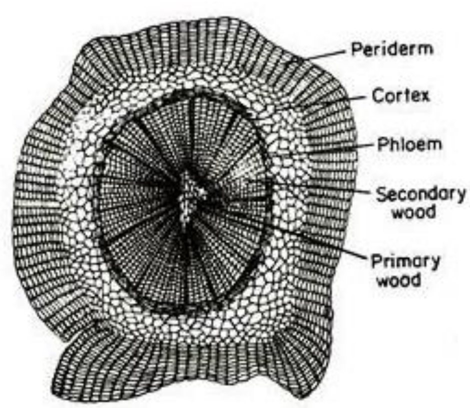


Fig. 10.21: T.S. through root of *Amyelon* sp.

13. *Cordaianthus*

Systematic position:

Division: Gymnospermae
Class: Coniferopsida
Order: Cordaitales
Family: Cordaitaceae
Genus: *Cordaianthus*

Age: Upper Carboniferous.
Locality: Lower Gondwana (India).

Identifying Features:

Median L.S. Of *Cordaianthus* (Strobilus) Shows the Following Features:

(i) A male strobilus contains a few microsporophyll's or stamens each supporting terminal sporangia.
(ii) The female strobilus contains a few megasporophylls or carpels each bearing a terminal mega sporangium or ovule.
(iii) The ovule or mega sporangium shows an elongated oval nucellar mass completely free from the single integument which is extended into a short micropylar canal at the top.

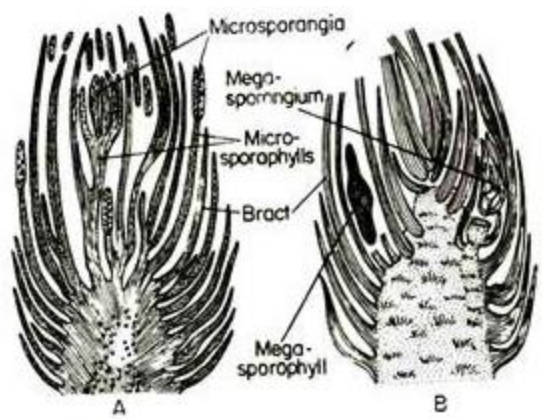


Fig. 10.22: V.S. through *Cordaianthus* sp. A- Microsporophylls, B- Megasporophylls

14. *Mitrospermum*

Systematic position:

Division: Gymnospermae
Class: Coniferopsida
Order: Cordaitales
Family: Cordaitaceae
Genus: *Mitrospermum*

Age: Upper Carboniferous.
Locality: Lower Gondwana (India).

Identifying Features:

L. S. Through *Mitrospermum* (Seed) Shows the Following Features:

(i) The seed is flattened and heart shaped.

(ii) The nucellar portion is surrounded by an integument whose outer layer is expanded into a wing-like outer testa and the inner layer forms a hard, sclerotic testa.

(iii) There is a vein derived from the pedicel which divides into two and then supplies the integument.

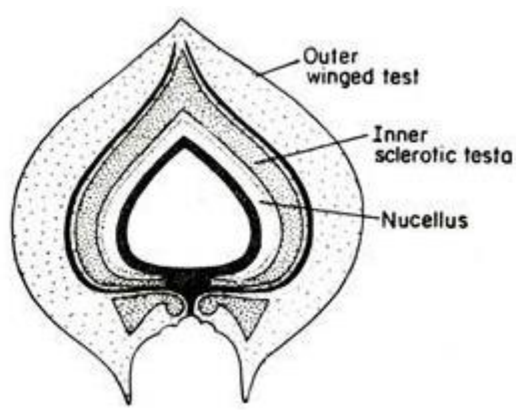


Fig. 10.23: V.S. through Ovules *Mitrospermum* sp.

15. *Heterangium*

Systematic position:

Division: Gymnospermae
Order: Pteridospermales
Family: Lyginopteridaceae
Genus: *Heterangium*

Age: Upper and lower Carboniferous.

Locality: Lower Gondwana (India),

Anatomical Features:

T.S. Of Stem:

i) The outline of stem in transverse section appears somewhat angular because of presence of large decurrent bases on it.

ii)T. S. of stem shows the presence of outer epidermal layer , outer and inner cortex and a vascular cylinder.

iii) The outer cortex shows radially elongated fibrous bands and the inner cortex has horizontal plates of thick walled cells.

iv)The vascular cylinder is present in the central region.it is denoted by a terete mixed protostele.

v) The vascular stand possesses groups of six to twelve tracheids uniformly scattered throughout the parenchyma. The xylem is mesearch.

vi) Small amount of secondary xylem is found around the protostele.

vii) There is a single strand in leaf.

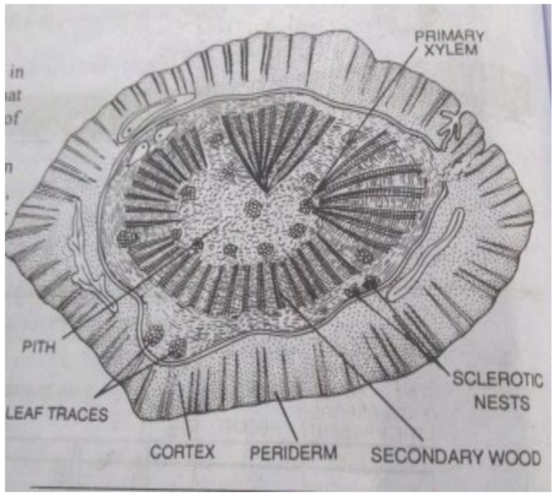


Fig. 10.24: *Heterangium*. T.S. of stem

16. *Lyginopteris (Calymatotheca)*

Systematic position:

Division: Gymnospermae
Order: Pteridospermales (Cycadofilicales)
Family: Lyginopteridaceae
Genus: *Lyginopteris*

Age: Upper Carboniferous.
Locality: Lower Gondwana (India)

Morphological Features

i) The stem was slender and covered with large scaly leaves.
ii) Near the base of the plant adventitious roots were developed.
iii) The plant seems to have been a climber.

Anatomical Features:

T.S. Of Stem:

i) The primary structure was an ectophloic siphonostele with large pith surrounded by a number of primary mesarch bundles.
ii) Older plants showed normal secondary growth.
iii) In some specimens, the xylem portion of primary vascular bundles was in a continuous ring.
iv) Mesarch vascular bundles, 5-10 in number, surrounded the pith in the form of ring.
v) The bulk of the primary wood was centripetal, but centrifugal xylem was also well developed the primary xylem, therefore had mesarch structure.
vi) Secondary wood formed a continuous ring round the primary xylem, while at places was interrupted by leaf traces.

vii) It consisted of large tracheids with multiseriate bordered pits on radial walla along with a large number of broad, many celled high, medullary rays.
viii) Secondary wood on its outer side was surrounded by phloem and pericycle.
ix) Phellogen developed from the outer layers of pericycle and produced the periderm.
x) The pericycle like the pith, possessed a large number of sclerotic cells.

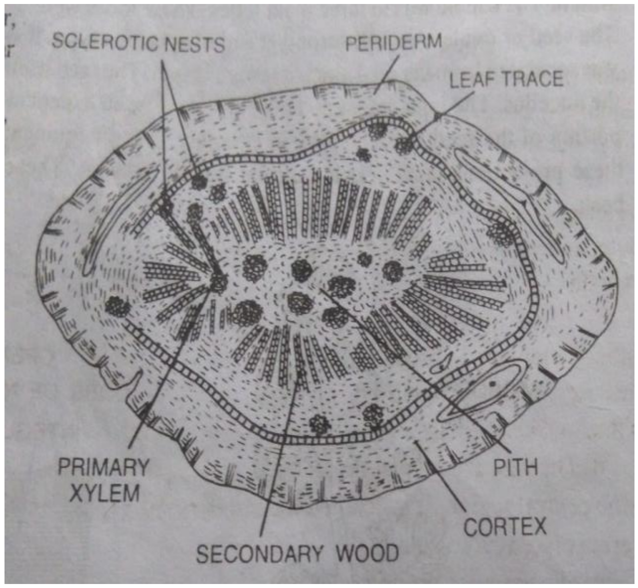


Fig. 10.25: *Lyginopteris oldhamia*, T.S. of stem showing well developed secondary wood and leaf traces

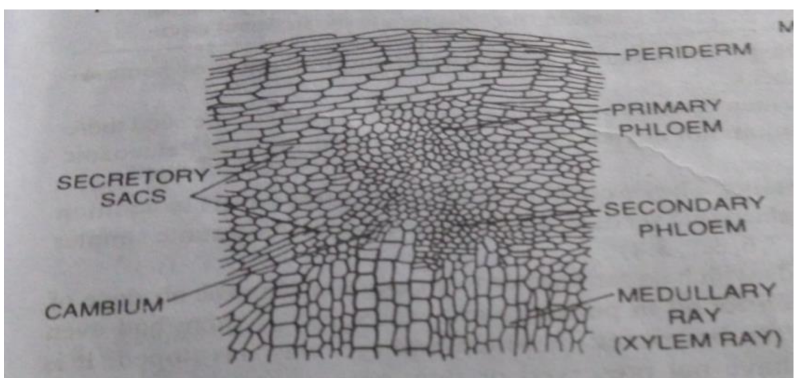


Fig. 10.26: *Lyginopteris oldhamia*: A part of T.S. of stem showing the outer portion of the stele

Reproductive Structure:

i) Leaves bore microsporangia on them. The fertile pinnules were more or less peltate in form and on their underside they bore usually six sporangia.
ii) These sporangia are usually bilocular. Such a type has been known as Crossotheca type.
iii) The microspores seem to have formed a male prothallus.
iv) The sperm seems to have been like those of the present day cycads.

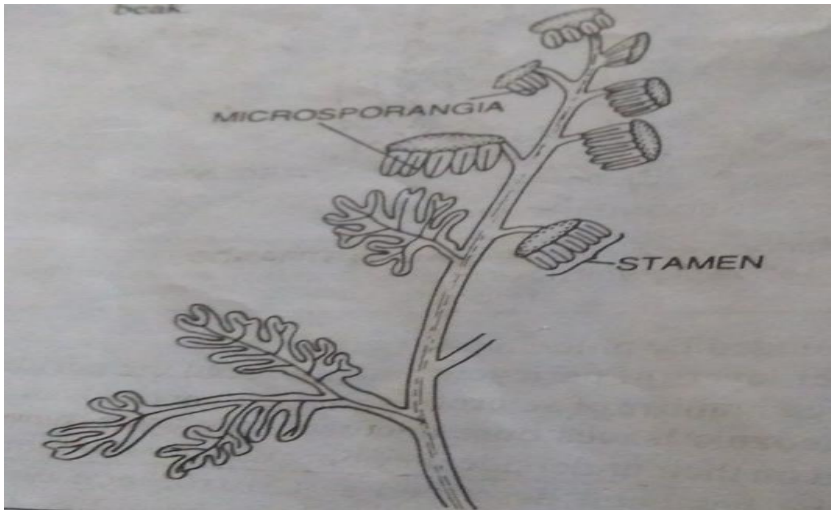


Fig. 10.27: *Crossotheca* sp. The male reproductive structures of *Lyginopteris oldhamia* with few stamens and pendant sporangia

Seeds:

i) The seeds have been described under the name Lagenostoma.
ii) These seeds were small in size, only ¼ inches but they were highly organised.
iii) It was barrel shaped and whole seed enclosed in cupule.
iv) This cupule opened out when seed was mature.
v) Each seed was borne at the tip of stalk.
vi) The seed or ovule was orthrotropous and of cycadian type.
vii) It was radially symmetrical.
viii) The seed had an integument which surrounds the nucellus.
ix) The nucellus and nucellus were fused except at the top.
x) The integument in the upper portion of the seed was complex in structure.
xi) The integument formed nine projections. In each of these projections there was a vascular bundle present. These projections surrounded the nucellar beak.

17. *Cycadeoidea (Bennettites*)

Systematic position:

Division: Gymnospermae
Class: Cycadopsida
Order: Cycadeoidales
Family: Cycadeoidaceae
Genus: *Cycadeoidea*

Age: Jurrasic to Upper Cretaceous
Locality: Raj Mahal hills (India),

Morphological Features:

i. The cycadeoid trunks were sub spherical, oval or columnar in shape, their diameter varied from a few centimetres to even 60 cm and height of 3.0 to 3.6 meters.
ii. The stem is un branched with a single crown of pinnate leaves at the tops
iii. The stem was covered by leaf bases.

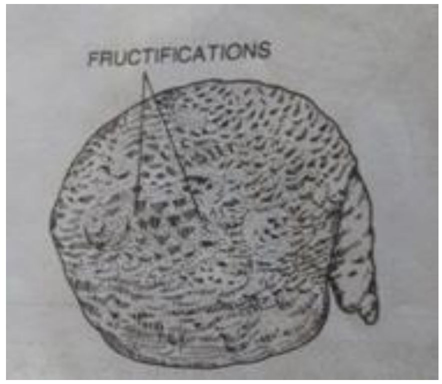


Fig. 10.28: *Cycadeoidea* sp. Lateral view of an unbranched trunk

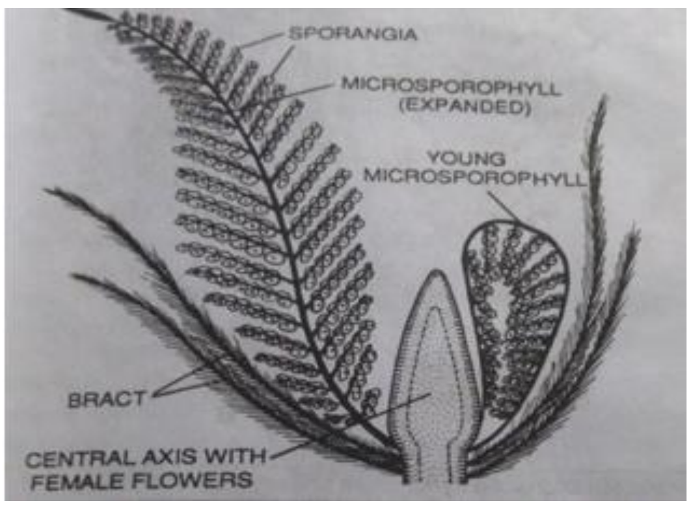


Fig. 10.29: *Cycadeoidea dacotensis*, apical portion with expanded and curved microsporophylls; the conical axis possesses female reproductive structures

Anatomical Features:

i) The stem possessed centrally situated large, parenchymatous pith which was surrounded by a thin zone of xylem.
ii) The xylem cylinder was punctuated by radially extending, parenchymatous medullary rays.
iii) The protoxylem was endarch and the metaxylem was situated towards the cortex.
iv) The thick cortex possessed a number of gum canals and leaf traces.
v) There was small amount of secondary growth.
vi) The xylem had scalariform thickenings, pitted thickenings rather rare.

Reproductive Structure:

i) The fructification was bisporangiate.
ii) The strobili were developed in the upper part of the plant in large numbers.
iii) The whole of the strobilus and bases of leaves were covered up by large sized scales, strobili so were axillary and born at the tip of axillary stalk.
iv) Each strobilus was made up of a number of heavy imbricate reduced leaves or bracts, these bracts completely surrounded the strobilus.
v) The second whorl was made up of a number of leaves like sporophylls, all of which were united at the base to form a cup shaped structure round the central part of strobilus.
vi) The third central portion was hemispherical or, dome shaped in appearance bearing ovules on the stalks, ovule was orthrotropus and terminal.
vii) The central part was made up of a number of ovulate sporophylls, these megasporophylls were simply staked, at the tip of the stalk was developed an ovule, some stalks were sterile and their tips were flattened.
viii) The microsporophylls or the stamens were 10 or 20 in number.
ix) The microsporophylls or stamens were all united at the base and each stamen was pinnate in form and on each stamen there were about twenty slender pinnae on either side, under the pinnate were developed two rows of fused sporangia or synangium had a short stalk and two pollen sacs in it, so each stamen was pinnate in structure.

18. *Williamsonia*

Systematic position:

Division: Gymnospermae
Class: Cycadopsida
Order: Cycadeoidales
Family: Williamsoniaceae
Genus: *Williamsonia*

Age: Jurrasic
Locality: Rajmahal hills (India),

Morphological and Anatomical Features:

1. Plants are more ancient than *Cycadeoidea.*
2. The stem was erect, cylindrical and branched.
3. The branches were covered by the scales and also the leaf bases.
4. The stem anatomy is similar to those of conifers.
5. The pith was large, dense compact mass of xylem and phloem and the cortex was comparatively narrow.

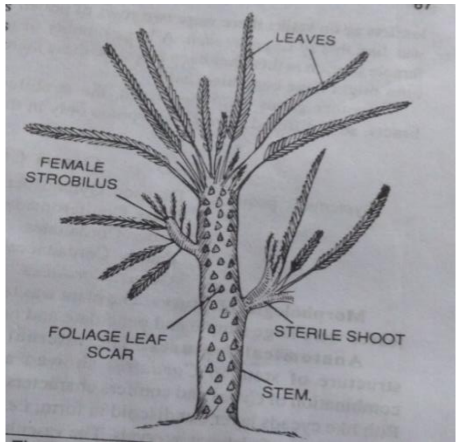


Fig. 10.30: *Williamsonia sewardiana* sahni: Recontruction showing a female strobilus and a sterile shoot

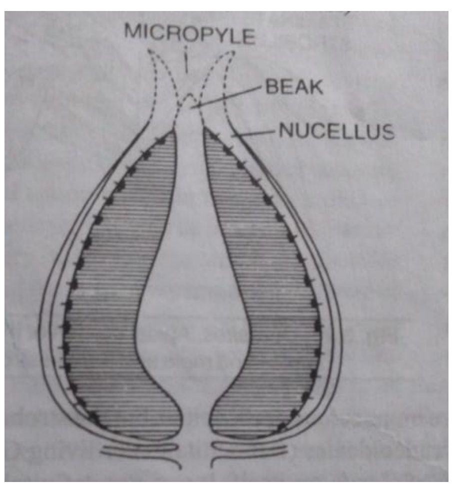
Reproductive Features:

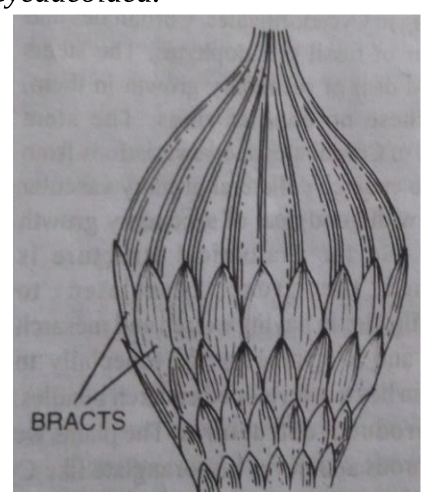
i) The strobili were born on short branched lateral shoots. They differ from those of *Cycadeodea* in that they were monosporangiate.

ii) In *Williamsonia sewardiana* only the female has been described so far but dr. sahni was of opinion that this Indian form might have been bisporangiate. The specimen got separated from the strobilus.

iii) The ovules were born on short stalks which has interstaminal scales in between.

iv) The ovule structure was similar to that of *Cycadeoidea*.





A **B**

Fig.10.31: *Williamsonia gigas* A: V.S. of ovuliferous flower, B: floral bud

10.6 SUMMARY

From the above description, the students now understand fossil definition, its types and applications of studying the fossils. In India, the fossils are found in Gondwana land which is further divided into three stages. These regions were flourished with pteridophytes and gymnosperms. Some of the important fossils found in this region are *Nissonia compta*, *Sagenopteris*, *Pterophullum*, *Ptiophullum*, *Otozamites*, *Weltrichia spectabilis*, *Cycadeoidea*, *Williamsonia sewardiana*, etc. These fossils were differentiated on the basis of morphological, anatomical and reproductive feature. Studies on the reproductive biology of the fossils help in routine investigation of the life history of different taxa. Besides studying the anatomical studies, presently emphasis is given on the in vitro propagation of Pteridophytes and Gymnosperm for rehabilitation of forest etc.

10.7 GLOSSARY

Amber: the fossilised resin of extinct coniferous trees, *Pinus succinifera* in particular, is called amber.
Branch traces: the vascular bundles connecting those of a main stem to those of a branch
Endarch: with central protoxylem or, with several surrounding a central pith.
Exarch: with protoxylem strands outside metaxylem, or, in touch with pericycle.
Stele: a bulky strand or cylinder of vascular tissue contained in stem and root of plants, developed from plerome.

10.8 SELF ASSESSMENT QUESTIONS

1. What do you understand by fossil?
2. Name different types of fossils.
3. Why fossils are important for us?
4. What is the important of Gondwana land in India?
5. Give important plant fossils found in India.

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10.11 TERMINAL QUESTIONS

1. Describe the term fossils. How fossilization takes place.
2. Describe the distribution of fossils in India with their suitable examples.
3. Describe the morphological and anatomical features of important fossils of Gondwana land.
4. Discuss about the reproductive characters of floral fossils found in India.

UNIT-11 COMPARATIVE STUDY OF THE ANATOMY OF VEGETATIVE AND REPRODUCTIVE PARTS OF GYMNOSPERMS

11.1 OBJECTIVES

After reading this unit students will be able -

- To know the morphological features of the important genera of Gymnosperm
- To learn the anatomical of vegetative parts and reproductive parts of important genera of Gymnosperm

11.2 INTRODUCTION

Gymnosperms form a large group of evergreen, slow growing plants. Though true seeds are formed, the group differs from others of seed bearing plants the angiosperms, mainly in possessing naked ovules, in the lodging of pollen grains directly on the micropyle, and in absence of true vessels and companion cells. Main characteristic features of the gymnosperms are as follows:

1. Plants are woody and even green, trees, shrubs or lianes without having any herbaceous member.
2. Plants have a tap root system, generally persists for a long time.
3. Xylem is made up of tracheids, parenchyma and rays. Vessels are only present in the members gnetales which have evolved from pitted tracheids.
4. Phloem consists of sieve cells only where sieve areas commonly occur on the radial wall. The companion cells are absent.
5. Secondary growth is present in all members, where mature metaxylem shows bordered pits
6. The anther has an exothecium which produces anemophilous pollen grains. Pollen exine is alveolar or granular.
7. Prothalial cell is present in male gametophyte, male gametes rarely motile.
8. Ovule consists of a single integument which is exposed.
9. The development of female gametophyte shows a prolonged free nuclear phase and there is a long interval between pollination and fertilization.
10. Endosperm is haploid and produced before fertilization.
11. There is a free nuclear stage in the development of proembryo.

Gymnosperms are classified broadly into three classes namely-

1. **Cycadopsida:** *Cycas*
2. **Coniferopsida:** *Cedrus, Ginkgo, Pinus, Taxus, Cupressus, Araucaria, Podocarpus*
3. **Gnetopsida:** *Gnetum, Ephedra*

11.3 MORPHOLOGICAL, ANATOMICAL AND REPRODUCTIVE CHARACTERS OF IMPORTANT GENERA

By studying this unit, Students are acquainted with the basic morphological, anatomical and reproductive characters of important genera of gymnosperms.

11.3.1 *Cycas*

From these studies, students will know about the morphological, anatomical features of different vegetative parts like stem, root, leaf and reproductive characters of *Cycas*:

11.3.1.1. Systematic Position

Class: Cycadopsida
Order: Cycadales
Family: Cycadaceae
Genus: *Cycas*

11.3.1.2. General Morphology of *Cycas*:

1. *Cycas* is a palm-like, evergreen plant.
2. The plant body consists of a columnar aerial trunk with a crown of pinnately compound leaves at top.

Fig. 11.1: A mature *Cycas* tree

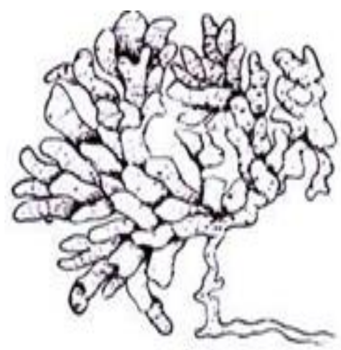

Fig. 11.2: A bunch of coralloid roots

3. Roots in *Cycas* are of two types, i.e., normal tap roots forming a tap root system, and coralloid roots.
4. The stem is thick, woody and usually un-branched. It is tuberous when young but columnar, erect and stout at maturity.

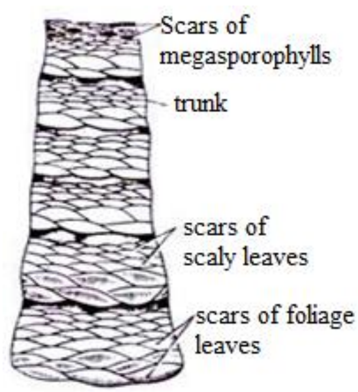

Fig. 11.3: *Cycas circinalis*: Basal part of columnar trunk

5. Two types of leaves are present in *Cycas*. These are green, assimilatory or foliage leaves, and scaly leaves or cataphylls.
6. Margins of the leaflets are revolute in *C. revoluta* and *C. beddomei*, while in *C. rumphii* and *C. circinalis* they are flat. Leaves, when young, have circinately coiled pinnae like those of ferns. Very young parts of *Cycas* are also covered by fern-like hairs or ramenta.

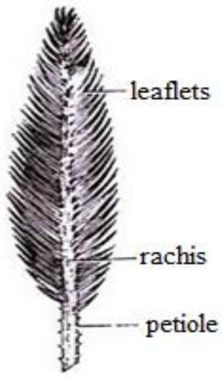

Fig. 11.4: *Cycas*: A single foliage leaf

Fig. 11.5: *Cycas*: A young leaf showing circinate vernation

7. Scaly Leaves or Cataphylls are dry, brown-coloured, somewhat triangular leaves with their one end pointed. They are present at the apex of the stem and remain covered with several ramental hairs.

Fig. 11.6: A scaly leaf of *Cycas*

11.3.1.3. Anatomy of Vegetative Parts of *Cycas*:

(i) Normal Root (Young):

1. It is circular in outline and resembles structurally with dicotyledons.

2. Outermost layer is epiblema or exodermis, which surrounds the large parenchymatous cortex. Epiblema consists of tangentially elongated cells. From some of its cells arise root hairs.

3. In parenchymatous cortex, there are present many intercellular spaces. Cells of the cortex remain filled with starch. Some tannin-filled cells, mucilage cells and sphaeraphides are also present in the cortex. The cortex is delimited by a single- layered endodermis. Casparian steps are present in the barrel-shaped cells of the endodermis.

4. Endodermis is followed by multilayered pericycle.

5. Xylem and phloem bundles in the roots are radially arranged, i.e. present on different radii. The roots are usually diarch but sometimes the number of protoxylem strands range between 3 to 8.
6. The protoxylem consists of spiral tracheids while the metaxylem consists of scalariform tracheids. Vessels are absent.
7. Phloem is present alternately with xylem groups and consists of sieve tubes and phloem parenchyma.
8. Pith is generally absent.

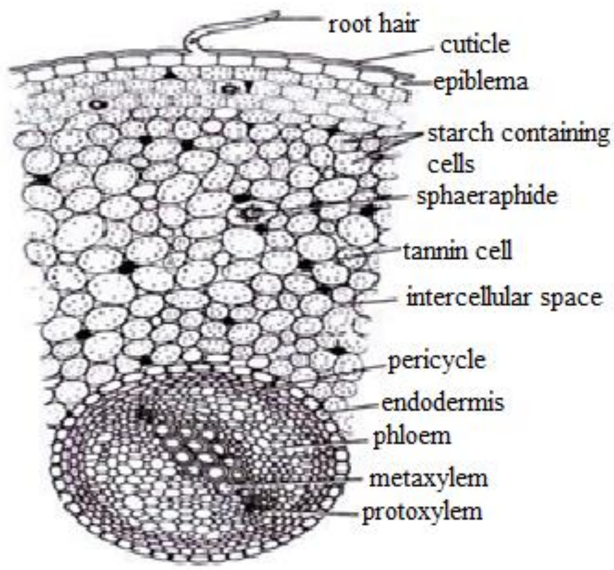

Fig. 1.7: *Cycas revoluta*: A transverse section of young Root

(ii) Normal Root (old) Showing Secondary Growth:

1. The older roots undergo secondary growth. The cambium cuts secondary phloem towards the outer side and secondary xylem towards the inner side. After sometime the pericycle cells also become meristematic and form a complete cambial ring.
2. The secondary xylem consists of radial rows of tracheids separated by parenchymatous cells. The crushed primary phloem is present in the form of dark streaks outside the secondary phloem. The secondary xylem is manoxylic and contains many multiseriate rays.
3. Periderm starts to develop in the cortex of old roots. Some of the cells of the outermost cortical region start to become meristematic and function as cork cambium. It cuts cork towards outer side and secondary cortex towards inner side. Cork cells are dead and remain filled with suberin. *Cycas* roots often show two layers of periderm.
4. Epiblema is ruptured and there are no root hairs in the older roots.

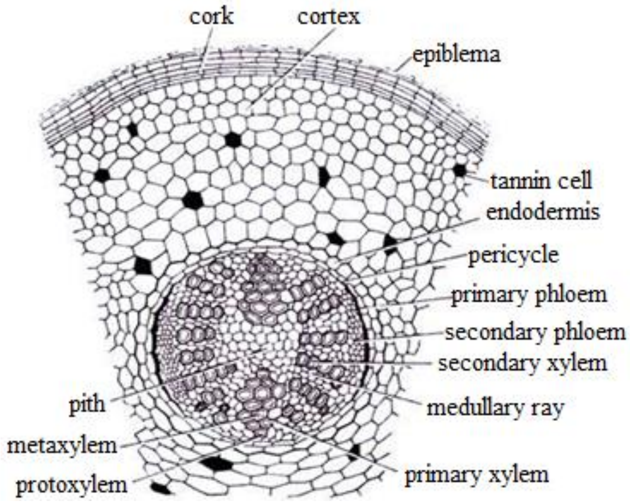

Fig. 11.8: A transverse section of an old root of *Cycas*

(iii) Coralloid Root:

Students must know anatomically that the coralloid roots resemble normal roots except some under mentioned differences:

1. The secondary vascular tissue in coralloid roots is either totally absent or poorly-developed.
2. The cortex is wider in comparison with the normal root.
3. Presence of a greenish algal-zone in the middle of the cortex. The coralloid roots are negatively geotropic which are infected by algal members.
4. Algal-zone consists of radially elongated, large, thin-walled cells having large intercellular spaces occupied by algae. *Anabaena cycadae, Nostoc punctiforme*, *Oscillatoria*, *Azotobacter, Pseudomonas radicicola* and even a few fungi have been reported from the algal zone of coralloid roots. These algae fix nitrogen and promote the growth of host plant.
5. The presence and structure of endodermis, pericycle and vascular bundles in the coralloid roots are similar to that of normal roots. The xylem is exarch and triarch.

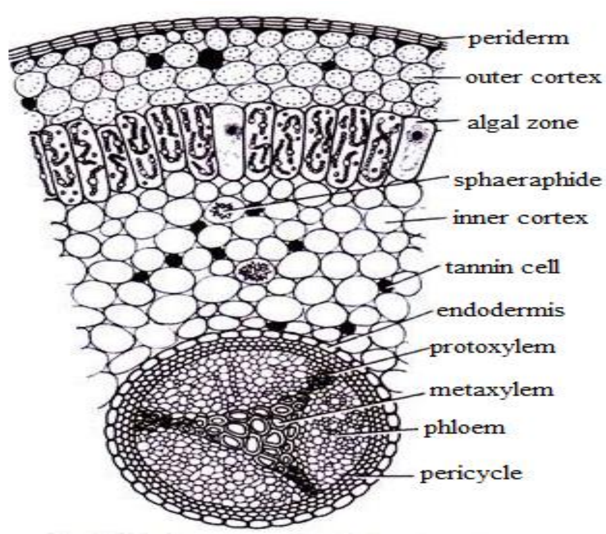

Fig. 11.9: *Cycas revoluta*: T.S. coralloid root

(iv) T.S. of Stem: From the following anatomical features, we now know that the stem of *Cycas* resembles internally with a dicotyledonous stem. It shows the following anatomical features:

1. Epidermis is the outermost layer consisting of compactly arranged thick- walled cells. Presence of several persistent leaf bases makes the epidermis a discontinuous and ruptured layer.
2. Cortex is large and consists of thin- walled, parenchymatous cells, filled densely with starch grains. It contains numerous mucilaginous canals and girdle traces.
3. Each mucilage canal is lined with many radially elongated epithelial or secretory cells. Medullary rays connect the mucilage canals of the cortex with that of the pith Starch in the parenchymatous cells of the cortex is the source of 'sago'**.**
4. Endodermis and pericycle are not clearly demarcated.
5. Numerous vascular bundles remain arranged in a ring. The stele is ectophloic siphonostele. Each vascular bundle is conjoint, collateral, open and endarch. The xylem consists of tracheids and xylem parenchyma. Protoxylem contains tracheids with spiral thickenings while the metaxylem has scalariform thickenings with bordered pits. Vessels are absent. The phloem is located outside the xylem and consists of sieve tubes and phloem parenchyma. Companion cells are absent.
6. Between the xylem and phloem lies the primary cambium, which remains active only for a short period. It is soon replaced by another ring of secondary cambium somewhere in the cortex. These successive cambial rings form 2-14 different vascular rings showing polyxylic condition in the old stem.
7. Several broad and well-developed medullary rays are present between the vascular bundles. Pith is large, well-developed and parenchymatous. It contains many mucilaginous canals.

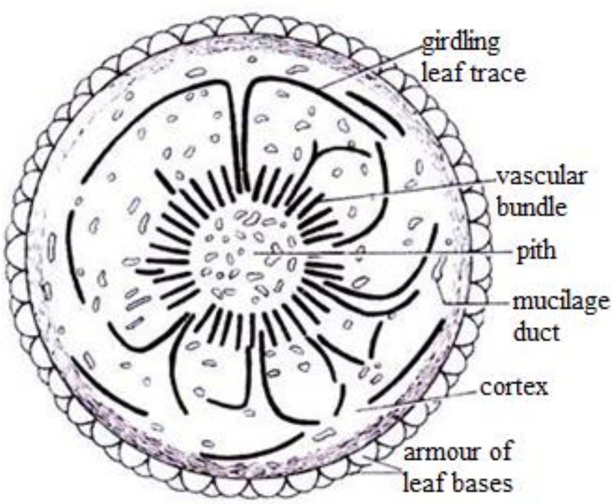

Fig. 11.10: *Cycas*: Diagrammatic representation of T.S. young stem

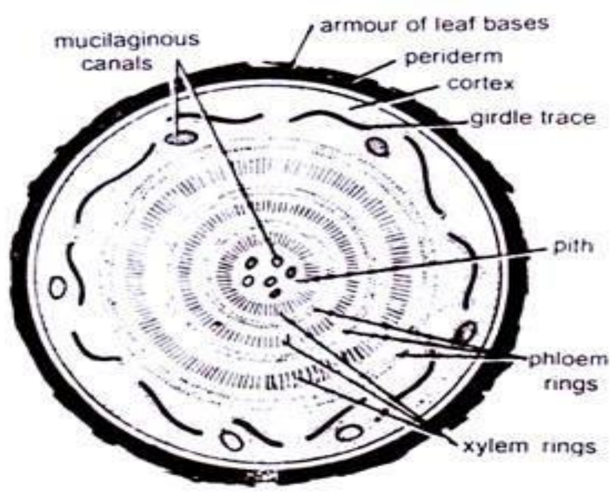

Fig. 11.11: *Cycas*, Diagrammatic representation of T.S. old stem

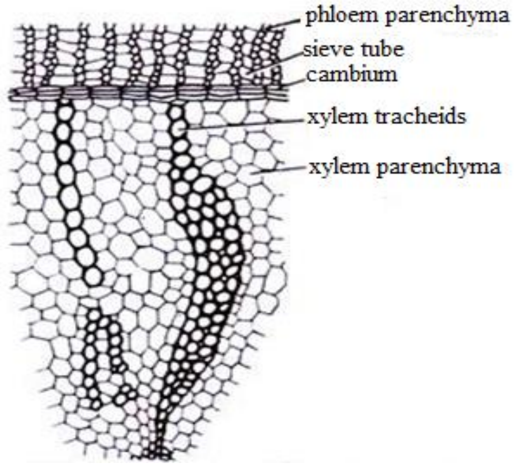

Fig. 11.12: ***Cycas revoluta*; T.S. Stem showing a part of vascular bundle**

(v) Leaf Traces:

1. The leaf traces remain scattered in the cortical region of the stem and constitute the vascular supply to the leaves from the main vascular cylinder. Normally, there are four leaf traces which form the vascular supply to the leaf.
2. Two of these are direct traces, while the remaining two axe girdle traces.
3. The direct traces originate from the vascular cylinder lying in front of the leaf base while the girdle traces develop from the vascular cylinder lying opposite to that of direct traces. They proceed together and curve soon in opposite directions, and by girdling round the vascular cylinder they enter in the leaf base.
4. In the cortical region the girdle traces also remain connected with other leaf traces. At the time of their entrance in the petiole, the leaf trace bundles subdivide and form many petiole bundles. Such type of unique girdle traces of *Cycas,* which also occurs in Magnoliaceae and shows a close relationship of Cycadales of Gymnosperms and Magnoliaceae of dicotyledons.

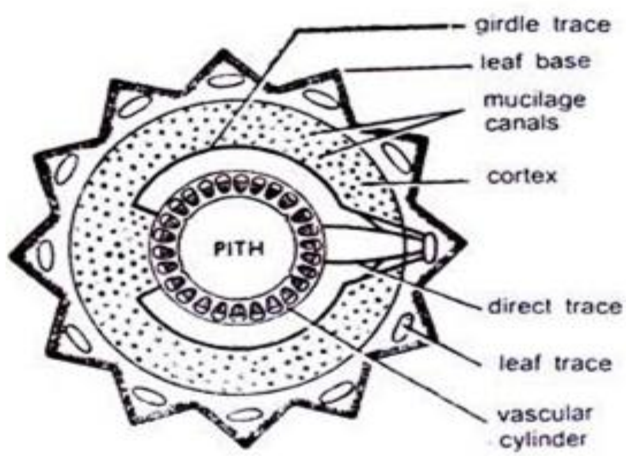

Fig. 11.13: ***Cycas*, Diagrammatic representation of T.S. Stem showing Distribution of Leaf traces**

(vi) Secondary Growth:

1. It is similar to that of dicotyledons.

2. In the beginning, *Cycas* is monoxylic, i.e. contains a single ring of vascular bundles. But one or more concentric rings of vascular bundles appear outside the primary ring of bundles in the older stems showing polyxylic condition.
3. By the activity of inter-fascicular and intra-fascicular cambia, which unite to form a cambium ring, the secondary growth is initiated. This cambium ring cuts secondary phloem towards outer side and secondary xylem towards inner side.
4. Well-developed medullary rays traverse through the so-formed secondary vascular tissue.
5. After a short while this cambium ring stops functioning and a second cambium ring develops either in the parenchymatous cortex or in the region of pericycle. This cambium ring also behaves in the similar fashion. As many as 14 rings of vascular tissues may develop in the stem of *Cycas pectinata* of about 20 cm diameter showing polyxylic condition and 22 such rings in the stem of *C. rumphii* having a diameter of about 85 cm.
6. The cork cambium develops on the outer region of the cortex and cuts cork towards outer side and secondary cortex towards inner side.

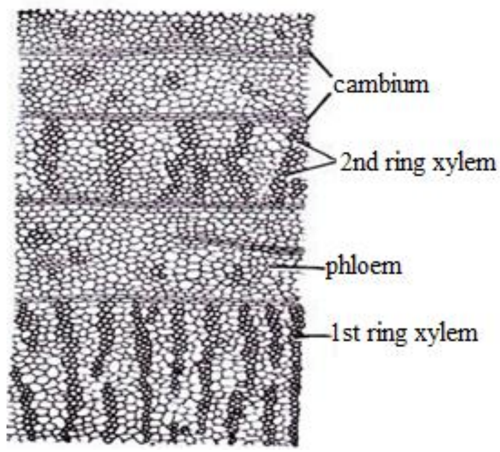

Fig. 11.14: *Cycas*- A part of T.S. stem showing secondary vascular tissues

(vii) Rachis:

1. The outline of transverse section is rhomboidal in the basal region of the rachis, biconvex in the middle cambium and roughly cylindrical at the tip region or at the apex of the rachis.
2. Two arms of the bases of leaflets are present on the rachis, one on each side.

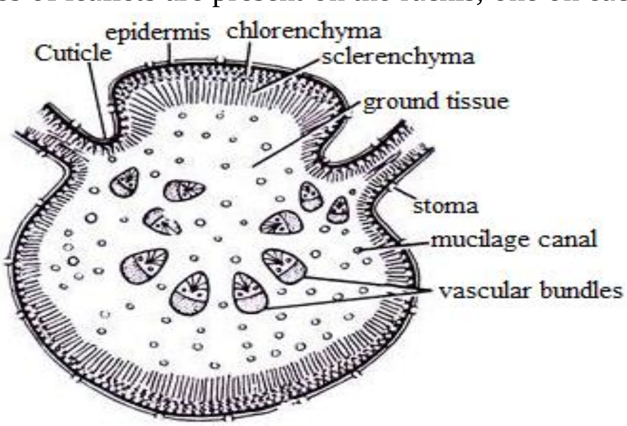

Fig. 11.15: Cycas. Diagrammatic representation of T.S. of Rachis

In T.S. the rachis reveals the following structures from outside within:

1. Epidermis is the outermost layer of the rachis consisting of thick-walled cells. It is heavily circularized. On its upper as well as lower sides are present irregularly distributed sunken stomata.
2. Hypodermis is present below the epidermis. It is differentiated into outer 2-3 layers of chlorophyll-containing thin-walled cells of chlorenchyma and inner 4-6 layers of thick-walled lignified cells of sclerenchyma. Sclerenchyma is poorly-developed on the lateral sides. It is also seen intermixed with chlorenchyma.
3. Ground tissue is a large region consisting of thin- walled, parenchymatous cells.
4. Many mucilaginous canals and vascular bundles are present in this region. The number and arrangement of mucilage canals have no definite relation with that of vascular bundles. Each mucilage canal is a double-layered structure consisting of an inner layer of epithelium cells surrounded by an outer layer.
5. Vascular bundles are arranged in the shape of an inverted Greek letter Omega (Ω). Towards the tip of the rachis the bundles are arranged in C-shaped manner and their number is comparatively less. Each vascular bundle remains surrounded by a bundle sheath. It is conjoint, collateral and open.
6. The xylem in each vascular bundle is present towards inner side. It consists of tracheids and xylem parenchyma. Cambium separates the xylem from the phloem. Vessels are absent.
7. The vascular bundles are diploxylic, i.e. consists of two types of xylem viz. centripetal xylem and centrifugal xylem. Phloem present towards the outer side of the vascular bundle, consists of sieve tubes and phloem parenchyma. Companion cells are absent.
8. The vascular bundles show different structure at different levels of rachis starting from the base up to the apex, especially with regard to their diploxylic nature.

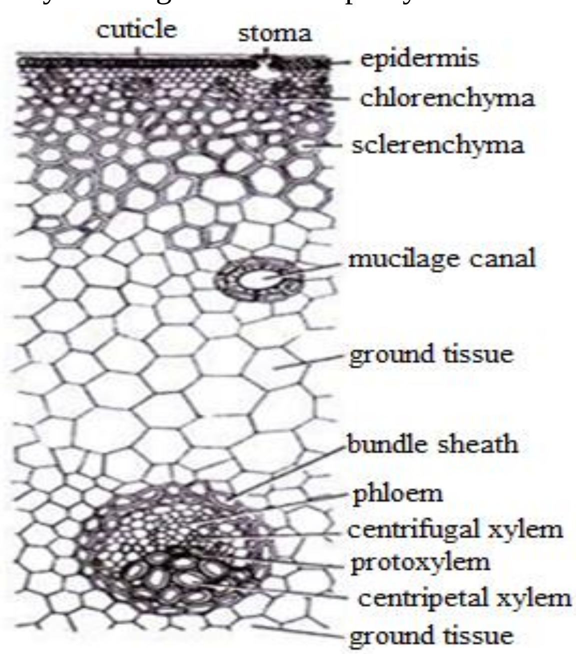

Fig. 11.16: ***Cycas revolute*****, A part of T.S. of Rachis**

(viii) T.S. of Leaflet:

1. *Cycas* leaflets are large, tough, thick and leathery.
2. In a vertical section the leaflet is differentiated into a swollen midrib portion and two lateral wings.
3. In *C. revoluta* and *C. beddomei* the wings are curved downward or revoluted at the margins but in *C. circinalis, C. rumphii, C. pectinata* and *C. siamensis* the margins are flat.

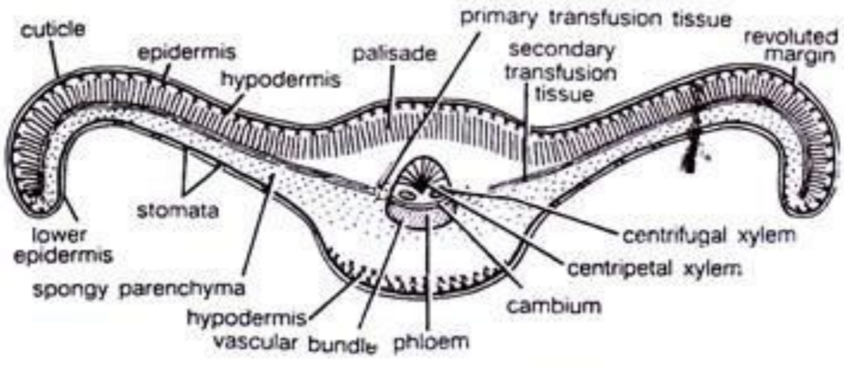

Fig. 11.17: *Cycas*- Diagrammatic representation of T.S. of Leaflet

4. Epidermis is the outermost layer consisting of thick-walled cells. It is surrounded by a thick layer of cuticle. Upper epidermis is a continuous layer while the continuity of the lower epidermis is broken by many sunken stomata.
5. Hypodermis is sclerenchymatous and present below the epidermis. It is absent below the lower epidermis but in the midrib region it is several-celled thick.
6. Mesophyll is well-developed and remains differentiated into palisade and spongy parenchyma.
7. A continuous layer of palisade is present below the sclerenchymatous hypodermis. Its cells are radially elongated and filled with chloroplasts. The palisade may be a continuous layer over the midrib as in *Cycas beddomei, C. media, C. pectinata* and C. revoluta, or it may be a discontinuous layer as in *C. circinalis* and *C. rumphii*.
8. Spongy parenchyma is present only in the wings, directly above the lower epidermis. Its cells are oval, filled with chloroplasts, and loosely arranged having many air-filled intercellular spaces. Transfusion tissue consists of two small groups of short and wide tracheid-like cells with reticulate thickenings or bordered pits on their walls.
9. Few layers of transversely elongated cells are present in both the wings just in between the palisade and spongy parenchyma. This represents the accessory transfusion tissue or secondary transfusion tissue.
10. Vascular bundle is one, and present in the midrib region of the leaflet. It is conjoint, collateral, open and diploxylic. The triangular centrifugal xylem is well-developed with endarch protoxylem. It is represented by two or sometimes more small groups on either side of the protoxylem. Phloem is arc-shaped and remains separated by cambium. Phloem consists of sieve tubes and phloem parenchyma. Companion cells are absent. The portion of

the midrib in between the palisade layer and lower hypodermal region is filled with parenchymatous cells. Some of these cells contain calcium oxalate crystals.

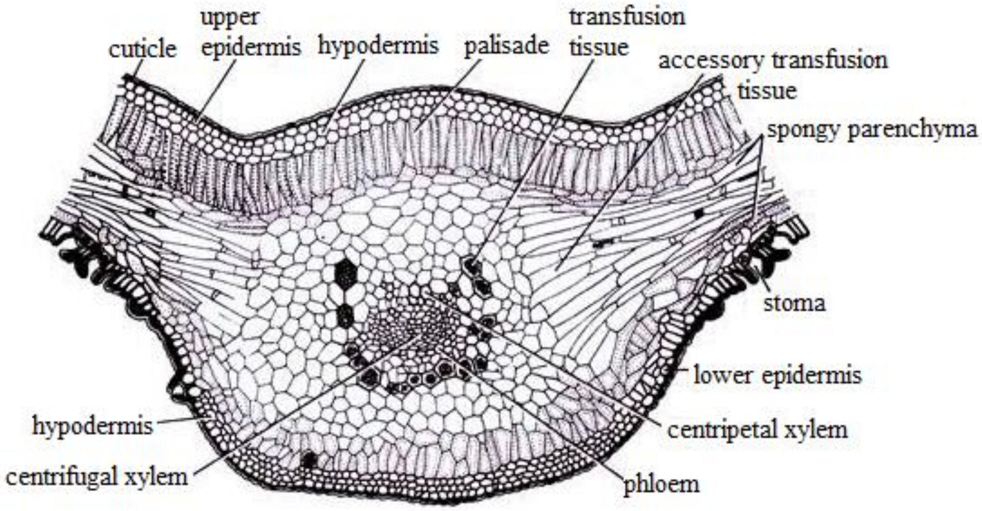

Fig. 11.18: ***Cycas revoluta*- A part cellular of T.S. leaflet**

11.3.1.4. Reproduction in *Cycas*:

(i) Vegetative Reproduction:

1. The most common method of vegetative propagation in *Cycas* is by bulbils.
2. The bulbils develop from the axil of the scaly leaves.
3. They are more or less oval structures with a broad base narrowing towards the apex.
4. Several scaly leaves are arranged spirally and compactly over a dormant stem in a bulbil.
5. On detachment from the stem, a bulbil starts germination by producing many roots towards the lower side and a leaf towards the upper side.
6. A bulbil from male plant will develop only into the male plant, while from the female plant will form only the female plant because Cycas is a strictly dioecious plant.

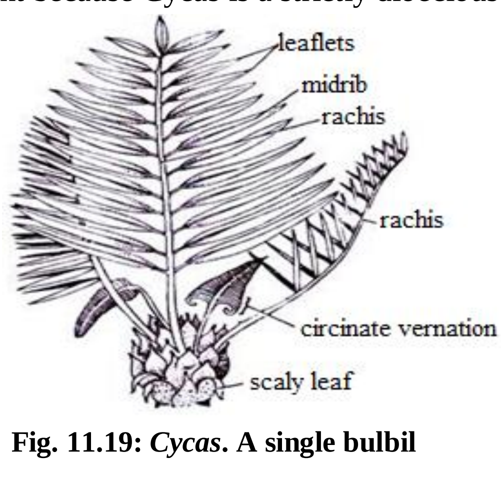

Fig. 11.19: ***Cycas*. A single bulbil**

(ii) Sexual Reproduction:

1. *Cycas* is strictly dioecious, i.e. male and female sex organs are borne on separate plants.
2. Generally, Cycads of more than 10 years of age produce the sex organs.

3. The male plants develop male cones or male strobili bearing microsporophyll’s, while the female plants produce a loose collection of megasporophylls.
4. The male cone is terminal while the megasporophylls are produced in succession with the leaves at the top of the stem.

a) Male Reproductive Structures:

1. Male Cone:

i) The male cone or male strobilus is a large, conical or ovoid, compact, solitary and shortly-stalked structure, which is generally terminal in position.

ii) It sometimes attains a length of as much as 1.5 metre.

iii) In the centre of the cone is present a cone axis.

iv) Several perpendicularly attached microsporophyll’s are arranged around the cone axis in closely set spirals.

v) At the base of male cone are present many young leaves.

vi) All the microsporophyll’s in a male cone are fertile except a few at its basal and apical parts.

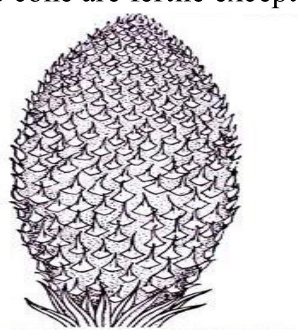

Fig. 11.20: *Cycas*. A single male cone

2. Microsporophyll’s, Microsporangia and Microspores:

i) Microsporophyll’s are flat, leaf-like, woody and brown-coloured structures with narrow base and expanded upper portion.

ii) The upper expanded portion becomes pointed and is called apophysis. Narrow base is attached to the cone axis with a short stalk.

iii) Each microsporophyll contains two surfaces, i.e. an adaxial or upper surface and an abaxial or lower surface.

iv) On the adaxial surface is present a ridge-like projection in the middle and an apophysis at the apex.

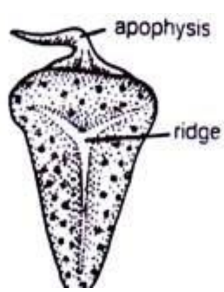

Fig. 11.21: *Cycas*, Adaxial surface of a microsporophyll

v) On the abaxial surface are present thousands of microsporangia in the middle region in the groups of 3-5. Each such group is called a sorus. In between these groups are present many hair-like structures, which are very soft and one or two- celled structures.

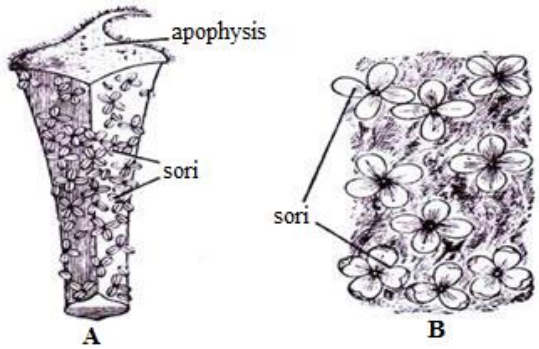

Fig. 11.22: *Cycas*. A. Abaxial surface of a microsporophyll, B. Groups of microsporangia (sori) enlarged

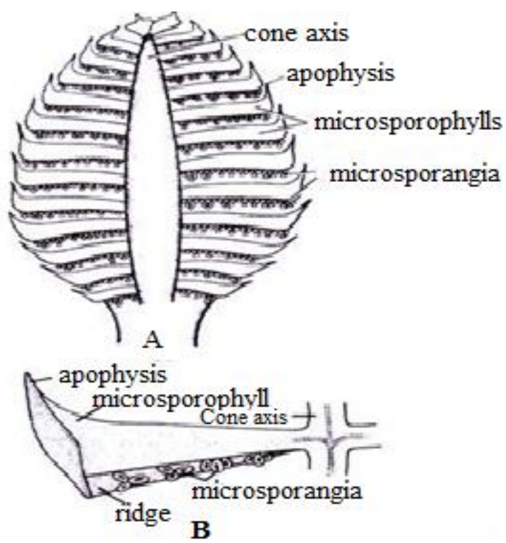

Fig. 11.23: *Cycas.* A) L.S. cone, B. L.S. of a single microsporophyll along with cone axis

vi) In T.S. of a microsporophyll, there are present many microsporangia on the abaxial side. Each shortly-stalked, oval or sac-like microsporangium is surrounded by 5-6 layers. The wall layers of each sporangium include an outer thick epidermis or exothecium, middle zone of thin-walled cells and an innermost layer of tapetum.

vii) Many pollen grains or microspores are present in each sporangium. In the expanded region of microsporophyll are present many mucilaginous canals and vascular bundles. Each sporangium is provided with a radial line of dehiscence, which helps in the dispersal of spores.

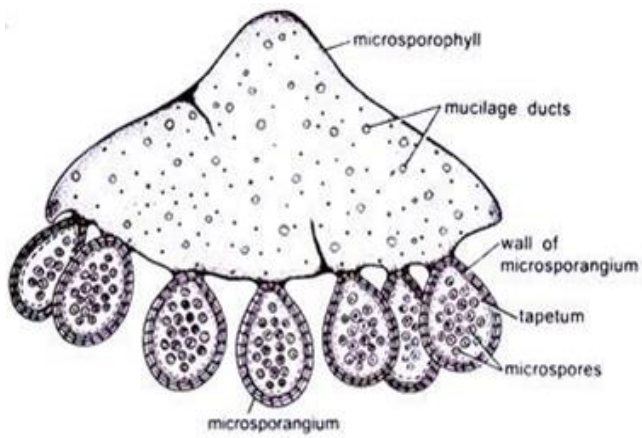

Fig. 11.24: T.S. microsporophyll of Cycas showing an enlarged sporangium

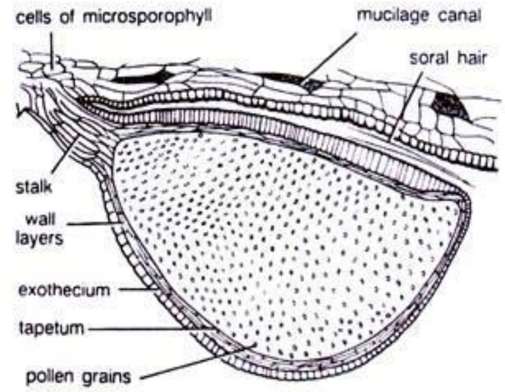

Fig. 11.25: Cycas. A part of T.S. microsporophyll cut longitudinally

viii) Each microspore or pollen grain is a rounded, unicellular and uninucleate structure surrounded by an outer thick exine and inner thin intine. Cytoplasm surrounds the centrally located nucleus. A large vacuole is also present.

b) Female Reproductive Organs:

i) True female cone or strobilus is absent *Cycas*.

ii) Female reproductive organs are present in the form of megasporophylls.

iii) Many megasporophylls are present around the apex of the monopodial trunk of the female plant above each crown of foliage and scaly leaves.

iv) Similar to foliage leaves, megasporophylls also remain spirally arranged at the apex of the stem but their number is very large and thus they appear like a rosette.

v) Pant (1953) observed that usually the megasporophylls in *Cycas* are produced only once in a year. From the apex of the main stem the megasporophylls arise in an acropetal succession.

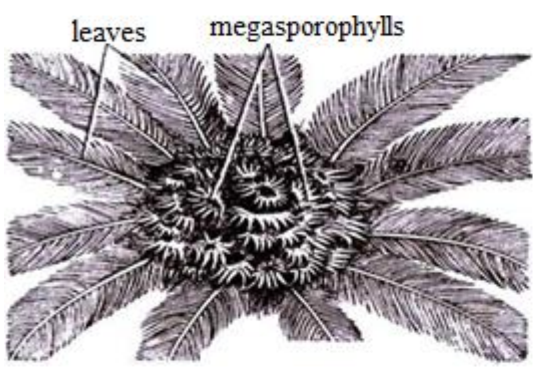

Fig. 11.26: *Cycas*. Apex of a female plant showing rosette of megasporophylls

1. Megasporophyll:

i) Each megasporophyll is considered a modification of foliage leaf.

ii) It reaches up to 30 cm or more in length in different species.

iii) It is a flat body consisting of an upper dissected or pinnate leafy portion, middle ovule-bearing portion and proximal petiole.
iv) Petiole varies in length in different species. The middle part is comparatively wider than petiole and bears ovules arranged in two pinnate rows.
v) The number of ovules varies between 2-12 in different species. The ovules are green when young but at maturity they are fleshy and bright orange or red-coloured structures.
vi) The upper, conical sterile part of the megasporophyll is pinnately divided in *Cycas revoluta*, *C. pectinata* and C. siamensis. But the margin of the upper part is variously serrate with a tapering acute apex in *C. beddomei, C. circinalis* and *C. rumphii*.

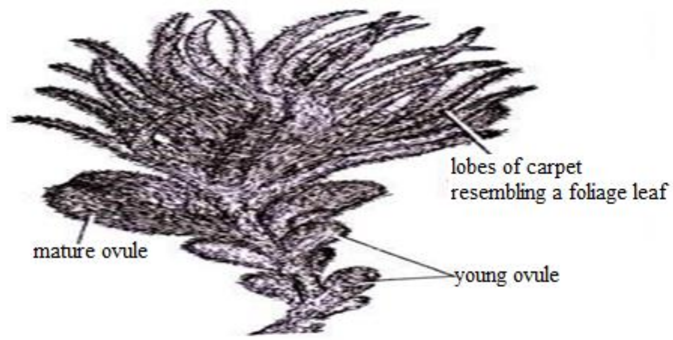

Fig. 11.27: Megasporophyll of *Cycas revolute*

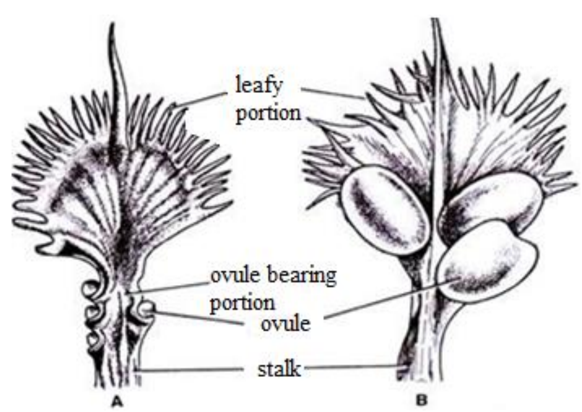

Fig. 11.28: Megasporophylls of *Cycas*.
A) *C. siamensis,* B) *C. pectinata*

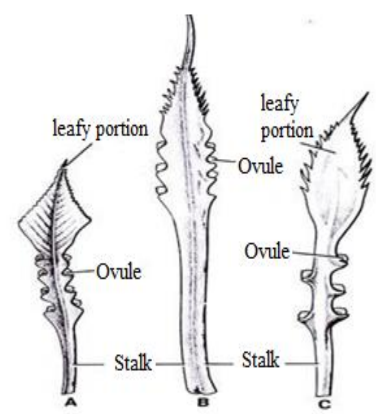

Fig. 11.29: Megasporophylls of *Cycas*,
A) *C. circinalis,* B) *C. rumphii*, C) *C. beddomei*

2. Structure of Ovule:

i) *Cycas* ovules are orthotropous, unitegmic and shortly-stalked.
ii) Outer surface of the ovule may be smooth as in *C. circinalis* or covered with orange-yellow hairs as in *C. revoluta*. After fertilization these hairs are lost, the ovule changes into seed and its colour changes from orange-yellow to bright red.
iii) The single integument is very thick and covers the ovule from all sides except a mouth-like opening called micropyle. The integument consists of three layers:

- Outer, green or orange, fleshy layer called sarcotesta,
- Middle, yellow, stony layer called sclerotesta, and
- Inner fleshy layer.

iv) Several tannin cells and mucilage canals are present in the parenchymatous region of sarcotesta. Some pigments are also present in sarcotesta and epidermis. The sclerotesta consists of lignified thick-walled cells. The inner fleshy layer consists of parenchymatous cells, and it remains in close association with the nucellus.

v) The nucellus grows out into a beak-like portion called nucellar beak. The latter protrudes into the micropylar canal. Certain cells at the top of the nucellus dissolve and form a cavity like structure called pollen chamber.

vi) Pollen grains are received in the pollen chamber after pollination. The nucellus gets reduced in the form of a thin papery layer in mature seeds and encloses the massive female gametophyte (endosperm).

vii) An enlarged megaspore or the embryo-sac is present within the nucellus. The endosperm is formed by the repeated divisions of the megaspore nucleus followed by free cell formation.

viii) Just below the pollen chamber is present an archegonial chamber. 3-6 archegonia are present in the female gametophyte near the archegonial chamber. The latter remains filled with a fluid.

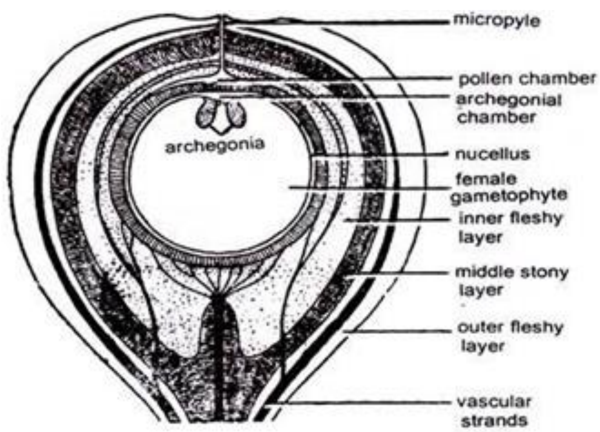

Fig. 11.30: *Cycas*. L.S. Ovule showing two archegonia and female gametophyte

11.3.2. *Araucaria*

From these studies, students will know about the morphological, anatomical features of different vegetative parts like stem, root, leaf and and reproductive characters of *Araucaria*:

11.3.2.1. Systematic Position

Class: Coniferopsida
Order: Coniferales
Family: Araucariaceae
Genus: *Araucaria*

11.3.2.2. Vegetative Structure:

1. Plants are branched evergreen trees.
2. The branching pattern is horizontal or in whorls.
3. Leaves are persistent for many years, and spirally arranged. They are also clasping with the stem and overlapping or thrown into 2 or more ranks by means of a basal twist.
4. The leaves are of two types a) those on the young trees and lateral branches are spirally arranged, lanceolate, straight, long and sharply pointed, b) those on old trees and branches cones, are crowed, overlapping, short, slightly oblique and pointed.
5. Bark is resinous, ridged, rough, peeling off as papery scales.

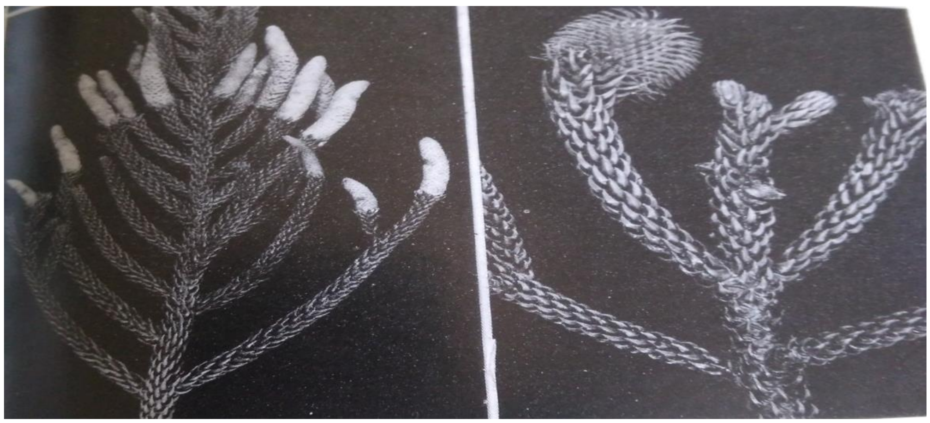

Fig. 11.31: *Araucaria cunninghamii*. A) Twigs bearing male cones; B) twigs bearing female cone (After Kaur, 1979)

11.3.2.3. Anatomy of *Arucaria:*

1) T.S. of root:

1. The single layered epidermis is followed by a 6 to 7 layered parenchymatous cortex.
2. The pericycle is 5 to 7 layered encircled by a single layered tanniferouse endodermis.
3. The pericycle zone exhibits resin ducts in a ring.
4. The root is diarch with a small parenchymatous pith.
5. Secondary growth in root takes place in the usual manner.
6. The secondary xylem tracheids show bordered pits on their radial walls, whereas parenchymatous cells are solitary and tanniferous.
7. The rays are uniseriate, 1-12 cells high.
8. The secondary phloem consists of sieve cells, phloem fibres and parenchyma in the axial system and ray parenchyma in the ray system. The phloem ray is continuous with the xylem ray. It is uniseriate, 1-10 cells high and homogeneous.

2) T.S. of stem:

1. T.S. of young stem gives a lobed appearance because of the imperceptible merger of the leaf bases with the shoot.

2. The epidermis is made up of isodiametric, tanniferous cells which are heavily cuticularized and interrupted by sunken stomata.
3. The hypodermis comprises of a single layer of compact cells.
4. Hypodermis is followed by a layer of columnar, tannin filled palisade cells. The spongy tissue consists of large, rounded parenchymatous cells with intercellular spaces.
5. The true cortical zone is small, parenchymatous and exhibits leaf traces which are associated with resin ducts.
6. The stele comprises of many endarch collateral and open vascular bundles arranged in a ring.

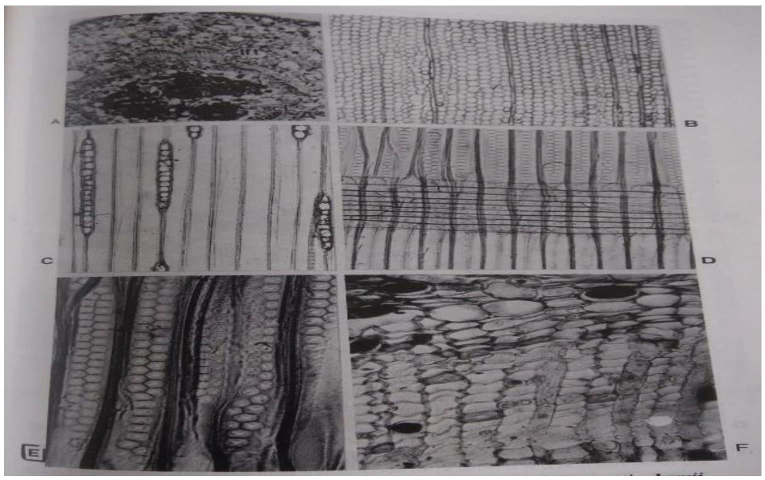

Fig.11.32: *Araucaria cunninghamii.* A) T.S. of young stem; B-D) T.S., TLS and RLS wood, respectively; E) Tracheids in RLS enlarged showing araucarian pitting; F) T.S. through secondary phloem(After Kaur, 1979)

3) T.S. of Leaf

1. The epidermis consists of thick walled, cuticularized cells with many cells containing tannin and interrupted by sunken stomata.
2. It is followed by 2 or, 3 layers of compactly arranged hypodermal cells.
3. A single resin duct is present below the phloem in type a) and two rows of resin duct are presents in type b).
4. The mesophyll consists of only parenchymatous cells with intercellular spaces in type a) and in type b) a single layer of well developed palisade and many layered spongy tissue are present.

11.3.2.4. Reproductive Structure: Male and female strobili are usually borne on different trees, but sometimes on different branches of the same tree.

1) Male Strobilus:

a) It is dense and cylindrical, solitary or in clusters at the points of the branches, or from axillary buds.
b) It consists of many spirally arranged micro-sporophylls (stamens). Pollen – sacs are five to fifteen.

c) Pollen grains are wingless.

2) Female Strobilus:

a) It is woody, globose or ovoid with closely overlapping scales which fall off when mature.

b) Seeds are one on cach scale and adherent to it, winged on each edge, scales completely united with sporophylls.

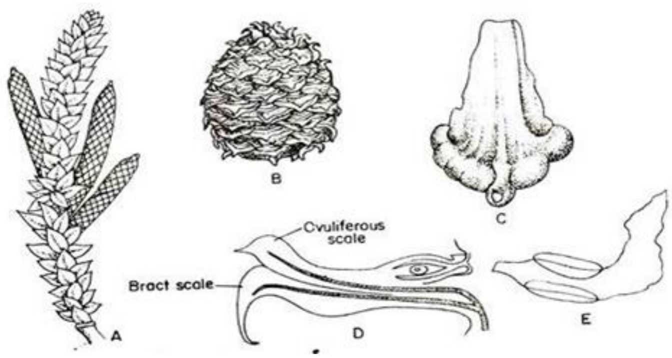

Fig. 11.33: *Araucaria* sp. A). a fertile twig with male cone, B)- Female cone, C) & D) - ovuliferous scales, E)- Microsporophyll.

11.3.3. *Cedrus*

From these studies, students will know about the morphological, anatomical features of different vegetative parts like stem, root, leaf and and reproductive characters of *Cedrus*:

11.3.3.1. Systematic Position

Class: Coniferopsida
Order: Coniferales
Family: Pinaceae
Genus: *Cedrus*

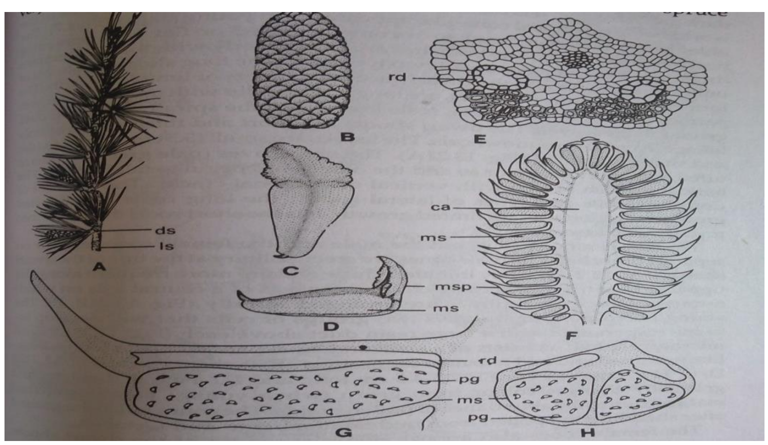

Fig. 11.34: *Cedrus deodara*: A) Long shoot bearing dwarf shoots; B) Male cone showing spiral arrangement of microsporophyll; C, D) dorsal and lateral views respectively of microsporophyll bearing two abaxial microsporangia; E) T.S. young microsporophyll showing initiation of

microsporangia and resin ducts ; F) L.S. male cons G,H) L.S. and T.S. respectively through microsporophyll showing pollen grain in the sporangium (ca: cone axis; ds: dwarf shoot; ls: long shoot; ms : microsporangium; msp: microsporophyll; pg: pollen grain; rd: resin duct)

11.3.3.2. Vegetative Structure:

1. Plants are evergreen branched trees.
2. Branchlets are of two kinds – long terminal shoots, bearing scattered leaves and short spur shoots which bear tufts of leaves in false whorls.
3. Leaves are needle like, persistent, lasting 3-6 years, usually 3 sided.
4. Internally leaves have almost identical features of *Pinus* leaf, except the presence of 2 marginal resin canals on the inner surface.
5. The bark of young trees are greyish, thin and smooth, at length becoming brown, thick, deeply furrowed and broken into small irregular plates.

11.3.3.3. Anatomical Features

1) T.S. of stem:

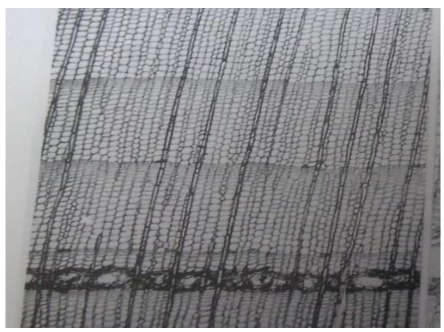

Fig. 11.35: *Cedrus deodara,* T.S. of wood showing annual rings and resin ducts

i) Outline of T.S. of young stem shows awavy outline wothb ridges and furrows boung by a thick walled epidermis.
ii) The cortex is made up of 6-8 layers of cells.
iii) The cells are thick walled below the ridges and thin walled below the furrow.
iv) The xylem is endarch.
v) The pith is parenchymatous and contains starch.
vi) Secondary growth takes place very early in the development.

a) In long shoot:

i. The long shoot is covered by a cork made up of parenchymatous cells filled with some tanniferous material.
ii. It is followed by thin walled cortical cells, some containing starch and other containing tannin.
iii. The cortical cells are interrupted by large resin ducts which are arranged in a ring.
iv. The xylem is pycnoxylic.
v. The pith is small and parenchymatous.

b) In dwarf shoot:

- **i.** Outline is circular with persistent leaf bases.
- **ii.** A cork cambium differentiated in the cortex which is parenchymatous with few tanniferous cells.
- **iii.** Resin ducts are more prominent than in long shoot.
- **iv.** A number of sclerids are present in the cortex and pith.
- **v.** Leaf traces are seen in cortex.
- **vi.** Vascular cylinder is in central portion of the shoot.

2) T.S. Of leaf:

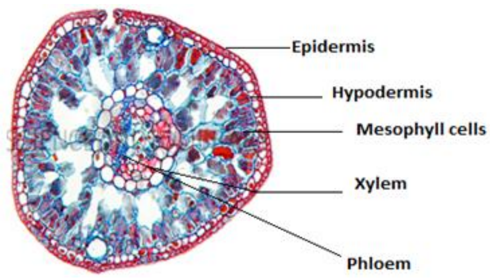

Fig. 11.36: Himalayan cedar (*Cedrus deodara*). T.S. leaf

a) Light micrograph of a section through a needle (leaf) from a Himalayan cedar tree, shows its thick cuticle and thick-walled epidermis and hypodermis (subcutaneous tissue).
b) Stomata (pores) and guard cells can also be seen, along with chloroplasts, and mesophyll tissue composed of parenchyma cells.
c) The vascular tissue is composed of xylem tracheid cells and phloem sieve tube cells.

11.3.3.4. Reproductive Structure:

1. Male and female strobili are borne on the same or on separate trees.
2. Strobili are solitary and erect on the short shoots.

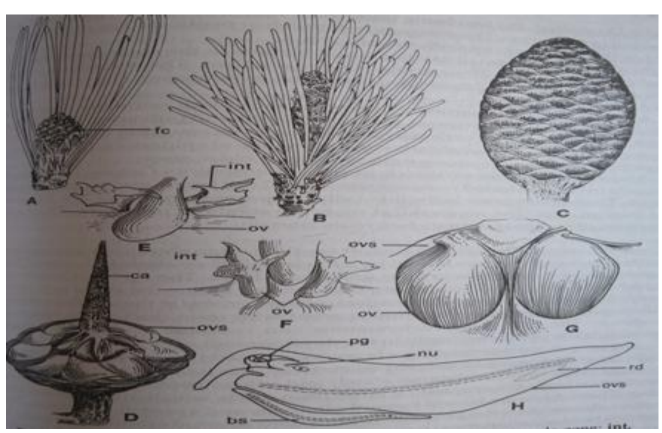

Fig. 11.37: *Cedrus deodara*: A) Shoot bearing a young female cone; B) first year pre-pollination female cone; C) second year female cone after winter rest; D) mature female cone after seeds and

ovuliferous scales are shed. The cone axis is persistent; E,F) a pair of ovules at the time of pollination in their ventral and dorsal views, respectively; G.) same, after pollination; the integument in micropylar region has shrivelled; H) L.S. ovule after pollination (bs: bract scale; ca: cone axis; fc: female cone; int: integuments; nu: nucellus; ov: ovule; ovs: ovuliferous scale; pg: pollen grain; rd: resin duct)

a) **Male Strobilus:**

1. It is stiff, erect, cylindrical, catkin like and up to 7 cm long and 1 – 1.5 cm. wide.
2. It consists of numerous densely crowded anthers which open longitudinally.
3. Pollen grains are wingless.

b) **Female Strobilus:**

1. It is small, greenish, about 1.5 cm. long and 0.5 cm. in diameter in young stage.
2. Cones arc larger, and woody at maturity and composed of several woody bract scales which arc closely overlapping, fan shaped with a basal stalk like claw.
3. Seeds – 2, attached to each ovuliferous scale. Each seed has a broad membranous apical wing several times larger than the seed.

11.3.4. *Cupressus*

From these studies, students will know about the morphological, anatomical features of different vegetative parts like stem, root, leaf and and reproductive characters of *Cupressus*:

11.3.4.1. Systematic Position

Class: Coniferopsida
Order: Coniferales
Family: Cupressaceae
Genus: *Cupressus*

11.3.4.2. Vegetative Structure:

1. *Cupressus* is an evergreen tree species with finely divided branchlet systems arising at various angles.
2. The leaves are persistent, small, scale-like, adpressed; mostly in opposite pairs.

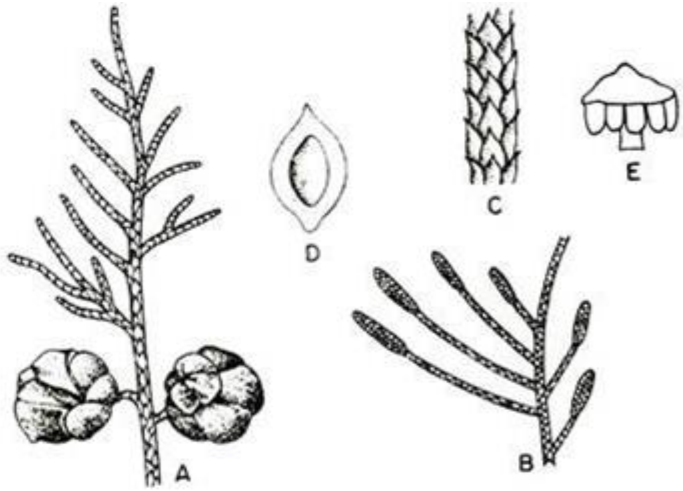

Fig. 11.38: *Cupressus* sp.: A) A fertile twig female cone; B) A fertile twig with male cone; C) Twig showing leaf arrangement; D) Seed; E) Microsporophyll

11.3.4.3. Anatomical features of *Cupressus:*

Anatomically stem is identical with *Pinus* sp., wood is light yellow to brownish, there are conspicuous medullary rays, and resin canals in the wood.

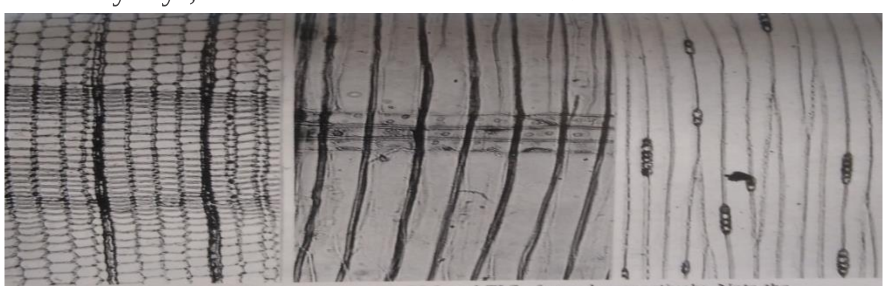

Fig. 11.39: *Cupressus*, A-C) T.S., RLS, TLS of wood, respectively

11.3.4.4. Reproductive Structure:

The cones are globose or sub-globose composed of several scales, male and female strobili appear on the same tree.

1) **Male Strobilus:**
   a) They are small, cylindrical and situated terminally on branchlets, micro-sporophylls are spirally arranged on the axis.
   b) Each microsporophyll bears 2 to 6 microsporangia and they are somewhat peltate in shape.
   c) Pollen grains are not winged.
2) **Female Strobilus:**
   a) Female cones occur on short branches bearing a few peltate scales with ovules in several rows at the base.
   b) Cones are dry, globose or ellipsoid, formed of 6 – 12 woody, shield like ovuliferous scales fitting closely together by their margins while growing, but separating when

mature, each consists of a central boss or triangular process on the outer surface, each scale with numerous winged seeds.

c) The cones are retained on the branches for an indefinite period after maturing, which takes place during the second year.

11.3.5. *Ginkgo*

From these studies, students will know about the morphological, anatomical features of different vegetative parts like stem, root, leaf and reproductive characters of *Ginkgo:*

11.3.5.1. Systematic Position

Class: Coniferopsida
Order: Ginkgoales
Family: Ginkgoaceae
Genus: *Ginkgo*

11.3.5.2. Morphological Features of Ginkgo:

1. *Ginkgo* is known as living fossil by the botanists. Or, it may also be referred as the oldest living seed plant. It is commonly called Maiden-hair Tree because its new leaves resemble very much like those of *Adiantum* (called maiden hair fern) both in form and venation.
2. *Ginkgo biloba* is a tall slender and beautiful tree. The plant body of *Ginkgo biloba* is sporophytic, and the sporophyte resembles several conifers in general habit.
3. The trees have a pronounced ex-current habit of growth and attain a height up to 30 metres.
4. A very irregular pattern of branching is shown by *Ginkgo* trees.
5. The branches are dimorphic i.e. bear long shoots which are of unlimited growth with scattered leaves and dwarf shoots which are short branches of limited growth.
6. *Ginkgo biloba* possesses a long tap root system.
7. The roots are extensively branched and penetrate deep into the soil.

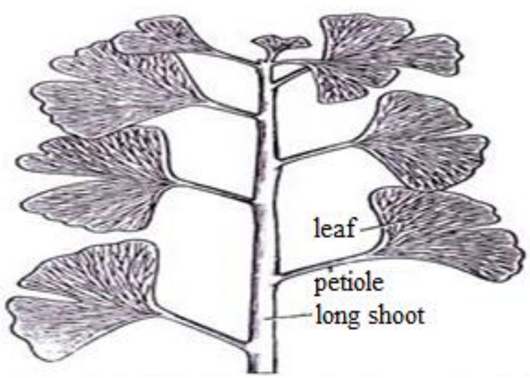

Fig. 11.40: *Ginkgo biloba.* A long shoot bearing deeply lobed leaves

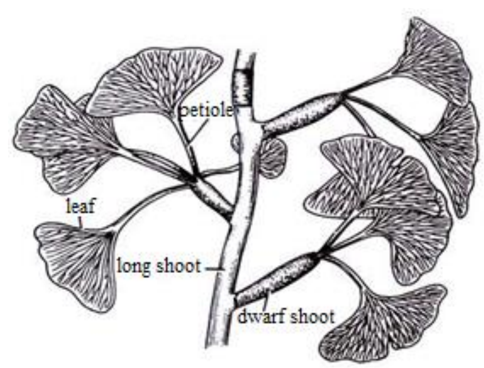

Fig. 11.41: *Ginkgo biloba,* A long shoot bearing dwarf shoots

8. The foliage leaves are simple, large, petiolate and wedge-shaped or fan-shaped with expanded apex and narrow base.

11.3.5.3. Anatomy of *Ginkgo*:

(i) T.S. of Root:

1. In transverse section the roots are somewhat circular in outline.
2. Mature roots are surrounded by phellogen or suberized cells of cortex.
3. A large portion of the young root is occupied by multilayered, thin-walled cortex which contains several tannin- filled cells and calcium oxalate crystals.
4. Mucilage canals are also prominently visible
5. In young roots, a layer of endodermis and uni-layered pericycle are clear. Mature roots, however, lack such a distinction.
6. Diarch condition is clearly visible in the young roots. Xylem is exarch. It remains separated by the phloem strands. Sometimes the roots also show triarch condition.

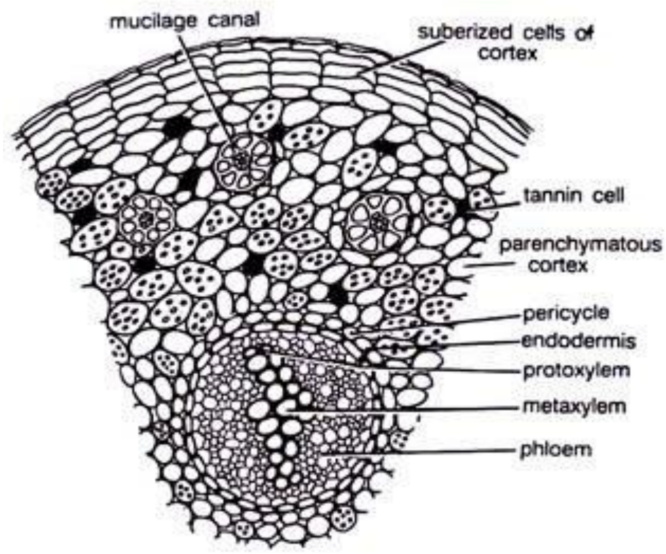

Fig. 11.42: *Ginkgo biloba*. T.S. young root

(ii) T.S. of Stem:

1. The young stem (long shoot) is more or less circular in outline and remains surrounded by a single-layered, thickly circularized epidermis made of brick-shaped cells.
2. Epidermis is replaced by periderm in the older stems.
3. Inner to the epidermal layer is present a well-marked region of parenchymatous cortex. It contains mucilaginous canals, sphaeraphides and many tannin-filled cells.
4. Cortex is comparatively less extensive in long shoots than dwarf shoots. Endodermis and pericycle are not well-marked in long shoot.

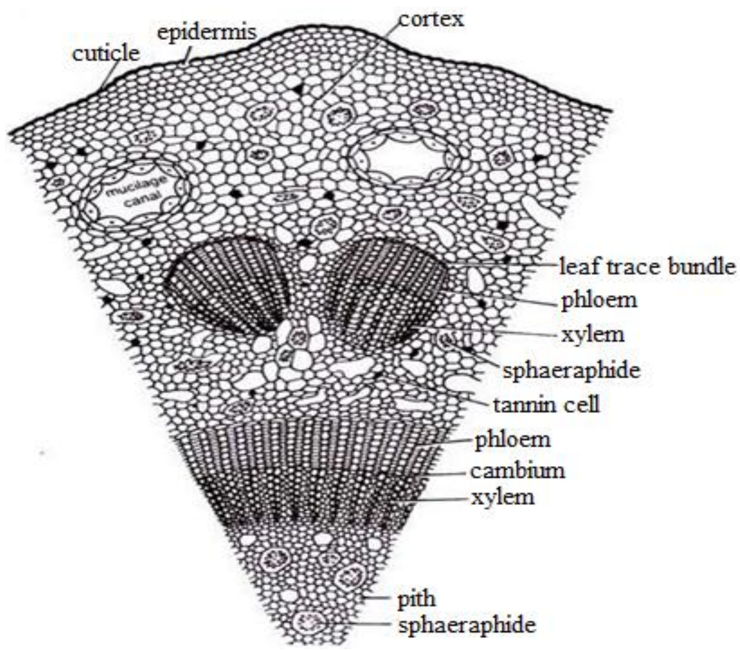

Fig. 11.43: *Ginkgo biloba*. T.S. young stem (Long shoot)

5. Several conjoint, collateral, open and endarch vascular bundles are arranged in a ring in very young stem. Two leaf traces, one for each leaf, are given out. After the onset of the secondary growth, the vascular cylinder of the stem becomes an endarch siphonostele with no parenchyma in the wood except that of uniseriate medullary rays.
6. Protoxylem has spiral thickenings while bordered pits are present on the radial walls of the metaxylem tracheids. Sieve tubes and phloem parenchyma constitute the phloem.
7. A narrow pith, containing mucilage canals and sphaeraphides, is present in the centre of long shoot, while in dwarf shoot the pith is comparatively more extensive.

iii) Secondary Growth in Stem:

1. Cork cambium cuts periderm towards outer side and secondary cortex towards inner side. Periderm replaces the epidermis. Mucilage canals are absent.
2. A single ring of cambium remains active throughout and cuts secondary phloem towards outer side and secondary xylem towards inner side. Crushed patches of primary phloem towards outer side and primary xylem towards inner side are present. Secondary phloem consists of sieve tubes and phloem parenchyma. Secondary xylem consists of tracheids.
3. Study of the tangential longitudinal sections of long and dwarf shoots show that uniseriate medullary’ rays are 1 -3 cells in height in long shoot while 1-15 cells in height in dwarf shoot.
4. One or two rows of bordered pits are present on the radial walls of the tracheids.
5. Pits are circular in outline and have a clear torus. Bars of Sanio are also present. Bars of Sanio do not occur in primary wood. Trabeculae of Sanio, which cross the lumen of the tracheids, are also present.

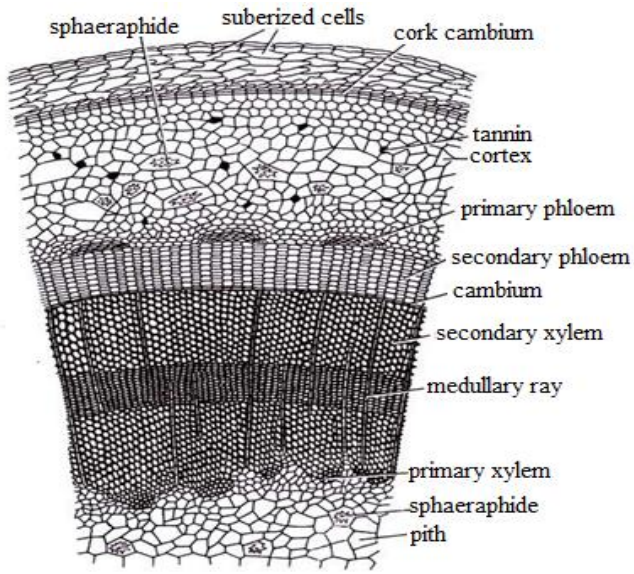

Fig. 11.44: ***Gikgo biloba.*** **T.S. old stem showing secondary tissues**

(iii) T.S. of Leaf:

1. A layer of epidermis is present on upper as well as lower sides of leaf. The epidermis is thickly cuticularised and consists of rectangular to polygonal cells.
2. Haplocheilic type of stomata, restricted only to the lower epidermis, is present.
3. Mesophyll is present in between the two epidermal layers. It is not well-differentiated into palisade and spongy parenchyma.
4. The leaves of long shoot, however, show a distinct palisade region.
5. Many mucilage canals or secretory canals and a few tannin-filled cells are also present in the mesophyll region.
6. Vascular bundles of the vein have an indistinct mesarch structure. Each vascular bundle may be surrounded by a sclerenchymatous bundle sheath in mature leaves.

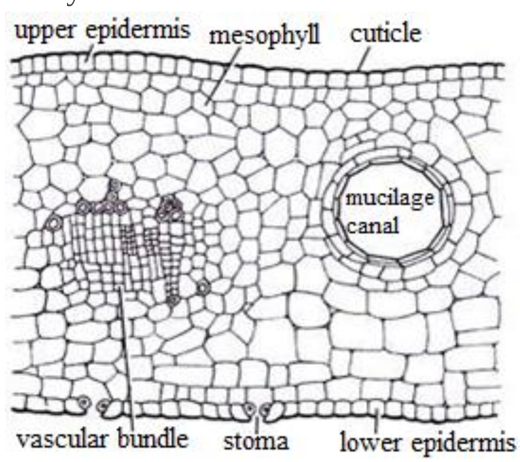

Fig. 11.45: ***G. biloba*** **T.S. young leaf (Modified from Chamberlain, 1935)**

(iv) T.S. of Petiole:

1. The petiole remains covered by a layer of thickly cuticulanzed epidermis, the continuity of which is broken by stomata. Inner to the epidermis are present a few hypodermal layers.
2. Few mucilage canals, tannin-filled cells and sphaeraphides are irregularly distributed in the cortex. The petiole is supplied by a pair of endarch vascular bundles.
3. It remains surrounded by a sclerenchymatous bundle sheath. Protoxylem has spiral thickenings. Cambium is clearly visible. Uniseriate rays are present in the xylem. These are continuous with those of the phloem.

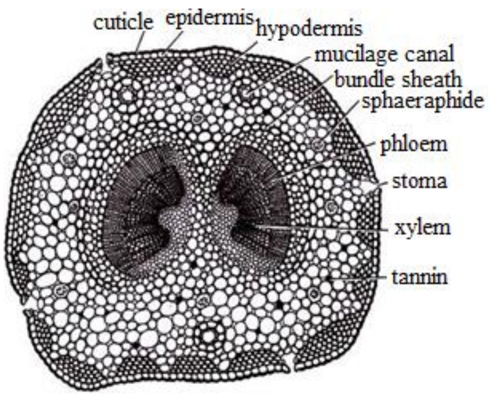

Fig. 11.46: *G. biloba*: T.S. petiole

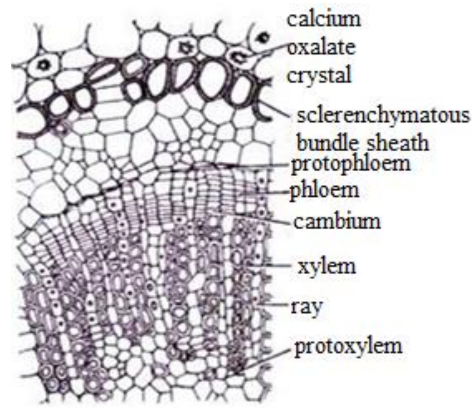

Fig. 11.47: *Ginkgo biloba*, A vascular bundle of petiole (modified from Chamberlain, 1935)

11.3.5.4. Reproductive Structures of Ginkgo:

1. *Ginkgo biloba* is dioecious.
2. Male and female plants are, however, difficult to be differentiated, when young. According to Lee (1954) sex in Ginkgo is determined by sex chromosomes (XY in male and XX in female).
3. Reproductive bodies of Ginkgo are most primitive among living seed plants except some Cycadales.

(i) Male Strobilus:

1. Male or microsporangiate fructifications develop in catkin-like clusters on the dwarf shoots of male frees.
2. Each male strobilus contains several microsporophyll's arranged loosely on a central axis. Each microsporophyll has a long stalk terminating into a hump or knob.
3. It contains two pendant microsporangia. According to some workers this terminal knob represents an abortive sporangium. A mucilage duct is present in the knob. Rarely more than two sporangia are present in a microsporophyll.
4. Each sporangium is a tubular structure surrounded by many layers.
5. The outermost layer of sporangial tissue differentiates into a tapetum.
6. The sporogenous cells of the sporangium undergo reduction division and form many haploid microspores.

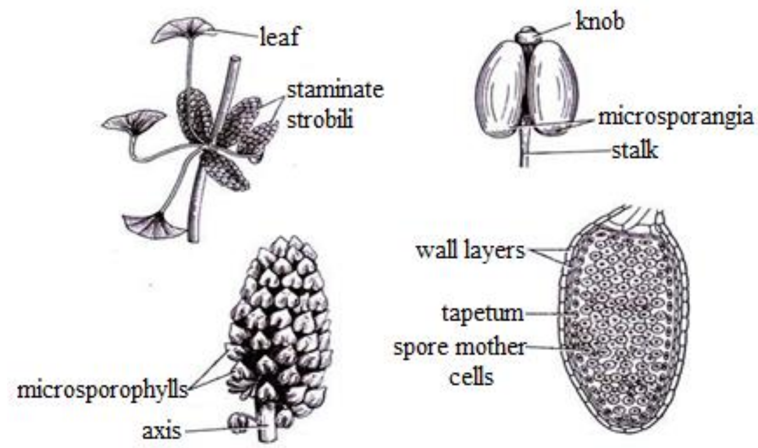

Fig. 11.48: G. biloba: Male reproductive structures. A). Showing a dwarf shoot with male strobili; B). A single male strobilus; C). A. microsporophyll; D). A. microsporangium

(ii) Female Strobilus:

1. The female strobili develop in groups in the axil of leaves or scaly leaves present on the dwarf shoots.
2. These are much reduced structures, each having a long stalk or peduncle, which bifurcates apically. Each bifurcation usually bears a single ovule. Out of the two sessile ovules one generally aborts earlier.

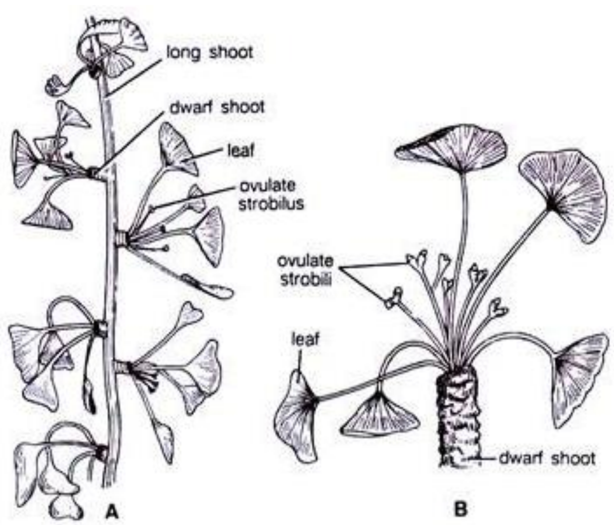

Fig. 11.49: *Ginkgo biloba.* A) a part of long shoot bearing some dwarf shoots and ovulate strobili; B) A dwarf shoot bearing leaves and ovulate strobili

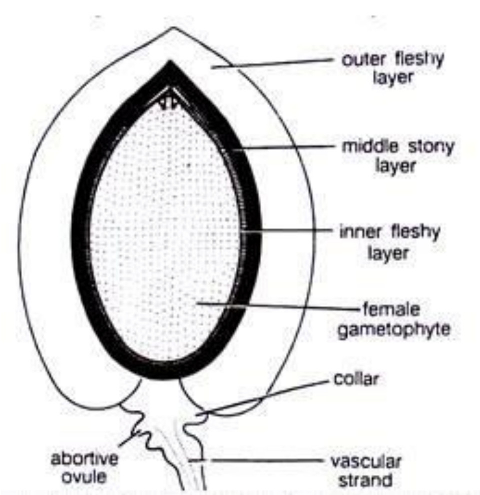

Fig. 11.50: *Ginkgo biloba.* L.S. of an ovule shortly after pollination (modified from Coulter and Chamberlain, 1917)

3. Each ovule has a large and prominent nucellus.
4. Free apex of the nucellus breaks down into a pollen chamber forming the nucellar beak.
5. Quite deep in the nucellus tissue, a functional spore mother cell becomes prominent.

6. The spore mother cell develops into a tetrad, of which only the innermost megaspore remains functional and develops into female gametophyte.
7. The vascular supply of the ovule is ill-developed.
8. Two vascular strands enter the inner fleshy layer and reach up to the free part of the nucellus without branching. Outer fleshy layer lacks any prominent vascular supply.

11.3.6. *Podocarpus*

From these studies, students will know about the morphological, anatomical features of different vegetative parts like stem, root, leaf and reproductive characters of *Podocarpus*:

11.3.6.1. Systematic Position

Class: Coniferopsida
Order: Coniferales
Family: Podocarpaceae
Genus: *Podocarpus*

11.3.6.2. Morphological characters:

1. Evergreen, trees and shrubs.
2. Resinous (with resin canals in the leaves, but only resin-containing parenchyma cells elsewhere).
3. The leafy branchlets flattened in one plane, or not flattened. Phyllocladineous (*Phyllocladus*), or with normal leaves. Mature leaves relatively broad and flat, or linear, or scale-like; when linear, acicular, or relatively soft; not clustered; alternate (mostly), or opposite and decussate (decussate, in *Microcachrys*).
4. Longitudinal resin canals present in the leaves, or absent from the leaves; when present, 1 per leaf, this median-abaxial.

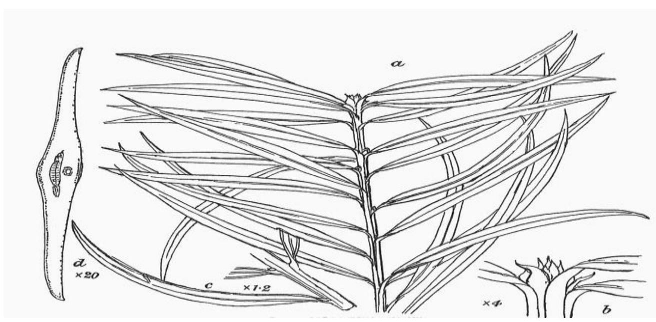

Fig. 11.51: *Podocarpus* a) Shoot, b) Leaf bud, c) under surface of leaf, d) section of leaf

11.3.6.3. Anatomical features:

1) T.S. of Leaf:

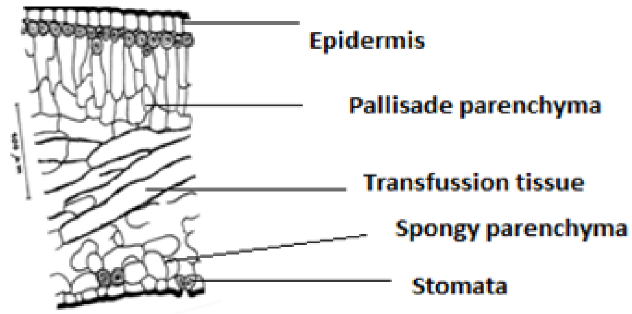

Fig. 11.52: *Podocarpus*: T.S. of leaf

1. **Epidermis:** Cells more or less in longitudinal rows, Outer wall and radial walls thickened, Cuticle thicker on the upper side.
2. **Hypodermis:** Consisting of sclerenchyma fibres with their long axis parallel to the epidermis and to the long axis of the leaf, absent under the rows of stomata. Generally more uniform at the upper side and broader (2-4 layers) at the leaf margin.
3. **Palisade tissue:** One layer in *P. milanjanus*, One to two layers in *P. milanjanus*, Normally dorsiventraly, palisade tissue at the upper side. Only a few small intercellular spaces.
4. **Spongy mesophyll:** Consisting of Central transfusion tissue, Parenchyma with chloroplasts (at the lower side).
5. Special cells (resin canals, sclereids)
6. Transfusion tissue consisting of tracheids and parenchyma, in *P. gracilior* not present at the leaf margin.
7. Leaves are hypostomatic (bifacial or dorsiventral leaves).
8. Stomata in rows between the bundles of sclerenchyma fibres of the hypodermis

2) Wood anatomy:

1. Growth rings indistict, or distinct.
2. Heartwood present and distinctively coloured, or present but not distinctively coloured, or absent. Latewood not conspicuous.
3. Wood without distinct odour; without distinct taste; not greasy; with dimpled grain (*Podocarpus spicatus*), or without dimpled grain (usually).
4. Tracheids with neither alternate nor opposite bordered pits; without callitroid pit-border thickenings. Margins of the tori not scalloped. Torus extensions conspicuously present (e.g., in *Lagarostrobus*), or absent.
5. Early wood tracheids without spiral thickenings.
6. Axial parenchyma present, or absent. Axial parenchyma when present, abundant, or scarce. Axial parenchyma not zonate.
7. Ray tracheids regularly present (usually, in *Podocarpus*), or absent or very infrequent. Ray tracheids when present, not dentate. Early wood ray cells with horizontal walls thinner than those of the adjacent vertical tracheids above and below the ray, or with walls similar in thickness to those of adjacent vertical tracheids. Latewood ray cells with unpitted horizontal walls, or with pitted horizontal walls. The pitting when present, strong, or weak. Ray cells

exhibiting indentures at the corners, or without indentures; without nodular thickenings on their end walls. Ray tissue without crystals. Early wood Normal vertical resin ducts absent.

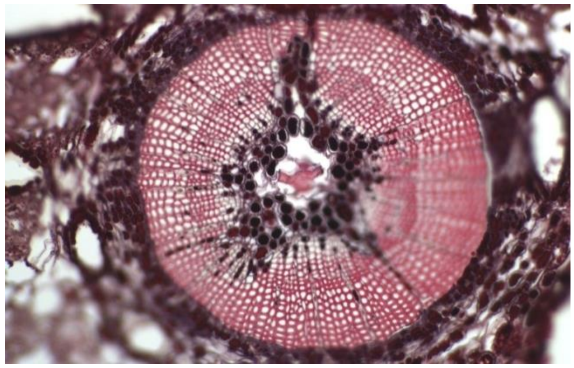

Fig. 11.53: *Podocarpus*: T.S. of wood showing the secondary growth

11.3.6.4. Reproductive characters:

1. Monoecious (rarely), or dioecious.
2. The female cone is generally unstrobiloid i.e. it is not a compact cone-like body.
3. It is a uniovulate or bi-ovulate structure situated at the top of a flattened short segment in *Podocarpus macrophylla*.
4. The ovule-bearing segment also contains a few reduced leaves.
5. The ovule remains enclosed completely or partially by the folded ovuliferous scale, which represents epimatium.
6. In *P. spicatus* the female cones appear like loose spikes, and the epimatium remains fused with the integument throughout its length. In *P. ferruginens*, however, the integument remains fused with the epimatium only at its chalazal end. The ovule is erect and anatropous.
7. The female gametophyte remains enclosed by the nucellus.
8. The endosperm and the archegonial complex are present in the female gametophyte.
9. The megaspore mother cell in *P. gracilior* and some other species lies quite deep in the nucellus tissue. It divides meiotically and form a linear tetrad of four megaspores in *P. gracilior* and *P. falcatus*.
10. After the formation of several free nuclei in the megaspore and prior to the start of wall formation, the female gametophyte passes through a long resting period. Wall formation is centripetal. The archegonia develop in groups of 15 to 25 in different species.
11. They are oval with round base in *P. gracilior* and long with pointed base in *P. andinus*. Archegonial neck consists of 4-6 cells arranged in a single tier in *P. gracilior*

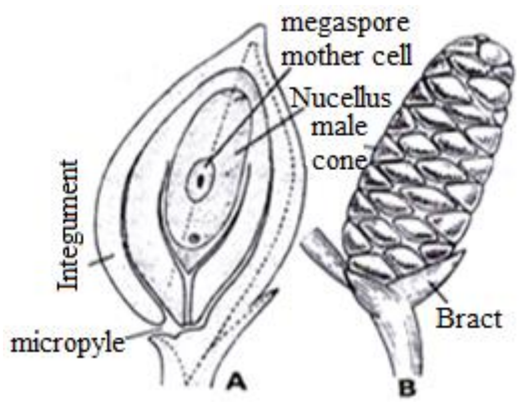

Fig. 11.54: *Podocarpus* spp. A. L.S. of ovule; B. single male cone arising from axil of bract

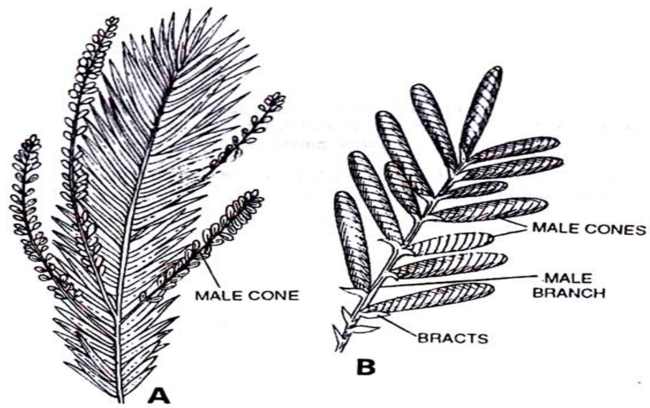

Fig. 11.55: *Podocarpus* spp. A. Shoot bearing male cones; B. Male branch with male cones in bracts

12. Male cones are catkin-like, with numerous sporophylls each bearing two sporangia. Pollen-sacs are 2 per microsporophyll. Pollen is with air bladders (2 or 3, sometimes well developed, sometimes poorly developed or vestigial), or without air bladders (e.g., *Saxegothaea*). The pollination mechanisms are diverse, being by "liquid drop" mechanism only when the grains are equipped with well developed air bladders (cf. *Pinaceae*).

13. The sporangial wall is 5-7 layered, of which the innermost layer functions as a tapetum. Each pollen grain develops into a male gametophyte. Male prothallus cells are 1-8 in number in different species of *Podocarpus*. The spermatogenous cell or body cell divides into three unequal male gametes.

11.3.7. *Taxus*

From these studies, students will know about the morphological, anatomical features of different vegetative parts like stem, root, leaf and and reproductive characters of *Taxus*:

11.3.7.1. Systematic Position

Class: Coniferopsida
Order: Coniferales
Family: Taxaceae
Genus: *Taxus*

11.3.7.2. Morphological Features of *Taxus*:

1. *Taxus baccata*, commonly known as 'Yew', is an evergreen tree attaining a height of 9-20 metres with a massive trunk.
2. The stem is profusely branched and remains covered with a thin brown-coloured bark.
3. It differs from *Pinus* in not possessing dimorphic branches.
4. All the branches are of unlimited growth and form a very dense canopy, thus making *Taxus* a shade-providing tree. Only the green leaves are present on the vegetative branches.

5. The leaves are linear, small, only 2-3 cm. long and spirally arranged. Each leaf possesses a single strong vein and recurved margins.
6. The upper surface is dark green while the lower surface is pale or rusty red in colour.
7. The apex is sharply pointed mainly because of accumulation of silica. This sharply pointed apex may cause death of catties eating these leaves. Each leaf is shortly stalked. The stalk broadens into a flat persistent base which shows a slight twist. The scaly leaves present on the fertile shoot are opposite and decussate. *Taxus* possesses a long and well- developed tap-root. The roots are deep-feeders and highly branched.

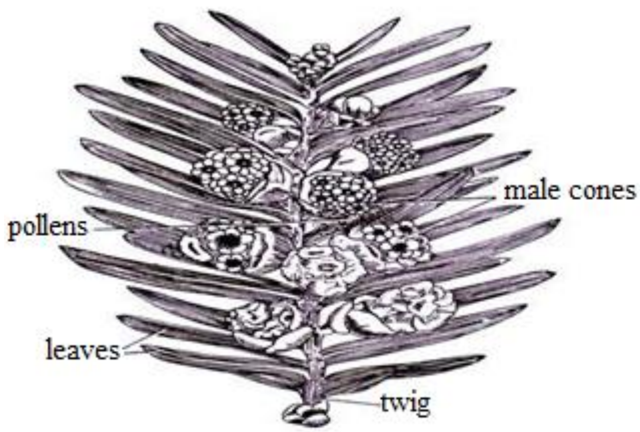

Fig. 11.56: A twig of *Taxus baccata* bearing male cones at different stages of development

11.3.6.3. Anatomy features of *Taxus*:

(i) T.S. of Stem:

1. In transverse section the stem is irregular in outline and resembles *Pinus* in structure. It is surrounded by a thickly cuticularised single-layered epidermis.
2. Inner to the epidermis is parenchymatous cortex having some tannin-filled cells.
3. It is followed by endodermis and sclerenchymatous pericycle.
4. The young stem shows a ring of conjoint, collateral, open and endarch vascular bundles enclosing distinct pith in the centre.
5. The protoxylem consists of spiral tracheids, and the phloem contains sieve cells with sieve plates and phloem parenchyma.
6. Companion cells are absent.
7. The cambium is persistent and develops a thick vascular cylinder due to secondary growth. The cambium cuts secondary phloem towards outer side and secondary xylem towards inner side.
8. The secondary wood is devoid of resin canals and wood parenchyma. Its tracheids show uniseriate bordered pits only on their radial walls.

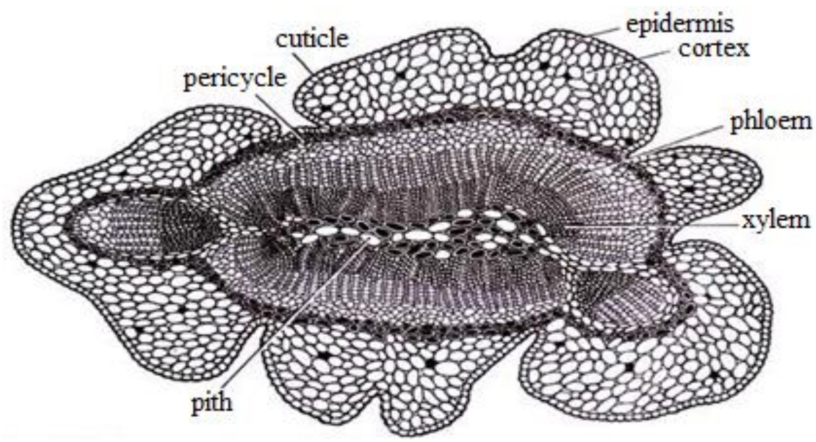

Fig. 11.57: *Taxus baccata*. T.S. stem (young)

9. The tracheids also show spiral thickenings.
10. The medullary rays are uniseriate and homogeneous but in *Taxus baccata* they are sometimes bi-senate. The wood is strong and dense. Due to the presence of tertiary spirals the wood is elastic in nature.
11. Phellogen may develop in the older stems showing extrastelar secondary' growth.

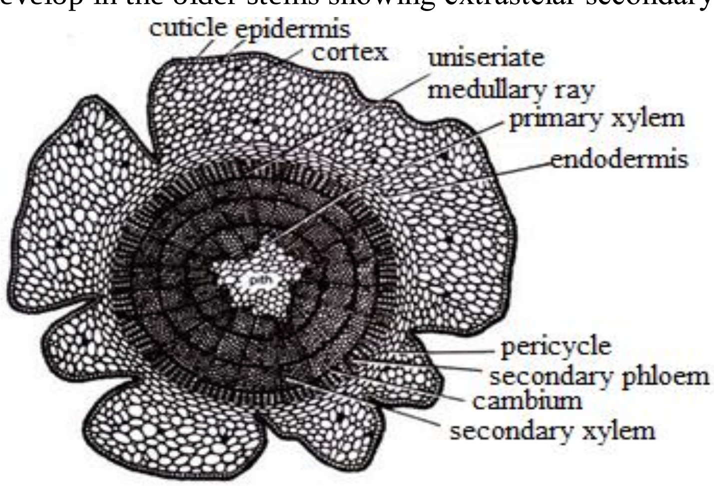

Fig. 11.58: *Taxus baccata*. T.S. stem (old) showing secondary growth

(ii) T.S. of Root:

1. Except that of the absence of resin canals, the root anatomy of *Taxus* resembles very much with that of *Pinus*.
2. The root is diarch.

(iii) T.S. of Leaf:

1. The leaf is dorsiventral. It shows xerophytic characters.
2. Upper and lower epidermal cells are rectangular in shape and thickly circularized. The cuticle is comparatively thin on the lower surface.

3. The stomata are of sunken type and restricted only to the lower epidermis. They are haplocheilic in development.
4. The mesophyll is differentiated into palisade and spongy-parenchyma. The palisade is generally two-layered.
5. Only one vascular bundle is present in the mid-rib region. Enclosed by a distinct endodermal layer or bundle sheath the collateral vascular bundle contains phloem towards the lower side and xylem towards the upper side.
6. Transfusion tissue is present on both the sides of the vascular bundle.
7. Resin canals are generally absent.
8. The xerophytic characters of the leaf include the presence of thick cuticle, sunken stomata, transfusion tissue and differentiation of mesophyll into palisade and spongy parenchyma.

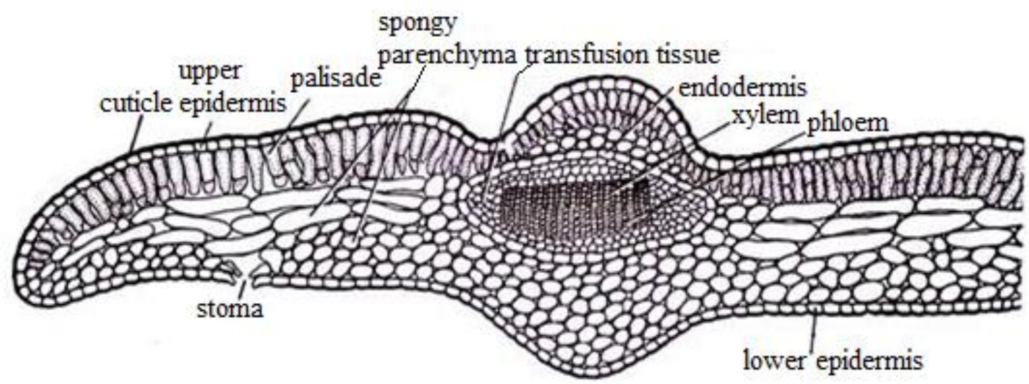

Fig. 11.59: *Taxus baccata* V.S. leaf

11.3.6.4. Reproduction of *Taxus*:

1. *Taxus* is usually dioecious, but occasionally monoecious trees are also reported.
2. The reproductive structures become prominent on the plant in February-March. The male and female plants do not show any distinction in their vegetative organisation, and the differentiation between them can be made only when the plants are in the flowering or fruiting stage.
3. Vegetative reproduction in *Taxus* is not known.

(i) Male Strobilus or Male Flower:

1. The ‘male flowers’ or ‘male strobili’ are usually yellowish in colour and develop in the axil of foliage leaves.
2. Each strobilus contains a number of overlapping sterile bracts.
3. Some of the bracts towards the tip of the strobilus are replaced by stamens or micro-sporangiophores.
4. Each stamen is shortly-stalked any has a peltate disc bearing 4-8 pendant microsporangia.
5. The microsporangia surround the stalk completely. The axis of the male strobilus contains a broad apex which is consumed in the formation of a stamen.

6. The microsporangia in the young male strobilus are compactly arranged but at maturity they get loosened and undergo dehiscence.
7. The presence of peltate micro-sporangiophores is one of the most remarkable features of *Taxus*.

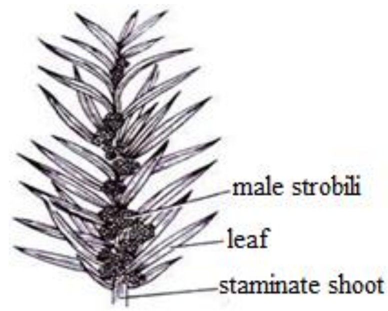

Fig. 11.60: *Taxus baccata*: Male shoot with many staminate strobili (modified after chamberlain, 1935)

8. A mature microsporangium remains surrounded by an epidermal layer followed by two wall layers and sporogenous tissue.

9. The outermost sporogenous cells differentiate into a tapetum.

10. The sporogenous cells start to behave as microspore mother cells which undergo meiosis and form microspores or pollen grains.

11. The microspores remain arranged isobilaterally or tetrahedrally for quite some time.

12. The development of microsporangium is of eusporangiate type and is identical with that of *Pinus*. Four to eight archesporial cells develop hypo-dermally. They divide and form wall layers and sporogenous tissue.

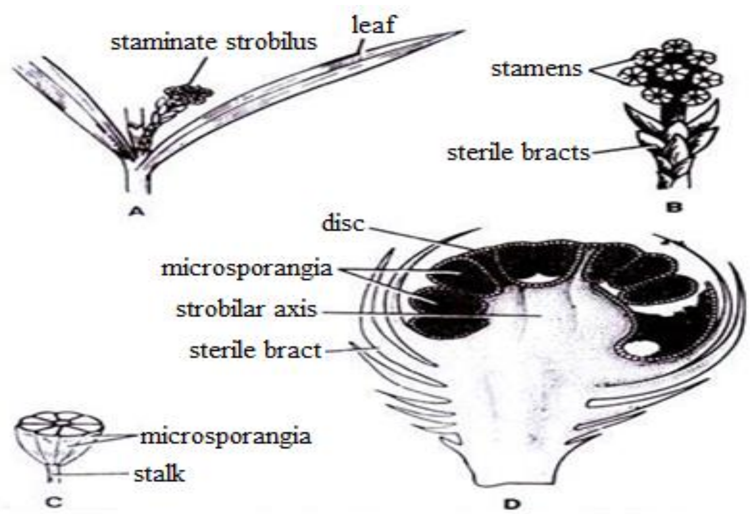

Fig. 11.61: *Taxus baccata*. Male reproductive structures. A.) a branch with male strobilus; B) a male strobilus showing many stamens; C) a single stamen with microsporangia; D) L.S. male strobilus

(ii) Female Strobilus or Female Flower:

1. The female strobili in *Taxus* are so highly reduced that they hardly appear as cones or strobili.
2. They arise in the axils of leaves early in the season and mature in the next season.
3. Each female reproductive organ consists of a short primary axis having scaly leaves or bracts arranged in opposite decussate manner.
4. A short secondary axis develops from the axil of upper three scaly leaves.This secondary axis bears a few pairs of scaly leaves and a terminal ovule.

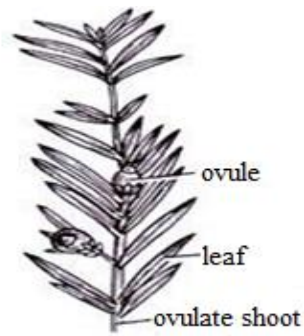

Fig. 11.62: *Taxus baccata*. An ovulate shoot (modified after Chamberlain, 1935)

iii) Ovule:

1. The ovule is somewhat rounded or oval in shape and orthotropous.
2. A single thick integument is present. Integument is free from the nucellus right up to its base forming a long micropyle. The integument is differentiated into outer fleshy, middle stony and inner fleshy layers. Two vascular strands enter the integument from the base of the ovule and reach up to its top.
3. A ring-like outgrowth develops from the base of the integument. It surrounds the entire ovule. It is called 'aril' or 'cupule'.
4. Aril is green and saucer-shaped when young but at maturity it is red and cup-shaped.

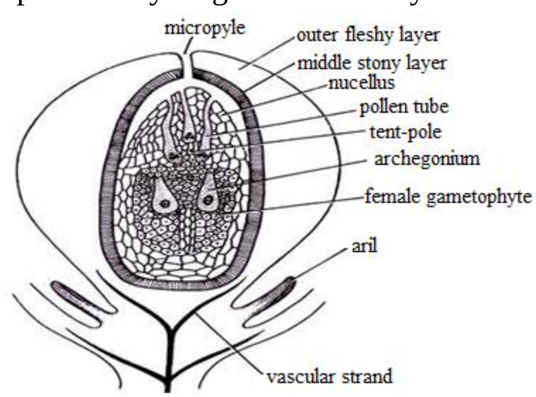

Fig. 11.63: *Taxus baccata*. V.S. ovule

11.3.8. *Ephedra*

From these studies, students will know about the morphological, anatomical features of different vegetative parts like stem, root, leaf and and reproductive characters of *Ephedra*:

11.3.8.1. Systematic Position

Class: Gnetopsida
Order: Gnetales
Family: Ephedraceae
Genus: *Ephedra*

11.3.8.2. Morphological Features of *Ephedra*:

(i) The plant body is sporophytic and shows xerophytic characters.

(ii) Mostly the plants are woody shrubs, a very few species are lianas and some species grow into a small tree.

(iii) Plant body can be differentiated into three parts – root, stem and leaves.

1. Root:

i) There is a prominent underground tap root system.

ii) Later on the adventitious roots develop.

iii) Many root hairs are present but there is no mycorrhiza.

2. Stem:

i) The stem is green, ribbed, branched, fluted and differentiated into nodes and internodes.

ii) It performs the function of photosynthesis and may be called as phylloclade. The branches arise from the axillary buds and are, therefore, in pairs of threes or fours according to the number of the scaly leaves at the nodes in different species.

iii) The branches are also green and differentiated into nodes and internodes.

3. Leaves:

i) Leaves are small scaly, present in pairs at the nodes and are arranged in opposite decussate manner.

ii) These leaves unite at the base to form a basal sheath.

iii) Each leaf contains two unbranched, parallel veins

iv) In the axil of each leaf is present a bud for the branch. True foliage leaves are absent.

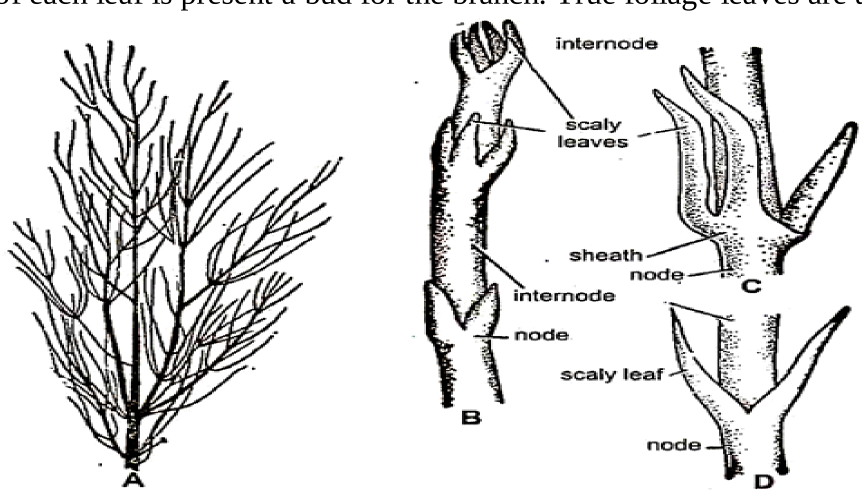

Fig. 11.64: *Ephedra*: A) Shrubby habit. B) A branch showing nodes and internode C) and D) nodes showing different number of scaly leaves.

11.3.8.3. Anatomy of Different Parts of *Ephedra*:

Students now cut the thin transverse sections of young and old stems stain them in safranin-fast green combination, mount in glycerine and study.

(A) Stem: T.S. Young stem:

1. The outline shows many ridges and grooves.
2. Outermost layer in epidermis with a thick layer of cuticle. Continuity of the epidermis is broken by many sunken stomata present in the grooves.
3. Below the ridges are present the patches of sclerenchyma.
4. Cortex is separated into palisade and spongy parenchyma. Some sclerenchyma patches are also irregularly distributed in the cortex.
5. Vascular bundles are arranged in a ring and the stele is ectophloic siphonostele.
6. Stele is bounded by a layer of endodermis and unilayered pericycle.
7. Each vascular bundle is conjoint, collateral, open and endarch.
8. In each vascular bundle phloem is present on the outer side and xylem on the inner side and both are separated by cambium.
9. Parenchymatous pith is present at the centre of the stem.

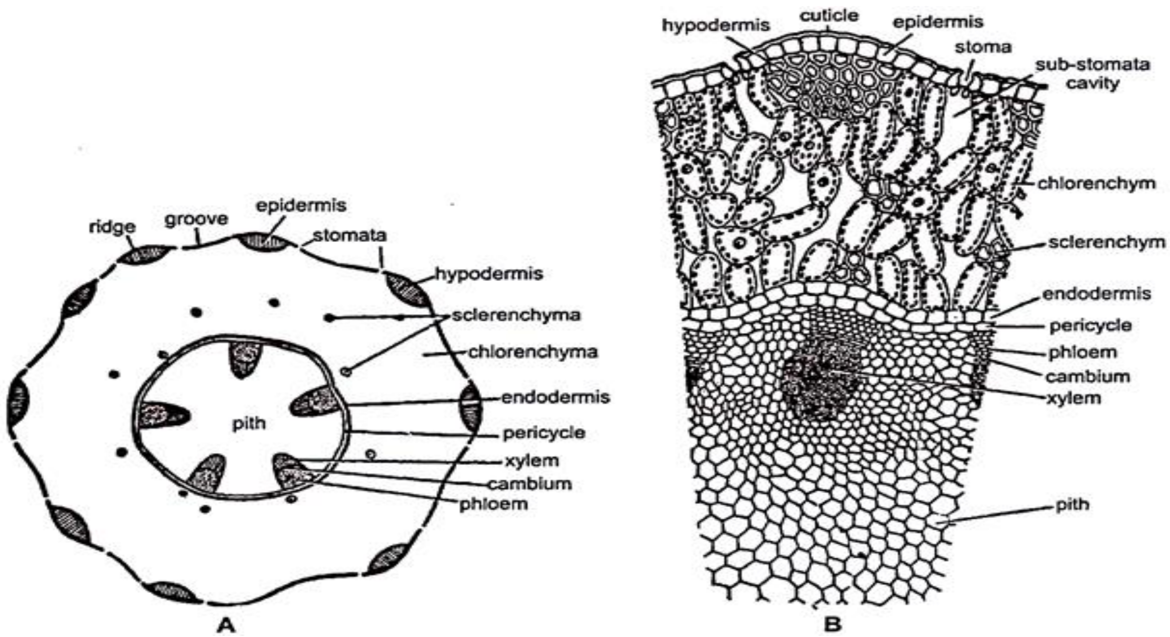

Fig. 11.65: *Ephedra.* A) T.S. Young Stem a; B) a part of cellular

(B) Stem: T.S. Old stem:

1. It is wavy in outline with ridges and grooves and remains surrounded by a single-layered, heavily cuticularized epidermis.
2. The cortex is also differentiated into palisade and spongy parenchyma.
3. In older stems, the periderm replaces these primary cortical structures.

4. Secondary tissue is externally bounded by a layer of sclerotic cells or stone cells.
5. Cambium cuts secondary phloem towards outer side and secondary xylem towards inner side.
6. Secondary tissue crushes and pushes the primary phloem towards outer side and primary xylem towards inner side.

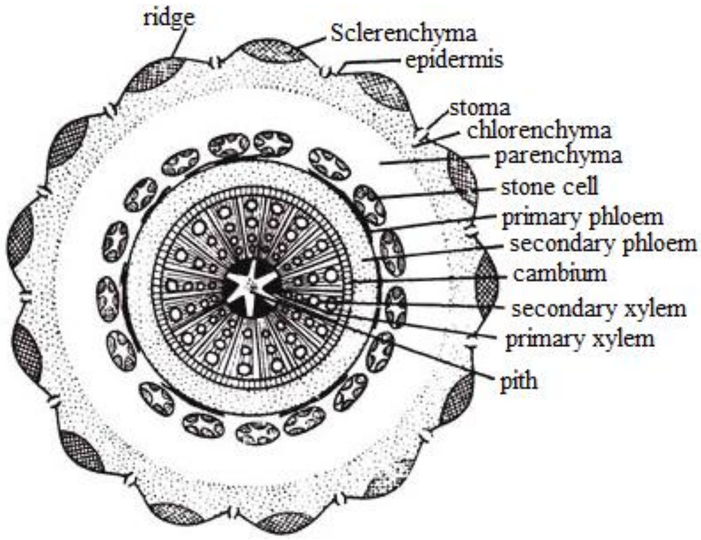

Fig. 11.66: *Ephedra*, T.S. old stem showing secondary growth (Diagrammatic)

7. Thin-walled spring wood and thick-walled autumn wood are present in the secondary xylem in the form of regular alternate rings.
8. Sieve tubes and phloem parenchyma are present in phloem.
9. Presence of vessels is the characteristic feature of the wood of *Ephedra*.
10. Primary medullary rays connect primary phloem and primary xylem while the secondary medullary rays connect secondary phloem and secondary xylem. Medullary rays are uniseriate in young stem while in the old stem these are multiseriate.
11. Resin canals are absent. Parenchymatous pith is present in the centre.

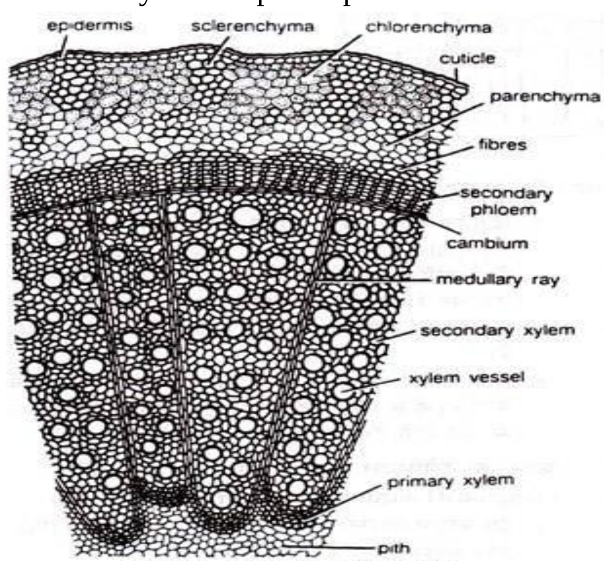

Fig. 11.67: Ephedra T.S. old stem

(C) T.S. of Leaf: The transverse section of scaly leaf is oval in shape and can be differentiated into epidermis, mesophyll tissue and vascular tissue.

(i) Epidermis: It is outer most single layer of thick walled elongated cells. The cells are covered with thick cuticle. Sunken stomata are present.

(ii) Mesophyll tissue: Two or three layers of palisade tissue are present inner to epidermis. The cells are filled with chloroplast and large intercellular spaces are present between them. In the centre of the leaf parenchymatous tissue is present.

(iii) Vascular tissue: Two vascular bundles are embedded in the parenchymatous tissue. The vascular bundles are collateral and closed. Xylem is present towards the upper side.

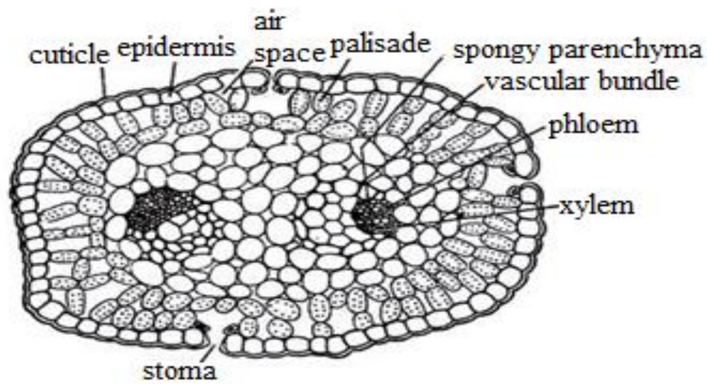

Fig. 11.68: *Ephedra*. L.S. of leaf

(D) Root:

(i) The transverse section of root shows single layer epiblema, outer cortex (composed of collenchymatous cells), inner cortex (composed of parenchymatous cells) endodermis and pericycle.

(ii) Vascular bundles are radial and exarch. The root may be diarch or triarch.

11.3.8.4. Reproductive Parts *Ephedra*:

(i) *Ephedra* is heterosporous, i.e., two types of spores (microspores and megaspores) are present.

(ii) Microspores are present in male flowers while the megaspores in female flowers.

(iii) These flowers are present in the form of cone-like compound strobili.

(iv) Male flowers are present in the form of male strobilus while many female flowers form the female strobilus.

(v) Each strobilus arises on the node in the axil of a scaly leaf.

(vi) Plant is generally dioecious.

1) Male Strobilus:

(i) Male strobili develop in the axil of scaly leaves on the nodes.

(ii) Each strobilus is round or ovoid in shape.

(iii) In the centre is present the strobilus axis or cone axis.

(iv) On the strobilus axis are arranged 2 to 12 pairs of bracts in opposite decussate manner.

(v) All the bracts are fertile except a few on the lower side.
(vi) A single staminate flower or male flower arises in the axil of each bract.
(vii) Each male flower consists of two bracteoles and a stamen.
(viii) Each stamen is a stalked structure with 2 to 4 anthers or microsporangia at the top.

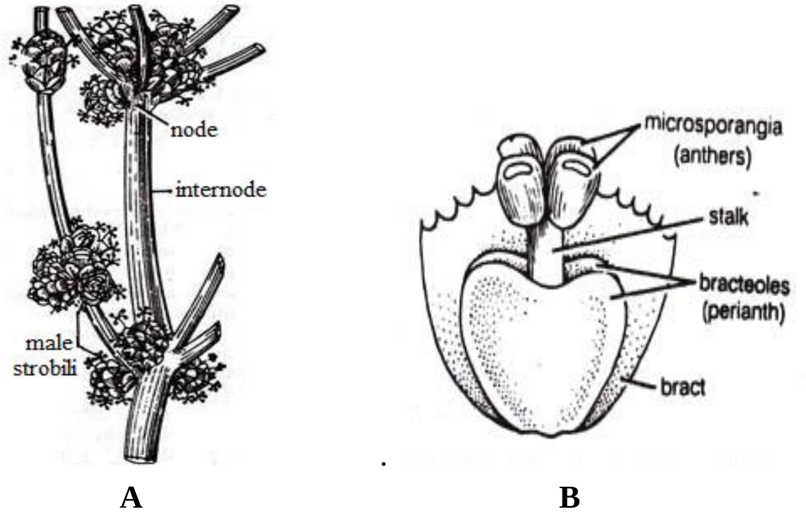

Fig. 11.69: *Ephedra viridis*: A. Part of a staminate plant; B. A single male flower

(ix) Each anther or microsporangium is bilocular or trilocular, and each locule is surrounded by a double-layered wall and an innermost layer of tapetum.
(x) Many pollen grains or microspores are present in each locule. Each pollen grain is a uninucleate structure surrounded by a thin intine and thick outer layer of exine.

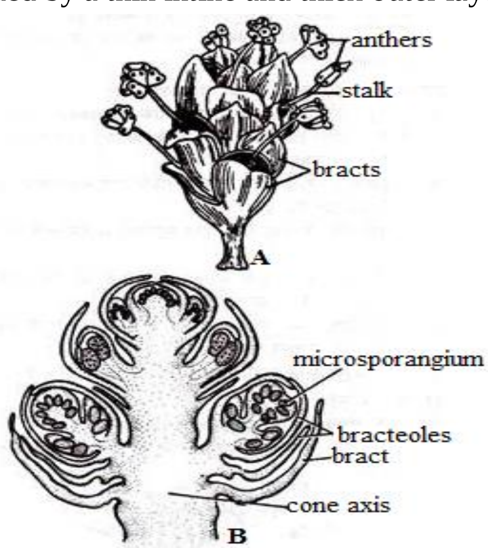

Fig. 11.70: *Ephedra*, A) A compound male strobilus B) L.S. male strobilus

2) Female Strobilus:

(i) Similar to the male strobilus, the female strobilus also develops in the axil of the leaf on the node.

(ii) It is sessile and smaller than male strobilus.
(iii) Two to four pairs of bracts are arranged in opposite decussate manner on the strobilus axis.
(iv) Except the uppermost pair of bracts, all are sterile.
(v) Two ovules are present in the axil of uppermost pair of bracts, out of which generally only one ovule survives.

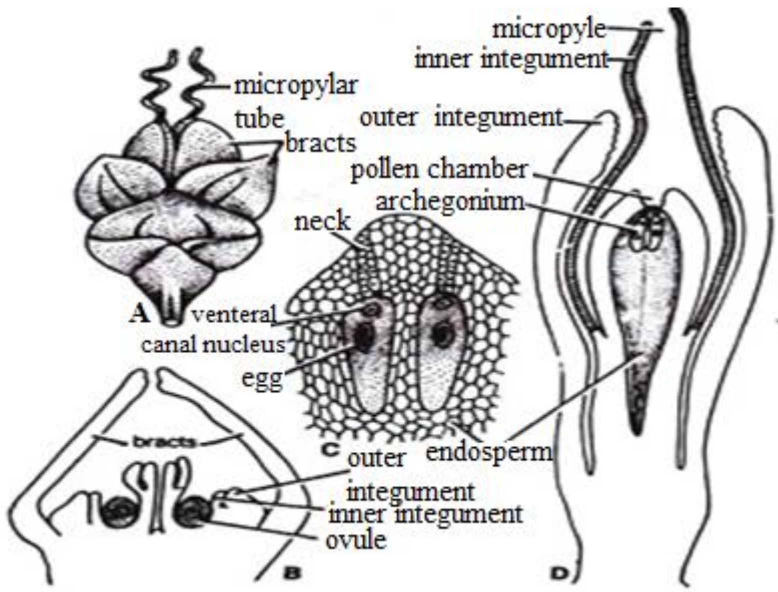

Fig. 11.71: *Ephedra*. A) A single Female spike; B) L.S. of a female flower; C) Endosperm with two archegonia; D) L.s. ovule

11.3.9. *Gnetum*

From these studies, students will know about the morphological, anatomical features of different vegetative parts like stem, root, leaf and reproductive characters of *Gnetum*:

11.3.9.1. Systematic Position

Class: Gnetopsida
Order: Gnetales
Family: Gnetaceae
Genus: *Gnetum*

11.3.9.2. Morphological features

1. *Gnetum*, represented by about 40 species is confined to the tropical and humid regions of the world.
2. Five species (*Gnetum contractum*, *G. gnemon*, *G. montanum*, *G. ula* and *G. latifolium*) have been reported from India.
3. *Gnetum ula* is the most commonly occurring species of India.
4. Majority of the *Gnetum* species are climbers except a few shrubs and trees. *G. trinerve* is apparently parasitic.
5. Two types of branches are present on the main stem of the plant, i.e. branches of limited growth and branches of unlimited growth.

6. Each branch contains nodes and internodes.
7. Stem of several species of *Gnetum* is articulated.
8. In climbing species the branches of limited growth or short shoots are generally un-branched and bear the foliage leaves.
9. The leaves (9-10) are arranged in decussate pairs.
10. They often lie in one plane giving the appearance of a pinnate leaf to the branch.
11. The leaves are large and oval with entire margin and reticulate venation as also seen in dicotyledons.
12. Some scaly leaves are also present.

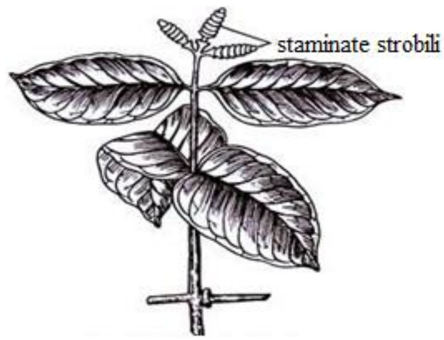

Fig. 11.72: A branch of *Gnetum*

11.3.9.3. Anatomy of *Gnetum*:

(1) Root:

(i) Young root has several layers of starch-filled parenchymatous cortex, the cells of which are large and polygonal in outline.

(ii) An endodermal layer is distinguishable.

(iii) Casparian strips are seen in the cells of the endodermis.

(iv) The endodermis follows 4-6 layered pericycle.

(v) Roots are diarch and exarch. Small amount of primary xylem, visible in young roots, becomes indistinguishable after secondary growth.

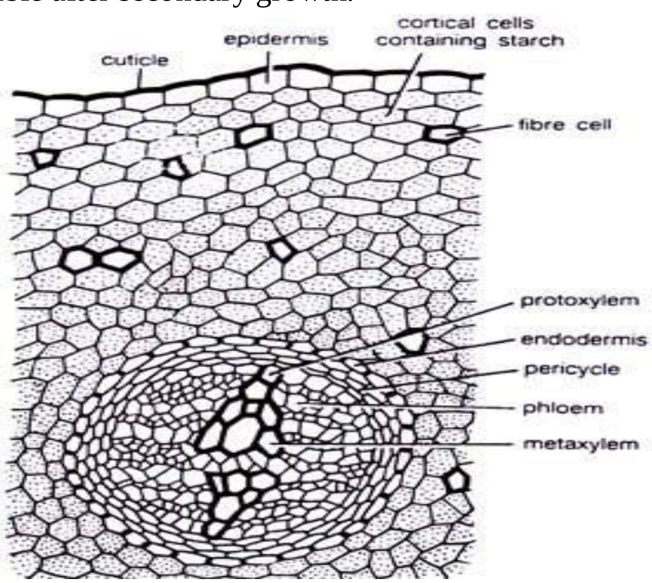

Fig. 11.73: *Gnetum*, T.S. young root

(vi) The secondary growth is of normal type.

(vii) A continuous zone of wood is present in the old roots. It consists of tracheids, vessels and xylem parenchyma. The tracheids have uniseriate bordered pits along with bars of Sanio.

(viii)Vessels have simple or small multiseriate bordered pits.

(ix) Some of the xylem elements have starch grains. Bars of Sanio are generally absent in the vessels. Phloem consists of sieve cells and phloem parenchyma.

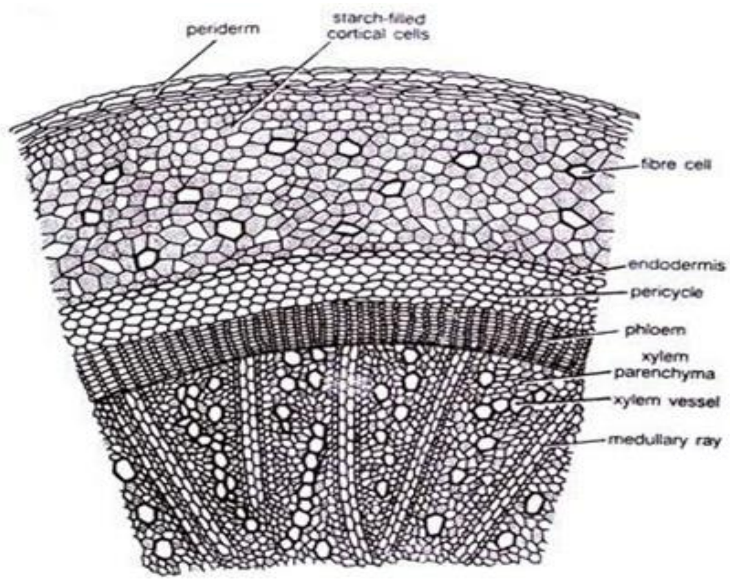

Fig. 11.74: *Gnetum*: T.S. old root showing secondary growth

(2) Young Stem:

(i) The young stem in transverse section is roughly circular in outline, and resembles with a typical dicotyledonous stem.

(ii) It remains surrounded by a single-layered epidermis, which is thickly circularized and consists of rectangular cells. Some of the epidermal cells show papillate outgrowths. Sunken stomata are present.

(iii) The cortex consists of outer 5-7 cells thick chlorenchymatous region, middle few-cells thick parenchymatous region and inner 2-4 cells thick sclerenchymatous region.

(iv) Endodermis and pericycle regions are not very clearly distinguishable. Several conjoint, collateral, open and endarch vascular bundles are arranged in a ring in the young stem.

(v) Xylem consists of tracheids and vessels. Presence of vessels is an angiospermic character. Protoxylem elements are spiral or annular while the metaxylem shows bordered pits which are circular in outline.

(vi) The phloem consists of sieve cells and phloem parenchyma.

(vii) An extensive pith, consisting of polygonal, parenchymatous cells, is present in the centre of the young stem.

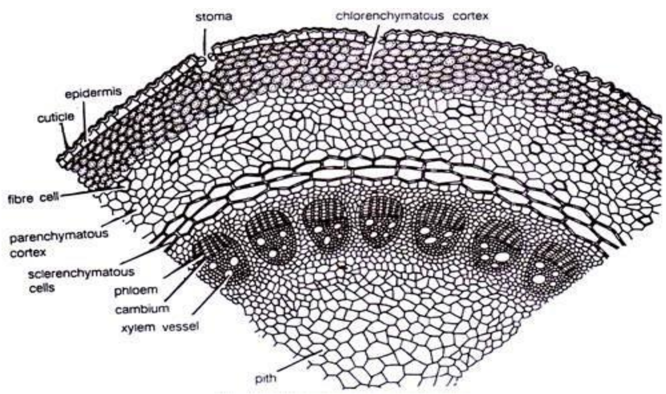

Fig. 11.75: *Gnetum*. T.S. young stem

(3) T.S. of Leaf

(i) Internally, *Gnetum* leaves also resemble with a dicot leaf.

(ii) It is bounded by a layer of thickly circularized epidermis on both the surfaces.

(iii) Stomata are distributed all over the lower surface except on the veins.

(iv) The mesophyll is differentiated generally into a single-layered palisade and a well-developed spongy parenchyma.The latter consists of many loosely-packed cells. Many stellately branched sclereids are present near the lower epidermis in the spongy parenchyma.

(v) Many stone cells and latex tubes are present in the midrib region of the leaf.

(vi) Several vascular bundles in the form of an arch or curve are present in the prominent midrib region. A ring of thick-walled stone cells is present just outside the phloem. Each vascular bundle is conjoint and collateral.

(vii) The xylem of each vascular bundle faces towards the upper surface while the phloem faces towards the lower surface. The xylem consists of tracheids, vessels and xylem parenchyma while the phloem consists of sieve cells and phloem parenchyma.

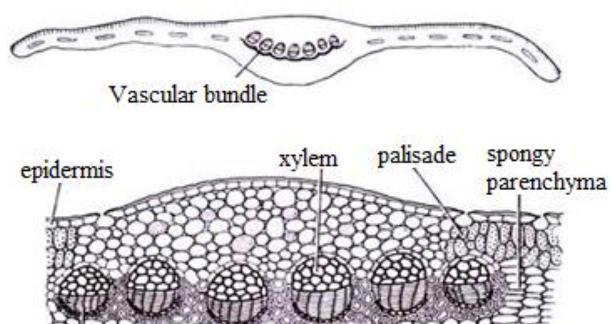

Fig. 11.76: *Gnetum,* Upper- T.S. leaf (Diagrammatic); Lower- T.S. leaf (a part cellular)

11.3.9.4. Reproduction of *Gnetum*:

(i) *Gnetum* is dioecious.

(ii) The reproductive organs are organised into well-developed cones or strobili.

(iii) These cones are organised into inflorescences, generally of panicle type. Sometimes the cones are terminal in position.
(iv) A cone consists of a cone axis, at the bases of which are present two opposite and connate bracts.
(v) Nodes and internodes are present in the cone axis.
(vi)Whorls of circular bracts are present on the nodes. These are arranged one above the other to form cupulas or collars.
(vii) Flowers are present in these collars. Upper few collars may be reduced and are sterile in nature in *G. gnemon*.

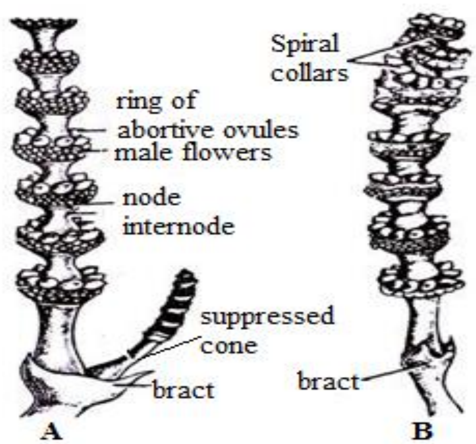

Fig. 11.77: *Gnetum*. A.) A branch bearing a panicle of a well developed male cone and a suppressed cone in *G. ula*; B) an old cone of *G. gnemon* showing spiral collars at the apical end (modifie after Madhulata, 1960)

1. Male Cone and Male Flower:

(i) The male flowers are arranged in definite rings above each collar on the nodes of the axis of male cone.
(ii) The number of rings varies between 3-6.
(iii) The male flowers in the rings are arranged alternately. There is a ring of abortive ovules or imperfect female flowers above the rings of male flowers.
(iv) Each male flower contains two coherent bracts which form the perianth.
(v) Two unilocular anthers remain attached on a short stalk enclosed within the perianth.
(vi) At maturity, when the anthers are ready for dehiscence, the stalk elongates and the anthers come out of the perianth sheath. In *Gnetum gnemon* a few (2-3) flowers are sometimes seen fusing each other.

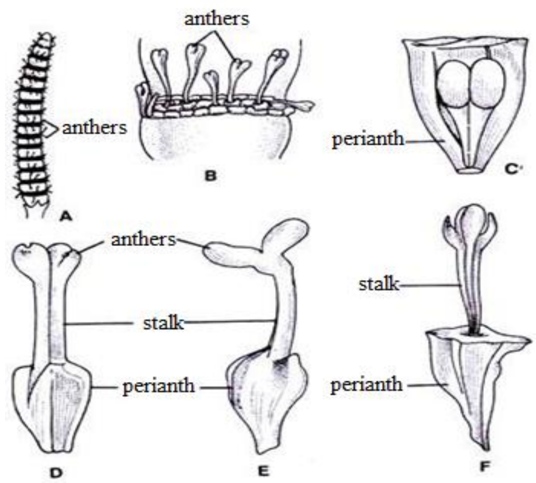

Fig. 11.78: *Gnetum ula,* A) A male cone; B) a part of A showing male flower; C) L.S. male flower; D-E) Male flowers with anthers emerged out of a perianth; F) dehisced male flower

2. Female Cone:

(i) The female cones resemble with the male cones except in some definite aspects. A single ring of 4-10 female flowers or ovules is present just above each collar.

(ii) Only a few of the ovules develop into mature seeds.

(iii) In the young condition, there is hardly any external difference between female and male cones. All the ovules are of the same size when young but later on a few of them enlarge and develop into mature seeds. All the ovules never mature into seeds.

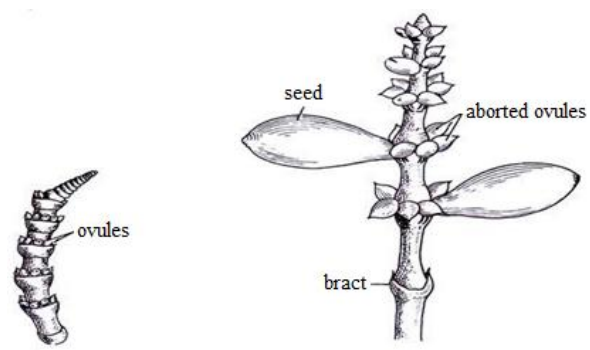

Fig. 11.79: *Gnetum*, A.) An old female cone of *G. ula; B)* A female cone of *G. gnemon* bearing two seeds

3. Ovule or Female Flower:

(i) Each ovule consists of a nucellus surrounded by three envelopes.

(ii) The nucellus consists of central mass of cells.

(iii) The inner envelope elongates beyond the middle envelope to form the micropylar tube or style.

(iv) The nucellus contains the female gametophyte. There is no nucellar beak in the ovule of *Gnetum*.

(v) Stomata, sclereids and laticiferous cells are present in the two outer envelopes. Madhulata (1960) observed the formation of a circular rim from the outer epidermis of the inner integument in *G. gnemon*. The ovules in *G. ula* are stalked.

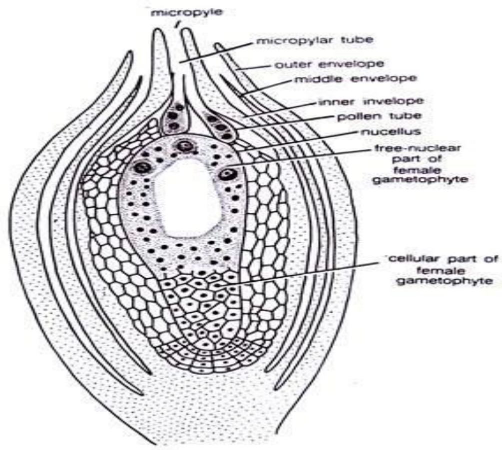

Fig. 11.80: *Gnetum*. L.S. ovule

11.4 SUMMARY

From the above description, the students now understand the similarities and differences in morphological and anatomical features of important genera belongs to both Cycadopsida and Coniferopsida. They also come across the male and female reproductive organs, arrangement of micro and megasporophyll on the axis. The structures of male and female gametophytes provide the idea of their organisation and their further development. From this Unit, students will know about the link between the gymnosperms and other higher plants.

11.5 GLOSSARY

Apophysis: Exposed outer surface of either an ovuliferous scale or megasporophyll as seen when the cone is closed.

Aril: An outgrowth from the stem forming a fleshy covering of the seed; e.g., *Taxus, Torreya*; or only rudimentary at base of the fleshy seed e.g., *Cephalotaxus.*

Bract: Modified leaf subtending the ovuliferous scale; may be distinct or fused to the scale.

Cone (strobilus): Aggregation of sporangia-bearing structures at tip of the stem (either sporophylls or scales in the Gymnosperms).

Endarch: with central protoxylem or, with several surrounding a central pith.

Epimatium: Fleshy covering of the seed and more or less fused with the integument; arising from the chalazal end of the ovule like an additional integument; e.g., *Podocarpus.*

Exarch: with protoxylem strands outside metaxylem, or, in touch with pericycle.

Female Cone (megasporangiate strobilus): Bearing ovules or seeds.

Linear Leaf: Narrow, flattened, triangular, or quadrangular leaf usually 1/2-2 in. long; e.g., *Taxus, Picea.*

Long Shoot: Elongated internodes, rapid annual growth.

Male Cone (microsporangiate strobilus): Bearing pollen sacs (microsporangia).

Megasporophyll: Modified leaf bearing o w les; e.g., *Zamia.*

Microsporophyll: Modified leaf bearing microsporangia or pollen sacs.

Ovuliferous Scale: Highly modified lateral branch in the axil of a leaf (bract), and bearing ovules. May be flat or peltate, woody or fleshy; e.g., Pinaceae.

Receptaculum: A fleshy structure below the seed formed from the bases of bracts and the swollen receptacle or cone axis; e.g., *Acmopyle*, and some *Podocarpus* spp.

Scale Leaf: Small, usually appressed and imbricate; e.g., *Juniperus, Thuja.*

Short Shoot: Very short or inconspicuous internodes and growth very slow if at all.

Stele: a bulky strand or cylinder of vascular tissue contained in stem and root of plants, developed from plerome.

11.6 SELF ASSESSMENT QUESTIONS

Q.1. Write the difference between endarch and exarch conditions.

Q.2. Write about the corolloid roots.

Q.3. Difference between the male gametophyte and Female gametophyte.

Q.4. Difference between microsporophyll and mega sporophyll.

Q.5. Write about polyembryony.

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11.9 TERMINAL QUESTIONS

Q.1. What are gymnosperms? Describe the main characters of them.
Q.2. Write the differences between Cycadopsida and Coniferopsida.
Q.3.Describe the anatomical features of vegetative parts of *Gnetum*.
Q.4. Describe the reproductive organs of *Taxus*.

BLOCK-4 TAXONOMY OF FLOWERING PLANTS (ANGIOSPERMS)

UNIT-12 TOOLS AND TECHNIQUES RELATED TO THE PLANT TAXONOMY

12.1 OBJECTIVES

After reading this unit student will be able-

- To observe, record, and employ plant morphological variation and the accompanying descriptive terminology.
- To gain experience with the various tools and means available to identify plants.

12.2 INTRODUCTION

This laboratory is designed to provide practical experience in plant identification using the tools of classification and identification, and gaining a real world experience in plant identification. The laboratory will illustrate different patterns of variation, the collection of various types of data, the collection and documentation of specimens, including basic herbarium techniques. Variations in plant forms will be studied along with their practical uses in plant identification. It acquints the students with the flora of a particular geographical area. It helps to identify known organisms and determine whether they have discovered a new organism entirely. The information of the plant is presented with relevant information in a structured form.

12.3 TOOLS AND TECHNIQUES RELATED TO THE PLANT TAXONOMY

To get acquainted with tools and techniques related to the plant taxonomy following are the points related to the Plant Taxonomy-

a) Exploring the Floral diversity of a particular geographical region by plant exploration.
b) Collection of plant specimens, identification and classification of locally available plants belonging to families included in the syllabus from fresh specimens, herbarium or preserved materials. After identification up to family level any suitable regional flora may be used for generic identification if required.
c) Studies to find out the location of key characters and preparation of keys at generic level.
d) Preparation of herbarium sheets and submission of herbarium and museum specimens and/or live potted specimens of taxonomic interest and submission of the excursion report.

Detail description of tools and techniques used in the plant taxonomy are-

1- Plant exploration: the oldest method to study the variety of plants occurring the area, species distribution and understanding the floristic physiognomic patterns and benefiting from their characteristic and diverse qualities. It helps to distinguish native species from exotic species. It helps to focus on the realities of climate change and habitat loss; change in the forest covers the reasons for loss of biodiversity.

2- Plant collection: The first target is to obtain records and specimens of plants, either for a personal collection or to be stored in a herbarium. Small collections of common plants can have great value as reference for identification. It may result in unknowingly taking rare plants and thereby possibly reducing already critically small populations. The second major reason for plant collecting is to later identify an unknown specimen observed during fieldwork.

Following measures should be taken while collecting plants-

(i) Specimens for collection should be as complete as possible. Plants should be collected with flower or fruit. Specimens without these reproductive organs are termed "sterile", and cannot provide correct information

(ii) In case of herbs, the entire plant should be collected.

(iii) For large herbs, a part of the stem with attached leaves plus the inflorescence and flowers should be present in the sample.

(iv) In case of woody plants, branches or twigs bearing leaves and flowers (fruits) are sampled; leaves should be kept with extra paper, so that the large twigs do not cause air-pockets in the press while the leaves are drying.

(v) Excessive collecting by students in botany classes should be discouraged. It can cause in unknowingly uprooting rare plants and thus possibly reducing already critically small populations.

(vi) Every specimen should contain comprehensive notes retained in a field book (collection note book). The field book should contain following information:

Flora of: ……………………………………………………………..
Collection number:……………… Date:…………………………..
Botanical Name:……………………………………………………...
Family:……………………… Altitude:………………………
Locality:………………………….. Habit:………………………….
Latitude:…………………………. Longitude:……………………..
Distribution:……………………… Flower & Fruit:………………..
Notes:…………………………………………………………………
……………………………………………………………………..
Vernacular Name(s) & Uses:…………………………………………
Photo Data:………………. Collector(s):…………………….

3- Plant identification: The identification of plant involves following steps-

(i) The specimen: It is best to use fresh material for identification. Notes about the plant should provide details of habit, growth form, description etc. One of the major reasons for this is that floral parts tend to remain much more stable through time and also under different environmental conditions than do the vegetative parts, and they provide the true relationships of plants.

(ii) Equipment needed: The most important is a relevant flora of that area. The best books or flora at least provide information related to elementary keys. Important equipment is a hand lens, dissecting microscope, or some kind of magnifier. It helps to identify some of the minor features of the collected plant which are of great importance and significance.

(iii) Keys: Identification keys are a series of specially arranged statements. Using the key characters the possibility of identifying the plant increases while without it gradually narrows down. When the number of possibilities is reduced to one the specimen is identified. Nevertheless, keys are the quickest and most accurate means of identifying unknown plants. With practice use of keys becomes easier and familiar. A very simple example, based on Gleason (1978) illustrates the principle of a key.

1. Plant without green colour
    2. Flowers regular, radially symmetric
        3. Flowers solitary, one to a stem . . . .Indian pipe
        3. Flowers several or each stem . . . . Some other species
    2. Flowers irregular . . . . Some other species
1. Plant with green colour . . . . All other species

(iv) Technical terms: For the preparation of proper keys and identification of the plants understanding of technical terms is essential. The purpose of using such terms is precise about descriptions

4- Plant preservation: The ways to press and preserve plants:

(i) The specimen is selected, tagged along with notes.

(ii) The collected specimen is kept in a vasculum or plastic bag whose mouth is tied.

(iii) Clean up the plant. Remove off loose soil and blot off moisture.

(iv) Arrange the plant on a sheet of newspaper with its complete information.

(v) Make layers. Place the pieces of newspaper with your specimen between two pieces of blotting paper, then between two pieces of corrugated cardboard for air circulation. (Fig.12.2)

(vi) Place the prepared package in the plant press and gently screw it down. (Fig 12.1)

(vii) Check the plants every two or three days, and replace the damp papers with dry ones. It will take two to four weeks for the specimens to get completely dry.

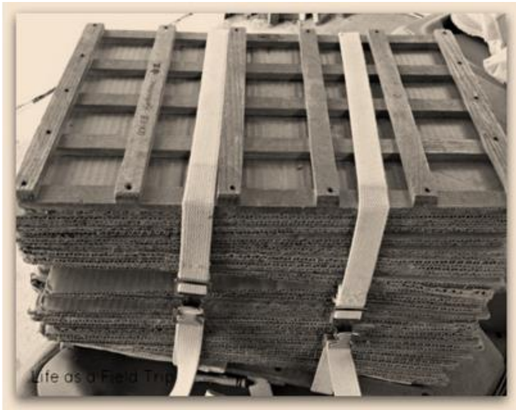

Fig. 12.1: Plant press

Fig. 12.2: Plant pressing method

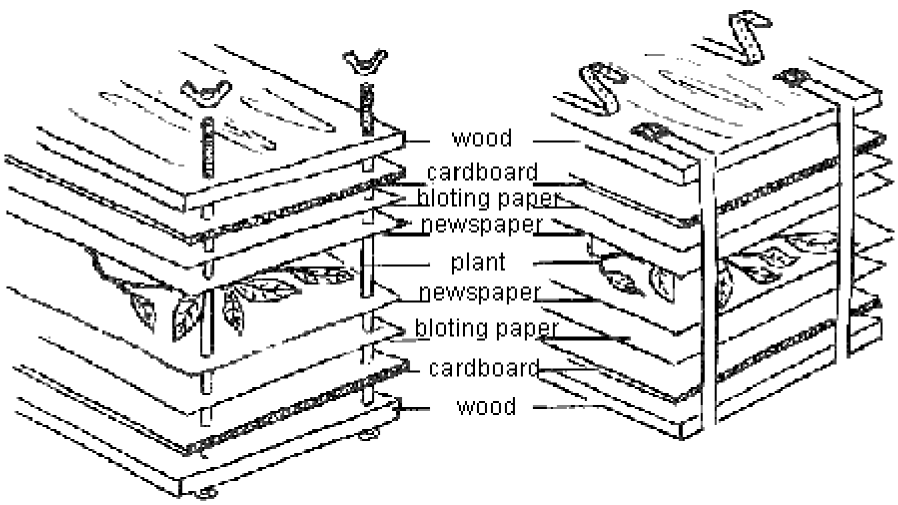

Fig. 12.3: Preservation method

5- Herbarium sheet and documentation: The method of mounting the specimen on the herbarium sheet are-

(i) Usually, specimens are mounted on sheets of standard size herbarium sheet (11.5" × 16.5")

(ii) All the harbarium sheets/preserved specimens should be properly identified and labelled

(iii) The label should contain the name and family of the plant and also the date of collection, locality of collection and any other habitat feature of importance.

(iv) The plant mounted on the herbaria are sticked with use of a glue or paste.

(v) Delicate specimens can also be preserved in 5 – 10% formalin solution in a glass jar.

(vi) Different insecticides, like Para dichlorobenzene (PDB), Carbon tetra-chloride or DDT etc., can be used to prevent insect damage.

(vii) Fumigation is made within the storing home or cabinets from time to time.

(viii) To retain green colour of collected plant specimens, the plants, after collection, should be placed directly in a special solution for a few days and then dried for herbarium preparation. The composition of one such solution as suggested by Keefe (1926) is as follows: 90 ml. 50% ethyl alcohol, 5 ml. formalin, 2.5 ml. glycerine, 20 gms. Cupric chloride, 2.5 gm. uranium nitrate.

Collection No:..Date of collection:..

Scientific name:...

Family:...Habitat:..

Nature:..Flower Colour:..

Locality:..

Collector:..

Identified by:...

Remarks:..

Fig. 12.4: Documentation on the herbarium (Label)

12.4 SUMMARY

The tools and techniques of plant identification will demonstrate plants that are arranged into groups enable a large population to be categorized and understood. Field work will provide knowledge and experience in data accumulation, specimen collection and preparation, identification of major taxa. The study will enable to arrange data or information and knowledge about plants. This gives information about plants and vegetation. This will help to enhance the knowledge in field of taxonomy, the distribution of plants, their habitat and economic importance. It helps to differentiate similar to another known entity. Procedures and stored information that is useful in identification and classification of organisms are called taxonomic aids. The notes of field book will not only help the identification of the specimens, but also can be compared and added to the current botanical knowledge

12.5 GLOSSARY

Plant exploration: Visit to the areas which are rich in plant diversity**.**
Plant collection: gathering of plant specimen**.**
Taxa: any unit used in the science of biological classification, or taxonomy.
Taxonomic aids: information that is used for identifying and classifying of specimens.
Classification: A hierarchical system is used for classifying organisms to the species level.
Keys: a simple tool used to identify a specific specimen

Floristic: relating to the study of the distribution of plants.
Physiognomic patterns: the set of functional and morphological attributes
Exotic species: Introduced species.
Herbarium: collection of dried plant specimens mounted on sheets of paper.
Field notebook: Notebook consisting of recording of field data at the time of collection.
Population: Same group of species inhabiting in an area and capable of interbreeding
Vasculum: a container used during plant collection.
Corrugated cardboard: cardboard usually made of three different layers.
Monograph: It consists of all information about particular taxon like family or genus
Flora: It is a book containing all the information about habit, habitat, climate, distribution, description and index of plants found in an area.
Screw: an act of twisting or turning done to fasten or tighten something.
Specimen: an individual plant used as an example of its species or type for scientific study.

12.6 SELF-ASSESMENT QUESTIONS

12.6.1 Multiple Choice Questions:

1- A Place of collection of dried plant specimen is:
(a) Arbarium (b) Herbarium
(c) Botanical garden (d) All the above

2- The term taxon refers to –
(a) Name of a species (b) Name of genus
(c) Name of family (d) taxonomic group of any rank

3- The standard size of herbarium sheets is –
(a) 11.5" × 16.5" (b) 15.5" × 16.5"
(c) 18.5" × 10.5" (d) 20.5" × 21.5"

4. The largest herbarium is located in
(a) New York (b) Kew
(c) Geneva (d) Berlin

12.6.2 Fill in the blanks:

1. Taxonomic key is one of the taxonomic tools in the ....and ....of plants
2. Taxonomic key is used in the preparation of...........
3. An identification .... are a series of specially arranged statements

4. Procedures and stored information that is useful in identification and classification of organisms are called**..............**

12.6.2 True/ False

1- Monograph consists of all information about particular taxon like family or genus (T/F)
2- Introduced species are also called exotic species (T/F)

12.6.1 Answers Key: 1-(b), 2-(d), 3-(a), 4-(b)
12.6.2 Answers Key: 1-identification, classification 2.flora, 3. Keys, 4. taxonomic aids
12.6.3 Answers Key: 1- T, 2- T

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12.9 TERMINAL QUESTION

1. Write a short note on Plant collection.
2. Give the tools used for herbarium preparation.
3. Describe the method of plant preservation
4. Describe the key construction method.

UNIT-13 TERMINOLOGY RELATED TO VARIOUS PARTS OF THE PLANTS HELPFUL IN PLANT TAXONOMY

13.1 OBJECTIVES

After reading this unit students will be able-

- To introduce plant nomenclature and classification.
- To become familiar with basic plant morphology.
- To begin to identify plants using morphological characteristics.

13.2 INTRODUCTION

Plants can be identified by observing certain distinguishing morphological characteristics. Some plants are closely related, which is shown by the similarity of their flower structures. These plants are placed into a specific plant family. A herbaceous example of a family that is based on similarity of flower parts would be Asteraceae, the aster family, of which marigolds and zinnias are members. An example of a woody plant family would be Aceraceae to which maples belong. Within each family there are members that are more closely related than others. This relationship is demonstrated by the similarity of basic morphological traits like leaf shape or arrangement. These plants are placed in a group called a Genus. Maples belong to the genus *Acer* while marigolds are placed in the genus *Tagetes*. Members of a plant genus are again subdivided, according to their similar morphological characteristics, into a grouping called a species. For example, each different type of maple belongs to a different species (see list below). The **Nomenclature**, which we have just described, gives each plant a scientific name using the genus and species.

13.3 TERMINOLOGY RELATED TO VARIOUS PARTS OF THE PLANTS HELPFUL IN PLANT TAXONOMY

To get acquainted with terminology related to various parts of the plants helpful in plant Taxonomy are given below-

1. Habitat: The dwelling place or locality of plant, *i.e.* terrestrial or aquatic, whether cultivated or naturally growing, cultivated ornamental or food crop *etc.*

2. Habit: Herbaceous or woody, woody shrub or tree. Whether annual, biennial, or) perennial. Any special feature like climber, liana, creeper, epiphyte, or parasite *etc.*

3. Root: Whether tap root or adventitious root, branched or un-branched or any modifications of root system *e.g.* nodulated, fibrous, tuberous, prop, stilt, epiphytic, climbing, napiform, fasciculated, beaded, assimilatory *etc.*

4. Stem: Whether aerial/ erect stem, or weak stem; if weak stem then climber or prostrate, trailer or creeper if climber then whether by leaf tendrils, or leaflet tendril or petiole or stem or any other specifications.

(i) S**pecial modifications of stem**: rhizome, corm, tuber, bulb, offset, runner, stolon, sucker, cladode or phylloclade *etc.*

(ii) Buds: Whether Lateral or axillary, terminal or pseudo-terminal.

(iii) Shape: cylindrical or angular or flattened or reduced.

(iv) Branching Pattern: Racemose or cymose, if cymose whether monochasial, bichasial or multichasial.

(v) Surface: Whether glaucous, or glabrous, waxy or spiny, or prickly or hairy. If hairy then pattern of hairs.

(vi) Colour: Green i.e. assimilatory, gray or any other *etc.*

5. Leaf:

(a) Structure: Whether stipidate or exstipulate; petiolate or sessile; simple or compound if compound whether pinnate or, decompounds or palmate, paripinnate, imparripinnate, bifoliate and trifoliate, unipinnate (or just pinnate), or bipinnate, or tripinnate *etc.*

(b) Attachment duration: Whether persistent, or deciduous, evergreen, or fugacious.

(c) Insertion: Whether cauline, or ramal, or radical.

(d) Arrangement: Whether opposite, superposed or decussate, alternate, or distichous, or whorled.

(e) Leaf Base: Whether auriculate, or amplexicaule, or semi-amplexicaul, perfoliate, or connate-perfoliate, acuniate, or cuniate, oblique, or obtuse, truncate, cordate, or obcordate, sagittate, or hastate, pellate, etc.

(f) Stipules: Whether free lateral, or scaly, adnate, or inter-petiolar, ochreate, or foliaceous, or bud-scales. Special modifications such as spines and tendrils, then describe them accordingly.

(g) Leaf Blade:

(i) Form: Whether vsubulate, or acicular, filiform, or linear, lyrate, or lanceolate, ovate, or obovate, elliptical, or oblong, oblanceolate, or spatulate, cuneiform, or runcinate, pan- durate, or deltoid, or rhomboidal, reniform, or orbicular *etc.*

(ii) Incision of Blade: Whether entire, undulate, or sinuate, crenate, or serrate, or serrulate, or double-serrate, dentate, or denticulate, ciliate, or spinous, or incised, or lacerate, or lanciniate, or lobed, cleft, or parted, or pinnatifid, or palmatifid, or crispate.

(f) Leaf Apices: Whether obtuse, or acute, or acuminate, caudate, or cuspidate, truncate, or retuse, emarginate, mucronate, or cirrhose *etc.*

(g) Leaf Surface: Whether glabrous, or rough, glutinous, glaucous, spiny, or hairy, pubescent, or puberulous, or pilose, or villous, or tomentose, or floccose, or hispid, or hirsute, strigose, or mealy, or pruinose.

(h) Venation: Whether parallel or reticulate if parallel then simple parallel, or penniparallel, if reticulate venation than unicostate or multicostate.

6. Inflorescence: The pattern of arrangement of flowers on axis is called inflorescence. Whether Racemose, or Cymose, or any special type. If Racemose (or Indeterminate), then whether Raceme, spike, spikelet, or catkin, spadix, corymb, umbel, or capitulum *etc*. If Cymose then whether uniparous , biparous, or multiparous. If uniparous then helicoid or Scorpioid cyme, If special type, then whether cyathium, verticillaster, or hypanthodium.

7. The Flower: Whether regular (actinomorphic), or zygomorphic (irregular); complete or incomplete; pedicelate or sessile; hermaphrodite (perfect) or unisexual (imperfect). If unisexual, then whether staminate (male) or pistillate (female).

(i) Arrangement of floral appendages on the receptacle: Whether hypogynous, perigynous, or epigynous.

(ii) Calyx (Sepals): Whether sepaloid, or petaloid; regular zygomorphic, or irregular; polysepalous (or aposepalous), or connate, gamosepalous (or synsepalous).

(iii) Corolla (Petals): Whether polypetalous, or gamopetalous, or connate (completely or incompletely). If polypetalous and regular corolla, then whether cruciform, caryo- phyllaceous, or rosaceous. If gamopetalous and regular corolla, then whether companulate or bell-shaped, tubular, or infundibuliform (or funnel-shaped), rotate (or wheel- shaped). If zygomorphic and polypetalous corolla, then whether paplionaceous or not. If zygomorphic and gamopetalous corolla, then whether bilabiate, personate, or ligulate.

(iv) Aestivation: Whether valvate aestivation, twisted aestivation, imbricate aestivation, or vexillary aestivation or quincuncial aestivation.

(v) Androecium (Stamens): the male reproductive whorl unit structure is called stamen.

(a) Attachment of the filament to the anther: Whether basi- fixed, adnate, dorsifixed, or versatile.

(b) Cohesion of stamens: Whether monoadelphous, diadelphous, or polyadelphous; syngenesious, or synandrous.

(c) Adhesion of Stamens: Whether epipetalous, epiphyllous, or gynandrous.

(d) Morphology of Stamens: Whether didynamous (2+2), or tetradynamous (4+2).

(e) Correlationship with corolla: Whether inserted, or exserted.

(vi) Gynoecium: The female reproductive whorl unit structure is called carpel or pistil. Whether gynoecium is syncarpous, or apocarpous.

(a) Stigma: Whether knob-shaped, slightly pointed, flattened, or elongated.

(b) Style: Whether terminal (or apical), lateral, or gynobasic.

(vii) Placentation: Whether marginal, axile, parietal, central, free-central, basal, or superficial.

8. Fruit: Mature ovary is called fruit. Whether it is simple, aggregate, multiple, legume or pod. Fleshy, or dry fruits, If fleshy then whether a berry, drupe, or pome. If Berry then whether pepo, or hesperidium. If dry then whether dehiscent or indehiscent. If Dehiscent then whether follicle, or legume (pod), siliqua, or silicula or a capsule. If Indehiscent then whether achene, caryopsis, nut, or samara.

9. Seed: Dicotyledonous or monocotyledonous; albuminous or ex-albuminous. Embryo position, size and shape, endospermic or non endospermic.

10. Floral Formula: Symbolic and numerical presentation of floral parts in form of formula *e.g.* floral formula of *Brassica*.

11. Floral Diagram: Floral diagram is a graphical representation of cross section of flower. It shows the number of floral organs, their arrangement manner and fusion. Different whorls of the flower are represented by symbols (Fig. 13.1).

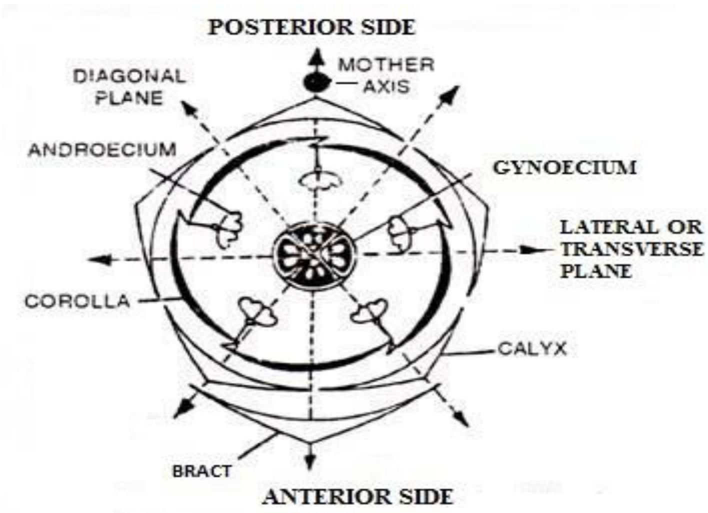

Fig. 13.1: Representation of floral whorl in floral diagram

12. Systematic position: The systematic position of a genus can be given with the help of key. In commonwealth countries Bentham and Hooker's System is followed for its practical utility and simplicity.

13.4 SUMMARY

Though the terminology used in describing the plant structures is extensive and technical, but they are concise and do give accuracy to the description. A plant is described in a set sequence, starting from its habit and roots and going up to its floral diagram and floral formula. The understanding of terminology will help to enhance the practical value. In gaining this knowledge it helps to group plants together in accordance with their presumed affinities. A feature or observable aspect of a plant is called a **character** and the specific form or expression of the character is called a **state.** Some characters are rather **variable** (e.g., leaf shape, stem height, time of flowering) while other characters are **fixed** (*i.e.*, floral characters).While studying taxonomy terminology needs to be descriptive for efficient and accurate information to be communicate. Terminology allows content to be:

- Consistent
- Standard
- Readable

13.5 GLOSSARY

Habit- It covers the plant's development, the length of the stem, its branching pattern, density, and the shape, arrangement, texture of its leaves.
Habitat- place in which it grows.
Annual- a plant which complete life-cycle in a single season.
Biennial- a plant which complete life-cycle in two years.
Pereninal- can live for more than two years.
Root- The part of the plant that grows under the soil.
Fibrous-a **root** that consists of groups of **roots** of similar size and length.
Epiphytic-the adventitious roots found in epiphytes
Prop-An aerial **root** that arises from a stem or trunk, penetrates the soil, and helps support the plant such as ficus.
Stilt-The roots arising from the nodes of the stem above the soil.
Climbing- the roots that help in climbing of plants.
Stem- Aerial part of the plant above the soil bearing leaves and buds.
Erect- Strong and upright stem.
Prostrate-plants grow flat on the soil surface.
Rhizome- horizontal underground stem bearing nodes.
Tuber-a short fleshy usually underground stem bearing minute scale leaves.
Leaves-Green coloured part of the plant.
Opposite-The leaves are paired at nodes.
Alternate-A single leaf is at each node.
Stipules-a leaf-like outgrowth at base of the petiole.
Venation- arrangment of veins in a leaf.
Flower-coloured part of the plant.
Epigynous-ovary is situtated below the floral parts(that is calyx and corolla) (inferior ovary).
Perigynous- sepals, petals and stamens inserted above hypanthium.
Hypogynous: Ovary is situated above the floral parts (Superior ovary).
Infloroscence- arrangment of flower on floral axis.
Racemose-Infloroscence which is unbranched, indeterminate growth and pedicellate
Cymose-A type of flowering shoot in which the first-formed flower develops from the growing region at the top of the flower stalk
Calyx-outermost green floral leaves present in flower .
Corolla- coloured whorl of petals present in flower.
Bisexual- both stamen and carpels are present in a flower.

Bracts- leaf-like structure at base of flower.
Bracteate- with bracts.
Aestivation- arrangment of sepals or petals in bud.
Polypetalous-free petals or sepals .
Gamopetalous- fused petals or sepals.
Monoadelphous- when the stamens of a flower are united as a tube around the style of the gynoecium.
Diadelphous- when the stamens are united into two bundles.
Polyadelphous- when the stamens are united into more than two bundles but the anthers remain free.
Syngenesious- Filaments are free and the anthers are united together into a tube.
Synandrous- Stamens are united throughout their whole length by filaments and anthers
Epipetalous- When the stamens are attached to the petals it is called epipetalous.
Gynandrous- When the stamens are attached to the carpels the condition called as gynandrous
Placentation- Arrangment of ovules on the placenta is called placentation
Syncarpous-When the carpels fused.
Apocarpous-when the carpels free

13.6 SELF-ASSESMENT QUESTIONS

13.6.1 Multiple Choice Questions:

1. The arrangement of leaf on branches is called
(a) Phyllotaxy (b) vernation
(c) venation (d) phytotaxy

2. Bulb is a modification of
(a) stem (b) root
(c) leaf (d) flower

3. The condition of stamen in a flower which are fused in a two budle is called
(a) monoadelphous (b) diadelphous
(c) polyadelphous (d) none of the above.

4. The plant which completes its life-cycle in two years is called
(a) annual (b) biennal.
(c) perennial (d) both a & b

5. The female reproductive whorl unit structure is called
(a) carpel or gynoecium (b) androecium
(c) stigma (d) petals

13.6.2 Fill in the blanks:

1. Monoadelphous condition is ……… bundle of stamen.
2. Arrangement of ovules on the placenta is called …….
3. The arrangement leaf arising at single node is called…….

13.6.3 True/ False

1. Actinomorphic flower is assymetrical flower.
2. Racemose inflorescence has indefinite growth.

13.6.1 Answers Key: 1-(a), 2-(a), 3-(b), 4-(b), 5-(a)

13.6.2 Answers Key: 1- Single, 2- placentation, 3-Alternate

13.6.3 Answers Key: 1- F, 2- F

13.7 REFERENCES

- Babu, C.R.1977. Herbaceous flora of Dehradun.CSIR, New Delhi.
- Harris, J.G. & M. W. Harris. 1994. *Plant Identification Terminology: An Illustrated Glossary*. Spring Lake Publ, Spring Lake, UT.
- Pandey, B.P.2000.Taxonomy of Angiosperms.S.Chand publication

13.8 SUGGESTED READING

- Pandey, B.P.2000.Taxonomy of Angiosperms.S.Chand publication.
- Text book of botany. Haiti,Bhattacharya, Gosh.Vol 2.New Central Book agency

13.9 TERMINAL QUESTION

1. Differentiate between
   i. epipetalous and polypetalous
   ii. actinomorphic and zygomorphic
   iii. syncarpous and apocarpous
2. Give different types of placentation.
3. Explain different types of aestivation in sepal or petals of flower bud.
4. What is tetradynamous condition? Give an example.

UNIT-14 DESCRIBE BOTANICALLY A FRESH/PRESERVED PLANT SPECIMEN OF LOCAL IMPORTANCE

14.1 OBJECTIVES

After reading this unit students will be able -

- Identify plant specimens of local importance of a particular taxonomic group.

14.2 INTRODUCTION

The earth is rich in vegetation from minute floating herbs with simple structure to gigantic trees attaining the height of about 100m with complex structure. This diversity of plants makes our earth more attractive and beautiful.

Plant taxonomy is the branch of plant science which deals with identification, classification and Nomenclature of plant. It is based mainly on the morphology including anatomy.

Identification of plant is an important part of all taxonomic works. A careful examination of specimen is essential before proceeding for identification. For identification complete specimen is required with vegetative parts, flower in unisexual both male and female flowers and fruits. Various types of taxonomical terminology used to describe plant becomes much easier.

14.3 METHOD OF STUDYING ANGIOSPERNIC PLANT

To study an Angiospernic plant, there are two main parts:-

1- In the first part list of plant characters, its classification and identification.
2- In the second part drawing the diagrams of plant, flower and specific parts of flower.

Students should maintain practical record Book. In this record Book, one has ruled sheet pages on one side on which characters of the plant are written in serial order, after description floral formula is also written.

Classification based on these characters is drawn and plant is identified upto its family. Another side, drawing sheets are generally used to draw a complete plant, longitudinal section of a flower, androecium or a stamen, transverse section of ovary and floral diagram.

To describe Angiospermic plants special method is adapted. These characters are written in serial order. Technical terms are used to describe a plant. There is terminology for every character of an organ.

Plant character should be written in following order.

1- Habit
2- Root system
3- Stem
4- Leaf- Phyllotaxy and venation
5- Inflorescence
6- Flower

7- Calyx
8- Corolla
9- Perianth- when calyx corolla cannot be differentiated.
10- Androecium
11- Gynoecium- along with placentation
12- Pollination
13- Fruit- type
14- Floral formula
15- Classification and identification
Division
Class
Order
Family

14.3.1 Magnoliaceae

Michelia champaca

Habit- A tall evergreen tree, flowering period April-June.
Root- Tap root.
Stem- Lower portion woody, aerial, erect, cylindrical, branched, solid.
Leaf- Ramal and cauline, alternate, exstipulate, simple, petiolate, ovate, entire, acute, unicostate reticulate.
Inflorescence- Clusters of axillary flower.
Flower- Bracteates, pedicellate, hermaphrodite, hypogynous and acyclic, actinomorphic, pale yellow pleasant smell, large.
Perianth- 9 tepals, 3 whorls of 3 each, all the 3 whorls petalloid or sometimes the outer 3 tepals becomes sepaloid, in that case calyx and corolla can be described as below.
Calyx- 3 greenish, valvate, inferior.
Corolla- 6 in 2 whorls of 3 each outer-valvate, inner-narrow, twisted pale yellow, inferior.
Androecium- Stamens indefinite, spirally arranged on an elongated thalamus, filament short, dithecous, adnate and extrorse.
Gynoecium- Multicarpellary, apocarpous, carpels are spirally arranged over an elongated thalamus, ovary superior, unilocular, ovules many placentation marginal, style short and bent, stigma flattened.
Fruit- An etacrio of follicles.
Floral formula- Br, $\oplus$, ⚥, P_{3+3+3}, A_{∞}, $\underline{G}_{\infty}$, or Br, $\oplus$, ⚥, K_3, C_{3+3}, A_{∞}, $\underline{G}_{\infty}$,

Classification and Identification

Class. ***Dicotyledonae***

1- Venation reticulate,

2- Flowers pentamerous.

Sub-Class. *Polypetalae*

1- Petals free.

Series. *Thalamiflorae*

1- Thalamus dome- shaped, and
2- Ovary superior.

Order. *Ranales*-

1- Stamens indefinite,
2- Carpels free.

Family. *Magnoliaceace*-

1- Flower spiral or spirocyclic with elongated floral axis,
2- Stamens and carpels
3- Numerous and free.

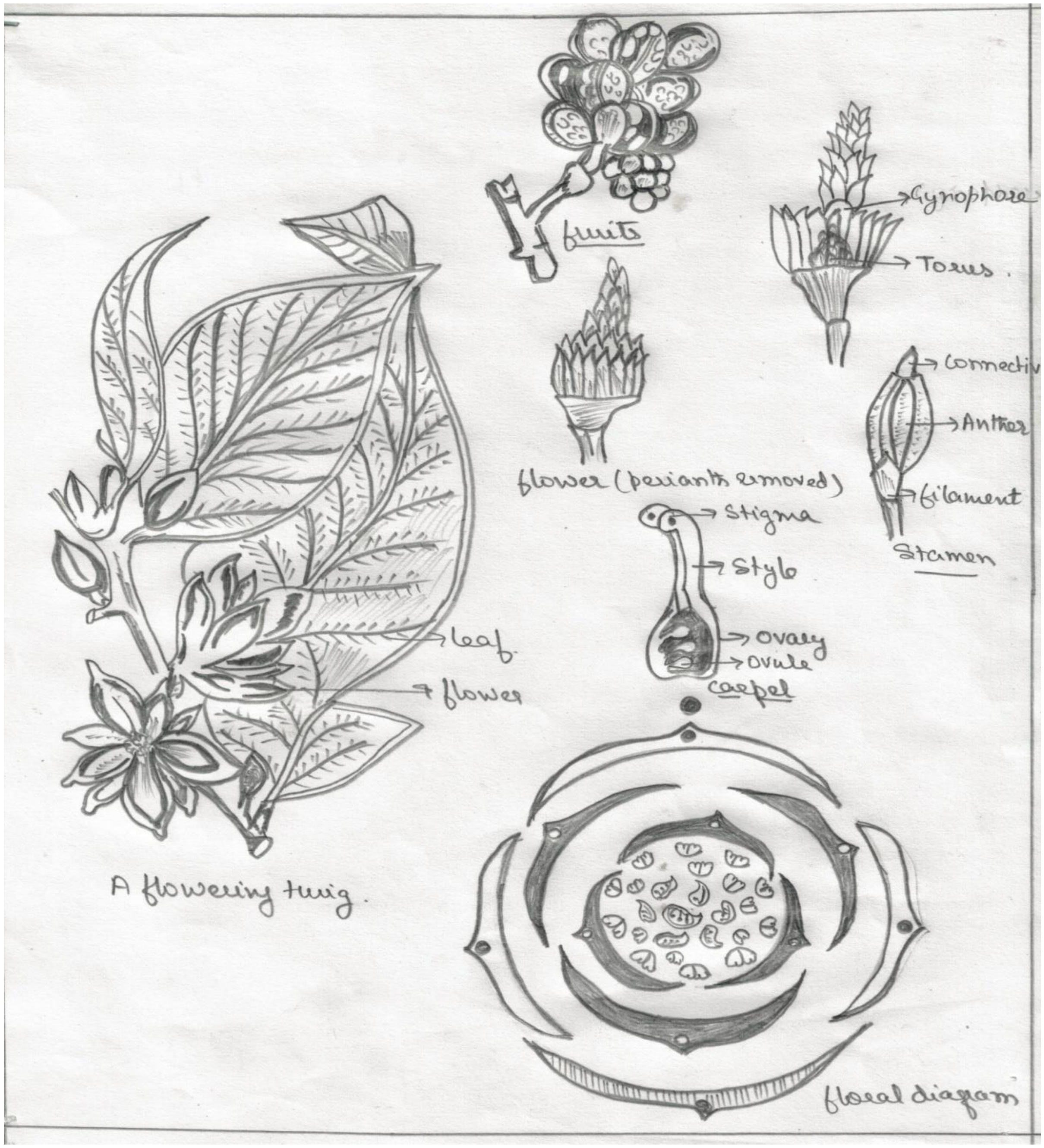

Fig. 14.1: ***Michelia champaca***

14.3.2 Ranunculaceae

Ranunculus sceleratus **Linn.**

Habit- An erect, annual herb.

Root- Tap Root System.

Stem- Erect, Green, Herbaceous, smooth, hollow, branched, nodes and internodes.

Leaf- Simple, alternate, petiolate, exstipulat, ovate shaped lobe, entire, obtuse, glabrous, multicostate reticulate.

Inflorescence- Dichasial cyme.

Flower- Bracteate, pedicellate, complete, actinomorphic, hermaphrodite, pentamerous, hypogynous, thalamus prominent, spirocyclic and yellow.

Calyx- Sepals 5, distinct, polysepalous, Boat shaped, slightly petaloid, quincuncial aestivation.

Corolla- Petals 5, polypetalous, yellow, imbricate, symmetrical, pocket shaped nectar inner side of each petal.

Androecium- Stamens indefinite, polyandrous, spirally arranged, long filament, dithecous, basifixes, extrorse.

Gynoecium- Polycarpellary, apocarpous, carpels are spirally arranged, ovary superior, unilocular, one ovule in each locule, stigma simple and sticky.

Fruits- A group of one seeded achenes.

Floral formula- Br, brl, $\oplus$, ⚥, K_5, C_5, A_∞, $\underline{G}_\infty$,

Classification and Identification

Class- *Dicotyledonae*

1- Venation reticulate.
2- Flowers pentamerous.

Sub- Class- *Polypetalae*

1- Petals free.

Series- *Thalamiflorae*

1- Thalamus dome-shaped
2- Flowers hypognous and ovary superior.

Order- *Ranales*.

1- Stamens indefinite.
2- Carpels free or immersed in torus.

Family- *Ranunculaceae*

1- Usually herbs often with divided leaves.
2- Flowers hemicyclic with one to many generally free carpels.
3- Stamens indefinite and extrorse, spirally arranged.

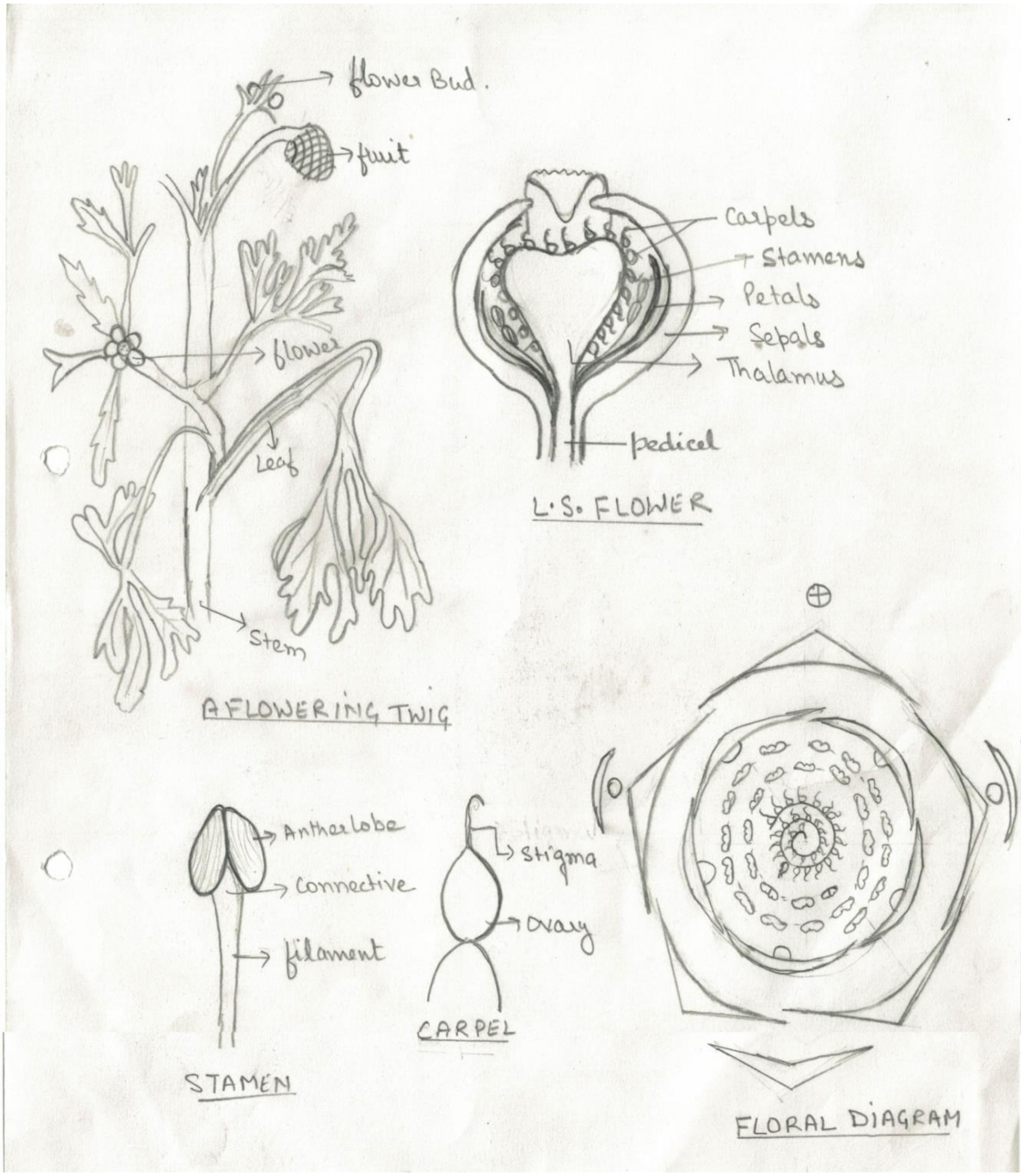

Fig. 14.2: ***Ranunculus scleratus***

14.3.3 Rutaceae

Citrus medica Linn. (Citrus; Bara nimbu)

Habit- Shrub.
Root- Branched tap roots.
Stem- Aerial, erect, branched, woody, often thorny; gland dotted.

Leaf- Exstipulate, alternate compound, unifoliate palmate, usually gland dotted; margins crenate or serrate, acute apex; unicostate, reticulate, petiole winged.

Inflorescence- Usually umbellate cyme.

Flower- Bracteate, pedicellate, actinomorphic, pentamerous, complete, hermaphrodite, hypogynous, creamy white, scented.

Calyx- Sepals 5, gamosepalous, pentafid, greenish, deciduous, valvate.

Corolla- Petals 5, polypetalous; imbricate, creamy white in colour.

Androecium- Stamens indefinite, polyadelphous, inserted round the cup shaped disc; filaments usually flat at the base; anthers dithecous, basifixed, yellow, introse.

Gynoecium- Polycarpellary, syncarpous, ovary superior, seated on a cupulate honey secreting disc; multilocular, axile placentation; ovules 1 in each locule, style stout and short, stigma capitate.

Fruit and Seeds- Fruits; hesperidium, Seeds; exalbuminous, embryo curved or straight, polyembryony (up to 13) common.

Floral formula- Br, $\oplus$, ⚥, $K_{(5)}$ $C_{5,}$ $A_{(\infty),}G_{(\underline{\infty})}$

Classification and identification

Class- *Dicotyledonae*

1- Venation reticulate.
2- Flowers pentamerous.

Sub- Class. *Polypetalae*

1- Petals free.

Series- *Disciflorae*

1- Flowers hypogynous and ovary superior.
2- A disc is usually present below the ovary.

Order- *Geraniales*

1- Disc usually annular, adnate to the stamens or reduced to glands.
2- Ovary multicarpellary, syncarpous with axile placentation.
3- Ovules ascending or pendulour and raphe usually ventral.

Family – *Rutaceae*

1- Leaves exstipulate and containing aromatic oil glands.
2- Stamens 2-5 or and obdiplostemonous.
3- Disc annular.
4- Fruit hesperidium.

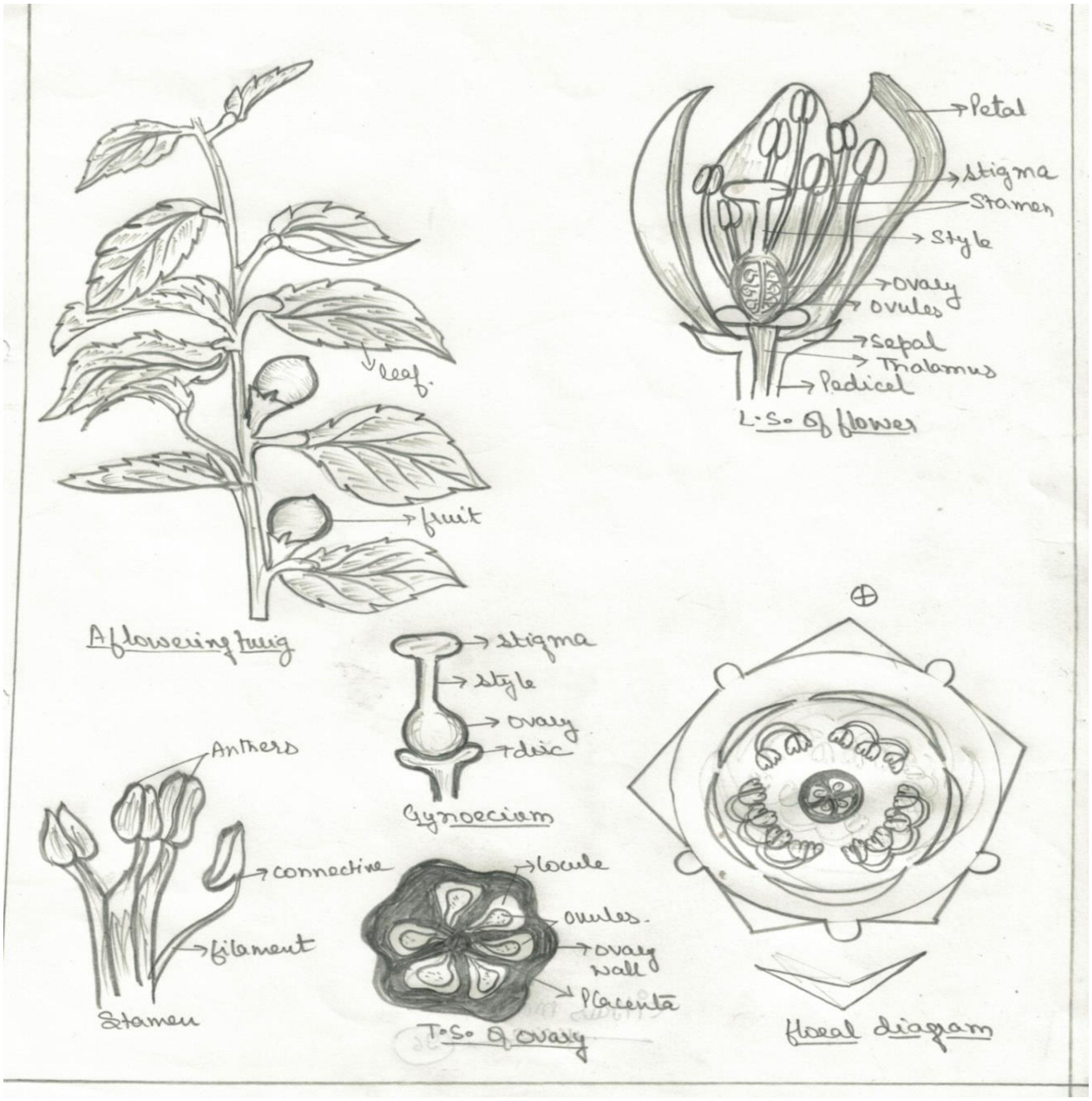

Fig. 14.3: ***Citrus medica***

14.3.4 Cruciferae (Brassicaceae)

***Brassica campestris Linn. Var. Sarson* Prain**

Habit- Herb, annual.

Roots- Tap root.

Stem- Herbaceous, aerial, erect, cylindrical, branched, solid, smooth and green.

Leaf- Ramal and cauline, exstipulate, simple, sessile, alternate, lower leaves lyrate with deeply cut margins, acute, glabrous, unicostate, recticulate.

Inflorescence- Racemose raceme.

Flower- Ebracteate, pedicellate, complete, actionomorphic, tetramerous, hypogynous, cyclic and yellow, hermaphrodite.

Calyx- Sepal 4 in two whorls of 2 each, polysepalous, slightly petaloid.

Corolla- Petals 4, polypetalous, cruciform, each petal is distinguished into a claw and a limb, valvate.

Androecium- Stamens 6 in two whorls (2+4), polyandrous, tetradynamous, 4 inner long and 2 outer short, dithecous, basifixed and introse, 4 longer stamens with glands at the base.

Gynoecium- Bicarpellary, syncarpous, ovary superior, unilocular but becomes bilocular later on due to the development of a false septum (replum), ovules many in each locule, placentation parietal, style short and stigma is bilobed.

Fruit- Siliqua

Floral formula- Ebr, $\oplus$, ⚥, $K_{2+2,}$ $C_{4,}$ A_{2+4}, $\underline{G}_{(2)}$,

Classification and identification-

Class- *Dicotyledonae*

1- Venation reticulate.
2- Flowers pentamerous.

Sub- Class. *Polypetalae*

1- Petals free.

Series- *Thalamiflorae*

1- Flower hypogynous and ovary superior.

Order- *Parietales*

1- Carpels united to form unilocular ovary with parietal placentation.

Family – *Cruciferae*

1- Herbs with alternate exstipulate leaves.
2- Corolla cruciform.
3- Stamens tetradynamous.
4- Ovary bicarpellary, syncarpous, unilocular but becomes bilocular due to the development of a false septum; fruit siliqua.

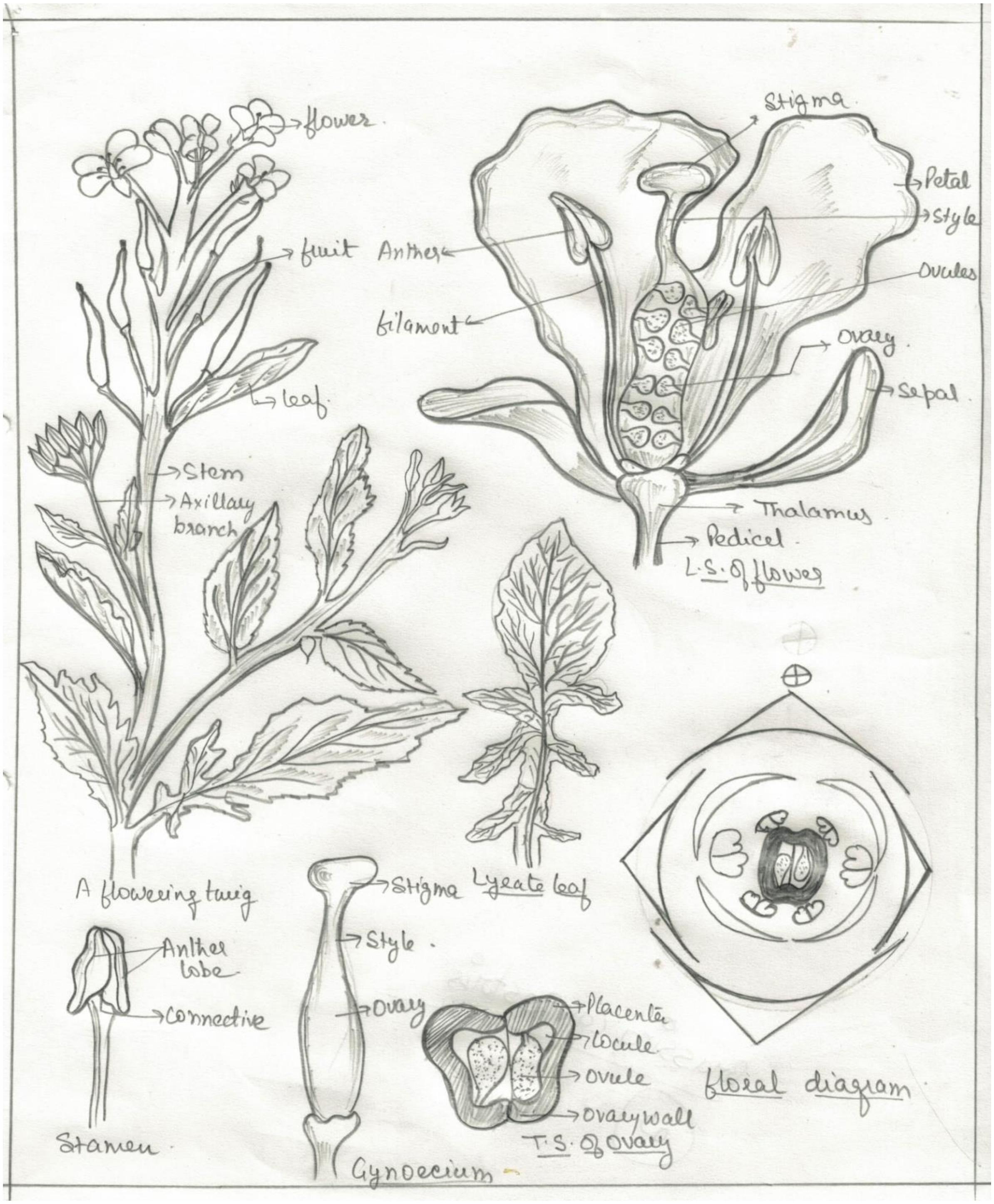

Fig. 14.4: ***Brassica campestris***

14.3.5 Rosaceae

Prunus persica (**L.) Batsch**

Habit- A cultivated, small tree.

Root- Branched, tap root.

Stem- Herbaceous, lower portions woody, aerial, erect, cylindrical, branched, solid, smooth and green.
Leaf- Ramal and cauline, alternate, stipulate, caduceus, simple, sub-sessile, lanceolate, serrulate, acute, unicostate reticulate, coriaceous.
Inflorescence- Solitary axillary.
Flower- Bracteate, Sessile, complete, actinomorphic, hermaphrodite, pentamerous, perigynous and cyclic.
Calyx- Sepals 5, gamosepalous, quincuncial.
Corolla- Petals 5, polypetalous, imbricate.
Androecium- Stamens about 40, in 4 whorls, ach whorl carries 10 stamens in five pairs of 2 each. The outer whorl of stamens is antesepalous and subsequent whorls alternate with each other, polyandrous, filaments long, dithecous, dorsifixed, introrse, bent in bud condition.
Gynoecium- Monocarpellary, ovary semi-inferior, unilocular with 2 pendulous ovules, placentation marginal, style long and stigma capitate, ovary and lower portion of style hairy.
Fruit- Drupe.
Floral formula- Br, ⊕, ⚥, $K_{(5),} C_{5,} A_{\infty}, \underline{G}_{1.}$

Classification and identification

Class- *Dicotyledonae*

1- Venation reticulate.
2- Flowers pentamerous.

Sub- Class- *Polypetalae*

1- Petals Free.

Series- *Calyciflorae*

1- Thalamus usually cup-shaped.
2- Ovary usually inferior.

Order- *Rosales*

1- Alternate stipulate leaves.
2- Carpels one or more.

Family - *Rosaceae*

1- Corolla rosaceous.
2- Stamens usually many and bent in bud condition.
3- Thalamus flat or hollowed.

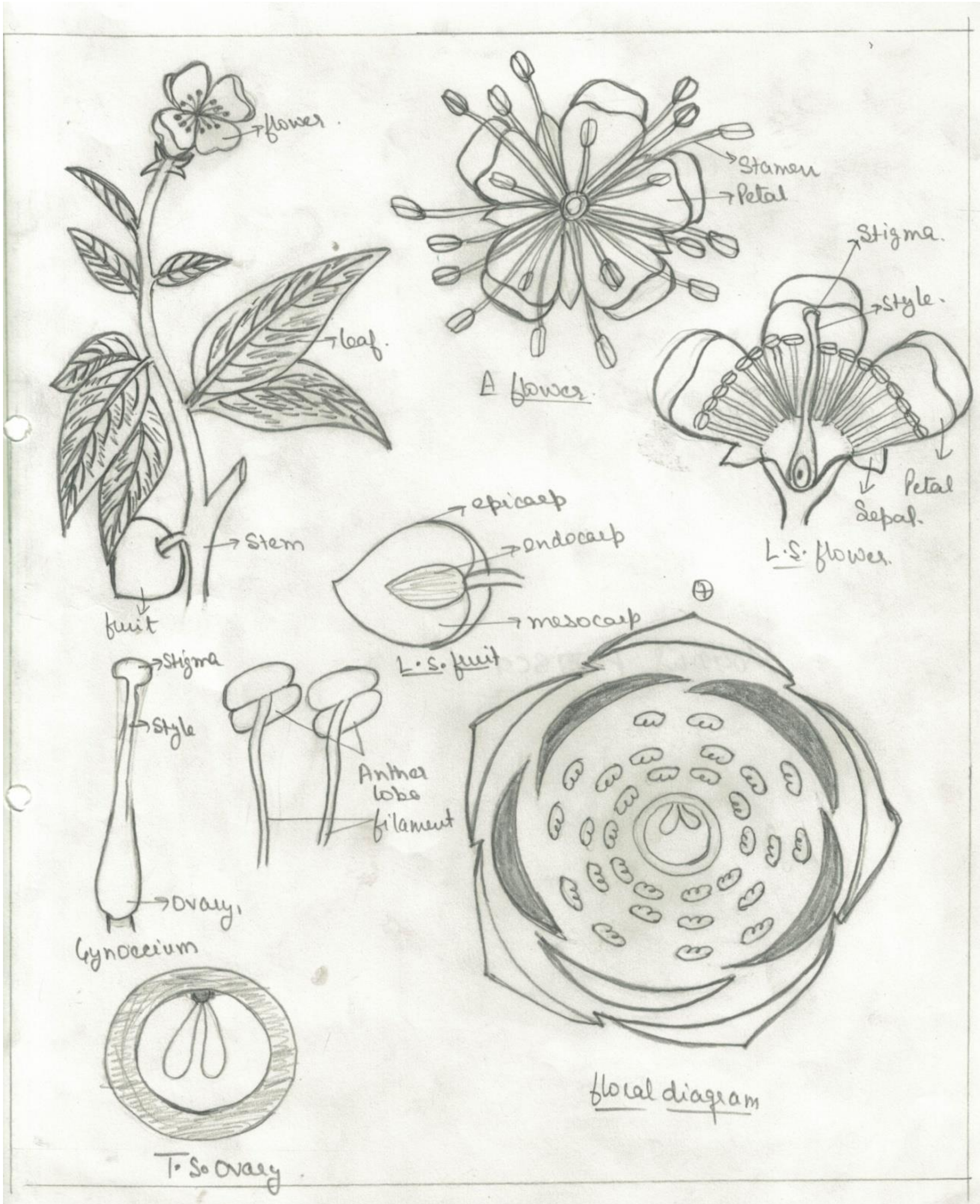

Fig. 14.5: ***Prunus persica***

14.3.6 Leguminaceae (Fabaceae)

Lathyrus odoratus (Sweet Pea or Phool Matar)

Habit- Annual climbing herb. Cultivated in gardens as an ornamental plant.

Root- Branched, nodulated, tap root, bearing nitrogen-fixing bacteria in the roots.

Stem- Herbaceous, aerial, weak, branched, flattened, climbing, green and glabrous.

Leaf- Ramal and cauline, alternate, petiolate, stipules leafy, pinnately compound, imparipinnate, eachleaflet is opposite, sessile ovate, entire, acute, unicostate reticulate, upper leaflets modified into trendrils.

Inflorescence- Racemose or solitary axillary.

Flower- Bracteate, pedicellate, complete, hermaphrodite, zygomorphic, pentamerous, perigynous, cyclic, variously coloured.

Calyx- Sepals 5, gamosepalous, companulate, odd sepal anterior, hairy and green.

Corolla- Petals 5,polypetalous, papilionaceous (i.e., one larger posterior petal called standard or *vexillum* two lateral petals called the *wings or alae* and two anterolateral or inner fused petals called *keel* or *carina)*, descending imbricate, variously coloured.

Androecium- Stamens 10, diadelphous (9+1), i.e, 9 united to form a tube and the 10^{th} posterior stamen free, dithecous, basifixed and introrse.

Gynoecium- Monocarpellary, superior or semi-inferior, unilocular, many ovules in the locule, marginal placentation, style long, hariry and curved, stigma capitates and hairy.

Fruit- A legume.

Seed- Non-endospermic.

Floral formula- Br, $\oplus$, ⚥, $K_{(5)}, C_{1+2+(2)}, A_{1+(9)}, \underline{G}_1$ or 1.

Classification and identification

Class- *Dicotyledonae*

1- Presence of two cotyledons.
2- Venation reticulate.
3- Flowers pentamerous.

Sub- Class- *Polypetalae*

1- Petals Free.

Series- *Calyciflorae*

1- Calyx gamosepalous.
2- Cup- shaped thalamus.

Order- *Rosales*

1- Leaves alternate and stipulate.
2- Diadelphous stamens.

Family - *Papilionaceae*

1- Climbing plant.
2- Zygomorphic flowers.
3- Papilionaceous corolla.

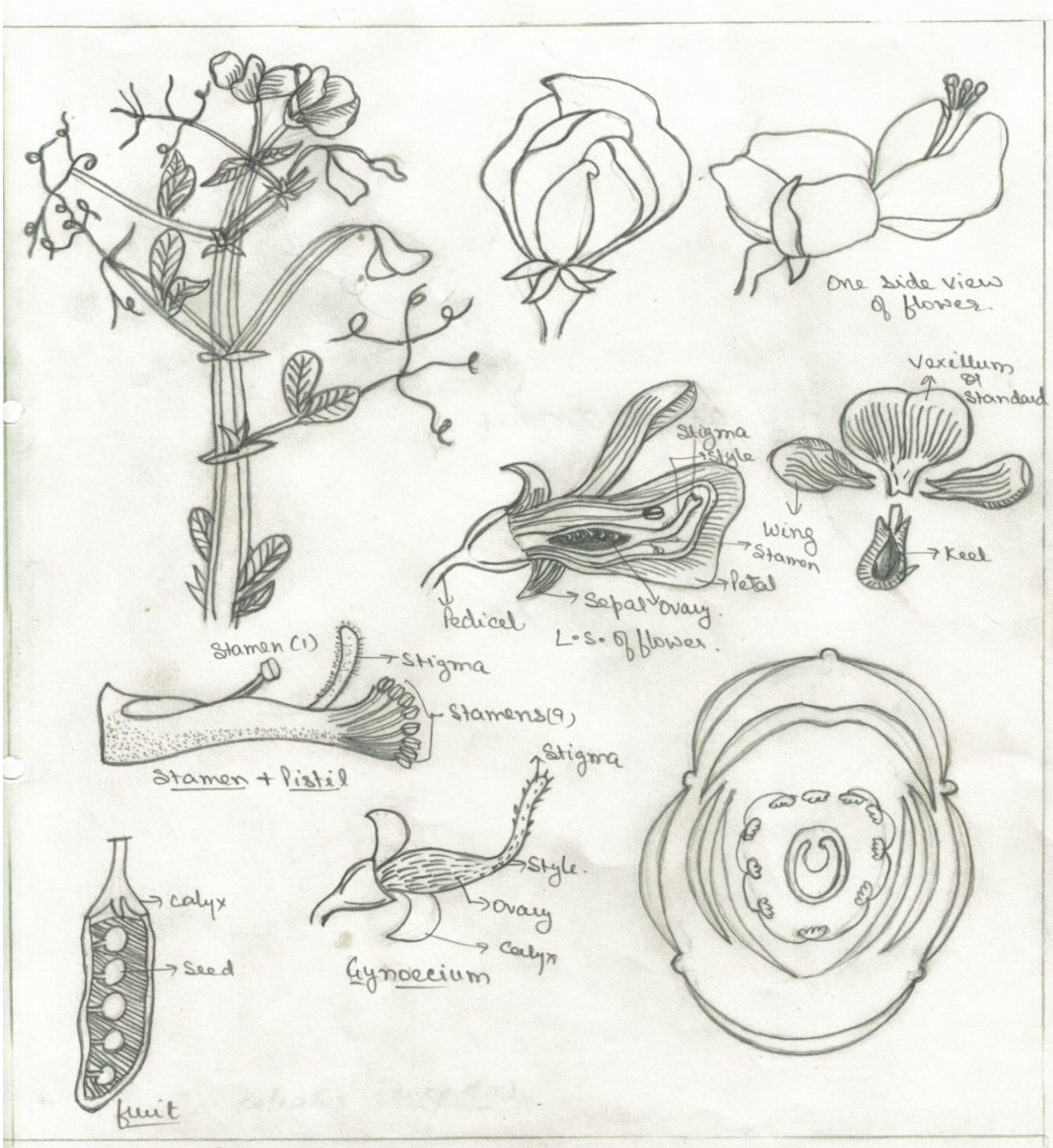

Fig. 14.6: ***Lathyrus odoratus***

14.3.7 Labiatae (Lamiaceae)

Ocimum sanctum Linn.

Habit- Herb or undershrub.
Root- Branched tap root.
Stem- Herbaceous, aerial, erect, quadrangular, branched, solid, pubescent, green.

Leaf- Cauline and ramal, opposite decussate, exstipulate, simple, petiolate, ovate, serrate, acute, pubescent, aromatic smell present,, unicostate reticulate.

Inflorescence- Verticillaster.

Flower- Bracteate, pedicellate, complete, zygomorphic, hermaphrodite, pentamerous, hypogynous and cyclic**.**

Calyx- Sepals 5, gamosepalous, calyx ¼ bilabiate, valvate, persistent.

Corolla- Petals 5, gamopetalous, corolla 4/1 bilipped, valvate.

Androecium- Stamens 4, polyandrous, epipetalous, didynamous, dithecous,dorsifixed, introrse.

Gynoecium- Bicarpellary, syncarpous, ovary superior, placentation axile, tetralocular, with one ovule in each locule, a disc is present below the ovary, style gynobasic and stigma bifid.

Fruit- Carcerules.

Floral formula- Br, brl. ⊕, ⚥, $K_{(1/4)}$ $C_{(4/1)}$, A_{2+2}, $\underline{G}_{(2)}$.

Classification and identification

Class- *Dicotyledonae*

1- Venation reticulate.
2- Flowers pentamerous.

Sub- Class. *Gamopetalae*

1- Petals fused.

Series- *Bicarpellatae*

1- Carpels two
2- Ovary usually superior.

Order- *Lamiales*

1- Flowers zygomorphic.
2- Corolla bilipped.
3- Stamens usually 4 didynamous or two.
4- Ovary 2-4 locular.
5- Fruit drupe or schizocarpic.

Family – *Labiatae*

1- Stem quadrangular.
2- Decussate or whorled exstipullate leaves.
3- Inflorescence verticillaster
4- Gynoecium generally bilocular with 2 ovlues in each locule.
5- Style gynobasic
6- Fruit carcerulus.

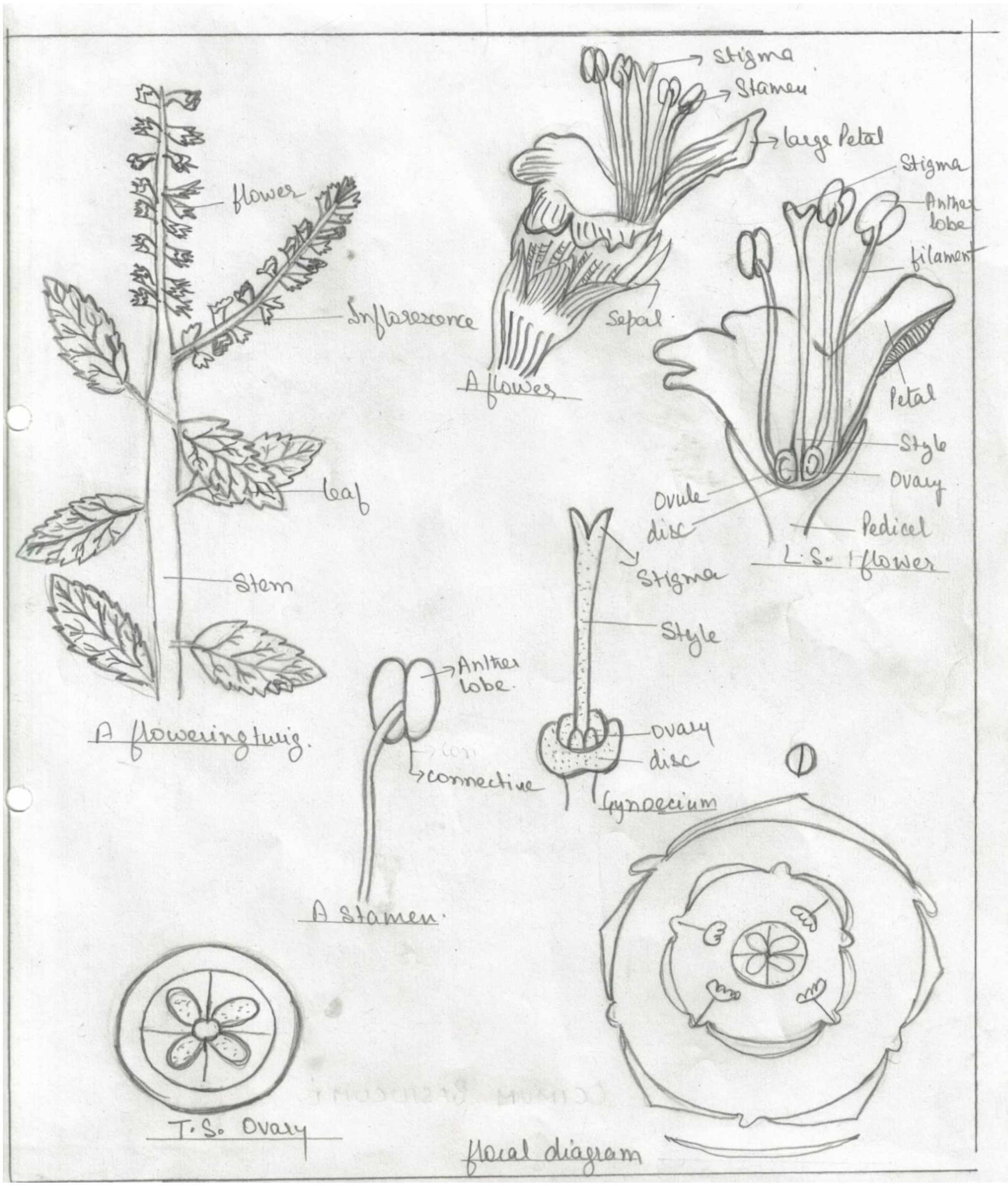

Fig. 14.7: ***Ocimum basilicum***

14.3.8 Solanaceae

Solanum nigrum Linn.

Habit- Herbs, annual.

Root- Branched, tap root.

Stem- Herbaceous, aerial, erect, cylindrical, branched, solid, smooth and green.

Leaf- Ramal and cauline, alternate, the leaves at some places seem to be opposite (floral region), exstipulate, simple, petiolate, ovate, entire or slightly lobed or sometimes serrate, acute, glabrous, unicostate, reticulate.

Inflorescence- Extra-axillary cyme.

Flower- Ebracteate, actinomorphic, pentamerous, hermaphrodite, hypogynous white.

Calyx- Sepals 5, gamosepalous, valvate, persistent.

Corolla- Petals 5, gamopetalous, valvate, rotate, white.

Androecium- Stamens 5, polyandrous, epipetalous, filaments broad at the base and hairy, anthers conniving, dithecous, basifixed and dehise by apical pores.

Gynoecium- Bicarpellary, syncarpous, ovary superior, bilocular with many ovules in each locule, placentation axile, septum oblique, placentae highly swollen, style long and hairy, stigma bilobed.

Fruit- Berry.

Floral formula- Ebr, $\oplus$, ⚥, $K_{(5)}$ $C_{(5)}$, $\overset{\frown}{A_5}$, $\underline{G}_{(2)}$.

Classification and identification-

Class- *Dicotyledonae*

1- Venation reticulate.
2- Flowers pentamerous.

Sub- Class. *Gamopetalae*

1- Petals fused.

Series- *Bicarpellatae*

1- Carpels two
2- Ovary usually superior.

Order- *Polemoniales*

1- Alternate, exstipulate leaves.
2- Flowers actinomorphic.

Family – *Solanaceae*

1- Flowers solitary terminal or cymosely umbelled.
2- Septum is oblique and the placentae are ghighly swollen.
3- Fruit- berry or capsule.

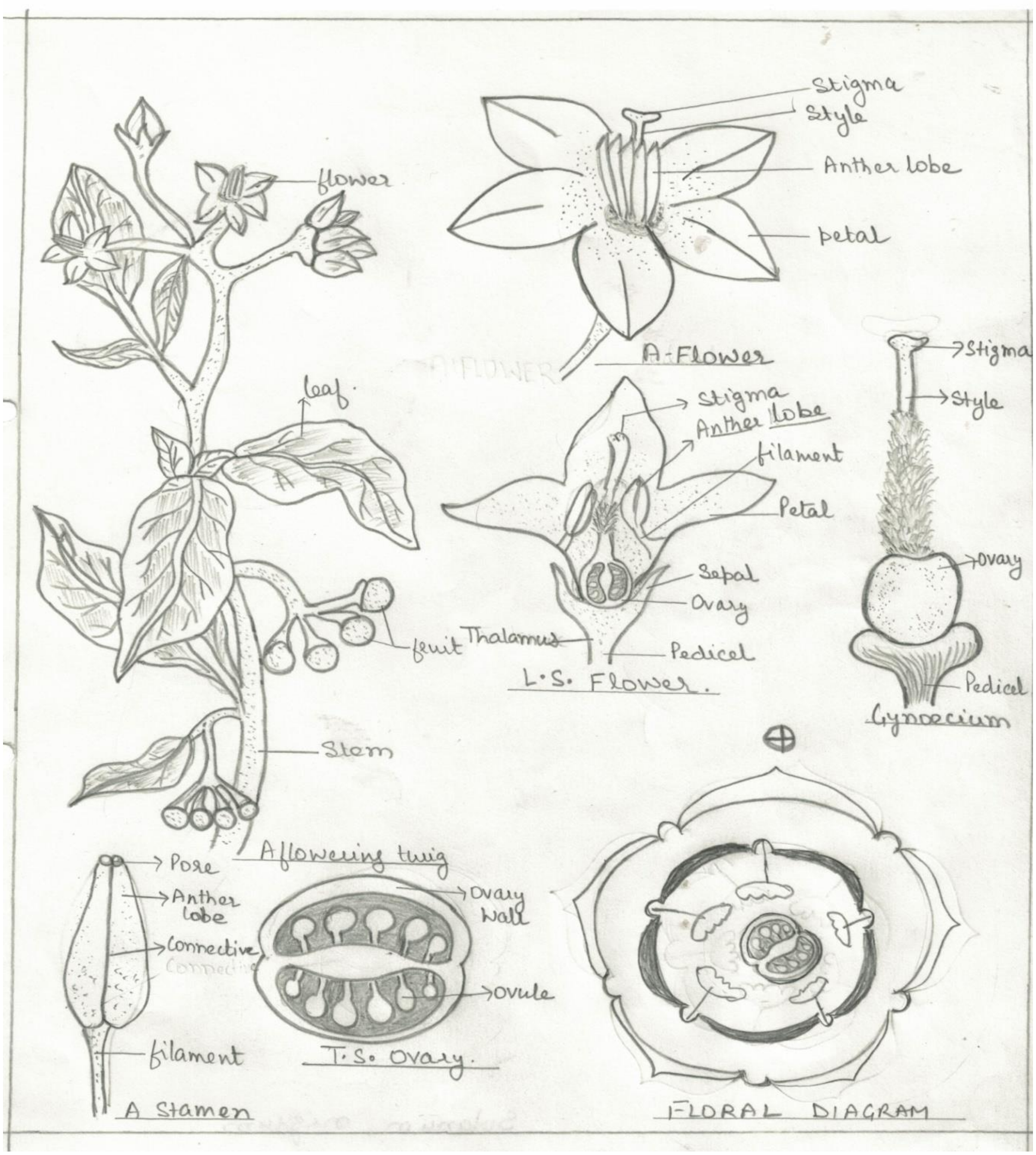

Fig. 14.8: ***Solanum nigrum***

14.3.9 Euphorbiaceae

(A) *Euphorbia pulcherrima* Willd. Ex Klotz.(=*Poinsettia pulcherrima* R. Grah.)

Habit- Shrub.

Root- Branched, tap root.

Stem- Herbaceous, lower portions woody, aerial, erect, angular, branched, solid, rough and green, milky latex present.

Leaf- Ramal and cauline, alternate, exstipulate, simple, petiolate, petiole filiform, ovate, entire, acute, smooth, unicostate reticulate, milky latex present.

Inflorescence- Cyathium, some bracts are leaf like and red in colour, whereas others form a cup like structure, yellowish red necetary is present outside and number of male flowers surrounding a single female flower are enclosed in cup shaped green involucre.

Male flower- It is represented only by a single stamen which has a long and slender filament having a joint in the middle. The anther is monothecous, basifixed and introrse. Male flowers are in the axils of scaly bracts.

Floral formula- Br, ♂, K_0 $C_{0,}$ A_1, $\underline{G}_{(0)}$.

Female Flower- Represented only by a gynoecium placed on a long stalk. Gynoecium is tricarpellary, syncarpous, ovary superior, trilocular with one ovule in each locule, placentation axiile, style short, stigmas three and each is bifid.

Fruit- Capsule.

Floral formula- Br, ♀, $K_{0,}$ $C_{0,}$ A_0, $\underline{G}_{(3)}$.

Classification and identification

Class- *Dicotyledonae*

1- Venation reticulate.
2- Flowers pentamerous.

Sub- Class. *Monochiamydeae*

1- Flowers usually with one whorl of perianth, commonly sepaloid or none.

Series- *Unisexuales*

1- Flowers unisexual.
2- Perianth sepaloid or much reduced or adsent.
3- Ovules 1 or 2 per carpel.

Family - *Euphorbiaceae*

1- Alternate stipulate leaves with latex.
2- Perianth usually in one whorl or absent.
3- Stamens 1 to indefinite, fre or united or branched.
4- Gynoecium tricarpellary, syncarpous, ovary superior, trilocular with one or two ovules in each locule.
5- Styles three.

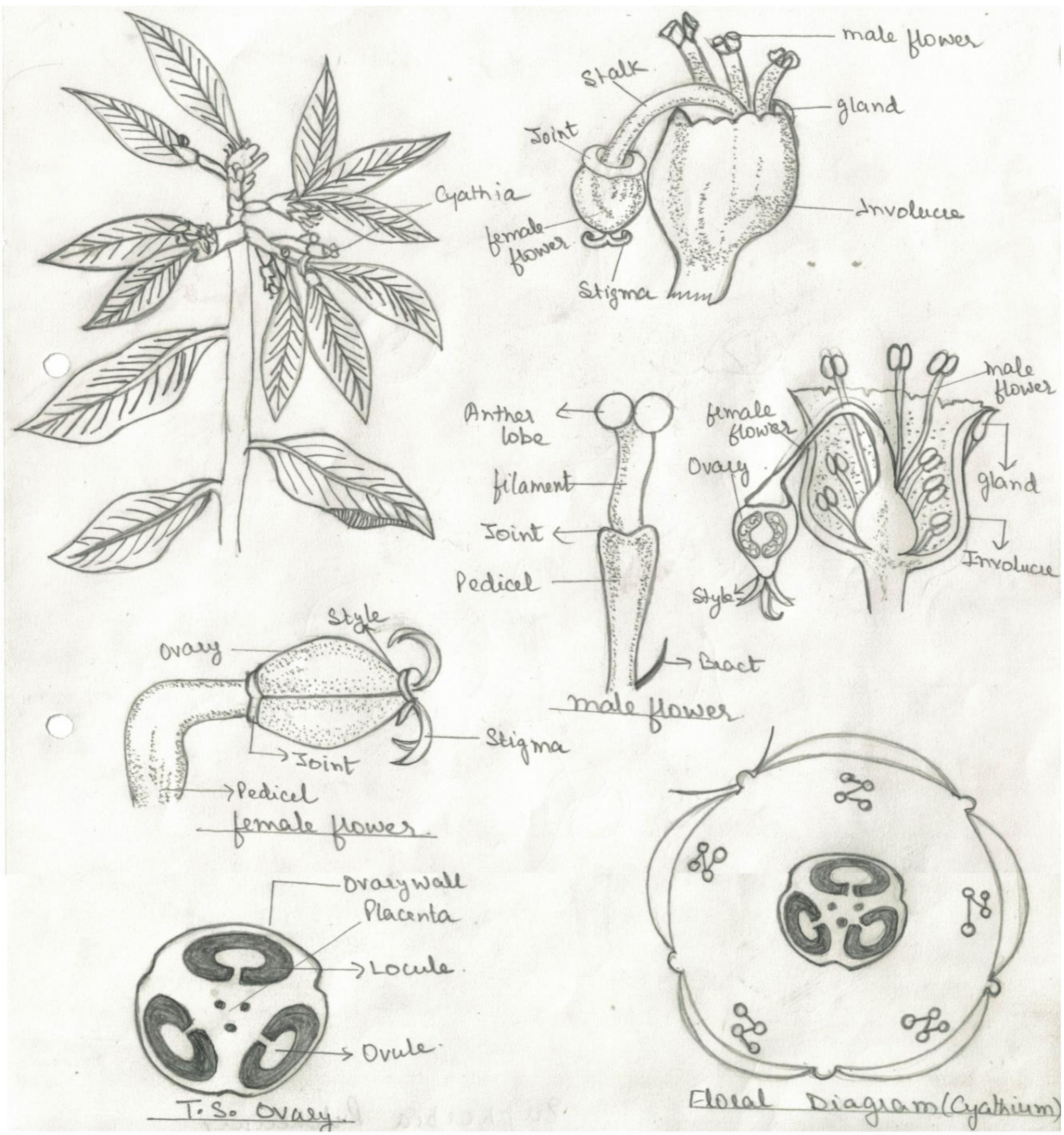

Fig. 14.9: ***Euphorbia pulcherrima***

(B) *Ricinus zcommunis Linn.*

Habit- Shrub.

Root- Branched, tap root.

Stem- Herbaceous, woody below, aerial, erect, cylindrical, branched, glabrous, green-purple, latex present.

Leaf- Ramal and cauline, alternate, stipulate, simple, palmately lobed, petiolate, petiole filiform, lobes, serrate, acute, glabrous, multicostate reticulate, divergent type.

Inflorescence- Panicle cyme. The male flowers are present at the base and the female flowers at the apex.

Male flower- Bracteate, pedicellate, incomplete, actinomorphic, unisexual, staminate, pentamerous and cyclic.

Perianth- Tepals 5, polytepalous valvate, slightly connate at the base.

Androecium- Stamens 5, polyandrous, anteposed, each stamen is profusely branched with the anthers borne on ultimate branches, monothecous, basifixed and intorse.

Gynoecium- Absent.

Floral formula- Br, ⊕, , ♂, P_{5}, A_{5}, $\underline{G}_{0}$,

Female Flower- Bracteate, pedicellate, incomplete, actinomorphic, unisexual, pistillate, trimerous,hypogynous and cyclic.

Perianth- Tepals 3, polytepalous valvate.

Androecium- Absent.

Gynoecium- Tricarpellary, syncarpous, ovary superior, trilocular with one ovule in each locule, placentation axile, style absent, stigma 3, bright red and each is bifid. Ovary has appendages on its outer wall.

Fruit- Regma, a carucle is present at the apex of the seed.

Floral formula- Br, ⊕, ♀, P_{3-5}, A_{0}, $\underline{G}_{(3)}$.

Classification and identification

Class- *Dicotyledonae*

1- Venation reticulate.
2- Flowers pentamerous.

Sub- Class. *Monochiamydeae*

1- Flowers usually with one whorl of perianth, commonly sepaloid or none.

Series- *Unisexuales*

1- Flowers unisexual.
2- Perianth sepaloid or much reduced or adsent.
3- Ovules 1 or 2 per carpel.

Family - *Euphorbiaceae*

1- Alternate stipulate leaves with latex.
2- Perianth usually in one whorl or absent.
3- Stamens 1 to indefinite, fre or united or branched.
4- Gynoecium tricarpellary, syncarpous, ovary superior, trilocular with one or two ovules in each locule.
5- Styles three.

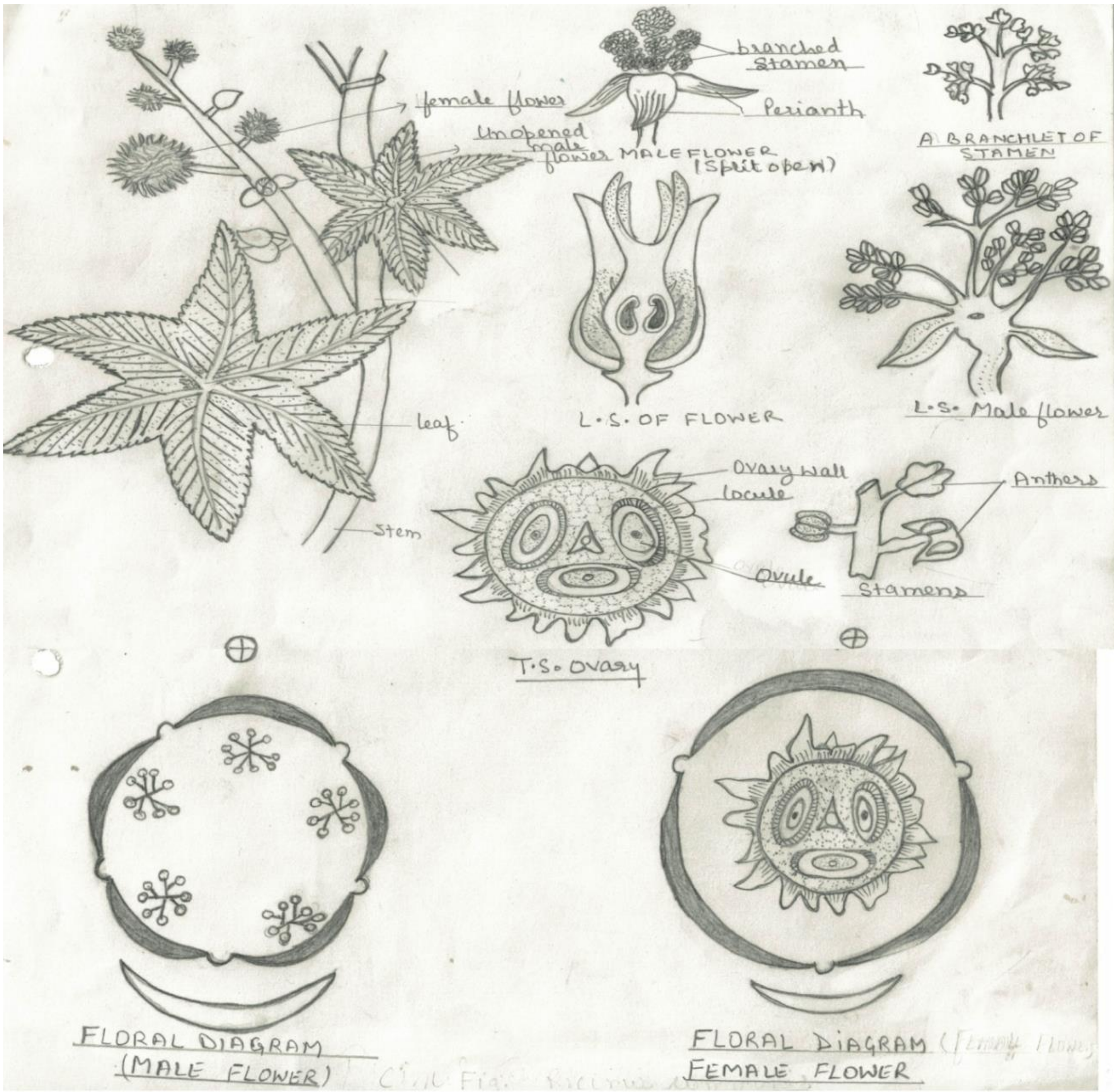

Fig. 14.10: *Ricinus communis*

14.3.10 Malvaceae

Abutilon indicum (Linn.) Sweet.

Habit- Woody shrub.

Root- Branched, tap root.

Stem- Herbaceous, aerial, erect, cylindrical, branched, solid, pubescent and green.

Leaf- Ramal and cauline, alternate, stipulate, simple, petiolate, deltoid, serrate, acute, slightly hairy and wrinkled, velvety, multicostate, reticulate, divergent type.

Inflorescence- Solitary axillary.

Flower- Bracteate, pedicellate, complete, actinomorphic, hermaphrodite, pentamerous, hypogynous, cyclic.

Calyx- Sepals 5, gamosepalous, free at the tips, valvate, persistent, green.

Corolla- Petals 5, polypetaous, slightly connate at the base and adnate to the stamina tube, twisted,

Androecium- Stamens indefinite, monadelphous, forming a tube around the style, the tube being united with petals (epipetalous). In the upper part of the stamina tube are borne monothecous, extrorse.

Gynoecium- Multicarpellary, syncarpous, ovary superior, multilocular, with one ovule in each locule placentation axile, style long and stigmas as many as carpels..

Fruit- Capsule.

Floral formula- Br, $\oplus$, ⚥, $K_{(5)}$ $C_{5,}$ $\overset{\frown}{A_{\infty}}$, $\underline{G}_{(5-\infty)}$,

Classification and identification

Class- *Dicotyledonae*

1- Venation reticulate.
2- Flowers pentamerous.

Sub- Class. *Polypetalae*

1- Petals fused.

Series- *Thalamiflorae*

1- Flowers hypogynous and ovary superior.

Order- *Malvales*

1- Stamens usually indefinite and monadelphous.
2- Ovary 3 to catpellary with axile placentation.

Family – M*alvaceae*

1- Leaves stipulate.
2- Calyx often with an epicalyx
3- Stamens monothecous and anthers reniform.
4- Fruit- capsule or schizocarp.

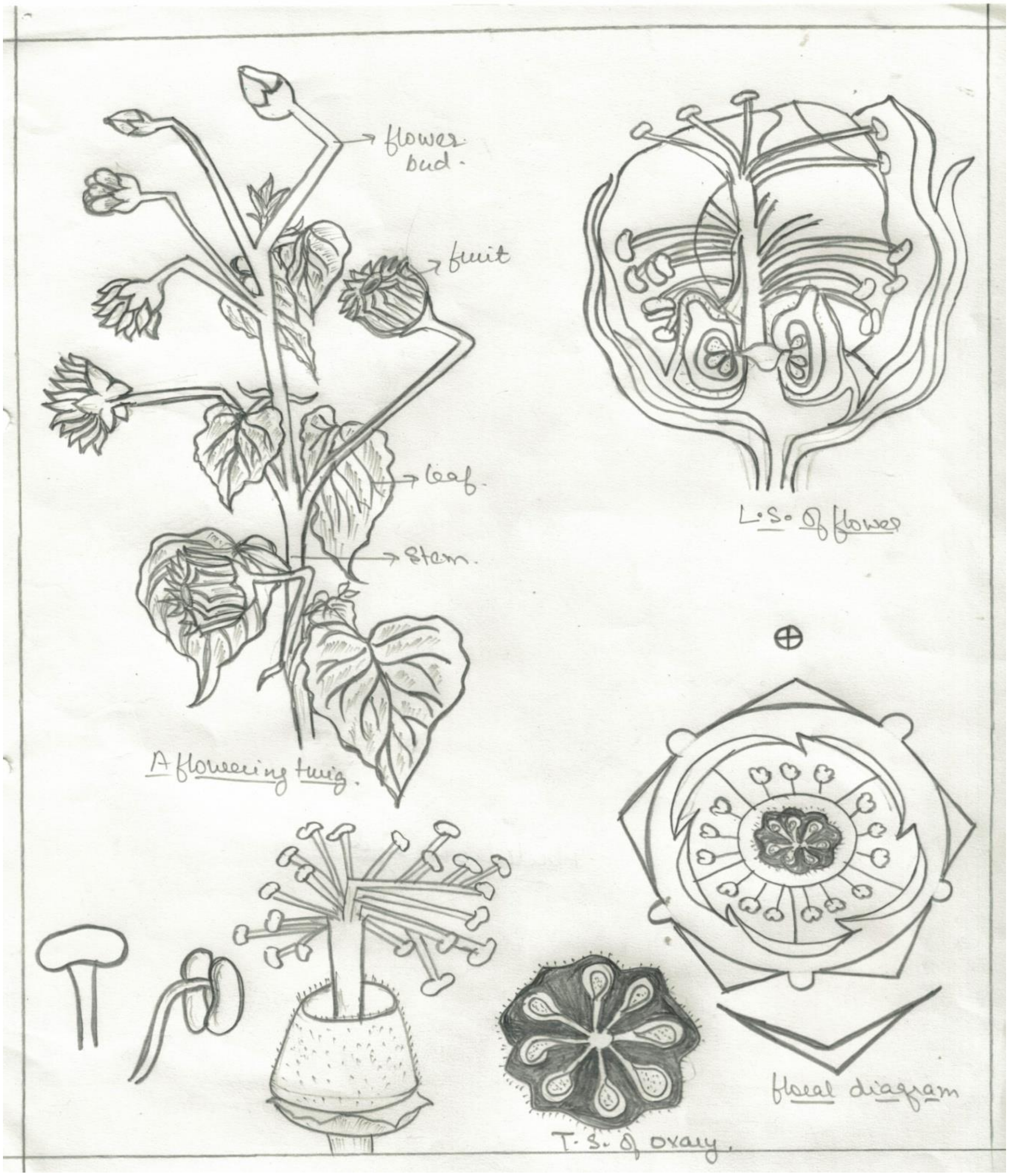

Fig. 14.11: ***Abutilon indicum***

14.3.11 Umbelliferae (Apiaceae)

Coriandrum sativum Linn.

Habit- Annual herb**.**

Root- Branched, tap root.

Stem- Herbaceous, aerial, erect, angular, branched, solid, glabrous, nodes are very prominent, aromatic smell present.

Leaf- Ramal and cauline, alternate, exstipulate, petiolate, sheathing leaf base, entire, acute, unicostate reticulate, aromatic smell present.

Inflorescence- Compound umbel.

Flower- Bracteate, pedicellate, complete, **central flowers** actinomorphic, **peripheral flowers** zygomorphic due to unequal size of petals, hermaphrodite, pentamerous, epigynous and cyclic.

Calyx- Sepals 5, polysepalous, valvate, persistent, narrow circular ridge at the top of ovary.

Corolla- Petals 5, polypetalous, valvate, each petal is bilobed. In central flowers (actinomorphic) the lobes of all petals are equal in size. In case of peripheral flowers (zygomorphic) one anterior petal has 2 large equally developed lobes, two lateral petals have one bigger and one smaller lobe and the rest two petals have two equal small lobes.

Androecium- Stamens5, polyandrous, filaments long and slender, dithecous, dorsifixed and introse.

Gynoecium- Bicarpellary, syncarpous, ovary inferior, bilocular, with one pendulous ovule in each locule, placentation axile, styles 2, stigmas 2 and capitates. A disc called stylopodium is present.

Fruit- Cremocarp splitting into 2 mericarps.

Floral formula-

(a) Br, $\oplus$, ⚥, $K_{5,}$ $C_{5,}$ A_5, G_2, - Central

(b) Br, %, ⚥, $K_{5,}$ $C_{5,}$ A_5, $G_{(2).}$ – Peripheral

Classification and identification

Class- *Dicotyledonae*

1- Venation reticulate.
2- Flowers pentamerous.

Sub- Class. *Polypetalae*

1- Petals free.

Series- *Calyciflorae*

1- Thalamus cup- shaped.
2- Ovary inferior.

Order- *Umbellales*

1- Inflorescence umbel
2- Ovary inferior with 1, 2, or 8 fused carpels and as many locules.
3- Ovules solitary, pendulous in each locule.

Family – *Umbelliferae*

1- Stems fistular. Leaves alternate, extipulate usually much dissected with sheathing leaf base.
2- Carpels 2, fused, with 2 styles on swollen style base (stylopodium).

3- Fruit schizocarp, splitting into 2 mericarps.

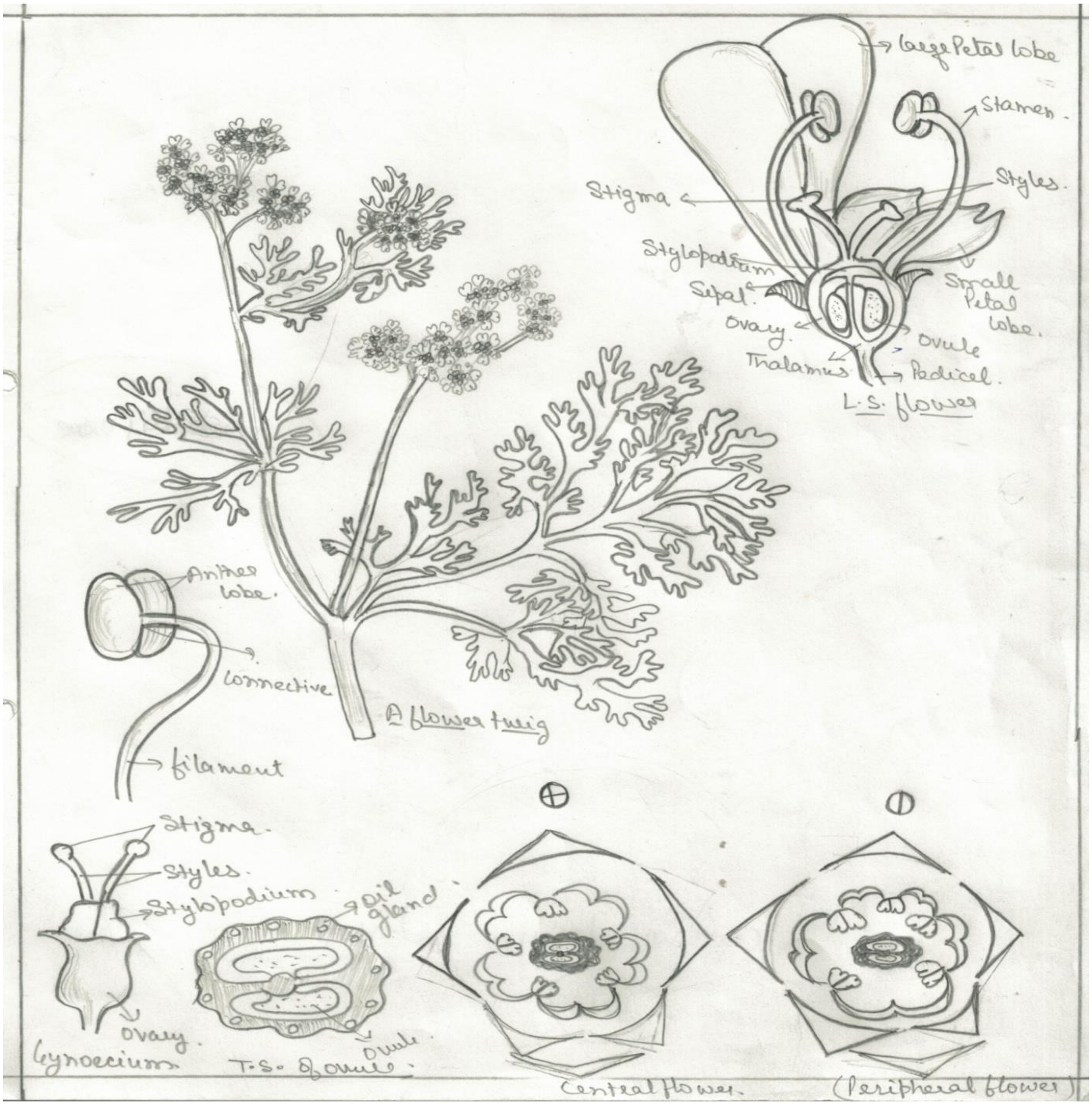

Fig. 14.12: ***Coriandrum sativum***

14.3.12 Asclepiadaceae

*Calotropis procera (*Willd.) Dryand. ex W. Ait. (= *Asclepias procera Willd.)*

Habit- Perennial shrub.

Roots- Tap roots.

Stem- Herbaceous, lower portions woody, aerial, erect, cylindrical, branched, solid, lower portions smooth, upper portions covered with woolly hairs, pale green, milky latex present.

Leaf- Ramal and cauline, acute, hairy, woolly, unicostate reticulate, hermaphrodite, pentamerous, hypogynous and cyclic.

Inflorescence- Polychasial cyme.

Flower- Bracteate, bracteolate, pedicellate, complete, actionomorphic, hermaphrodite pentamerous, hypogynous and cyclic.

Calyx- Sepal 5, polysepalous, quincuncial.

Corolla- Petals 5, gamopetalous, twisted, coloured..

Androecium- Stamens 5, united with the stigma to form gynostegium, each stamen is represented by two pollinia with their retinaculae. The pollinia of the adjacent anthers are joined by their retinaculae to corpusculum in a groove, to form a unit known as translator. A coronary outgrowth is present at the back of each stamen.

Gynoecium- Bicarpellary, ovaries free but upper portion of style and stigma are fused, superior, placentation marginal, ovules many per locule, stigmatic head pentagonal.

Fruit- Etaerio of follicle.

Floral formula- Br, brl, $\oplus$, ⚥, K_{5}, $C_{(5)}$, $A_{(5)}$, $\overset{\frown}{\underline{G}_{2}}$,

Classification and identification

Class- ***Dicotyledonae***

1- Venation reticulate.
2- Flowers pentamerous.

Sub- Class. ***Gamopetalae***

1- Petals fused.

Series- ***Bicarpellatae***

1- Carpels two.
2- Ovary usually superior.

Order- ***Gentianales***

1- Leaves opposite.
2- Flowers actinomorphic.
3- Stamens epipetalous.

Family – ***Asclepiadaceae***

1- Flowers solitary or in cymose umbels.
2- Petals usually convolute.
3- Stamens gynandrous, pollen usually in pollinia with translators.
4- Ovaries two, free, but united by the style.

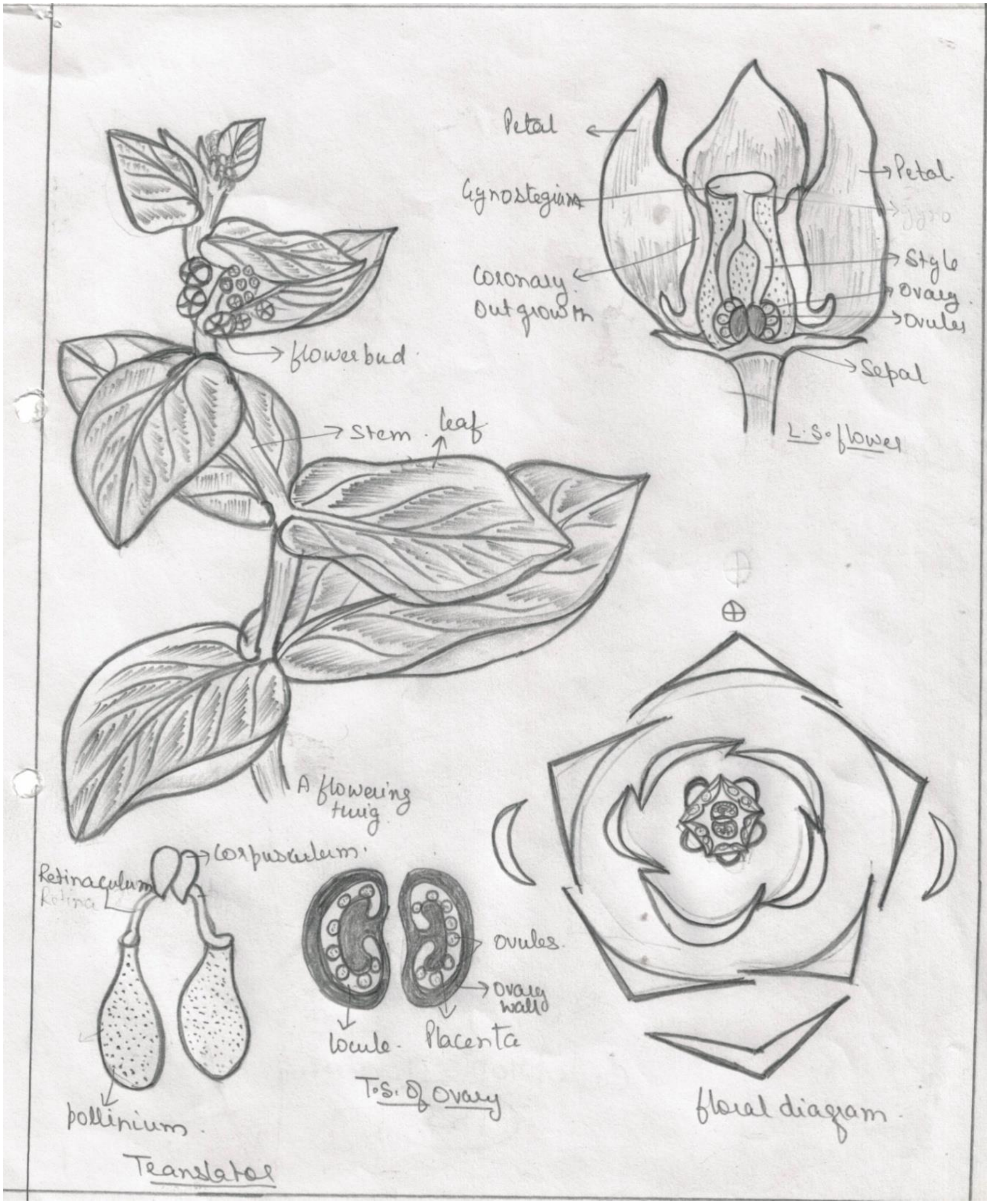

Fig. 14.13: ***Calotropis procera***

14.3.13 Cucurbitaceae

Coccinia cordifolia (L.) Cogn. (+ Coccinia indica Wight & Arn.)

Habit- Herb, Climbing by means of tendril.

Roots- Tap roots.
Stem- Herbaceous, aerial, weak, climbing, tendril climber, tendril leaf opposed and unbranched, angular, branched, solid, glabrous, green.
Leaf- Cauline and ramal, alternate, exstipulate, simple, palmatifid, petiolate, cordate, denticulate, acute, glabrous, multicostate reticulate diverging type venation, coriaceous.
Inflorescence- Solitary axillary.
[I] Male flower- Ebracteate, pedicellate, incomplete, actinomorphic, unisexual, staminate, pentamerous, cyclic.
Calyx- Sepal 5, gamosepalous, valvate.
Corolla- Petals 5, gamopetalous, valvate, campanulate.
Androecium- Stamens 5, arranged in 3 groups, 2 groups have 2 stamens and 1 group have only one stamen, monothecous and extrose.
Gynoecium- Absent.

Floral formula- Ebr, $\oplus$, ♂, $K_{(5)}$, $C_{(5)}$, $A_{(2)+(2)+1}$, G_0.

[II] Female Flower- Ebracteate, pedicellate, incomplete, actinomorphic, unisexual, pistillate, pentamerous, cyclic.
Calyx- Sepal 5, gamosepalous, valvate.
Corolla- Petals 5, gamopetalous, valvate, campanulate.
Androecium- Absent.
Gynoecium- Tricarpellary, syncarpous, ovary inferior, unilocular, placentation parietal, placentae intruding style short, stigma 3, forked and feathery.
Fruit- Pepo.

Floral formula- Ebr, $\oplus$, ♀, $K_{(5)}$, $C_{(5)}$, A_0, $G_{(3)}$

Classification and identification

Class- *Dicotyledonae*

1- Venation reticulate.
2- Flowers pentamerous.

Sub- Class. *Polypetalae*

1- Petals free.

Series- *Calyciflorae*

1- Thalamus cup- shaped.
2- Ovary inferior.

Order- *Passiflorales*

1- Tendril climbers.
2- Ovary usually inferior, syncarpous, unilocular with parietal placentation.

Family – *Cucurbitaceae*

1- Flower usually unisexual. 2- Stamens 5, free or each 2 united or all the 5 in a central synadrium.

2- Carpels usually 3, stigma forked. 4- Fruit a pepo.

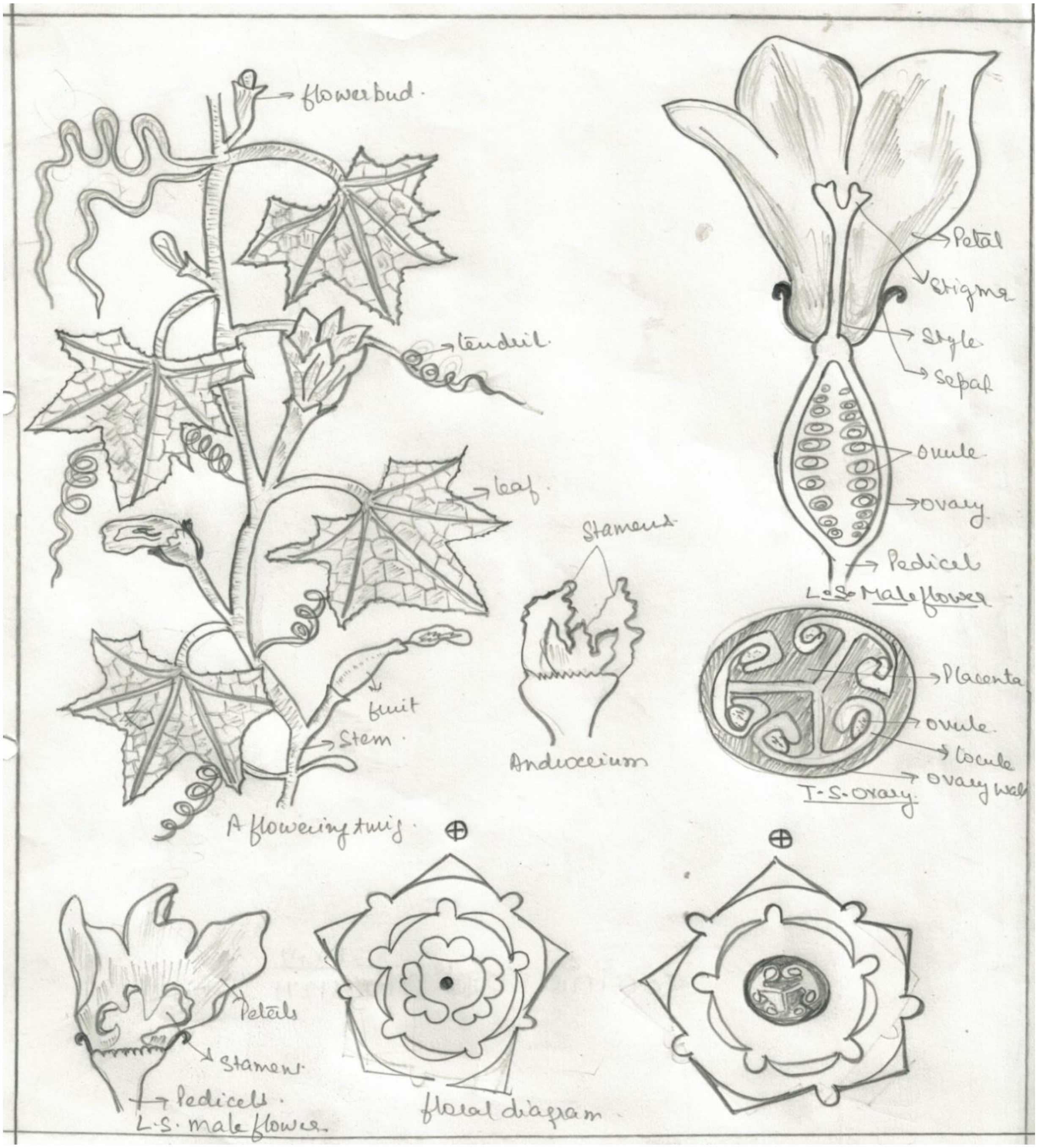

Fig. 14.14: ***Coccinia cordifolia***

14.3.14 Acanthaceae

***Justicia gendarussa* L. f.**

Habit- A perennial herb.

Root- Branched, tap root.

Stem- Herbaceous, aerial, erect, cylindrical, nodes prominent and flat, branched, solid, glabrous, red-brown.

Leaf- Ramal and cauline, opposite decussate, stipulate, simple, petiolate, petiole small, lanceolate, obtuse, glabrous, unicostate reticulate, coriaceous..

Inflorescence- Dichasial cyme, arranged in a racemose fashion.

Flower- Bracteate, bracteolate, pedicellate, complete, zygomorphic, hermaphrodite, pentamerous, hypogynous and cyclic.

Calyx- Sepals 5, gamosepalous, valvate.

Corolla- Petals 5, gamopetalous, valvate, corolla 2/3, bilabiate personate..

Androecium- Stamens 2, polyandrous, epipetalous, dithecous anthers lobes are situated at unequal heights and lower one bears an appendage, basifixed, introrse.

Gynoecium- Bicarpellary, syncarpous, ovary superior, bilocular with one ovule in each locule, axile placentation, style long, stigma simple and knob -like.

Fruit- Capsule.

Floral formula- Br, brl. $\oplus$, ⚥, $K_{(5)}$ $\overset{\frown}{C_{(2/3)},\ A_2}$, $\underline{G}_{(2)}$,

Classification and identification

Class- *Dicotyledonae*

1- Venation reticulate.
2- Flowers pentamerous.

Sub- Class. *Gamopetalae*

1- Petals fused.

Series- *Bicarpellatae*

1- Carpels two
2- Ovary usually superior.

Order- *Personales*

1- Flowers zygomorphic.
2- Corolla bilipped personate.
3- Stamens usually 4 didynamous or two.
4- Ovary uni-, bi-or tetralocular, ovules usually indefinite.

Family – *Acanthaceae*

1- Herbs or shrubs with opposite leaves.
2- Flowers in spikes, racemes or cymose umbels.
3- Anthers are situated at unequal heights.
4- Gynoecium bilocular, each locule with indefinite to two ovule.
5- Jaculators are present between the seeds.

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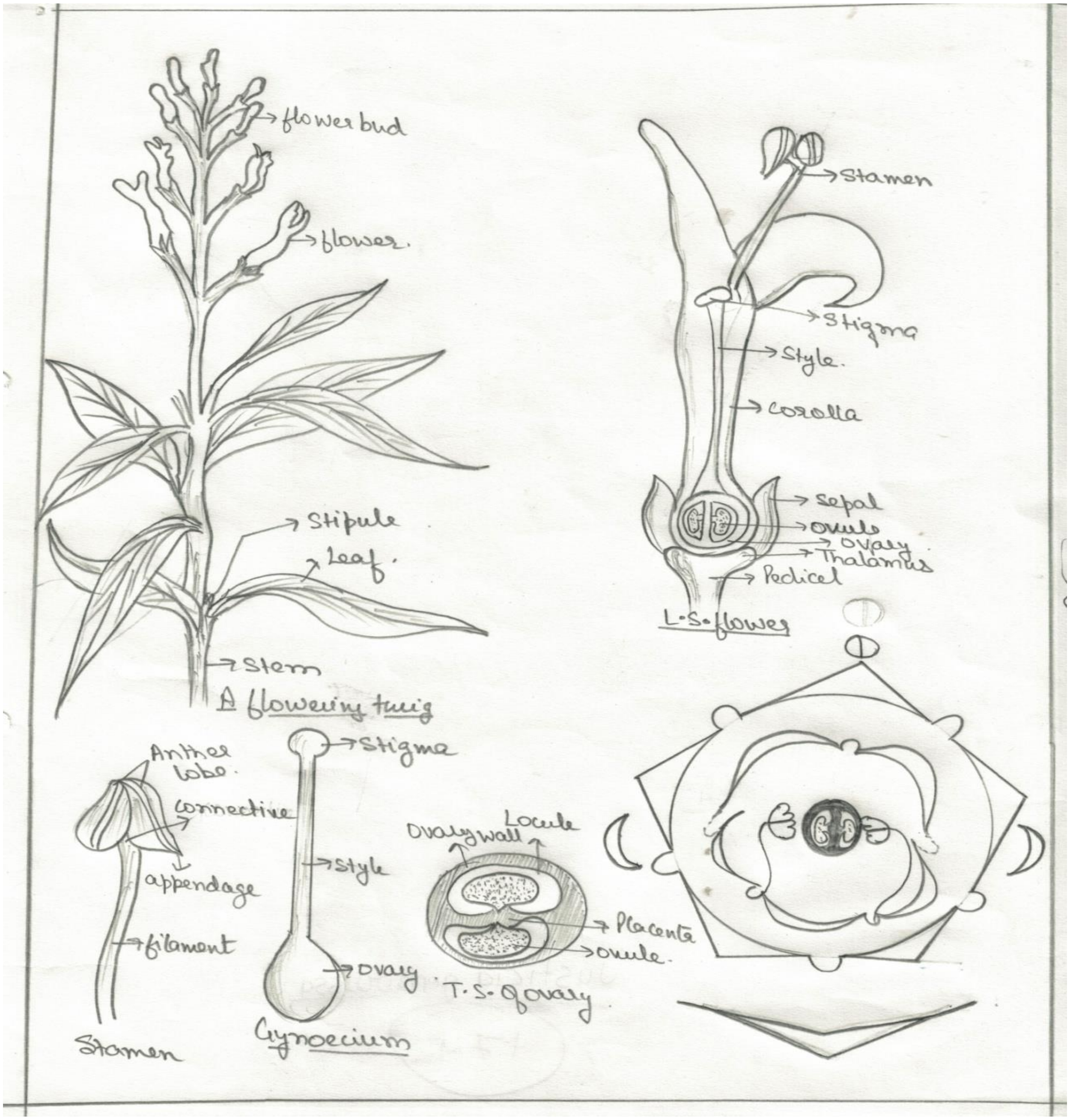

Fig. 14.15: *Justicia gendarussa*

14.3.15 Dipterocarpaceae

Shorea robusta

Habit- Gigantic trees rarely shrubs.

Root- Tap, branched, deep.

Stem- Erect, high, woody, few branches, with resin ducts.

Leaf- Simple, entire, coracious, stipulate, stipules small sometimes surrounding the internode.

Inflorescence- Panicualte terminal or axillary spikes or racemes.

Flower- Actinomorphic, hermaphrodite, hypogynous, pentamerous, flower axis broad. Saucer shaped or concave sometimes, complete.
Calyx- Sepals 5, unequal, polysepalons persistent and wing –like in fruit (*Shorea),*imbricate or valvate.
Corolla- Petals 5, polypetalous, imbricate contorted or much imbricate.
Androecium- Stamens 5 to 15 or indefinite, in one to several whorls, filaments short usually, rarely long, anther lobes unequal, connective produced at th apex very often.
Gynoecium- Carpels 3 usually, ayncarpous, superior, trilocular, axile placentation, ovules 2 in each locule, stigma always exceeds the stamens.
Fruit- Leathery, woody, indehiscent, surrounded by persisitent winged calyx segments.
Seed- Non-endospermic.
Pollination- Entomophilous sweet scented flowers.
Floral formula- $\oplus$, ⚥, K_5 C_5, $A_{5-\infty}$, $\underline{G}_{(3)}$.

Classification and identification

Class- ***Dicotyledonae***

1- Venation reticulate.
2- Flowers pentamerous.

Sub- Class- ***Polypetalae***

1- Petals free.

Series- ***Thalamiflorae***

1- Thalamus dome-shaped
2- Flowers hypognous and ovary superior.

Order- Guttiferales.

1- Usually trees or shrubs.
2- Latex present.

Family- ***Dipterocarpaceae***

1- Gigantic trees with an abundant resin.
2- Coracious leaves.

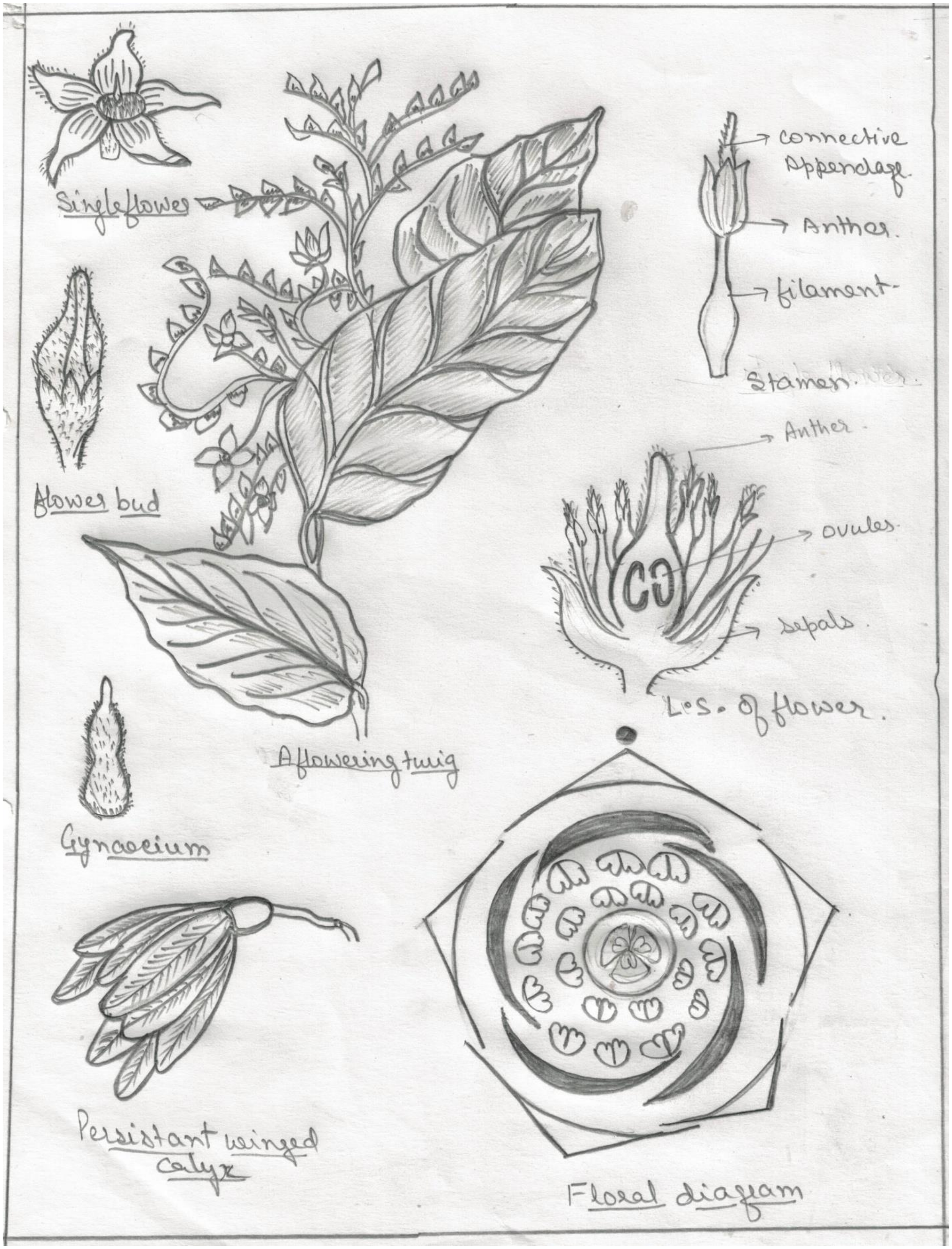

Fig. 14.16: ***Shorea robusta***

14.3.16 Ericaceae

Rhododendron arboreum

Habit- Small evergreen trees, rough, pinkish brown back.

Root- Tap root system.

Stem- Young shoot clothed with white scales.

Leaf- Crowded towards the end of the branchehes, lanceolate, narrowed at both the end. Glossy green above, pale beneath from a flim of small white scales at midrib and neeves prominent below. Petiole stout coverd with white scales when young.

Inflorescence.

Flower- Red or pale pink, hermaphrodite, large globose, compact corymbs.

Calyx- Small with broadly ovate, pale yellow, 5 sepals, valvate

Corolla- 5 recurved fringed lobes, campanulate, quincuntial

Androecium- 10 stamens, hypozygous declining, filament filiform. Anthees ovate, no appendage.

Gynoecium- Style capitates ovary custy woody, ovary superior.

Fruit- Capsule, curved, longitudinally ribbel.

Floral formula- Br., $\oplus$, ⚥, K_5 $C_{5,}$ $\widehat{A_{10}}$, $\underline{G}_{(5)}$,

Classification and identification

Class- ***Dicotyledonae***

1- Venation reticulate.
2- Flowers pentamerous

Sub- Class- ***Gamopetalae***

1- Petals fused.

Series- ***Heteromere***

1- Carpels more than two.
2- Stamens as many as corolla lobes.

Order- ***Ericales***

1- Stamens as many as corolla lobes and alternating to them.

Family- ***Ericaceae***

1- Trees, shrubs or undershrubs.
2- Leaves alternate, opposite or whorled, stipules 0.
3- Flowers hermaphrodite.

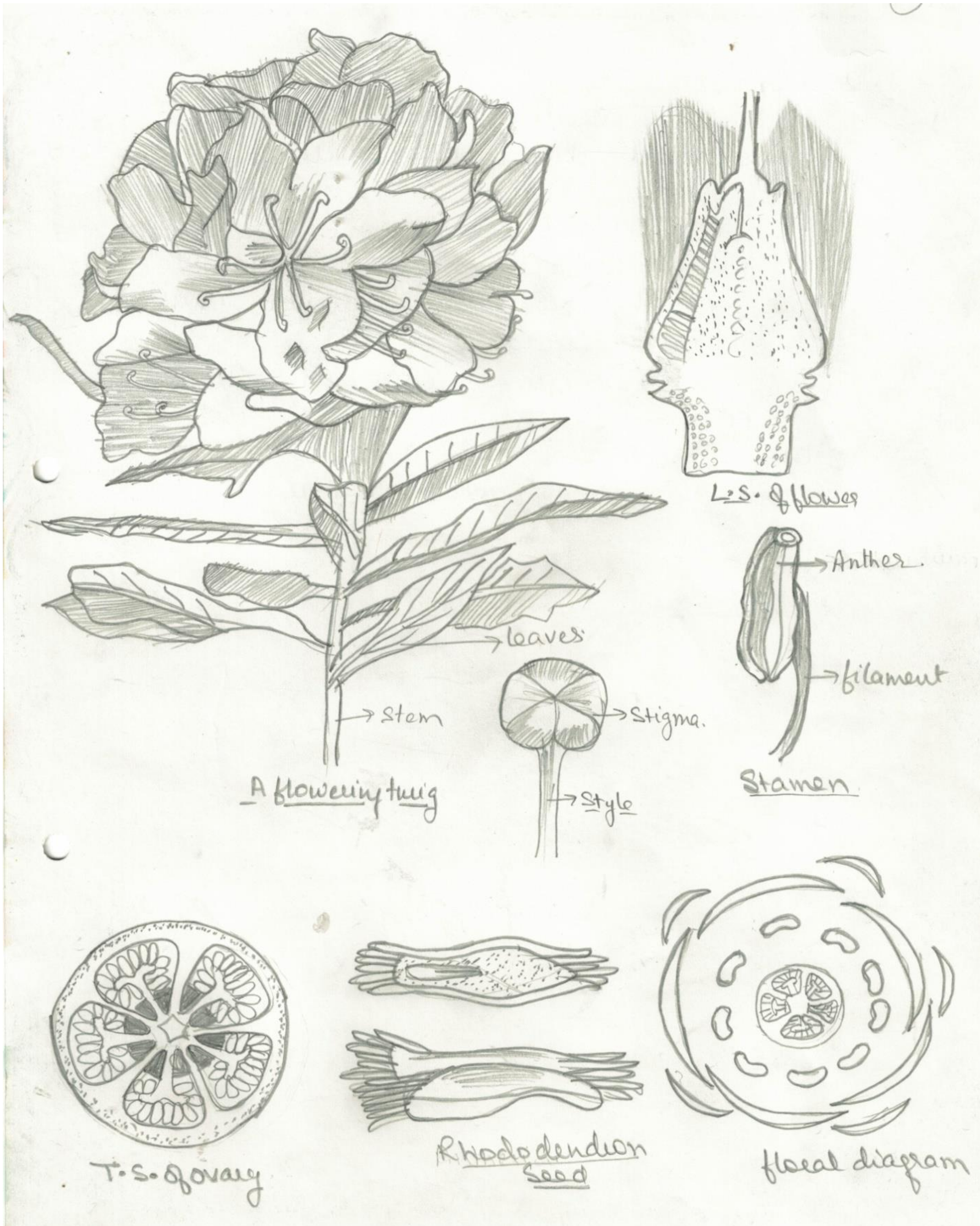

Fig. 14.17: ***Rhododendron arboreum***

14.3.17 Orchidaceae

***Zeuxine strateumatica* (Linn.) Schlect. (=*Z. sulcata* Lindl.)**

Habit- Herb.

Root- Adventitious root.

Stem- Herbaceous, aerial, erect, cylindrical, unbranched, solid and smooth..

Leaf- Alternate, exstipulate, simple, sessile, leaf base sheathing, linear, acuminate, parallel.

Inflorescence- Terminal raceme.

Flower- Bracteate, pedicellate, complete, zygomorphic, hermaphrodite, trimerous, epigynous and cyclic, resupinate at anthesis.

Perianth – Tepals 6 in two whorl of 3 each, polyphyllous, the anterior tepal of the outer whorl large, the posterior tepal of the inner whorl saccate forming the lip or the labellum, labellum adnate to the column or gynostegium, lip yellowish, other tepals pinkish, inner whorl imbricate and outer valvate.

Androecium- Fertile stamen one and staminodes two, one on either side of the stamen and attached to the base of the anther. The fertile stamen is united with the style to form a column or gynostegium which is opposite the labellum, column or gynostegium short, having a pair of flaps or wings covering the anther. The stamen is connected to the ovary by rostellum. The anther is modified into a pair of pollinia, each having a caudicle which are attached to the corpusculum.

Gynoecium- Tricarpellary, syncarpous, ovary inferior, unilocular, parietal placentation, ovules amny on each placenta. The column has 2 fertile stigmas and a specialized organ rostellum which represents the third stigma.

Fruit- Capsule.

Floral formula- Br, %, ⚥, $P_{3+3,}$ A_1, $\overline{G}_{(3).}$

Classification and identification

Class- *Monocotyledonae*

1- Venation parallel.
2- Flowers trimerous.

Series- *Microspermae*

1- Inner perianth petaloid.
2- Ovary inferior with 3 paerietal or rarely axile placentae.
3- Seeds minute.

Family - *Orchidaceae*

1- Flowers hermaphrodite, zygomorphic and often resupinated.
2- Perianth in two whorls of 3 each.
3- Stamen one or two united with the style to form column.
4- Gynoecium tricarpellary, syncarpous, inferior with indefinite ovules.
5- Stigma 3, the third usually rudimentary or forming a rostellum.

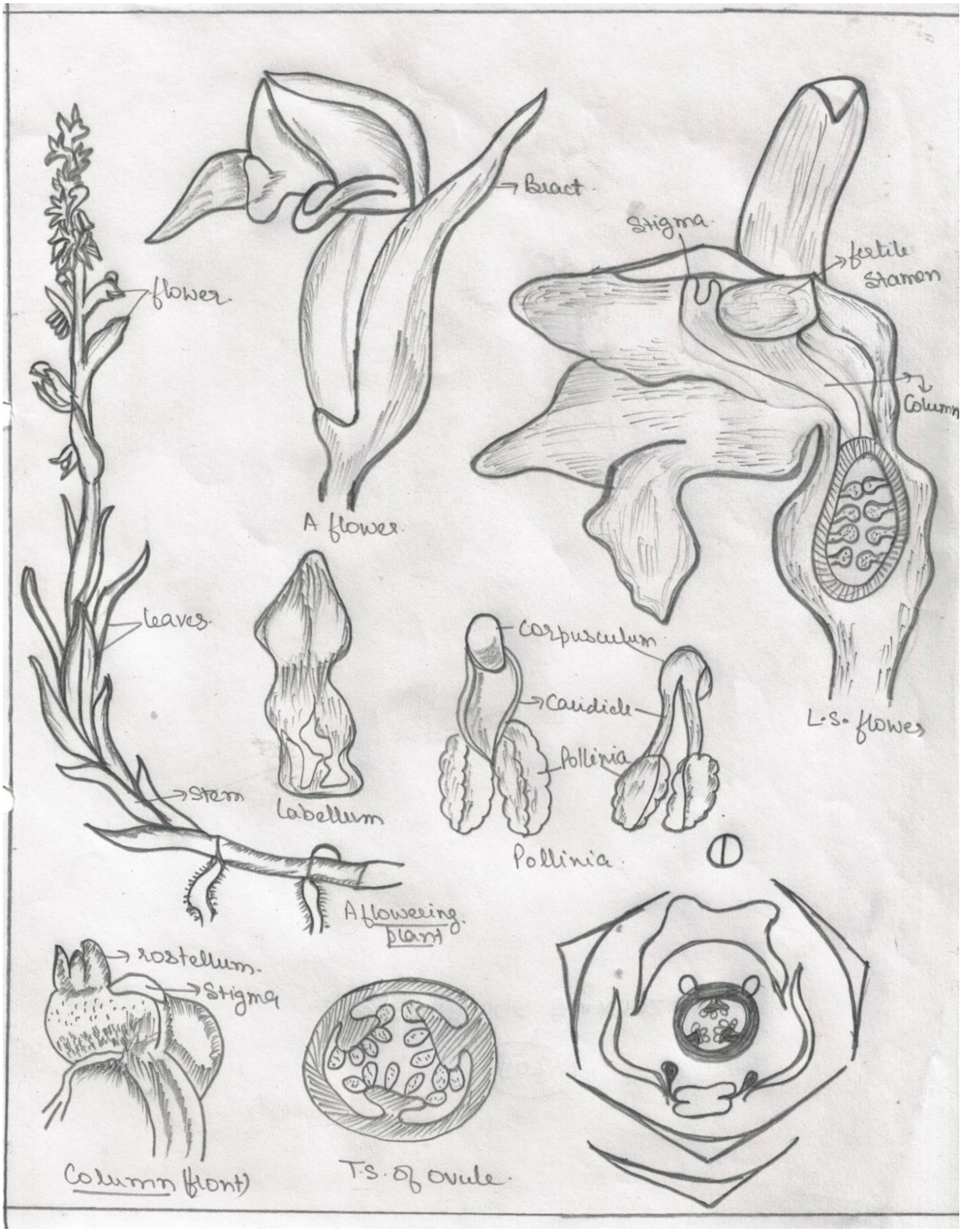

Fig. 14.18: *Zeuxine strateumatica*

14.3.18 Arecaceae (Palmae)

***Phoenix sylvestris (*Linn.) Roxb. (= *Elate sylvestris* Linn.)**

Habit- Tree.

Root- Adventitious roots.

Stem- Woody, aerial, erect, cylindrical, covered with the persistent bases ofpetioles, unbranched, solid, rough and brown. It is known as caidex.

Leaf- Cauline, forming a dense terminal crown, exstipulate, compound, unipinnate petiolate, pinnae sub-sessile, lanceolate, entire, glabrous, unicostate parallel venation..

Inflorescence- Spadix.

Male Flower- Bracteate, sessile, incomplete, actinomorphic, unisexual, staminate, trimerous and cyclic.

Perianth – Tepals 6 in two whorls of 3 each, the outer 3 tepals united in a cupular 3 toothed calyx, inner tepals free, twisted.

Androecium- Stamens 6 in two whorls of 3 each, polyandrous, filaments short, dithecous, dorsifixed and introrse.

Gynoecium- Absent.

Fruit- Capsule.

Floral formula- Br, ⊕, ♂, P_{3+3}, A_{3+3}, G_{0}.

Female Flower- Bracteate, sessile, incomplete, actinomorphic, unisexual, pistillate, trimerous, hypogynous and cyclic.

Perianth – Tapals 6 in two whorls of 3 connate in a globose persistent calyx, the inner 3 free and imbricate or valvate.

Androecium- Absentt.

Gynoecium- Tricarpellary, apocarpous, ovary superior, ovule one per carpel, style absent, stigma uncinate.

Fruit- Berry.

Floral formula- Br, ⊕, ♀, $P_{(3)+3}$, A_{0}, $\underline{G}_{3}$

Classification and identification

Class- *Monocotyledonae*

1- Venation parallel.
2- Flowers trimerous.

Series- *Calycineae*

1- Perianth sepaloid, herbaceous or membranous.
2- Ovary superior.

Family - *Palmae*

1- Tree- like plants with fan leaves.

2- Flowers actinomorphic, unisexual and in spikes.
3- Perianth in two whorls and sepaloid.
4- Stamens 3+3, or 3, 9 or 8.
5- Gynoecium tricarpellary, trilocular with one ovule in each locule.
6- Fruit berry or drupe.

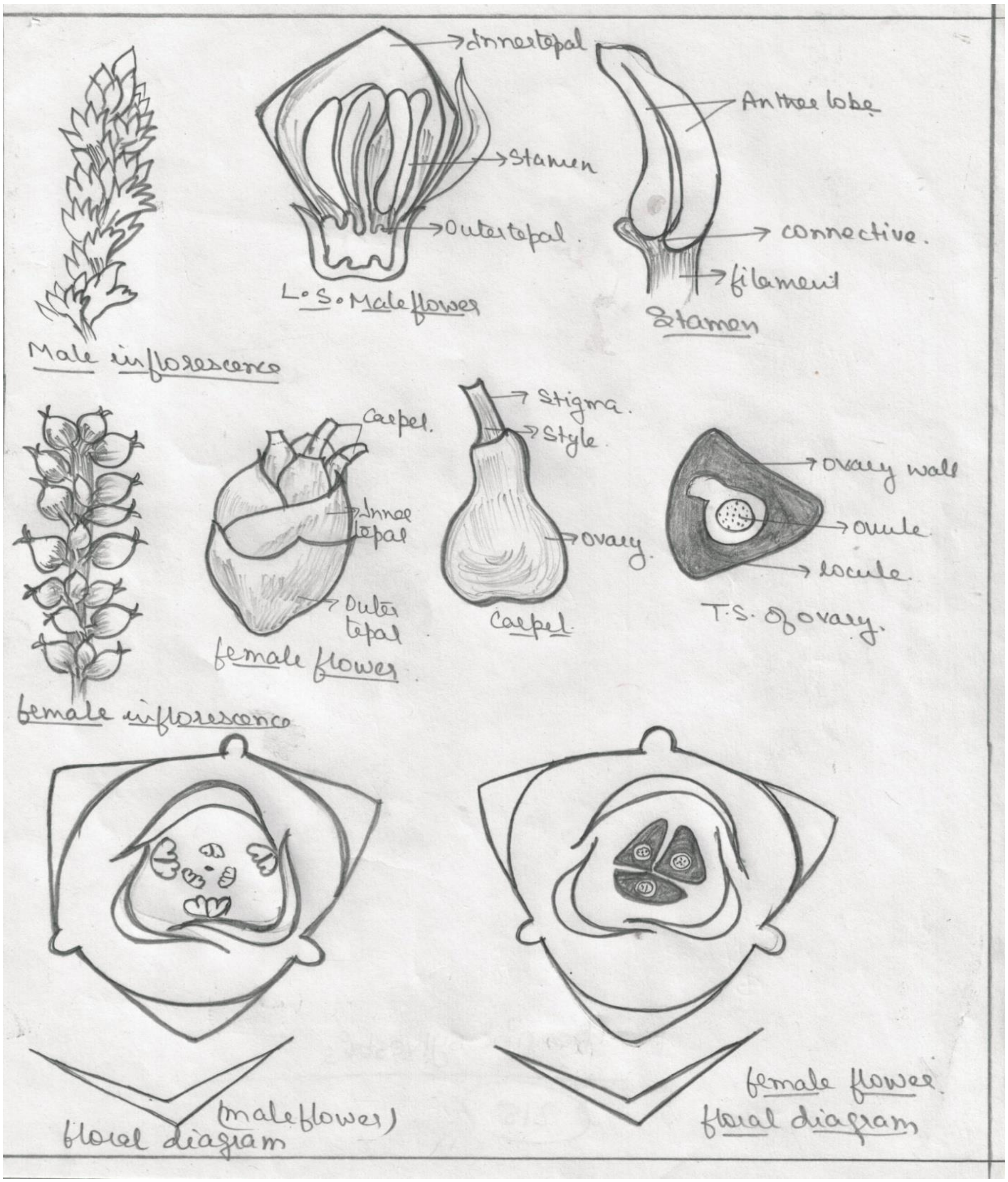

Fig. 14.19 ***Phoenix sylvestris***

14.3.19 Liliaceae

Asphodelus tenuifolius **Cav.**

Habit- Herb.

Root- Adventitious.

Stem- Reduced underground.

Leaf- Radical, arising in a rosette- like manner, acicular, acute, cylindrical, venation multicostate parallel.

Inflorescence- Scapiferous racemose raceme, the scape is aerial, erect, cylindrical, b ranched, solid, smooth and green.

Flower- Bracteate, bracts boat –shaped and keeled at the back, pedicellate, complete, actinomorphic, hermaphrodite, trimerous, hypogynous and cyclic.

Perianth – Tepals 6, present in two whorl of 3 each, polytepalous, valvate, petaloid, white, a prominent brownish ridge in present in the centre of each tepal.

Androecium- Stamens 6, in two whorl of 3 each, polyandrous, epitepalous, filaments of outer whorls are longer and that of inner whorl short, dthecous, versatile, introrse.

Gynoecium- Tricarpellary, syncarpous, ovary superior, trilocular with two rows of ovules in each locule, palcentation axile, style slender and stigma bilobed..

Fruit- Capsule.

Floral formula- Br, $\oplus$, ⚥, $\overset{\frown}{P_{3+3}, A_{3+3}}$, $\underline{G}_{(3).}$

Classification and identification

Class- *Monocotyledonae*

1- Venation parallel.
2- Flowers trimerous.

Series- *Coronarieae*

1 Inner perianth petaloid.
2 Ovary superior.

Family - *Liliaceae*

1- Inflorescence usually scapiferous racemose type.
2- Perianth in two whorls and petaloid.
3- Stamens also in two whorls and epiptepalous.
4- Gynoecium 2-5 locular and placentation axile.

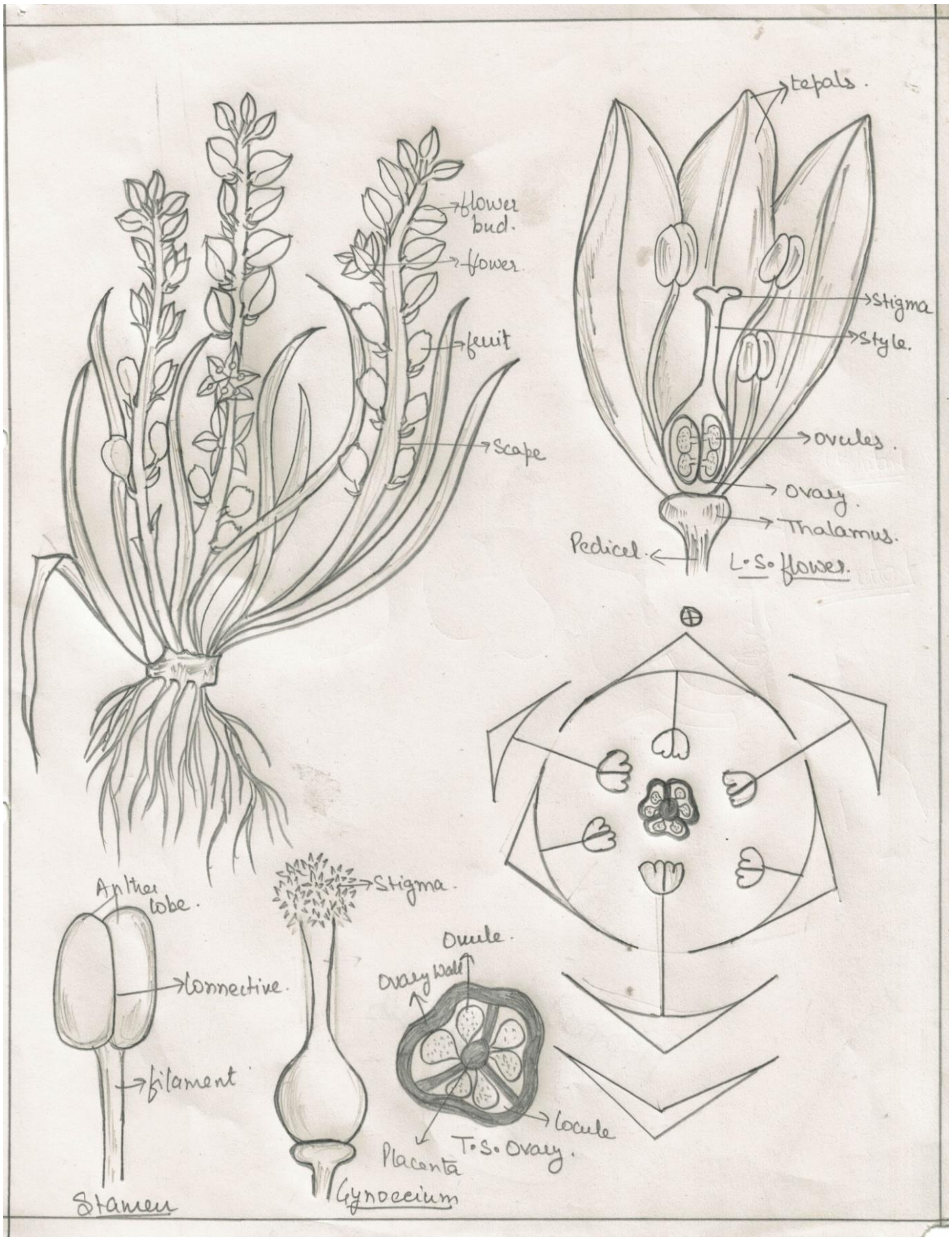
tepals.
flower bud.
flower.
fruit
Scape
Stigma
Style.
ovules.
ovary.
Thalamus.
Pedicel.
L.S. flower.
Anther lobe.
Connective.
filament
Stamen
Stigma.
Gynoecium
Ovule.
Ovary wall
locule
Placenta
T.S. ovary.

Fig. 16.20: ***Asphodelus tenuifolius***

14.3.20 Cyperaceae

Cyperus rotundus **Linn.**

Habit- A perennial herb.

Root- Adventitious roots.

Stem- Basal region rhizomatous bearing underground ovoid tubers, the aerial portion is erect, triangular, unbranched, solid, smooth, gren.

Leaf- Leaves crowded in the lower part of the stem, alternate with 1/3 phyllotaxy, exstipulate, entire, acute, glabrous, multicostate parallel.

Inflorescence- Spikelets are borne on branched inflorescence axis, subtended by leafy bracts.

Flower- Bracteate, bracts dry, greenish- brown and is known as glume. Sessile, incomplete.

Perianth – Absent.

Androecium- Stamens 3, polyandrous, filaments long, dithecous, basifixd, introrse.

Gynoecium- Tricarpellary, syncarpous, superior, unilocular, ovule one, palcentation basal, style one, stigmas 3 and feathery.

Fruit- Achene.

Floral formula- Br, ⊕, ⚥, $P_{0,}$ A_3, $\underline{G}_{(3).}$

Classification and identification

Class- ***Monocotyledonae***

1- Venation parallel.
2- Flowers trimerous.

Series- ***Glumaceae***

1- Flowers solitary, sessile in the axil of bract.
2- Perianth of scales or none.
3- Ovary usually unilocular and one ovuled.

Family - ***Cyperaceae***

1- Herbs with usually 3 angled stm and 3- ranked leaves with closed sheaths.
2- Flowers in spikelets, naked, hermaphrodite or unisexual.
3- Stamens 3 to 1.
4- Gynoecium 2-3 carpellary, syncarpous, superior, unilocular with one basal anatropous ovule.

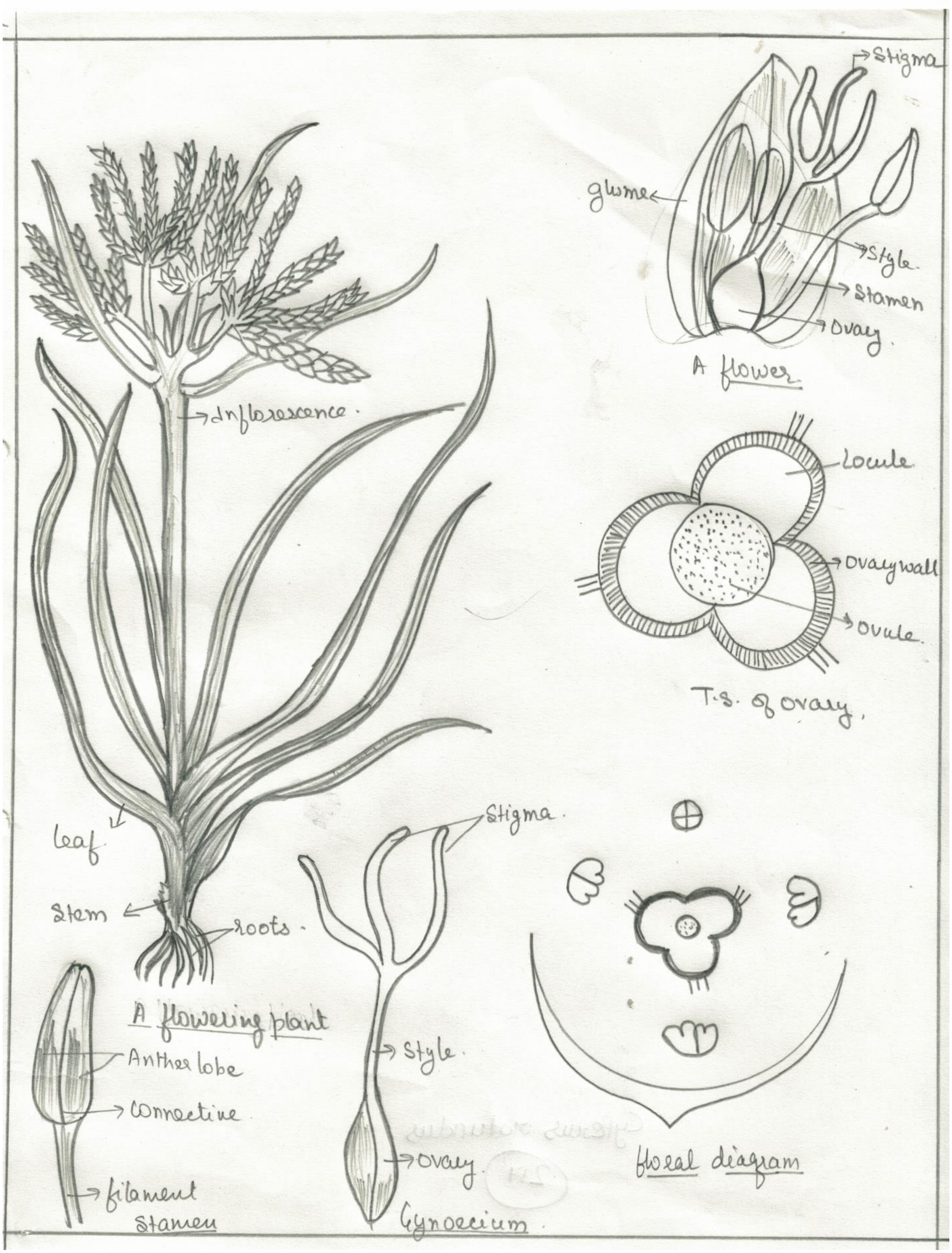

Fig. 14.21: ***Cyperus rotundus***

14.3.21 Poaceae (Gramineae)

***Triticum aestivum* Linn. (= *Triticum vulgare* Vill.)**

Habit- Herb.

Root- Adventitious, fibrous.

Stem- Herbaceous, aerial, erect, cylindrical, branched, branching is only at the basal region of the stem and is known as tillering, culm, smooth and green.

Leaf- Alternate, exstipulate, simple, sessile, leaf distinguished into a linear leaf blade and a leaf sheath, and at the junction of these two a small membranous ligule is present, lamina lanceolate, entire, acute, minutely hairy, multicostate parallel.

Inflorescence- Spike of spikelets. Each spikelet consisits of the following parts-

1- A pair of glumes present at the base, outer one is called the first glume and the inner one as second glume. These glume are barren.
2- After glume, is present lemma or inferior palea.
3- There is present superior palea or pale. The essential organs of flower lie between superior palea or lemma and inferior palea or pale.

Flower- Sessile, complete, zygomorphic, hermaphrodite, hypogynous and cyclic.

Perianth – Represented by 2 rudimentary free tepals known as lodicules.

Androecium- Stamens 3, polyandrous, filaments long, dithecous, versatile and introrse.

Gynoecium- Monocarpellary, ovary superior, unilocular, with one marginal ovule, style absent, stgma 2 and feathery.

Fruit- Capsule.

Floral formula- Br, ⊕, ⚥, $P_{2,}$ A_3, $\underline{G}_{1.}$

Classification and identification

Class- *Monocotyledonae*

1- Venation parallel.
2- Flowers trimerous.

Series- *Glumaceae*

1- Flowers solitary, sessile in the axil of bract.
2- Perianth of scales or none.
3- Ovary usually unilocular and one ovuled.

Family - *Poaceae*

1- Joined stems with alternate 2 ranked leaves with split sheath and ligule.
2- Inflorescence spilelet and each begins with one or two empty glumes then palea with axillary flowers.
3- Stamens usually three.
4- Gynoecium superior with one ovule.
5- Fruit caryopsis.

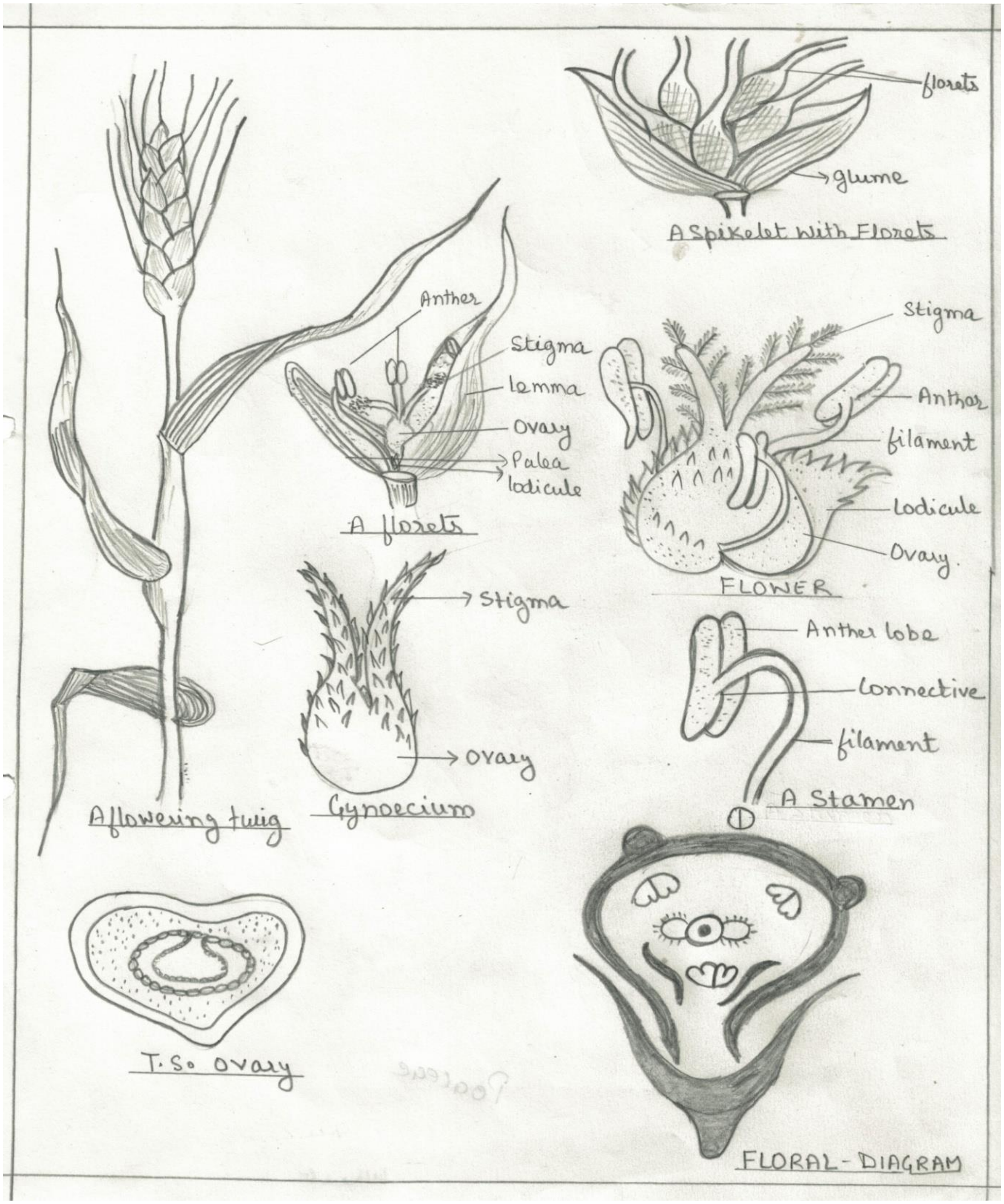

Fig. 14.22: ***Triticum aestivum***

14.4 SUMMARY

From above description, you now understand how the angiospermic plants are discribed. Plants are very carefully observed and appropriate technical terms are used for their description. Every organ has several alternative terms for each character. Alternative terms and illustrated terminology are important to describe plants.

14.5 GLOSSARY

Herb- A plant with soft stem.
Shrub- Woody plant.
Tree- Perennial woody plant with a single trunk.
Climber- Plant with thin and long stem.
Epiphyte- A palnt the grows upon other plant.
Ramal and cauline- The leaves which are borne by the main stem as well as branches.
Phyllotaxy- Arrangement of leaves Attente/opposite/whorled.
Exstipulate- Without stipules.
Stipulate- With stipules.
Petiolate- Petiole present.
Venation- Arrangement of veins in a leaf.
Coriaceous- Leaf is tough, thick, stiff, leather like.
Tepal- No defference between calyx and corolla.
Actinomorphic- Symmetrical in all direction.
Zygomorphic- Symmetrical in one direction.
Hermaphrodite- Male+female in one flower.
Receptacle- Top of the shalk of a flower.
Torus- Another name of receptacle.
Placenta- It is the margin of a carpel where the ovules remain attached.

14.6 SELF ASSESSMENT QUESTION

1- Write the silent features of the following:-

- a- Inflorescence of Euphorbiaceae.
- b- Flowers of Magnoliaceae.
- c- Spikelet of spike.
- d- Fruit of umbelliferae.
- e- Gynoecium of Cruciferace.
- f- Androceium in the Asclepidaceae.
- g- The primitive carpel.
- h- Floral morphology or Orchidaceae.
- i- Gynoecium of Rosaceae.
- j- Androceium of Cucurbitaceae.

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14.9 TERMINAL QUESTIONS

Q1- Explain the major defferences between tap root and adventitious root.

Q2- Name any two major characters of Polypetalae.

Q3- Name the type of fruit in the following:- *Citrus, Cucurbitaceae, Umbelliferae.*

Q4- Assigning to their respective families and point out features of morphological interest in the following: - *Ranunculus scleratus, Lathyrus aphaca.*

UNIT-15 PREPARE THE BRACKETED AND INDENTED KEYS AND TO PREPARE THE DENDROGRAMS FOR FAMILIES UNDER STUDY

15.1 OBJECTIVES

After reading this unit students will be able -

- To know the methods of plant identification
- To understand about the keys, its types
- To learn the methods for the preparation of keys.
- To know about dendrogram and its preparation

15.2 INTRODUCTION

This unit will provide information to the students about the identification, its methods for plants as “Identification is a basic activity and one of the primary objectives of systematic”. Identification is simply the determination of the similarities or differences between two elements, i.e., two elements are the same or they are different. The comparison of an unknown plant with a named specimen and the determination that the two elements are the same also involves classification, i.e., when one correctly decides that an unknown belongs to the same group (species, genus, family, etc.) as a known specimen, the information stored in classification systems becomes available and applicable to the material at hand. Both processes i.e., identification and classification involve comparison and judgment and require a definition of criteria of similarities. Identification is, therefore, a basic process in classification with nomenclature playing an essential role in the retrieval of information and as a means of communication.

The methods of identification include (1) expert determination, (2) recognition, (3) comparison, and (4) the use of keys and similar devices.

15.3 TAXONOMIC KEYS

A key is a device, which when properly constructed and used, enables a user to identify an organism. Keys are devices consisting of a series of contrasting or contradictory statements or propositions requiring the identifier to make comparisons and decisions based on statements in the key as related to the material to be identified. Thus, a taxonomic key is a device for quickly and easily identifying to which species an unknown plant belongs.

The key consists of a series of choices, based on observed features of the plant specimen. It provides a choice between two contradictory statements resulting in the acceptance of one and the rejection of the other.

A single pair of contradictory statements is called a couplet and each statement of a couplet is termed a lead. By making the correct choice at each level of the key, one can eventually arrive at the name of the unknown plant.

Suggestions for the Use of Taxonomic Keys

(a) Appropriate keys should be selected for the materials to be identified. The keys may be in a flora, manual, guide handbook, monograph, or revision. If the locality of an unknown plant is known, a flora, guide, or manual treating the plants of that geographic area may be selected.
(b) The introductory comments on format details, abbreviations, etc. should be read before using the key.
(c) Both the leads of a couplet should be read before making a choice. Even though the first lead may seem to describe the unknown material, the second lead may be even more appropriate.
(d) A glossary should be used to check the meaning of terms, which one does not understand.
(e) Several similar structures should be measured, when measurements are used in the key, e.g. several leaves and not a single leaf should be measured. No decision should be made on a single observation. Rather it is often desirable to examine several specimens.
(f) The results should be verified by reading a description, comparing the specimen with an illustration or an authentically named herbarium specimen.

Suggestion for Construction of Taxonomic Keys

(a) Constant characteristics rather than variable ones should be used.
(b) Proper measurements rather than terms like "**large**" and "**small**" should be used.
(c) Characteristics that are generally available to the user of the key rather than seasonal characteristics or those seen only in the field should be used.
(d) A positive choice should be made. The term "**is**" instead of "**is not**" should be used.
(e) If possible one should start both choices of a pair with the same word.
(f) If possible, different pairs of choices should be started with different words.
(g) The descriptive terms should be preceded with the name of the part to which they apply.

15.3.1 Types of Taxonomic Keys

There are two types of keys:
1-Dichotomous
2- Poly clave (also called Multiple Access or Synoptic).

1- Dichotomous Keys: Keys in which the choices allow only two (mutually exclusive) alternative couplets are known as dichotomous keys. In constructing a key, contrasting characters are chosen that divide the full set of possible species into smaller and smaller groups i.e. the statements typically begin with broad characteristics and become narrower as more choices are required.

Each time a choice is made, a number of species are eliminated from consideration and the range of possible species to which the unknown specimen may belong is narrowed. Eventually, after sufficient choices have been made, their range reduces to a single species and the identity of the unknown plant is revealed. Dichotomous comes from the Greek root dich meaning "**two**" and temnein meaning "**to cut**".

Couplets can be organized in several forms. The couplets can be presented using numbers (numeric) or using letters (alphabetical). The couplets can be presented together or grouped by relationships. There is no apparent uniformity in presentation of dichotomous keys.

(a) Types of Dichotomous Keys

There are two types of dichotomous keys. They differ in the method by which the couplets are organized and how the user is directed to successive choices.

Example of a numerical key with couplets
1. Seeds round—soybeans 1. Seeds oblong go to—2 2. Seeds white—northern beans 2. Seeds black—black beans
Example of an alphabetical key with same couplets

A. Seeds oblong go to—B
    B. Seeds white—northern beans
    B. Seeds black—black beans
A. Seeds round—soybeans

(*Courtesy:* Constructing a Dichotomous Key, Theodore M. Sperry Herbarium, Department of Biology, Pittsburg State University, Pittsburg, Kansas 66762)

(i) Indented Keys (also called yoked): Indents the choices (leads) of the couplet an equal distance from the left margin. The two choices of the couplet are usually labelled 1 and 1′ or la and lb. It is not necessary that the choices are numbered, but it helps. The user goes to the next indented couplet following the lead that was selected.

(ii) Bracketed Keys: Provides both choices side-by-side. The choices of the couplet must be numbered (or lettered). It is very helpful if the previous couplet is given. This key has exactly the same choices as the first example. The choices are separated, but it is easy to see the relationships. While this key might be more difficult to construct, it gives more information to the user.

2-Poly Clave Keys: Another type of key, which is relatively a new alternative to dichotomous keys and becoming increasingly popular, especially because of the ease of computerizing them, is termed multiple access or poly clave or synoptic key. The advantage of these keys is that they allow the user to enter the key at any point.

15.3.2. Instructions for Construction of Keys

The students will be aware of how the keys must be prepared if they collect data of the plants:

1. Identify all groups to be included in a key.
2. Prepare a description of each taxon.
3. Select "key characters" with contrasting character states. Use macroscopic, morphological characters and constant character states when possible. Avoid characteristics that can only be seen in the field or on specially prepared specimens, i.e., use those characteristics that are generally available to the user.
4. Prepare a Comparison Chart.
5. Construct strictly dichotomous keys.
6. Use parallel construction and comparative terminology in each lead of a couple.
7. Use at least two characters per lead when possible.
8. Follow key format.
9. Start both leads of a couple with the same word if at all possible and successive leads with different words.
10. Mention the name of the plant part before descriptive phrases, e.g., leaves or flowers blue not blue flowers, leaves alternate not alternate leaves.
11. Place those groups with numerous variable character states in a key several times when necessary.
12. Construct separate keys for dioecious plants, for flowering or fruiting materials and for vegetative materials when pertinent.

15.3.3. Data Analysis and Preparation the Dendrograms

The genetic data generated using various analytical techniques can be analyzed using either specific statistical methods or combination of methods. The choice of statistical method to be used is dependent on the achievable objectives laid out in the studies. The data often involve numerical measurement and in many cases, combinations of different types of variables. Base on the number of variables used data analysis can be viewed from two methods namely:

1-Univariate

2- Multivariate

1-Univariate Methods: Univariate analysis involves the examination across cases of one variable at a time. The analysis of this type of data can discussed from the distribution, the central tendency and dispersion.

2-Multivariate Methods: With increases in the sample size of germplasm accession used in crop improvement programs, classification and to create order in genetic variability assuming considerable significance. The use of established multivariate statistical algorithms is an important strategy for classifying germplasm, ordering variability for a large number of accessions, or analyzing genetic relationships among breeding materials.

Cluster Analysis: Cluster analysis refers to "a group of multivariate techniques whose primary purpose is to group individuals or objects based on the characteristics they possess, so that individuals with similar descriptions are mathematically gathered into the same cluster" (Hair et al., 1995). The resulting clusters of individuals should then exhibit high internal (within cluster) homogeneity and high external heterogeneity. Distance-based clustering methods can be categorized into two groups: Hierarchical and Nonhierarchical. Hierarchical clustering methods are more commonly employed in analysis of genetic diversity in crop species.

Dendrogram: The resulting cluster of individuals should then exhibit high internal (within cluster) homogeneity and high external (between cluster) homogeneity. Thus, if the classification is successful, individuals within a cluster shall be closer when plotted geometrically and different clusters shall be farther apart. A dendrogram is represented by its clusters.

Based on the data type used, different types of dendrograms are produced.
They include-

- Phenograms
- Cladograms
- Phylograms

15.4 PREPARE THE BRACKETED AND INDENTED KEYS AND PREPARE THE DENDROGRAMS FOR FAMILIES UNDER STUDY

15.4.1 Prepare the Bracketed and Indented Keys

Students will be acquainted with the keys of some of the important families by knowing the distinct morphological data:

1. Prepare the indented key to the species belonging to the Ranunculaceae
Key to the genera:

I. carpel 1 ovuled, fruits achene

1. Leaves opposite, compound, plants are usually climbing
   - i. Sepals 4, petaloid, petals and tendril absent……..*Clematis*
   - ii. Sepals as many as petals-4 or, 5, third or, terminal leaflet modified into tendril …………………………..*Naravelia*
2. Leaves alternate or radical, plants are usually herbs.
   - i. Sepals petaloid, petals absent, flowers involucrate……..*Anemone*

ii. Sepals petaloid, petals absent, flowers non-involcrate ….*Thalictrum*
iii. Sepals 3-5, deciduous, petals 5…….. *Ranunculus*

II. Carpels many ovuled, fruit follicles,
1. Leaves alternate or radical, plants are usually herbs
i. Carpels united at the base, flowers regular.
- Sepals petaloid and as many as petals, 5 petals long, clawed and bifid, leaves bi-pinnate….. *Nigella*

ii. Carpels free, flowers irregular.
- Sepals 5,yellow or, white, posterior one helmet- shaped, leaves palmatipartite or seldom entire, plants usually twining……*Aconitum*
- Sepals 5, purplish or pale blue,dorsal members spurred like those of petals, leaves palmately lobed, plants erect……..*Delphinium*

2. Prepare the indented key to the species belonging to the Magnoliaceae
Key to the genera:
1. Flowers terminal; gynoecium sessile………………..*Magnolia*
2. Flowers axillary; gynoecium stipulate…………………*Michelia*

3. Prepare the indented key to the species belonging to the Rosaceae
Key to the genera:
1. Ovary superior; the ripe carpals not enclosed within the calyx tube.
2. Carpel 1, style terminal:
3. Petals large……………….*Prunus*
3. Petals minute or 0 ………..*Pygeum*
2. Carpels 5 or more. Style subterminal:
4. Prickly shrubs. Fruit succulent……. *Rubus*
4. Unarmed shrubs. Fruit dry, indehiscent…..*Spiraea*
1. Ovary inferior; carpels connate and adnate
To the calyx tube. Fruit a pome…. *Pyrus*

4. Prepare the indented key to the species belonging to the *Prunus*
Key to species:
1. Leaves conduplicate in bud. Flowers subsessile.
Drupe usually pubescent stone bony, rugged:
2. Pericarp2-valved…. *P. amygdalus*
2. Pericarp indehiscent…………..*P. persica*
1. Leaves convolute in bud. Flower sessile or peduncle.
Drupe large, indehiscent downy; stone bony,
Smooth…………………………… *P. armeniaca*

1. Leaves conduplicate in bud. Flowers solitary,
   Fascicled, umbelled or corymbose. Calyx tube short or long. Drupe glabrous, not glaucous:
   3. Flowers solitary, fascicled or umbelled:
      4. Flowers appearing with the leaves:
         5. Roots without suckers…… *P. avium*
         5. Roots with many suckers……. *P. cerasus*
      4. Flowers appearing before the leaves……. *P. puddum*
   3. Flowers in corymbose racemes, fragrant…………… *P. mahaleb*
1. Leaves conduplicate in bud. Flowers in axillary or terminal,
   Many flowered racemes. Calyx tube short, obconic:
   6. Drupe glaucous or not:
      Drupe glabose, stone rugose. Flowers
      0.6-1.25 cm in dia. Stamens 30-40……………..*P. padus*
   7. Drupe ovoid, stone smooth. Flowers 0.5 cm diameter
      Stamens 15-20……………… *P. undulate*

5. Prepare the indented key to the species belonging to the Cruciferae (Brassicaceae):

Key to the genera:

I. Fruit Dehiscent

1. Pod short, cylindrical, seeds minute, biseriate, sepals spreading, stigma shortly divided, flowers yellow…… *Rorippa*
2. Pod short, flattened, acute, unnerved, seeds uniseriate; sepals erect; flowers white……………………………. *Cardamine*
3. Pod with indehiscent beak; cotyledons incumbent or folded
   i. Beak cylindrical or conical ; seeds uniseriate; sepals yellow, pouched at the base and marked with green veins……………………………………*Brassica*
   ii. Beak flattened; seeds biseriate; sepals lilac, produced at the base……. …………………… *Eruca*

II. Fruit indehiscent

1. Pod long, hollow or septate, breaking into 1 seeded fragments; seeds globose; sepals pouched at the base…… *Raphanus*
2. Pod short, globose; sepals spreading, not pouched at the base……………………………………………….*Senebiera*

6. Prepare the indented key to the species belonging to the Malvaceae:

Key to Genera:

1. Fruit capsular
   i. Stigma spreading and seeds reniform.

A. Ovary 3 celled ………………… *Kydia*

B. Ovary 5 celled…………………..*Hibiscus*

ii. Stigma cohering in club shaped mass.

Bracteoles (Epicalyx) 3, large, cordate; seeds cottony.… ……………………………………………………*Thespesia*

2. Fruit of ripe carpels separating from the axis

i. Styles as many as carpels

A. Epicalyx absent, without false septum.

a) Ovules 2 or more, ascending, reniform….. *Abutilon*

b) Ovules solitary; flowers small……………….*Sida*

B. Epicalyx 3 distinct bracteoles.

a) Stigma capitates; carpels 8 -12 ………… *Malvastrum*

b) Stigmas linear, carpels numerous …………*Malva*

C. Epicalyx of 6-9 bracteoles, united at the base….*Althaea*

ii. Styles twice as many as carpels

A. Epicalyx present; carpels 10 …………..*Malvaviscus*

B. Bracteoles 0 or mixed with flowers in dense heads; carpels unarmed…………………………… *Malachra*

C. Bracteoles 5; carpels opposite to petals…. *Urena*

D. Bracteoles 10; carpels opposite to sepals…. *Pavonia*

7. Prepare the indented key to the species belonging to Cucurbitaceae:

Key to Genera:

I. Anther-cells ‘S’ shaped or folded, corolla rotate or campanulate, divided or nearly so into 5 petals above:

1. Tendril divided.

i. Flowers white; petals fimbriated at the margin; seeds many………………………*Trichosanthes*

ii. Flowers large, white; petals entire; anthers included; petiole with 2 glands………………….. *Lagenaria*

iii. Flowers pale yellowish white; petals fimbriated; seeds many………………………………… *Hodgsonia*

Stamens inserted at the mouth of the calyx-tube; anthers free; flowers yellow:

a) Fruit dry, angled or ribbed, rarely smooth; endocarp fibrous, opening by special lid; male flowers borne in raceme……………………………………………..*Luffa*

b) Fruit fleshy, soft, indehiscent; male and female flowers both solitary……………………………………………… *Benincasa*

Stamens inserted below the mouth of the calyx tube

a) Male and female flowers large, yellow, solitary; corolla divided half way down, ovate- obtuse; anthers scarcely connate…. *Citrullus*

b) Male and female flowers solitary, yellow, large, corolla lobes short, triangular; anthers connate………… *Cucurbita*

2. Tendril simple.

   i. Leaves cordate; male flowers subraceme; calyx with 2-3 scales; fruit tuberculated, spinous…………….. *Momordica*

   ii. Leaves lobed; male flowers clustered; calyx without scales; fruit large, smooth, edible; connective protruding beyond the anther cells…………………… *Cucumis*

   iii. Leaves palmately lobed; flowers white; fruit a smooth cylindric berry…………………………….. *Coccinia*

   iv. Leaves toothed, angled or deeply lobed; flowers yellow; plants simple…………… *Zehneria*

II. Anther cells straight or somewhat curved. Male and female flowers clustered, small, yellow:

1. Tendril simple ………………………………………….. *Mukia*
2. Tendril divided………………………………………… *Bryonia*

8. Prepare the Indented Key to the Genera Belonging to the Family Euphorbiaceae

Key to the genera:

1. Flowers contained in a bowl shaped structure,

    2. No calyx or corolla………………………*Euphorbia*

1. Flowers with a distinct calyx and conspicuous

    2. Red corolla ……………………….*Jatropha*

9. Prepare the indented key to the species belonging to the Genus *Jatropha*

Key to the species:

1. Trees, stem irregular, leaves cordate
   To palmately 5 lobed…………………*J. curcus*
1. Shrubs
    2. Stem much swollen at the base…………..*J. podagrica*
    2. Stem not swollen at the base
        3. Leaves entire, fiddle shaped……. *J. panduraefolia*
        3. Leaves lobed:
            4. Lobes 5; petiole, leaves and stipules
               Glandular………*J. gossypifolia*
            4. Lobes 5-11; leaves etc not glandular *J. multifida*

10. Prepare the indented key to the species belonging to the *Rhododendron*

Key to the species:

1a. Flowers in shades of red………………….2

2a. Flowers blood red, leaves oblong ovate, leathery and thick matty texture……………………………….*R. sikkimense*

2b. Flowers crimson red, leaves broad, oval to elliptical oblong, shiny green above ………………….*R. fulgens*

1b. Flowers in shades of rose pink…………….

3a. Calyx obscure, 1-2 mm long, leaf under surface covered with tufts of brown hair…………… *R. wallichii*

3b. Calyx obscure, 1-2 mm long, leaf under surface covered with continuous indumentum…………….

4a. Corolla in shades of deep rose pink flushed externally with red-purple, young leaves aeruginose, leaf margins inrolled………… *R. aeruginosum*

4b. Corolla pale lavender blue, mauve or rose purple, rarely white, young leaves not aeruginose, leaf margins not inrolled…….. *R. campanulatum*

11. Preparation of bracketed key on *Rhododendron*

1a. Flowers in shades of red………………….2

1b. Flowers in shades of rose pink…………….3

2a. Flowers blood red, leaves oblong ovate, leathery and thick matty texture……………………………….*R. sikkimense*

2b. Flowers crimson red, leaves broad, oval to elliptical oblong, shiny green above ………………….*R. fulgens*

3a. Calyx obscure, 1-2 mm long, leaf under surface covered with tufts of brown hair…………… *R. wallichii*

3b.Calyx obscure, 1-2 mm long, leaf under surface covered with continuous indumentum…………….4

4a. corolla in shades of deep rose pink flushed externally with red-purple, young leaves aeruginose, leaf margins inrolled………… *R. aeruginosum*

4b. Corolla pale lavender blue, mauve or rose purple, rarely white, young leaves not aeruginose, leaf margins not inrolled…….. *R. campanulatum*

12. Prepare the bracketed key to the Genera belonging to the Gramineae (Poaceae)

Key to the Genera:

I. Herbs, flowers not dioecious:

1. Spiklets 2 flowered , upper bisexual, lower male or neuter

i. Mature spikelets surrounded by an involucres of bristles which fall off along with spikelets ……………………………….. *Pennisetum*

ii. Spikelets subtended by an involucres of bristles…………… *Setaria*.

iii. Spiklets not subtended by bristles; large grass stem solid; leaves broad, flat………………………………………………….. *Thysanolaena*

iv. Slender grasses, stem creeping below, branching; leaves ovate- lanceolate, thin, flat; ligules a ridge of long hairs… *Oplismenus*

v. Annual or perennial grasses; leaves broad or narrow , flat, or rarely plicate; ligules 0 or hairy; glumes II not fimbricate, glume III with a palea or quite empty ……… ……………………………*Panicum*

vi. Annual or perennial grasses; flowers in digitate spikes; lowest glume minute but usually present; glume III with a minute papea…………………………………………… *Digitaria*

2. Spiklets 1- flowered

i. Spikelets articulated on their pedicels and deciduous from them

a) Glumes I, II minute ……………………………….. *Oryza*

b) Floating grass, diffusely branched, rooting in dense masses at the nodes; glumes I and II absent ……………………………. *Hygroryza*

ii. Spiklets usually in pairs:

a)Spikelets all similar:

Racemes of spikelets in compound panicles

Panicle spiciform, silky, rachis tough; erect perennial grasses, stem leafy, internode solid, leaves narrow……………………….. *Imperata*

Panicle much branched, silky, rachis fragile, spikelets awnless; tall perennial grasses……………………………. …………..*Saccharum*

b)Spikelets dissimilar

Spikelets in alternating pairs or the lower solitary-

Sessile spikelets usually many, inflorescence long………………. ……………………………………………………….*Andropogon*

iii. Male and female spikelets in different spik*es*-

a) Fruiting spikelets crowed on a spongy rachis, the grain exposed; a tall annual cultivated grass…………………………………………*Zea*

b) Fruiting spikelets enclosed in the stony polished nut like bract……….. *Coix*

3. Spikelets 2- or more flowered ; annual or perennial cultivated grasses; leaves flat; spikelets with twisted awns………………….. ………………………………*Avena*

4. Spikelets 3-7 flowered , in decompounds panicles; tall perennial grasses with long leaves……………………………………………………………….. *Phragmates*

5. Spikelets many flowered, not pedicellate, with long silky hairs; outer glumes shorter than the lowest flowering glume; grain very minute; annual or perennial glabrous grasses, stem erect , leaves narrow ………………………….. *Eragrostis*

6. Spikelets 2-seriate and secured-

Spikelets not clustered, 1- flowered, awnless, spikes digitate; perennial creeping grasses, leaves narrow, flat ……………………………………………. *Cynodon*

7. Spikelets 3-12 flowered in numerous digitate or whorled spikes……. *Eleusine*

8. Spikelets inserted in notches or pits of a simple rachis

i. Spikelets solitary at nodes of the spikes; plant of spikelets tangential to the rachis; annual or biennial cultivated grass ………………… *Triticum*

ii. Spikelets 2 or more collected in fascicles at the nodes of the spikes; an annual cultivated grass…………………………………….. *Hordeum*

II. Shrubs or trees, rarely climbing ; stem sheaths broad, blade often triangular; leaves short-petioled

1. Pericarp crustaceous, not adnate to seed ………………………*Dendrocalamus*
2. Pericarp thin, adnate to seed………………………………….. *Bambusa*

15.4.2 Preparation of Dendrogram of the Given Data

A dendrogram is a graphical representation of hierarchical clusters, which are usually generated through a mathematical process, such as cluster analysis. The main objective of a dendrom is to display the relationships among distinct units by grouping them into smaller clusters. Dendrograms are created by computers programs such as Microsoft Excel, but anyone can create one from a list of related items.

Making a Dendrogram

1. Hierchical cluster analysis (as we've been doing here) can be portrayed graphically by a dendrogram, which represents the clustering process in a tree-like graph.
2. One axis will (usually) represent an agglomeration coefficient. This depends on the clustering algorithm used, but is usually the distance between clusters joined at each stage.
3. Along the other axis individual cases will be plotted giving a visualization of the relative size of each of the clusters.
4. The next step in this is to determine the number of clusters we want to work with. How many clusters are there?
5. Suppose we wish to cluster the bivariate data shown in the following scatter plot. In this case, the clustering may be done visually. The data have three clusters and two sinsingletons, 6 and 13.

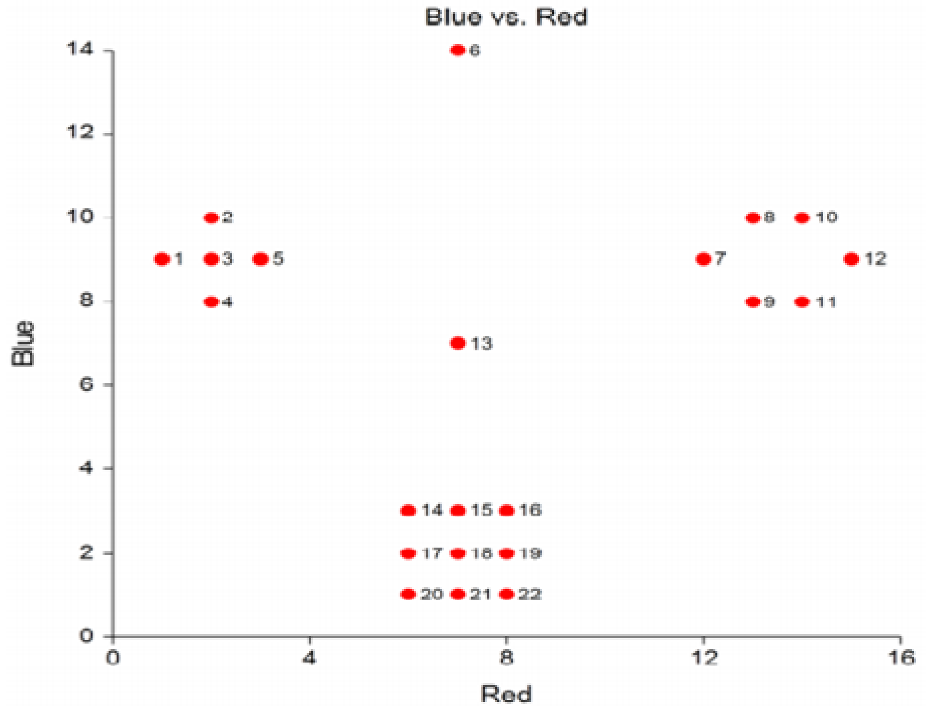

Fig.15.1: Hierchical cluster analysis of Data of Blue and Red Colour (Clusters are shown in Red colour dots)

6. Following is a dendrogram of the results of running these data through the Group Average clustering algorithm.

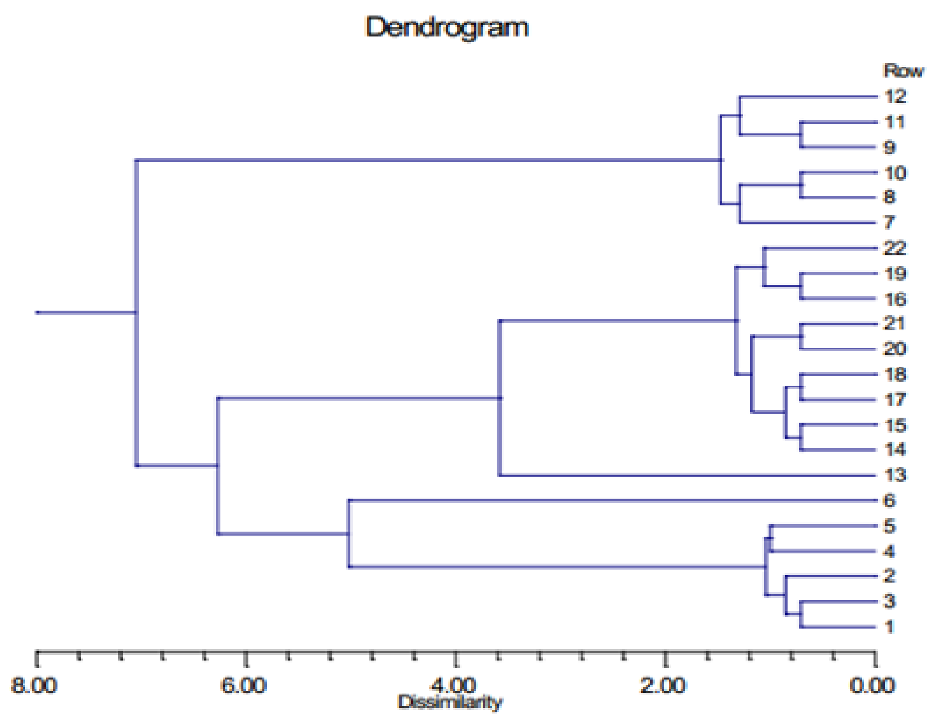

Fig.15.2: Dendrogram of the results of running above data (Figure 1) through the Group Average clustering algorithm.

9. Our main interest is in similarity and clustering. Each joining (fusion) of two clusters is represented on the graph by the splitting of a horizontal line into two horizontal lines. The horizontal position of the split, shown by the short vertical bar, gives the distance (dissimilarity) between the two clusters.
10. Looking at this dendrogram, we can see the three clusters as three branches that occur at about the same horizontal distance. The two outliers, 6 and 13, are fused in rather arbitrarily at much higher distances. This is the interpretation.

Exercise: Prepare a dendrogram of the following data on Cluster analysis with 10 data points and write its interpretations.

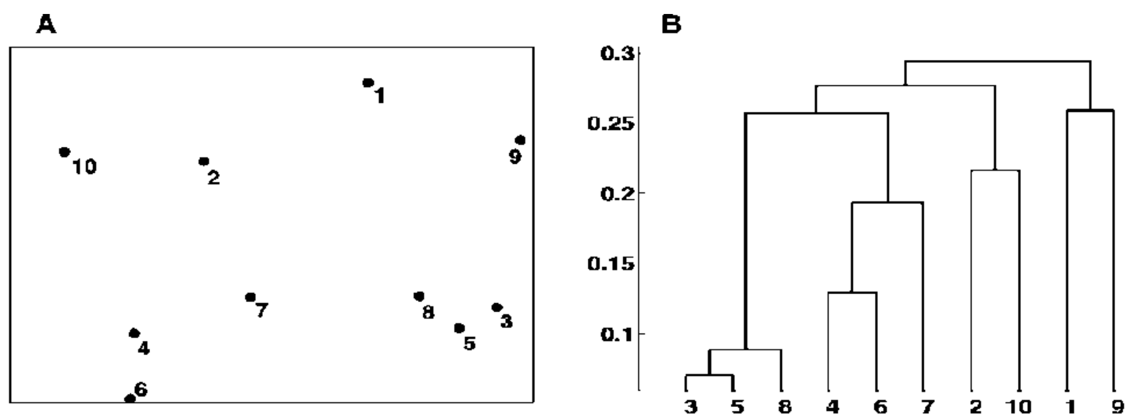

Fig.15.3: A. Data of Hierchical cluster analysis; B. Dendrogram of the Data Presented in (A)

15.5 SUMMARY

From the above description, the students now understand the importance of identification, its types. One of the methods is preparation of keys which uses a series of contrasting or contradictory statements or propositions requiring the identifier to make comparisons and decisions based on statements. Teachers must provide students with the best dichotomous keys for their level of experience. Thus, a taxonomic key is a device for quickly and easily identifying to which species an unknown plant belongs. For establishing the similarities and differences among the collected data cluster analysis is used, which will be represented in a graphical manner by using dendrogram.

15.6 GLOSSARY

Axillary: on or related to the axis.
Bipinnately compound: twice compound
Compound: made up of two or more parts.

Corolla: all the petals together

Cyme – A more or less flat-topped determinate inflorescence whose outer flowers open last, e.g. *Sambucus*, elderberry

Dioecious – Having unisexual flowers, each sex confined to a separate plant, said of species

Follicle – A dry dehiscent fruit opening only along one suture and the product of a single carpel (simple ovary), e.g.*Paeonia*, peony, *Aquilegia*, columbine, *Asclepia*, milkweed.

Glabrous – Not hairy.

Glandular – Bearing glands.

Glaucous – Covered with a waxy bloom or whitish material that rubs off readily, e.g. the bloom on many sorts of grape.

Head: a short, dense cluster of sessile flowers

Inflorescence: the mode of arrangement of flowers.

Irregular flower: longitudinally divisible into two equal halves

Monoecious – A species with unisexual flowers, having both male and female flowers on the same plant, e.g. corn

Panicle: compound inflorescence; branched raceme.

Pedicel: stalk of a flower or flower cluster

Petiole: stalk of a leaf

Pinnately compound: leaf with a central stalk in which leaflets arise

Raceme: elongated inflorescence with pedicellate flowers.

Rachilla – A diminutive or secondary axis; a branch of a rachis; the minute axis bearing the individual florets in grass and sedge spikelets; the secondary axes of decompound fern fronds.

Rachis – Axis-bearing leaflets or the primary axis of an inflorescence; the axis bearing pinnae of a fern frond.

Regular flower: symmetrical in shape.

Spike: elongated inflorescence with stalkless (sessile) flowers.

Trifoliate leaf: a compound leaf consisting of three leaflets.

Umbel: a flat-topped or rounded inflorescence in which the pedicels arise from a common point.

15.7 SELF ASSESSMENT QUESTIONS

Q.1. What do you understand by Identification?

Q.2. Name different methods of identification of plants.

Q.3. What do you understand by keys?

Q.4. What is the important of identification.

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15.10 TERMINAL QUESTIONS

Q.1. Define the term identification with its significance.
Q.2. Discuss in brief different methods of plant identification.
Q.3.What is key? Describe its types by using the suitable examples.
Q.4. Discuss about the dendrogram and its importance in taxonomy.