BIOLOGY AND DIVERSITY OF VIRUSES, BACTERIA, ALGAE, AND FUNGI AND OUTLINES OF BRYOPHYTES, PTERIDOPHYTES GYMNOSPERMS AND PLANT FOSSILS

PRACTICAL-II

M.Sc. BOTANY

SEMESTER-I, PAPER-VI

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FOREWORD

Since its establishment in 1976, Acharya Nagarjuna University has been forging ahead in the path of progress and dynamism, offering a variety of courses and research contributions. I am extremely happy that by gaining 'A+' grade from the NAAC in the year 2024, Acharya Nagarjuna University is offering educational opportunities at the UG, PG levels apart from research degrees to students from over 221 affiliated colleges spread over the two districts of Guntur and Prakasam.

The University has also started the Centre for Distance Education in 2003-04 with the aim of taking higher education to the door step of all the sectors of the society. The centre will be a great help to those who cannot join in colleges, those who cannot afford the exorbitant fees as regular students, and even to housewives desirous of pursuing higher studies. Acharya Nagarjuna University has started offering B.Sc., B.A., B.B.A., and B.Com courses at the Degree level and M.A., M.Com., M.Sc., M.B.A., and L.L.M., courses at the PG level from the academic year 2003-2004 onwards.

To facilitate easier understanding by students studying through the distance mode, these self-instruction materials have been prepared by eminent and experienced teachers. The lessons have been drafted with great care and expertise in the stipulated time by these teachers. Constructive ideas and scholarly suggestions are welcome from students and teachers involved respectively. Such ideas will be incorporated for the greater efficacy of this distance mode of education. For clarification of doubts and feedback, weekly classes and contact classes will be arranged at the UG and PG levels respectively.

It is my aim that students getting higher education through the Centre for Distance Education should improve their qualification, have better employment opportunities and in turn be part of country's progress. It is my fond desire that in the years to come, the Centre for Distance Education will go from strength to strength in the form of new courses and by catering to larger number of people. My congratulations to all the Directors, Academic Coordinators, Editors and Lesson-writers of the Centre who have helped in these endeavors.

Prof. K. Gangadhara Rao
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M.Sc. BOTANY

SEMESTER-I, PAPER-VI

106BO24 - BIOLOGY AND DIVERSITY OF VIRUSES, BACTERIA, ALGAE, AND FUNGI AND OUTLINES OF BRYOPHYTES, PTERIDOPHYTES GYMNOSPERMS AND PLANT FOSSILS

PRATICAL-II

SYLLABUS

Diversity of Bacteria Virus Algae and Fungi - Laboratory Exercises:

1) To study bacteria by using Gram's staining method.
2) Demonstration of the presence of nitrogen fixing organisms (Rhizobium sp.) and their isolation from root nodules of legumes.
3) Learning the methods of sterilization, media preparation and inoculation techniques of bacteria
4) Algal collection from different habitats and their identification.
5) Morphological and reproductive stages of some genera of Cyanophyta, Chlorophyta, Xanthophyta, Pheophyta and Rhodophyta.
6) Morphological studies and identification of the fungi through temporary and permanent mounts as mentioned in syllabus.

Biology and Diversity of Bryophytes and Pteridophytes: Laboratory Exercises:

1) Study of morphological and anatomical details of vegetative and reproductive structures of the Bryophytes as mentioned in the syllabus through specimens, temporary and permanent slides.
2) Study of morphological and anatomical details of vegetative and reproductive structures of the Pteridophytes as mentioned in the syllabus through specimens, temporary and permanent slides.
3) Study of important fossil Pteridophytes from permanent slides.
4) Study of morphology and anatomy of vegetative and reproductive parts of different genera as mentioned in theory syllabus.
5) Prepare the permanent slides to study the anatomical details of different Gymnospermic woods.
6) Study of important fossil Gymnosperms with the help of permanent slides.

CONTENTS

BIOLOGY AND DIVERSITY OF VIRUSES, BACTERIA, ALGAE AND FUNGI

BACTERIA:

EXPERIMENT: 1 GRAM STAINING OF BACTERIA

Aim: To differentiate Gram-positive and Gram-negative bacteria by differential Gram staining technique.

Requirements: 24hr.-oldcultures of *Bacillussubtilis* and *Escherichiacoli*, Crystal violet stain, Gram's iodine solution, Ethyl alcohol, Safranin, Wash bottle, Inoculatingloop, Glass slides, Blotting paper, Spirit lamp, Microscope.

Principle: The chemical and physical differences in cell walls of the bacteria respond differentially to the Gram stain in either retaining the primary stain (as in Gram-positive bacteria) or lose the primary stain and stained with counter stain (as in Gram-negative bacteria).

Procedure:

1) Make thin smears of *Bacillus subtilis* and *Escherichia coli* on separate glass slides.
2) Air-dry and heat fix the smears on the flame of spiritlamp.
3) Floodthesmearwithcrystalvioletstainfor30seconds.
4) Wash the smear with distilled water for few seconds.
5) Flood the smear with Gram's iodine solution for 30 seconds.
6) Wash-off the iodine solution from the smear with 95% ethyl alcohol. During this step, add ethyl alcohol drop by drop keeping the slide in slant position until no more color of stain flows from the smear.
7) Wash the slides with distilled water and drain.
8) Apply the counter stain, safranin to the smear for 30seconds.
9) Then, wash the smea rwith distilled water and blot-dry with absorbent paper.
10) 10. Observe the preparation through microscope under oil-immersion objective.

Result: Bacteria that appear purple are referred to as Gram-positive and those appear pink are described as Gram-negative.

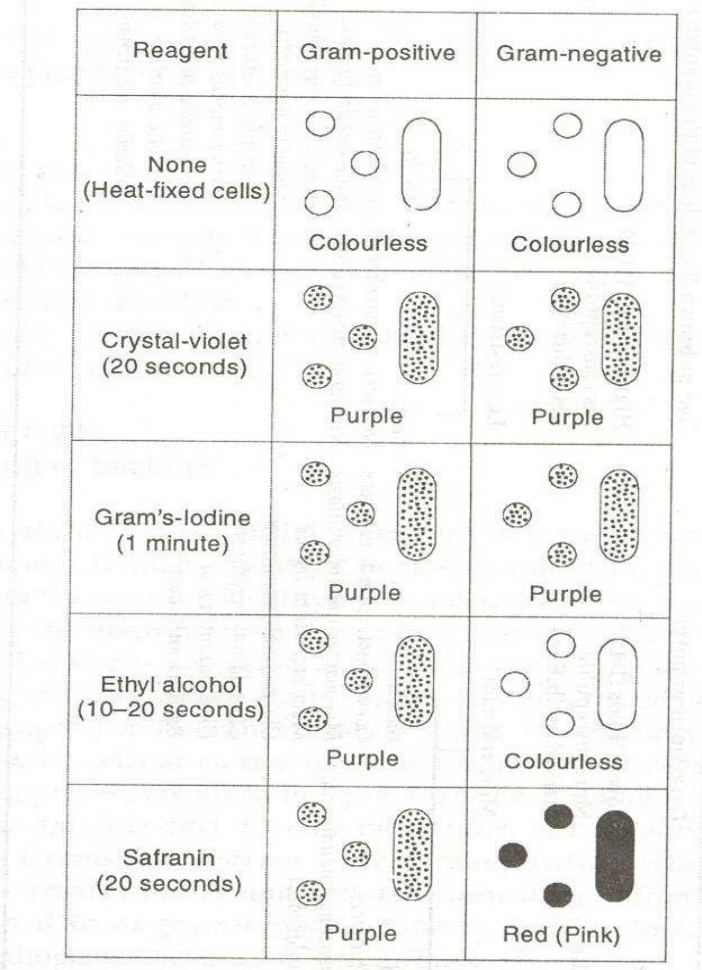

Fig. 1 Gram's Staining Procedure

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EXPERIMENT 2: PREPARATION OF NUTRIENT AGAR MEDIUM FOR BACTERIA

Aim: To prepare the Nutrient agar medium in Petri plates for the isolation of bacteria.

Materials Required:

Chemicals of Nutrient agar medium, Petri plates, Conical flask, Autoclave, Hot air oven, Laminar air flow chamber, etc.

Composition of Nutrient Agarmedium

Peptone - 5.0 g

Beef extract - 3.0 g

NaCl - 5.0 g

Agar agar - 20.0 g

Distilled water -1000ml

Procedure:

1) Weigh the medium ingredients as per the composition and dissolve them in distilled water in a conical flask.
2) Sterilize the medium in an autoclave at 121°C for 15 lbs pressure for 15 minutes.
3) Sterilize the clean and dry Petri plates in Hot-air oven at 160^{o} C temperature for 2 hours.
4) Then, transfer the sterilized Petri plates to the Laminar air flow chamber.
5) Cool the sterilized medium to molten state of temperature around 42^{o} C.
6) Pour about 20 ml aliquots of the molten state sterilized Nutrient agar medium into each Petri plate in Laminar air flow chamber and allow the medium to solidify.
7) After the complete solidification of the medium, store the Petri plates in invert position until further use.

***

EXPERIMENT 3: PREPARATION OF CZAPEK-DOX AGAR MEDIUM FOR FUNGI

Aim: To prepare the Czapek-Dox agar medium in Petri plates for the isolation of fungi.

Materials Required:

Chemicals of Czapek-Dox medium, Petri plates, Conical flask, Autoclave, Hot air oven, Laminar air flow chamber, etc.

Composition of Czapek-Dox Agar Medium:

Sucrose	- 30 gm
Sodium nitrate ($NaNO_3$)	- 2 gm
Dipotassium hydrogen phosphate (K_2HPO_4)	- 1 gm
Magnesium sulfate ($MgSO_4$)	- 0.5 gm
Potassium chloride (KCl)	- 0.5 gm
$FeSO_4$	- 0.01 gm
Agar agar	- 15-20 gm
Distilled water	- 1000 ml
pH	- 7.3 ± 0.2

Procedure:

1) Weigh the medium ingredients as per the composition and dissolve them in distilled water in a conical flask.
2) Adjust the medium pH to 7.3 ± 0.2 by adding HCl or NaOH as required to the medium.
3) Sterilize the medium in an autoclave at 121°C for 15 lbs pressure for 15 minutes.
4) Sterilize the clean and dry Petri plates in Hot-air oven at 160^{o} C temperature for 2 hours.
5) Then, transfer the sterilized Petri plates to the Laminar air flow chamber.

6) Cool the sterilized medium to molten state of temperature around 42^{o} C.

7) Pour about 20 ml of the molten state sterilized Czapek-Dox agar medium into each Petri plate in Laminar air flow chamber and allow the medium to solidify.

8) After the complete solidification of the medium, store the Petri plates in invert position until further use.

***

EXPERIMENT 4: LEGUME PLANT ROOTS WITH NODULATION

Fig 2: Morphology Legume root system showing rhuzobium nodules

1) Root nodules are the swellings found on the roots of many leguminous plants.
2) Nodule formation occurs because of symbiotic relationship between *Rhizobium* (nitrogen fixing bacterium) and roots of leguminous plants.
3) *Rhizobium* is a soil bacterium which is rod shaped but during this symbiotic association, the bacterial cells become irregularly shaped within the nodules which are called as bacteroids.
4) The root nodules are formed due to the tissue proliferation induced by the action of some growth promoters of bacterial (*Rhizobium*) origin.
5) The core of a mature nodule constitutes the ‘bacteroid zone’ which is surrounded by peribacteroid membrane.
6) The well developed and effective nodules are generally large and pink due to the presence of leghaemoglobin.

7) Leghaemoglobin is a red pigment similar to blood haemoglobin is found in the nodules between bacteroids and the surrounding membrane envelopes.

8) The haeme part is contributed by bacteria and globin part by plant.

9) Leghaemoglobin maintains a steady supply of oxygen at low concentration to the nodules which is required for nitrogen fixation.

10) The *Rhizobium* bacterium in the form of bacteroids inside the nodules fix the atmospheric nitrogen into ammonia.

***

EXPERIMENT 5: ISOLATION OF *RHIZOBIUM* BACTERIUM FROM LEGUME ROOT NODULES

Aim: Isolation of *Rhizobium* species from root nodules of the legume plants.

Materials Required:

Chemicals of YEMA medium, Root nodules, Petri plates, Laminar air flow chamber, Conical flask, etc.

Composition of the Yeast extract mannitol agar medium:

Mannitol - 10.0 g

K_2HPO_4 - 0.5 g

$MgSO_4$ - 0.2 g

NaCl - 0.1 g

Yeast extract - 0.5 g

Agar agar - 20.0 g

Distilled H_2O - 1000 ml

pH - 7.0

Procedure:

1) Collect healthy, firm and pink coloured nodules from the legume plant roots.
2) Wash the nodules under running tap water to remove soil and other debris material.
3) Sterilize the surface of nodules with 0.1% mercuric chloride or 2.5% sodium hypochlorite to eliminate any contaminating bacteria on the surface.
4) After sterilization, rinse the nodules thoroughly with sterile distilled water to remove the residual chemicals.
5) Crush the surface-sterilized nodules aseptically using a sterile glass rod and prepare a suspension of it with sterile distilled water.
6) Prepare the YEMA medium as per the composition and sterilize the medium in an autoclave at 121°C for 15 lbs pressure for 15 minutes.
7) Sterilize the clean and dry Petri plates in Hot-air oven at 160^{o} C temperature for 2 hours.
8) Then, transfer the sterilized Petri plates to the Laminar air flow chamber.

9) Cool the sterilized medium to molten state of temperature around 42^{o} C.

10) Pour about 20 ml of the molten state sterilized YEMA medium into each Petri plate in Laminar air flow chamber and allow the medium to solidify.

11) After solidification of the medium, spread a small portion of the nodule suspension prepared on the surface of the medium.

12) Incubate the inoculated plates at 28 – 30^{o} C temperature for 3-5 days for the development of *Rhizobium* colonies.

13) Record the features of colonies developed on the medium.

14) Select the colonies for further purification through sub-culturing on fresh YEMA plates or slants.

Result:

Rhizobium colonies appear with small, translucent and convex characters.

***

EXPERIMENT 6: ALGAL COLLECTION FROM DIFFERENT HABITATS AND THEIR IDENTIFICATION

(I) Collection and identification of algal samples of a stream or small river and ponds

Procedure:

- Choose a site that is representative of the bulk water.
- Label the sample bottles with a water proof pen.
- Enter the into waters, move towards midstream and face upstream to collect the sample
- Grip the bottle in one hand around the base and remove the lid with the other hand.
- Invert the sample container fully and submerge to a depth of 0.2m below the surface.
- Turn the mouth of the bottle upwards and towards the current.
- When the bottle is full of water, lift it from the water rapidly and replace the lid.
- If sampling an algal bloom, record notes about the surface scum (colour, odour, presence of dead organisms etc.).
- For algal bloom sampling, surface scums can be targeted by moving the sample bottle through the surface.
- If preservation with Lugol's solution is required to stain and preserve the sample, add a couple of drops of Lugol's solution into the sample to preserve it.
- Place the sample bottle(s) in a cool box or portable refrigerator that is suitable for transport to the analysing laboratory.
- Take a little alga from the collected water sample and place on a glass slide. Place a cover slip over the algal sample on the slide and remove the excess water with a tissue paper.
- Observe the algae under both low and high power objective lenses.
- Make diagrams of the algae present in the sample and note the all the features.

Chlamydomonas

Classification

Sub-division: Algae

Class: Chlrophyceae

Order: Volvocales

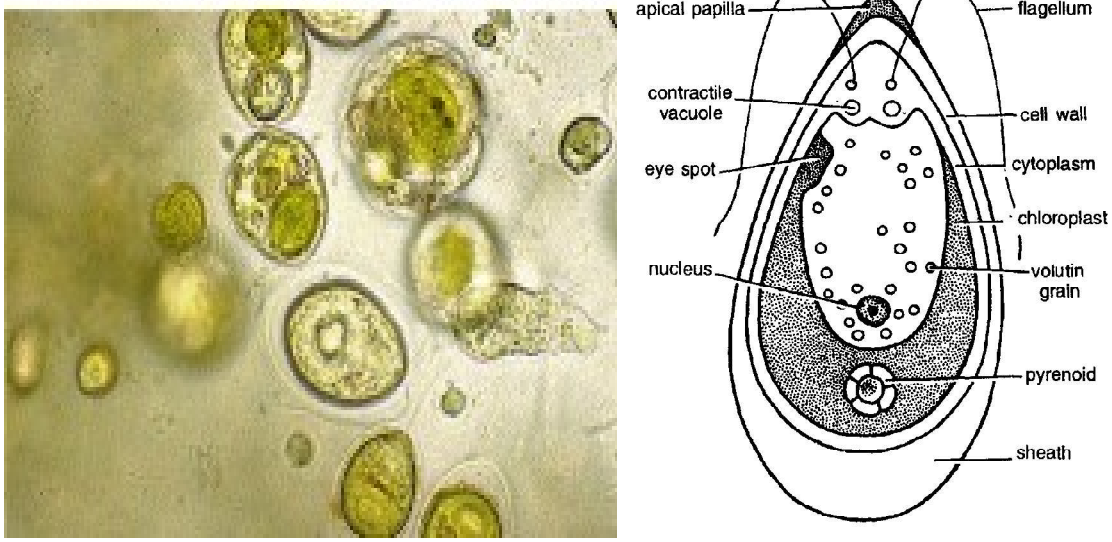
Family: Chlamydomonaceae

Genus: *Chlamydomonas*

Hint for Collection: It is found free-swimming in freshwater, stagnant water and ditches. It also occurs on damp soil and mostly forms a green surface layer on the water.

Important Features:

1) Thallus is unicellular and motile.
2) The cell is usually oval in shape. Sometimes spherical, oblong, pyriform or ellipsoidal.
3) The cell is surrounded by a cell wall. It is narrow at its anterior end and broad at the posterior end.
4) Anterior end bears two closely situated flagella (whiplash type).
5) At the base of each flagellum lies ablepharo plast or basal granule.
6) A small projection or papilla, known as apicalpapilla, is present in between the two anteriorly inserted flagella.
7) At the base of each flagellum one contractilevacuole is present.
8) Just near the cell wall, towards the anteriolateralpart of the cell, lies an orange or red coloured spot, called stigma or eye spot.
9) The broad posterior part has a large, massive and a single cup-shaped chloroplast. The thin sides of the chloroplast cup extend towards the anterior end.
10) The broad portion of the chloroplast has a single pyrenoid (sometimes two to many).
11) The cavity of the cup-shaped chloroplast is completely filled with the cytoplasm in which, a single nucleus occurs.
12) Many volutin grains, the main reserve food product, are irregularly distributed in the cytoplasm.



A **B**

Chlamydomonas **(A)Thallus(Microscopic) (B)Thallus(Diagrammatic)**

Volvox

Classification

Sub-division: Algae

Class: Chlorophyceae

Order: Volvocales

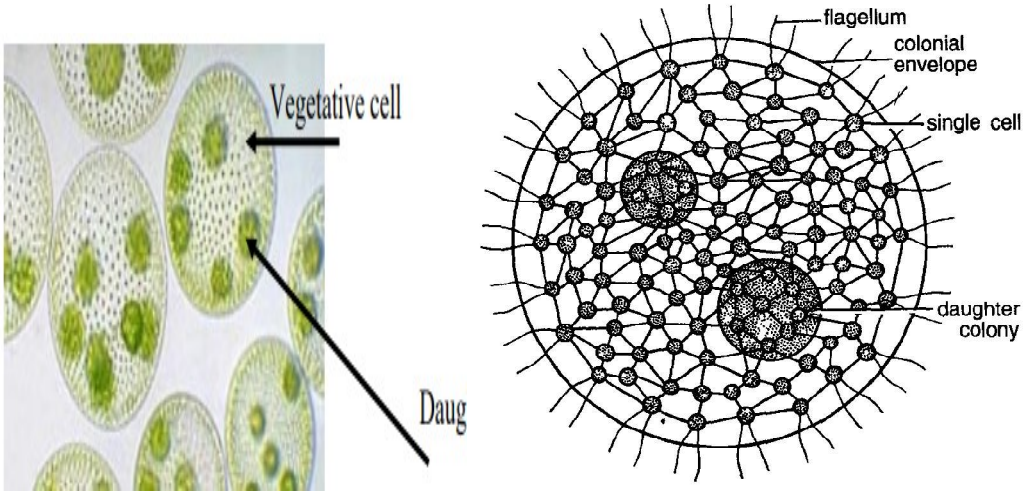
Family: Volovocaceae

Genus: *Volvox*

Hint for Collection: It can be collected from freshwater and permanent ponds and pools, where it occurs as small green balls on the surface layer. The alga grows abundantly during spring and disappears during summer.

Important Features:

1) Thallus is multicellular, motile and a coenobialcolony.
2) Colonies are mostly spherical, rounded or ovalin shape.
3) It is hollow in the centre and cells are arranged in a single layer towards the periphery.
4) Layer of cells is surrounded by a gelatinousmass which forms the outer and firm limiting layer.
5) The number of cells in a colony varies from 500-6,500 according to the species.
6) Each cell of the colony is connected with a few of the neighbouring cells by thin and delicate cytoplasmic strands.
7) Each cell is enveloped by an individual gelatinous sheath.
8) All the cells of a colony are typically chlamydomonad in shape, size and structure.
9) Each vegetative cell is biflagellate, motile andovoid. The two flagella are anteriorly inserted.
10) A contractile vacuole is situated one each atthe base of a flagellum.
11) Cup-shaped chloroplastoccupies much of the posterior part in which
12) 12is situated a single pyrenoid.
13) In the cavity formed by cup-shaped chloroplast lies a single nucleus, surrounded by cytoplasm.
14) Cytoplasmis rich in volutin granules.
15) Eyespot or stigmaoccupies anterio-lateral position.



Volvox **(A) Thallus (Microscopic) (B)Thallus (Digramatic)**

Hydrodictyon

Classification

Sub-division: Algae

Class: Chlrophyceae

Order: Chlrococcales

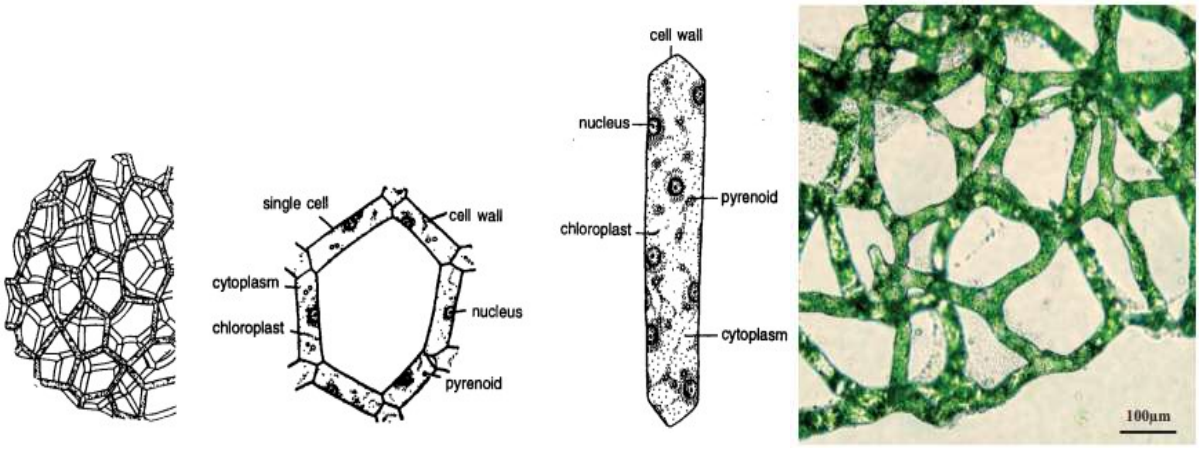
Family: Hydrodictyaceae

Genus: *Hydrodictyon*

Hint for Collection: This alga occurs in large quantities in permanent pools or other bodies of stagnant water. It forms an extensive net which covers the entire surface of water reservoir.

Important Features:

1) The thallus is a multicellular colony forming a net-like structure.
2) Colony is a hollow and sac-like or saucer-like (saccate), cylindrical network, closed at both the ends.
3) The spaces of the reticulum are bound by five or six cells (this number varies between 3-10 cells) which form a pentagonal or hexagonal structure.
4) The cells are cylindrical. End walls are angular to facilitate the formation of a mesh.
5) Cell has a large central vacuole and Cytoplasm lies towards the periphery.
6) Cells are multinucleate. The young cells are however, uninucleate.
7) Cell is called a coenocyte because of its multinucleate nature and presence of large central vacuole.
8) Young cells have zonate or entire chloroplast. Little mature cells possess reticulate chloroplast. However, during older stages chloroplast may assume discoid shape and diffuses throughout the cytoplasm.
9) Chloroplast contains large number of pyrenoids.



A **B** **C** **D**

***Hydrodictyon*-(A) Part of saccetthallus (B) A part of reticulum (C) Single cell (D) Microscopic**

(II) Collection and identification of algal samples from marine and brackish water:

- To collect the algal samples from the ocean, use a combination of methods depending on the type of algae and the desired sample.
- For surface blooms, dip a sample bottle and scoop water into a container.
- For deeper samples, plankton net can be dragged behind a boat or used by divers.
- Concentrate the collected samples by filtering through a coffee filter or using a sediment trap. Fix the samples in formalin solution for further use.
- Examine the algae under a microscope, noting their morphology, size, and shape to identify them.

Polysiphonia

Classification

Sub-division: Algae

Class: Rhodophyceae

Sub-class: Florideae

Order: Ceramiales

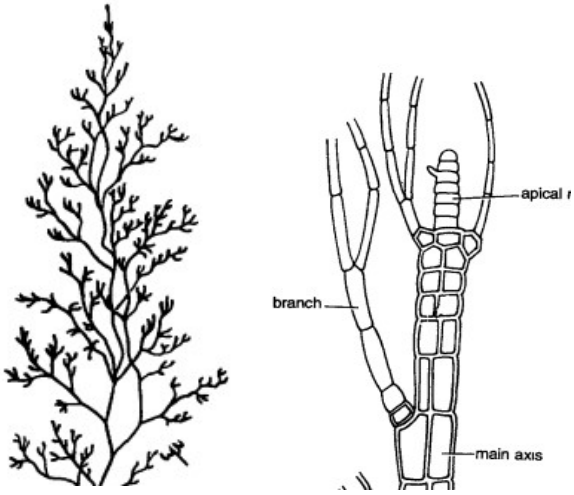
Family: Rhodomelaceae

Genus: *Polysiphonia*

Hint for Collection: Species of *Polysiphonia* are exclusively marine. These are the most commonly found along the Atlantic and Pacific coasts, in littoral and sub-littoral regions. A few species occur as epiphytes on mangroves or brown seaweeds. A small number of species are also found along the Indian coasts.

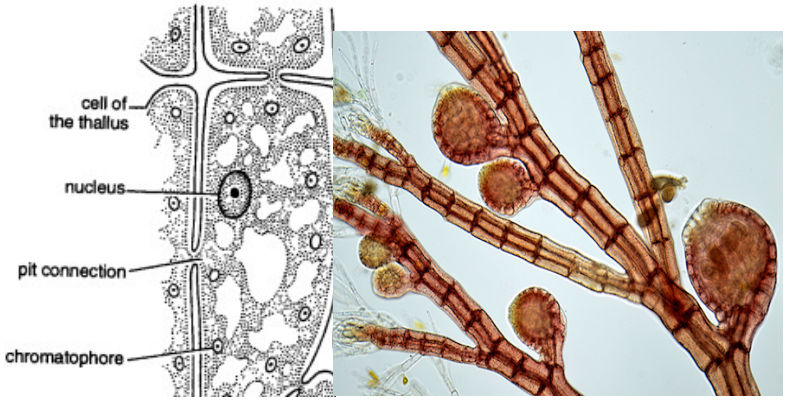
Important Features:

1) Plant body is filamentous which are multicellular, branched and polysiphonous.
2) Branching is dichotomous. Each branch terminates into a single celled apex, followed by a number of flat cells.
3) Thallus is polysiphonous i.e. made of series of parallel filaments.
4) Centre is occupied by a large barrel shaped cell (axial cell or central siphon) which is surrounded by 4-24 peripheral cells (pericentral siphons).
5) In the apical region, two or three cells below the apical cell, uniseriate, dichotomously divided, gradually tapering and multicellular filament is produced. It is known as trichoblast.
6) Many species remain attached to the substratum by thick walled, richly lobed and unicellular rhizoids (attaching organs) which arise from the peripheral cells of the creeping system.



(A) (B)

***Polysiphonia*- (A) Thallus Diagrammatic (B) Part of thallus with branches**



(A) (B)

***Polysiphonia*- (A) Single cell (B) Thallus (Microscopic)**

Sargassum

Classification

Sub-division: Algae

Class: Phaeophyceae

Order: Fucales

Family: Sargassaceae

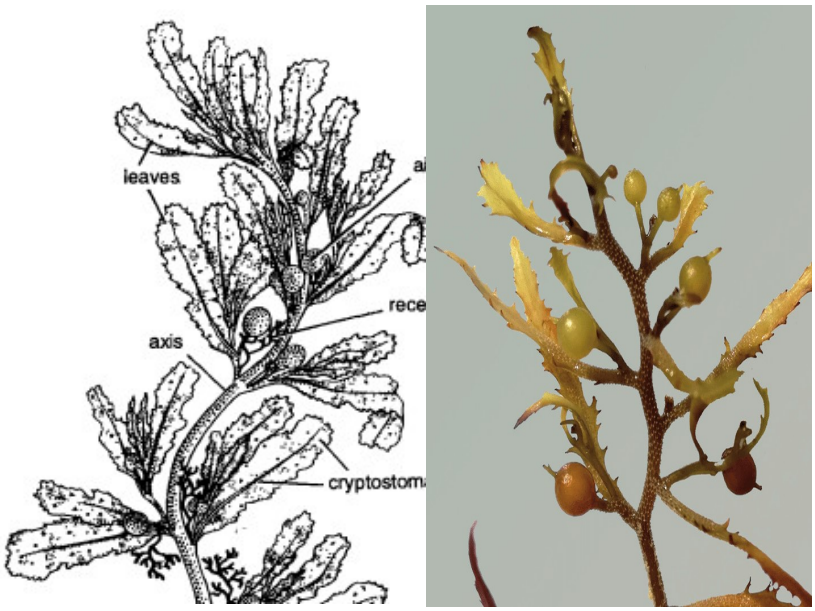
Genus: *Sargassum*

Hint for Collection: It is marine in habitat and remains restricted to tropical seas, mainly of southern hemisphere. In India, species of this genus are found along the east coast, west coast, and Andaman and Nicobar Islands.

Important Features:

1) Thallus is erectand branched.
2) It remains attached to the substratum by a discoid holdfast.
3) Main axis stands out from the holdfast. It varies from a few to many centimetres in height.
4) Main axis bears large number of primary laterals forming a larger part of vegetative structure. Branches are radially symmetrical and spirally arranged.
5) Secondary branches are repeatedly branched.
6) Many branches are flattened along the plane of branching into leaf-like structures called 'leaves'.
7) Leaves are narrow and their margins are mostly serrate. A few species also show a clear mid-rib.
8) In the lower parts, leaves are replaced by air bladders. However, leaf or its part is modified almost at any place into an air bladder.
9) Leaves show minute pores on both of the surfaces which are ostioles (or openings) of conceptacles (sterile) or cryptostomata or cryptoblasts.

10) In the axils of foliaceous branches (leaves), a series of repeatedly branched receptacles which bear reproductive structures are situated.



(A) **(B)**

***Sargassum*- (A) Thallus Diagrammatic (B) *Sargassum* thallus**

Fucus

Classification

Sub-division: Algae

Class: Phaeophyceae

Order: Fucales

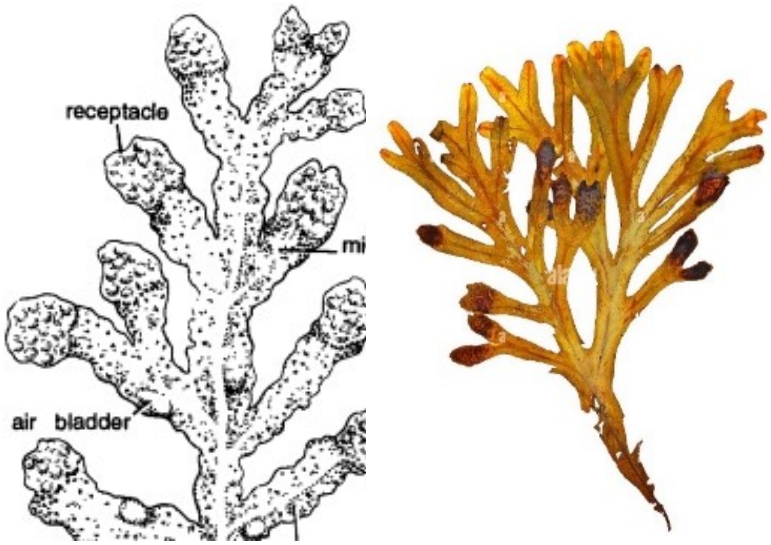
Family: Fucaceae

Genus: *Fucus*

Hint for Collection: *Fucus*is found attached to the rocks in the intertidal rocky coasts of the colder seas of the northern hemisphere. It is abundantly found along the coasts of British Isles, Northern European countries and Atlantic coast of America. During summers, rocks exposed to low tide remain exclusively covered with *Fucus*.

Important Features:

1) Thallus is flat, dichotomously branched and is attached by a rounded disc-shaped holdfast.
2) A mid-rib stands erect from the holdfast. It is prominent in older parts of the thallus than in younger regions.
3) Thallus bears many flat strap-like, dichotomously branched blades or wings with smooth or entire margins.
4) Some species of *Fucus* bear air bladders within the thallus. These regions of the thalli appear inflated.
5) Wings show small openings of sterile conceptacles (cryptostomata or cryptoblasts).
6) Fertile conceptacles are terminal. These swollen parts which lack midrib are called receptacles.



(A) **(B)**

***Fucus*- (A) Thallus Diagrammatic (B) *Fucus* thallus**

(III) Collection and identification of algal samples from soil:

- To collect the algal samples from soil, carefully excavate soil samples and then isolate the algae within.
- Use a sterile tool (like a soil probe or a small trowel) to collect soil samples from the desired location.
- Collect an adequate amount of soil to ensure a representative sample for analysis.
- Gradually rinse or wash the soil sample with distilled or deionized water to separate the algal cells from the soil particles.
- Allow the soil particles to settle or use centrifugation to concentrate the algal cells in a small volume of water and fix the samples in formalin solution for further use.
- Examine the algae under a microscope, noting their morphology, size, and shape to identify them.

Fritschiella

Classification

Sub-division: Algae

Class: Chlrophyceae

Order: Chaetophoriales

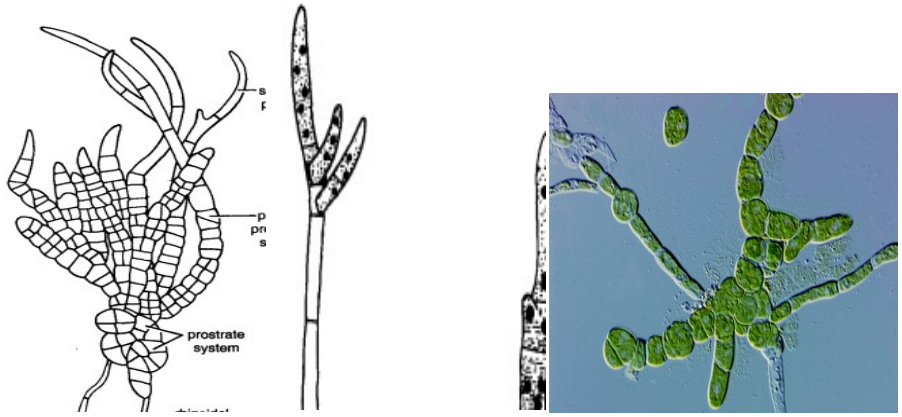
Family: Cheatophoraceae

Genus: *Fritschiella*

Hint for Collection: *Fritschiella* grows abundantly on moist, alkaline soil and on silt forming lush green cushions. It is particularly common on moist soil, drying after the monsoon rains.

Important Features:

1) Thallus is filamentous.
2) The filaments show heterotrichous habit.
3) Thallus show typical heterotrichous nature with distinct rhizoidal system, the prostrate system, primary projecting system and the secondary projecting system.
4) The rhizoidal system consists of one or more rhizoid-like outgrowths. These arise from prostrate system.
5) The prostrate system is made of clusters of cells. These cells are either rounded or irregular in shape. The plants with well-developed prostrate system consist of mature filaments.
6) The primary projecting system arises from the prostrate system and is aerial in nature. The fIlaments are uniseriate or biseriate which may be branched or unbrahched. The cells of these filaments are small and rounded. They are green and photosynthetic.
7) The secondary projecting system consists of freely branched uniseriate filaments. The cells are elongated. The end cells of the branches terminate into hair-like structures.
8) The cells of the projecting system are thin walled. These are uninucleate with a curved plate-like chloroplast that has 2-8 pyrenoids. The cells of primary projecting system and the prostrate system have poorly developed chloroplasts. In rhizoidal system, chloroplasts are completely absent.



(A) **(B)** **(C)**

***Fritshiella*- (A) ThallusDiagrammatic (B) Single cell (C) Microscopic**

Vaucheria

Classification

Sub-division: Algae

Class: Xanthophyceae

Order: Heterosiphonales

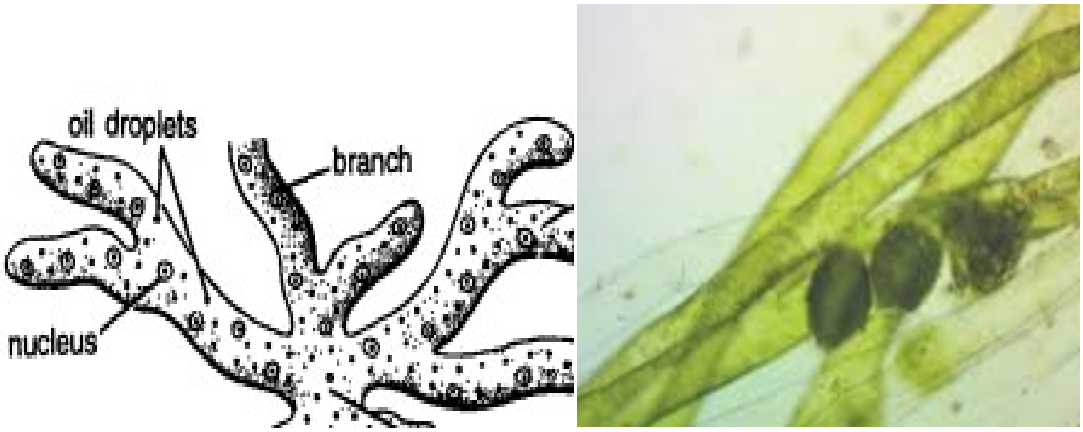
Family: Vaucheriaceae

Genus: *Vaucheria*

Hint for Collection: Species of this genus grow in aquatic as well as in terrestrial habitats. Terrestrial species occur on damp soils of gardens, lake sides, and ploughed fields. They form an extensive green belt on the soil surface, especially during early winters. The aquatic species also occur as a large green mat floating over the surface of water.

Important Features:

1) Thallus is unicellular, multinucleate, filamentous and branched (coenocytic).
2) Filaments are profusely branched. The branching is lateral but appears dichotomous.
3) Filaments are without any septation (aseptate filaments).
4) If terrestrial in habitat, a few colourless rhizoidal branches are given out which penetrate into the soil.
5) Cell wall is two layered. Outer layer is composed of pectose, while inner layer is having cellulose.
6) In the centre lies a big vacuole, continuous throughout the length of the filament.
7) The cytoplasm lies between vacuole and the cell wall.
8) Many small nuclei are scattered in the cytoplasm near the vacuole.
9) Small circular or elliptical shaped chromatophores are scattered in the cytoplasm. Pyrenoids are absent.
10) The reserve food material is in the form of small oil droplets.



A **B**

***Vaucheria* - (A) Thallus (Diagramatic) (B) Thallus (Microscopic)**

Scytonema

Classification

Sub-Division: Algae

Class: Myxophyceae

Order: Nostocales

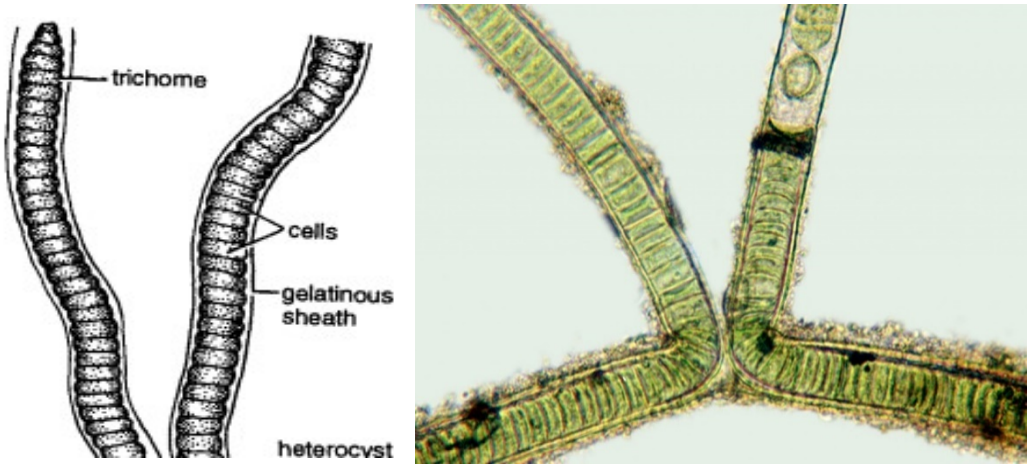
Family: Scytonemataceae

Genus: *Scytonema*

Hint for Collection: This genus is usually found in sub-aerial habitats such as damp walls, brick-work, bark of the trees, etc. Filaments are interwoven to form a felt-like mass of considerable extent. Few species grow best on damp soil and others on the dripping surfaces of rocky cliffs.

Important Features:

1) Filaments occur singly. The trichomes are enveloped in a sheath.
2) Filaments show false branching, branches being single or geminate.
3) The trichomes are of the same diameter throughout its length.
4) The trichome is covered by an individual sheath which is firm and either hyaline or coloured. It may be homogeneous or lamellated.
5) Heterocystsoccupy intercalary position. They may be one, two or three in number. These are approximately of the same size as those of vegetative cells. Lateral branches are generally produced in between heterocysts.
6) Heterocysts show two shining granules, one each in contact with the cells on either side. It is pale yellow in colour and contents are homogenous.
7) Cell structure is typically cyanophycean in nature. Central part which is known as centroplasm has DNA genetic material. Centroplasmis enclosed by peripheral pigmented chromatoplasm with scattered pigments and cyanophycean granules.



***Scytonema* - (A) Thallus (Digramatic) (B) Thallus (Microscopic)**

EXPERIMENT 7: MORPHOLOGICAL AND REPRODUCTIVE STAGES OF SOME GENERA OF CYANOPHYTA, CHLOROPHYTA, XANTHOPHYTA, PHAEOPHYTA AND RHODOPHYTA

I. CHLOROPHYCEAE

Coleochaete

Classification

Sub-division: Algae

Class: Chlorophyceae

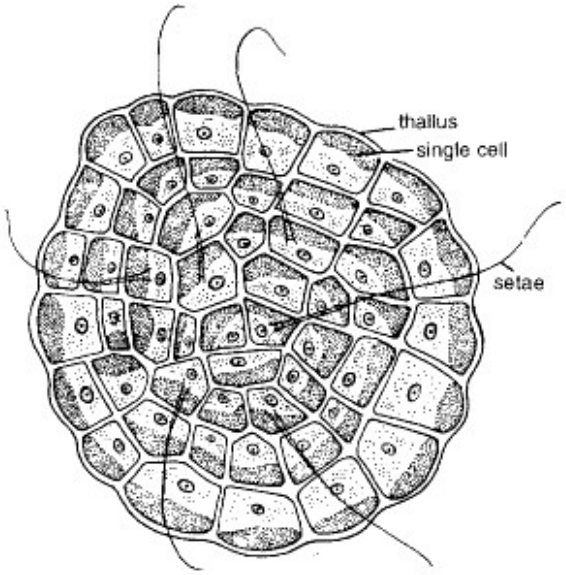
Order: Chaetophorales

Family: Coleochaetaceae

Genus: *Coleochaete*

Important Features:

1) Thallus is multicellular and heterotrichous.
2) It is either a disc-like structure i.e. majority of the species (e.g. *C. scutata*) or cushionoid or filamentous (e.g. *C. pulvinata*).
3) If thallus is disc-like, the disc represents only the prostrate system while a few setae or hair, represent erect system.
4) Filamentous thallus exhibits typical heterotrichous habit with a branched prostrate system and a branched projecting (erect) system.
5) In both the cases, a few cells possess a cytoplasmic outgrowth-setae. Setae are surrounded partly or wholly by a gelatinous sheath at the base.
6) The thallus is distinctly enveloped by a gelatinous sheath or mucilage.
7) In discoid species, cells of the thallus are joined end to end to form branches. These branches are laterally opposed to one another to form a pseudoparenchymatous disc.
8) Each cell is uninucleate. It has single, large, laminate and parietal chloroplast with a single pyrenoid. Rest of the cell is occupied by the cytoplasm.



***Coleocheate* sp. - Discoid thallus**

Oedogonium

Classification

Sub-division: Algae

Class: Chlrophyceae

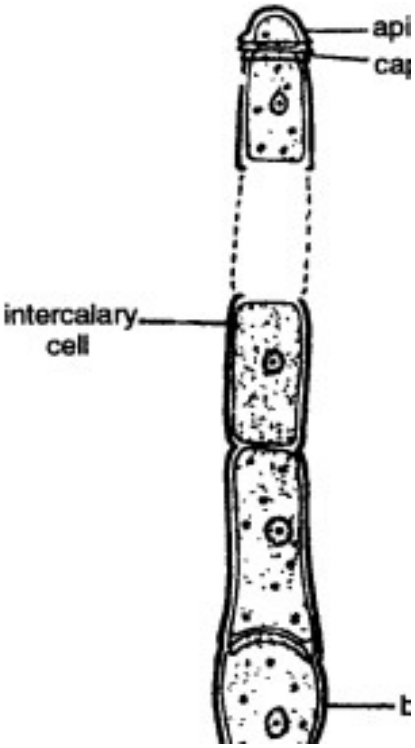
Order: Oedogoniales

Family: Oedogoniaceae

Genus: *Oedogonium*

Important Features:

1) Thallus is multicellular, filamentous and unbranched.
2) A filament is differentiated into three types of cells according to their position: (i) basal (ii) intercalary and (iii) apical.
3) The basal cell of a filament functions as a holdfast.
4) The lower part of the holdfast is either disc-like or finger-shaped.
5) The upper part is mostly broad and rounded. The basal part of the cell generally lacks green pigment and, therefore, is non-green unlike other cells of the filament.
6) Cell at the tip of the filament is known as'apical cell'. It is rounded at its free surface. The cells present between basal and the apical cells are intercalary cells. These show typical cell structure.
7) The typical cell is cylindrical and the cell wall is thick and three layered.
8) Inner to cell wall is a reticulate chloroplast that runs parallel to the long axis of the cell.
9) Many pyrenoids are present in the chloroplast.
10) The cell is uninucleate. The nucleus is situated near the cell wall and is held by thin and delicate cytoplasmic strands.
11) Mature and old cells show 'cap cells' at their upper end. These are characteristic of the members of Oedogoniales.

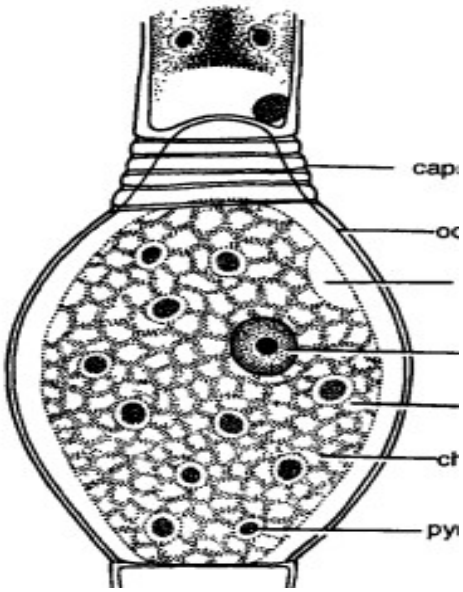


***Oedogonium* filament**

***Oedogonium*- Oogonium**

Important Features:

1) Oogonia are intercalary or terminal in position.
2) Oogonium may be solitary or occur in a row of 2-3 or even more.
3) Oogonium generally shows one or more cap cells at its upper end, indicating its development from a comparatively older cell.
4) It is mostly spherical or oval in shape and larger than a vegetative cell.
5) At the base of each oogonium lies a small and flat daughter cell, known as supporting cell.
6) Oogonium encloses a single large ovum.
7) The wall of the oogonium has a small pore on one side, known as receptive pore.
8) Just opposite to the receptive pore, protoplast of oogonium has a hyaline area-receptive spot.
9) Protoplast is uninucleate and rich in reserve food.

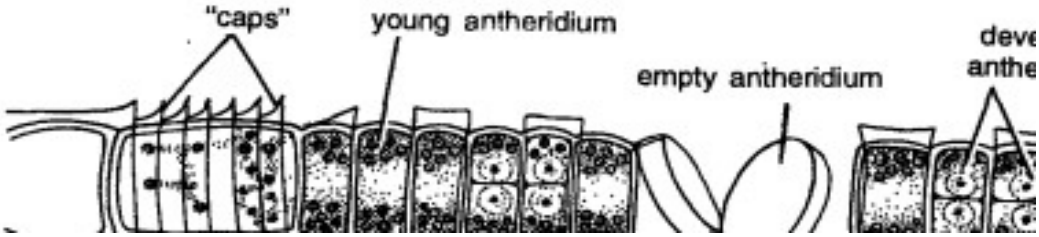


Oedogonium **mature oogonium**

Oedogonium **-Antheridia**

Important Features:

1) Antheridia are mostly intercalary in position.
2) Numerous antheridia form a long chain being arranged in a series.
3) An antheridium is a small and flat cell.
4) Each antheridium has two nuclei lying side by side, surrounded by dense cytoplasmic contents. Each of such protoplasmic groups later on metamorphoses into a multiflagellateantherozoid.



Oedogonium **filament showing antheridia**

Chara

Classification

Sub-division: Algae

Class: Chlrophyceae

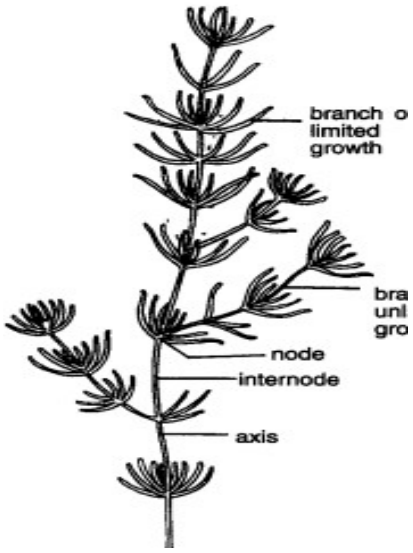
Order: Charales

Family: Characeae

Genus: *Chara* (stone wort)

Important Features:

1) Thallus is macrocopic, branched and multicellular. Calcium carbonate is deposited allover.
2) It remains attached to the substratum by multicellular rhizoids (branched) which bear an erect and branched main axis above.
3) These are borne by the lower nodes of the main axis.
4) Rhizoids possess oblique septa. The rhizoids are not differentiated into nodes and internodes.
5) The cytoplasm of a rhizoidal cell has a nucleus situated towards the upper side of the cell.
6) At the septum of a rhizoidal cell, the ends are protracted in opposite directions to form knotted part.
7) At this place, signifying a node, a plate of four cells or even more is formed which gives rise to rhizoidal branches. This part is known as rhizoidal plate.
8) Main axis is composed of long internodes alternating with small nodes.
9) Long internode is composed of a single cell enveloped by many corticating threads.
10) A node is a group of regularly arranged cells.
11) It bears two types of branches-(i) lateral branches of limited growth (short laterals) and (ii) lateral branches of unlimited growth.
12) Laterals of limited growth are borne in whorls around the nodes of the main axis.
13) Each short lateral is divided into nodes and internodes.
14) The internodes of short laterals are small as compared to those of the main axis.
15) Short laterals borne by the nodes of the main axis are also termed as primary laterals of limited growth.
16) From the nodes of the short laterals, secondary short laterals are produced which are usually small, unicellular and are variously termed as stipules or leaves.
17) Laterals of unlimited growth are borne by the nodes of the main axis only. These are situated in the axils of short laterals.
18) Long laterals possess the same characteristics as those of the main axis.

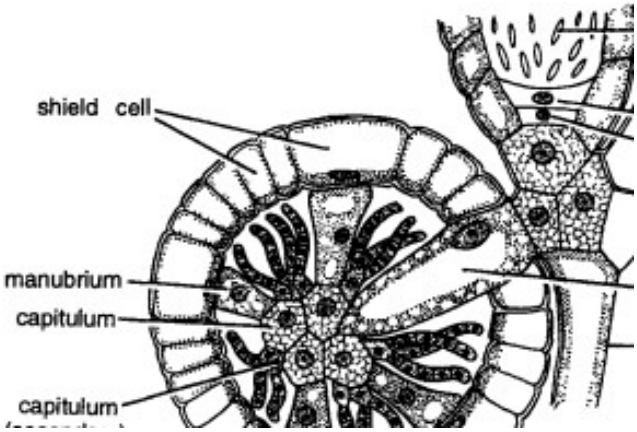


***Chara* thallus**

***Chara* - Globule (Male Reproductive Organ)**

Important Features:

1) A globule is a small, spherical and conspicuously red or yellow structure attached to the node by a long stalk cell.
2) Outermost wall of the globule is ornamented, composed of eight, large, curved and platelike cells called shield cells.
3) Ornamentation of the shield cell is due to the foldings in the cell wall.
4) Each shield cell is attached to a long handle or a rod-shaped cell called as manubrium.
5) At the tip of each manubrium are two groups of six cells each. The group directly in contact with the manubrium is primary capitulum while the next is secondary capitulum.
6) Each secondary capitulum bears 2-4, long and unbranched antheridial filaments.
7) Each antheridial filament is made of 100-230 small cells.
8) Each of these cells is an antheridium and produces a single biflagellate male gamete.

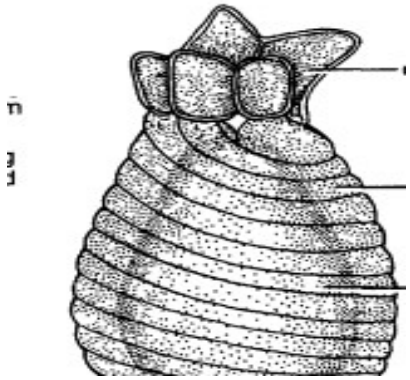


***Chara* Globule L.S**

***Chara*- Nucule(Female reproductive organ)**

Important Features:

1) Nucule is oval in shape and is situated above the globule at the node.
2) It is enveloped by spirally coiled (coiling clockwise) cells known as tube cells.
3) At the apex of the nucule, is a corona of five small cells arranged in one tier and attached at one point.
4) Oosphere is single celled where a nucleus lies surrounded by the cytoplasm.
5) It is rich in food reserves which are in the form of starch and oil.
6) After fertilization, the nucule gets modified into a zygote or oospore.
7) The oospore wall is thick and ornamented. It has a deposition of calcium.



***Chara* Nucule**

II. XANTHOPHYCEAE

Vaucheria - Antheridium

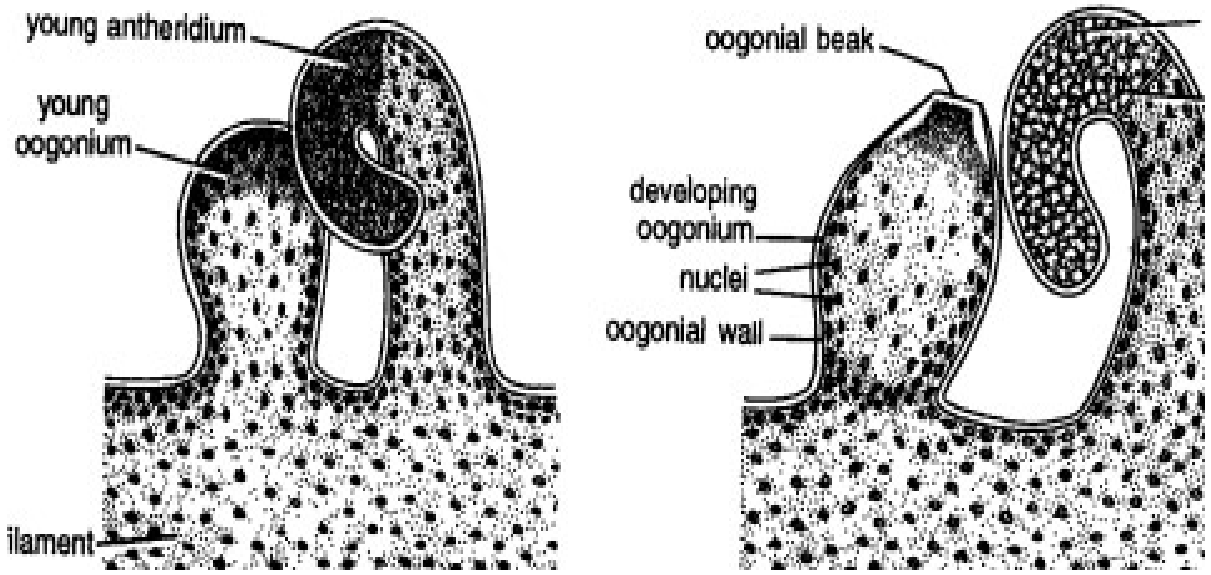
Important Features:

1) Filaments are mostly monoecious but a few species are dioecious.
2) Sexual reproduction is oogamous.
3) Male reproductive bodies are antheridia and female reproductive bodies are oogonia.
4) The antheridia and oogonia are borne side by side on the same filament. Sex organs are generally sessile but a stalk-like structure is present in a few species.
5) Antheridia are terminal, strongly curved, hook-like and cylindrical.
6) Antheridia are cut off from the main filament by a transverse septum at its base.
7) Protoplast accumulates towards the centre. It produces many biflagellate antherozoids.
8) Antherozoids are liberated through a small pore at the tip of antheridium.

Vaucheria - Oogonium

Important Features:

1) More than one oogoniumis present at the tip of the stalks which once again branch at their tips.
2) Oogonia are oval or spherical and terminate into a short beak.
3) The entire protoplast forms a single oosphere.
4) In younger stages, oosphere is multinucleate but at maturity it is always uninucleate.
5) Near the beak, in the apical part, the protoplasm leaves a small colourless area, known as receptive spot.
6) Protoplast is rich in food reserve which is in the form of oil droplets.



***Vaucheria*- (A) Young anthereida and oogonia (B) Mature antheridia and oogonia**

III. PHAEOPHYCEAE

Ectocarpus

Classification

Sub-division: Algae

Class: Phaeophyceae

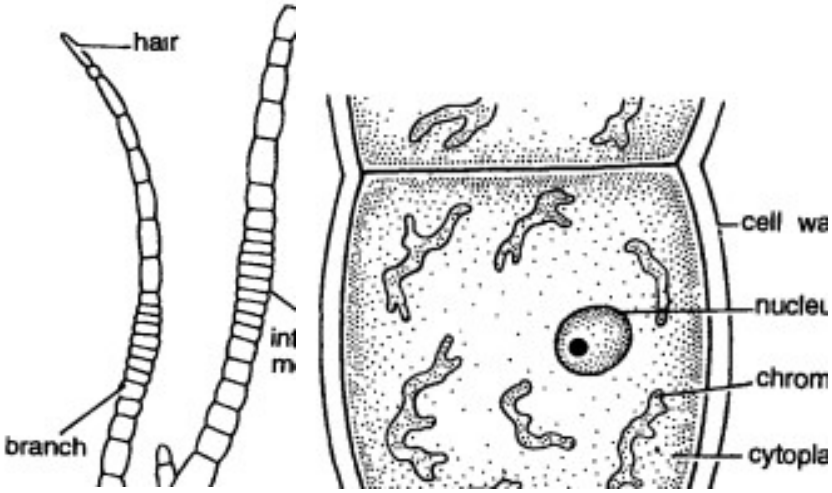
Order: Ectocarpels

Family: Ectocarpaceae

Genus: *Ectocarpus*

Important Features:

1) Thallus is multicellular, filamentous and branched.
2) Filaments are heterotrichous and differentiated into (i) prostrate portion and (ii) an erect portion.
3) In some species, prostrate portion is irregular and profusely branched or altogether absent. If present, it remains attached to the substratum.
4) Erect portion is a crowded tuft of branches.
5) Main axis is broad from which lateral branches arise just beneath the septum and taper into a point. Ultimate branches give an appearance of a hair.
6) The branches and the main axis are uniseriate.
7) The erect branches have intercalary meristem just below the terminal hair. It results in trichothallic growth.
8) The cells are square to cylindrical and uninucleate.
9) The cell wall is double layered. Outer is gelatinous and inner is firm and cellulosic.
10) There may be one or many chromatophores varying from irregular to band-like to discoid. Pyrenoids are absent.
11) Reserve food products occur as shining fucosan granules.
12) The cell is filled with cytoplasm with single nucleus.



(A) **(B)**

***Ectocarpus*- (A) Filamentous thallus (B) Single cell**

Ectocarpus - Unilocular sporangium

Important Features:

1) Unilocular sporangium is a structure of asexual reproduction, always present on diploid plants.
2) The sessile or stalked sporangium is situated terminally on lateral branches.
3) The shape varies from globose to ellipsoidal.
4) It is single celled and uninucleate when young but becomes multinucleate later.
5) Many biflagellate zoospores are produced when unilocular sporangium matures.

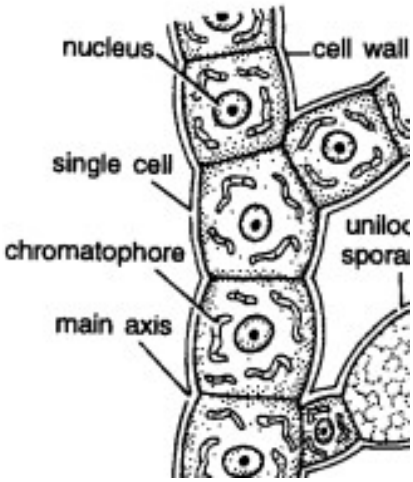


***Fig: Ectocarpus* - Unilocular sporangium**

Ectocarpus - Plurilocular sporangium

Important Features:

1) Plurilocular sporangia occur on both haploid and diploid plants.
2) The structure when borne by haploid plant serves as a gametangium whereas on diploid plant it functions as a sporangium.
3) Sporangia situated laterally may be sessile or stalked and may be ovate to siliquose.
4) Plurilocular sporangium is divided into large number of cells.
5) A mature sporangium produces biflagellate swarmers, one each from every cell.
6) If plurilocular sporangium is borne on a haploid plant, the swarmers behave as gametes and if borne on diploid plant, they act as haploid zoospores.

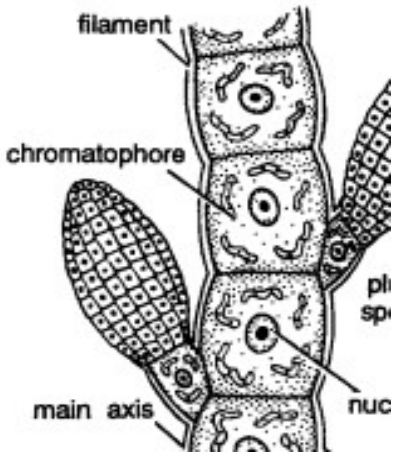


***Fig: Ectocarpus* filament with plurilocular sporangia**

IV. RHODOPHYCEAE

Batrachospermum

Classification

Sub-division: Algae

Calss: Rhodophyceae

Sub-class: Florideae

Order: Nemalionales

Family: Batrachospermaceae

Genus: *Batrachospermum*

Important Features:

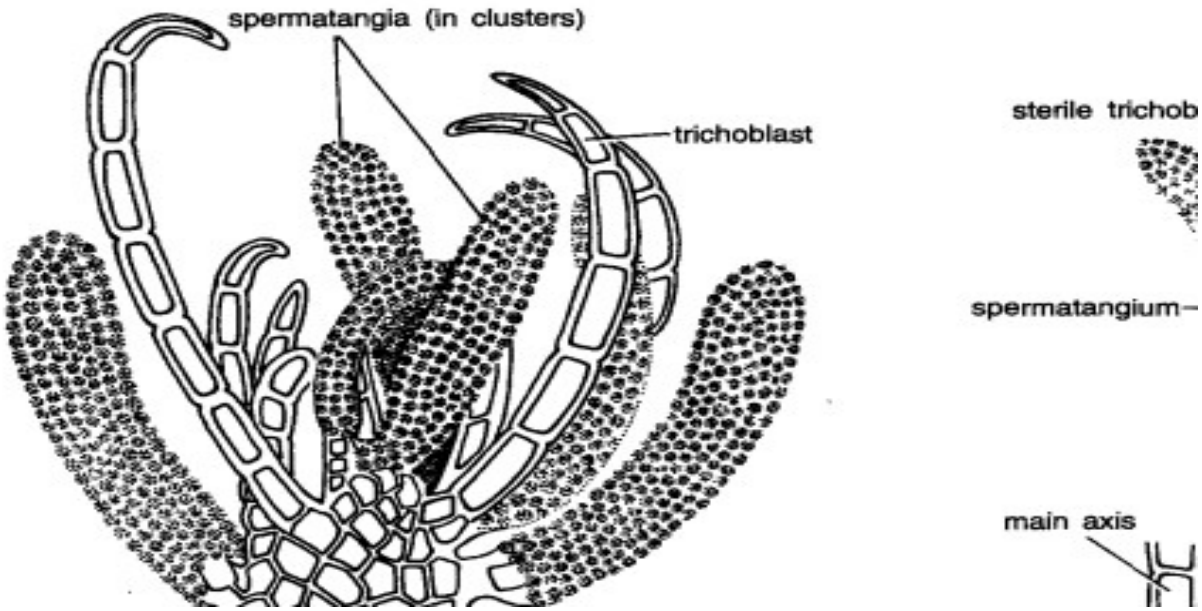
1) Thallus is multicellular and filamentous and branched.
2) Adult thallus appears as a chain of beads. It is mucilaginous and violet or blue in colour.
3) Thallus remains attached to the substratum by old shoots which form a prostrate system.
4) The main axis (primary axis) is corticated and differentiated into nodes and internodes.
5) Branches are borne at the nodes. Two types of branches occur-(i) branches of unlimited growth and (ii) branches of limited growth.
6) Primary axis and branches of unlimited growth arise from nodes. They show monopodial or pseudo-dichotomous branching.
7) Long branches or branches of unlimited growth are differentiated into small nodes and long internodes.
8) Primary axes and branches of unlimited growth are enveloped by several layered cortex.
9) Dwarf branches or branches of limited growth arise laterally in whorls from the nodes of primary axes. (Clusters thus formed give beaded appearances to the thallus).
10) Each cluster formed at the node, is called a glomerule.
11) The laterals consist of small, ellipsoidal or moniliform and uninucleate cells.
12) Among these lateral branches, large clusters of carpospores are situated.

***Batrachospermum*thallus**

***Polysiphonia*- Spermatangium**

Important Features:

1) The genus shows male plants bearing antheridia.
2) Antheridia are produced in clusters by fertile trichoblasts situated near the apex.
3) Antheridium is known as spermatangium. It is oval in shape, naked (without outer membrane) and contains many non-motile spermatia.
4) Each spermatium is small, oval to spherical, uninucleate and non-motile.



***Polysiphonia*- (A) Cluster of spermangia (B) Spermatangium**

***Polysiphonia*- Cystocarp**

Important Features:

1) Cystocarp is a post-fertilization product.
2) The thallus bearing this structure forms a phase called carposporophyte.
3) This oval or urn-shaped structure is attached to a lateral branch.
4) Cystocarp opens to the exterior by an opening called ostiole.
5) Wall of the cystocarp is called pericarp and is composed of a single layer of cells.
6) Carpospores are produced from the base of the cystocarp. These are arranged in single spherical layer.
7) Each carpospore is oval, uninucleate and diploid.

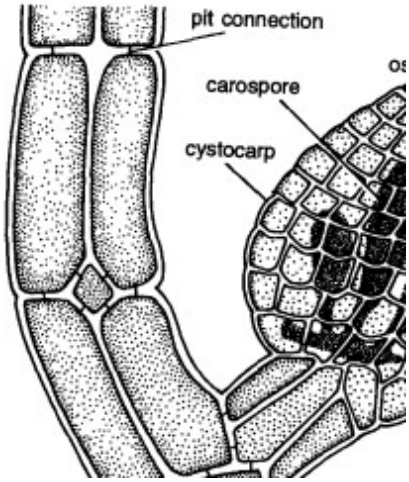
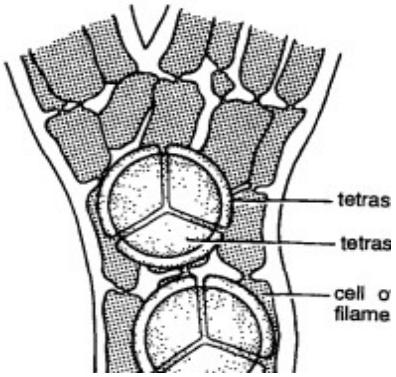


***Fig: Polysiphonia*thallus bearing cystocarp**

***Polysiphonia* with Tetrasporangia**

Important Features:

1) Tetrasporophytes are morphologically similar to male and the female gametophytes.
2) The thallus is polysiphonous being made of a central siphon surrounded by pericentral siphons.
3) Cell shows a nucleus, discoid chromatophores and pit connections.
4) The plant is diploid and bears tetrasporangia in longitudinal series, produced mostly by pericentral cells.
5) Tetrasporangia are small and spherical bodies borne on short one-celled stalk.
6) Each tetrasporangium possesses four tetrahedrally arranged uninucleate and haploid tetraspores.



***Polysiphonia* thallus with tetrasporangia**

V. CYANOPHYCEAE

Oscillatoria

Classification

Sub-division: Algae

Class: Cyanophyceae

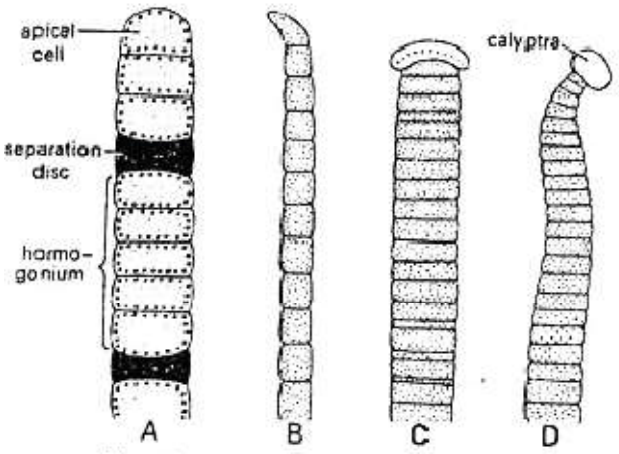
Order: Nostocales

Family: Oscillatoriaceae

Genus: *Oscillatoria*

Important Features:

1) Filaments occur either singly or interwoven to form a flat or spongy, free swimming mat.
2) Filament consists of an inconspicuous and barely recognizable sheath enclosing unbranched trichome.
3) Trichome consists of a single row of cells.
4) The apical cell of the trichome may have calyptra-thick wall on its outer free face.
5) The cells show typical myxophycean cell structure. It has no definite nucleus, no chloroplasts or no membrane bound organelles (prokaryotic cell).
6) The cell shows many shining cyanophycean granules.
7) Floating species show numerous gas vacuoles.



***Oscillatoria* Trichomes**

Nostoc

Classification

Sub-division: Algae

Class: Cyanophyceae

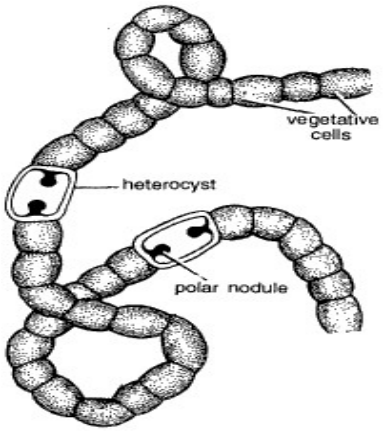
Order: Nostocales

Family: Nostocaceae

Genus: *Nostoc*

Important Features:

1) Thallus is colonial. Young colonies are microscopic, spherical and solid and mature colonies become irregular and hollow.
2) Colonial envelope encloses many filaments. These are much twisted, curved and entangled with each other.
3) Filament has diffluent gelatinous sheath.
4) The trichomes are unbranched. Each trichome is made of cells of uniform size and shape except those called heterocysts which occur throughout.
5) Structure of a cell is typically cyanophycean. It has a centrally located centroplasm, nucleus being altogether absent. Peripheral cytoplasm shows diffused pigments. A few shining cyanophycean granules are also present in this region.
6) Heterocysts are intercalary, double walled, pale yellow coloured with two shining polar granules, one each near the neighbouring cell on either side.
7) Heterocysts are much of the same size of slightly bigger than the vegetative cells.

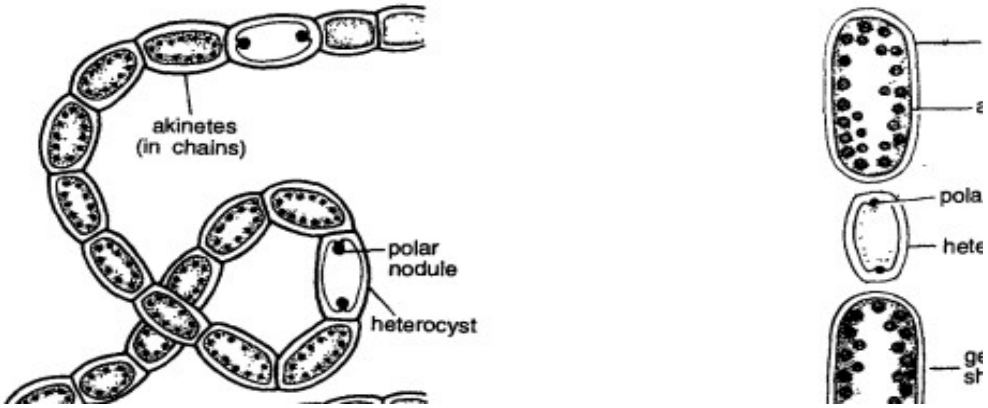


***Nostoc* Vegetative filament**

Nostoc - Akinetes

Important Features:

1) Akinetes are developed only in a mature colony.
2) They occur in large number, in series between two heterocysts.
3) Usually all vegetative cells between two successive heterocysts develop into akinetes.
4) Akinetes are thick walled, sometimes ornamented, rich in food reserves and cyanophycean granules.
5) Akinetes are liberated due to the decay of colonial sheath.
6) They germinate to form a new thallus.



(A) **(B)**

***Nostoc* - (A) Heterocystsand Akinetes in chains (B) Akinetes on both sides**

EXERIMENT 8: MORPHOLOGICAL STUDIES AND IDENTIFICATION OF THE FUNGI THROUGH TEMPORARY AND PERMANENT MOUNTS

Fungal Sample Collection:

1) Select samples of diseased plant tissue, ensuring they are representative of the disease symptoms.
2) Collect samples aseptically (using sterile tools and a sterile environment) to minimize contamination.
3) For root samples, wash the roots with tap water to remove soil debris, and then surface sterilize them with a solution like 1% sodium hypochlorite (NaOCl) for a short time(1 or 2 minutes), to remove any surface contaminants like bacteria or other fungi, followed by rinsing in sterile distilled water.
4) Place small pieces of sterilized (or unsterilized if desired) tissue onto a suitable culture medium (e.g., tap-water agar, TWA) in sterile Petri dishes.
5) Use a plain agar medium, which is beneficial because it favours the growth of the pathogen while suppressing the growth of fast-growing saprophytes.
6) Incubate the Petri dishes under appropriate conditions (temperature, humidity, light) for the fungal species to grow.
7) Observe the growth characteristics of the isolated fungal colonies, noting their colour, shape, texture, and any other distinguishing features.
8) 8.Pick up the mass of mycelium, stain with cotton blue, and mount in lacto phenol and observe under microscope to examine the hyphae (filaments) and fruiting structures of the fungus for further identification.

I. MYXOMYCOTA

Plasmodiophora

Classification

Kingdom: Mycota

Division: Myxomycota

Order: Plasmodiophorales

Family: Plasmodiophoraceae

Genus: *Plasmodiophora*

Important Features:

1) The fungus is an obligate endoparasite.
2) It infects the roots of Cruciferaemembers, particularly cabbage (*Brassica oleracea* var. capitata) cauliflower (*Brassica oleracea* var. botrytis) and turnip (*Brassica rapa*), grown in gardens particularly in acidic and poorly drained soil.
3) The disease caused by *Plasmodiophorabrassicae* is known as 'club-root' or 'finger-and toe' disease of crucifers.
4) The typical symptoms are shown by the roots which become much swollen, lobed, club-shaped and branched. This is due to hypertrophy, the abnormal enlargement of cells.

***Plasmodiophora* infection on cabbage**

II. EUMYCOTA

SUB-DIVISION 1: MASTIGOMYCOTINA

Synchytrium

Classification

Kingdom: Mycota

Division: Eumycota

Sub-division: Mastigomycotina

Class: Chytridiomycetes

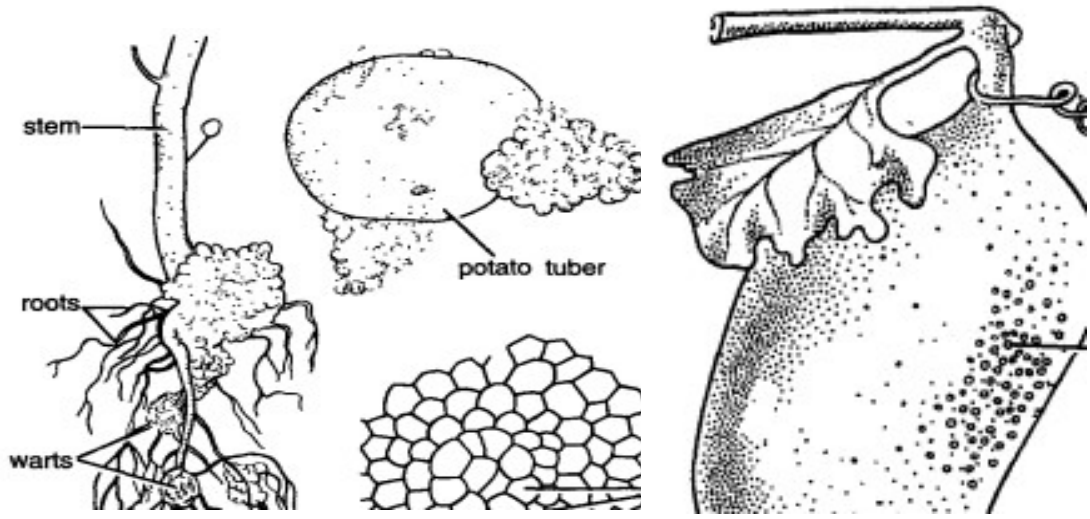
Order: Chytridiales

Family: Synchytriaceae

Genus: *Synchytrium*

Important Features:

1) The fungus generally occurs as an obligate parasite in the epidermal cells of various angiosperms.
2) *S. endobioticum* attacks potato (*Solanumtuberosum*; family-Solanaceae) andcauses serious disease called black wart disease or 'potato-wart disease', very common in Europe.
3) In India, it is common in Darjeeling and West Bengal.
4) Generally, the potato tubers are infected and show dark-brown, warty, cauliflower-like outgrowths. Galls may also be formed on aerial parts.
5) *S. trichosanthoides* and *S. lagenariae* attack cucurbits and cause warts.
6) *S. rhytzii* attacks *Peristrophebicalyculata* (Acanthaceae) and members of Labiatae.
7) *S. sesami* attacks *Sesamumindicum* (Pedaliaceae).



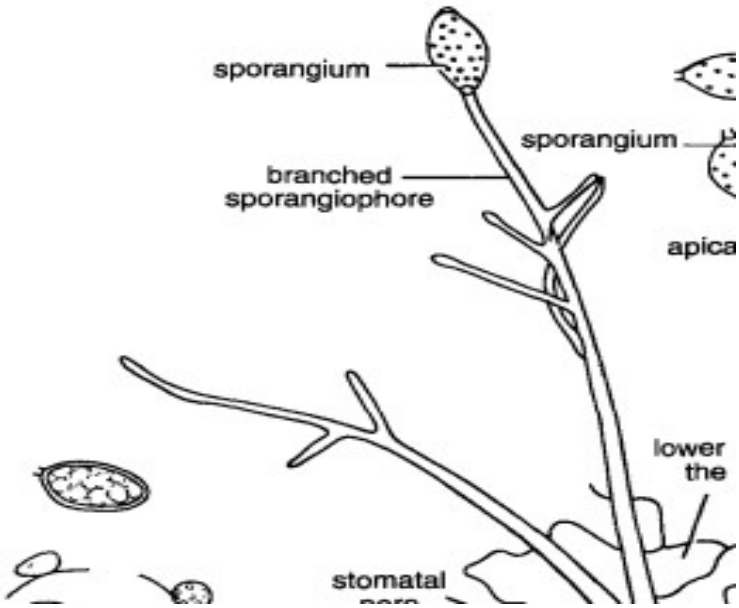
(A) **(B)**

(A) *Synchytriumendobioticum* infected potato tuber with black wart disease

(B) *Synchytriumtrichosanthoides* infected cucurbit

T.S of *Phytophthora* infected leaf showing sporangiophores with sporangia

1) *Phytophthora* is eucarpic, inter- or intracellular parasite.
2) The young mycelium is profusely branched and non-septate but old hyphae at the time of reproduction is septate.
3) Hyphae vary in diameter and develop finger-like haustoria which enter the cells of the host.



***Phytophthora*- T.S of infected leaf showing sporangiophores with sporangia**

SUB-DIVISION 2: ZYGOMYCOTINA

Rhizopus (Bread Mold)

Kingdom: Mycota

Division: Eumycota

Sub-division: Zygomycotina

Class: Zygomycetes

Order: Mucorales

Family: Mucoraceae

Genus: *Rhizopus*

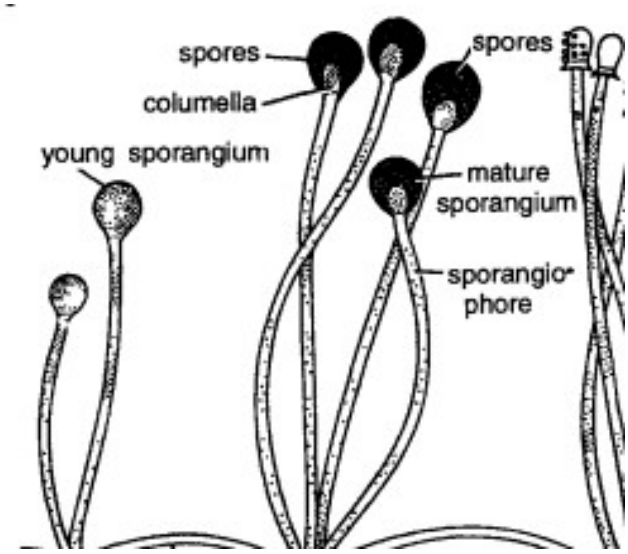
Important Features:

1) Most of the species of *Rhizopus* are saprophytic and grow on dead vegetables or animal matter.
2) *R. stolonifer* grows so frequently on bread that it is often called the 'bread mold'. It is also called 'black mold' for its black coloured sporangia and 'Pin mold' for globose sporangia at the tips of branches look like pin heads.
3) Only a very few species viz., *R. artocarpi* and *R. Arrhizus* are weak parasites.
4) Only a few species of Rhizopus attack the plants.
5) The mycelium shows abundant, white cottony growth.
6) The young mycelium is multinucleate, aseptate, with all the hyphae alike.
7) In the older mycelium three parts of hyphae can be distinguished (i) branched rhizoids that penetrate the substratum, (ii) stolon or runner growing horizontally above the substratum for some distance and then bending downward, producing another group of rhizoids and (iii) the sporangiophores which grow upward in tufts from the point where the stolons form rhizoids.
8) The asexual reproductive structures are sporangia borne by the sporangiophores.
9) Each sporangiophore is swollen at the tip and forms sporangium.
10) The sporangium has a columella in the centre and the space between columella and wall of the sporangium is packed with aplanospores. This is known as the spore sac.

11) The aplanospores are angular or rounded and multinucleate. The spores are colourless or coloured blue or brown with cuticularised or smooth wall showing longitudinal striations.

12) Spores are liberated by breaking of the sporangial wall.

13) Each spore germinates to form a new mycelium.



Rhizopus **mycelium with sporangiophores and sporangia**

SUB-DIVISION 3: ASCOMYCOTINA (ASCOMYCETES)

Erysiphe (Powdery Mildew)

Kingdom: Mycota

Division: Eumycota

Sub-division: Ascomycotina

Class: Plectomycetes

Order: Erysiphales

Family: Erysiphaceae

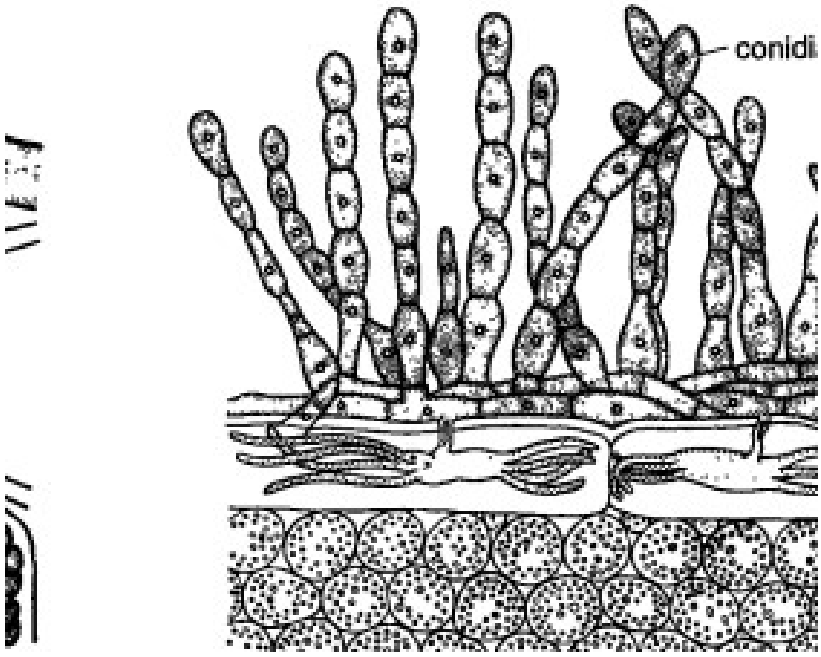
Genus: *Erysiphe*

Important Features:

1) All the species of *Erysiphe* are obligate parasites which grow superficially on host (i.e. as ectoparasites). These generally parasitize angiosperms.
2) This fungus causes a disease commonly known as powdery mildew of peas.
3) The earliest symptoms appear on the upper surface of the older leaves as small, white, circular and powdery spots and enlarge rapidly and cover the entire leaf surface.
4) It is first evidenced as numerous colonies of superficial, flocculent growth on the upper surface of the leaves.
5) They are white to begin and turn to grey or red later on with a powdery appearance and form a cushion-like growth.
6) The infection increases the transpiration and the plants become stunted through reduction in size and number of leaves.
7) The mycelium forms a white, interwoven covering on the host surface.
8) The branched mycelium is septate and the cells are uninucleate.
9) Mycelium produces simple, globose, lobed haustoria which penetrate the epidermal cells of the host.
10) The conidia are asexual reproductive bodies formed in chains at the tips of conidiophores.
11) A conidiophore arises vertically from the mycelium. It is unbranched and swollen at the base in a characteristic manner.
12) Each conidiophore bears, at its tip, many conidia arranged in a basipetal chain.

13) The mature conidia are elliptical, barrel-shaped or sometimes even cylindrical and measure about 30-40 microns in length and 10-19 microns in breadth.

14) The conidia are disseminated by wind and germinate by producing many germ tubes.

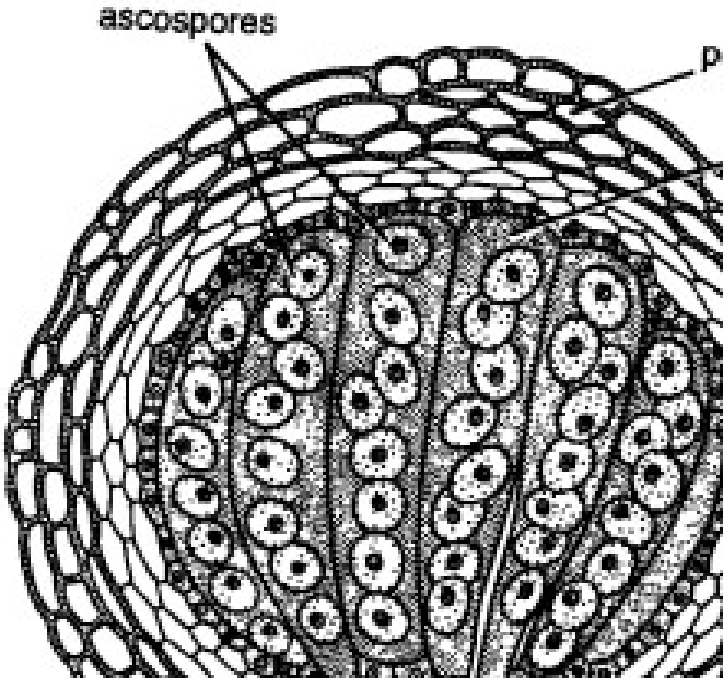


***Erysiphe* section through host leaf showing, conidiophores and conidia**

Erysiphe - *A*scocarp

Important Features:

1) The ascocarp is a cleistothecium which is formed after fertilization.
2) It is a globose structure surrounded by a protective covering-the peridium which becomes 6-10 cells in thickness, at maturity.
3) Certain superficial cells of the peridium develop into characteristic elongated unbranched appendages with free ends.
4) Within the peridium, many asciare present which are more or less stalked and ovate.
5) Each ascusis generally contains eight ascospores (four to five in *E. polygoni*; two or rarely three in *E. cichoracearum*).
6) The ascospores are elliptical, one celled, uninucleate and hyaline.
7) The ascospores are set free either by an irregular cracking of the supper part of the peridium or the cleistothecium may split transversely from its upper part and may come off as a lid.
8) The ascospores, after liberation, germinate by producing a germ tube, if they happen to fall on a suitable host.



***Erysiphe*- Ascocarp V.S**

Aspergillus

Kingdom: Mycota

Division: Eumycota

Sub-division: Ascomycotina

Class: Plectomycetes

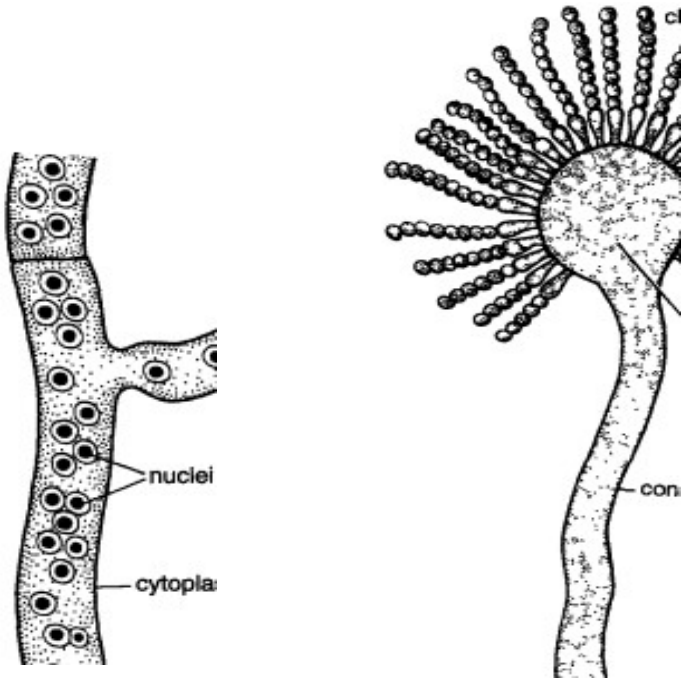
Order: Eurotiales

Family: Eurotiaceae

Genus: *Aspergillus*

Important Features:

1) Most of the species of *Aspergillus* are saprophytes growing on decaying vegetables, butter, bread, rice, jams, leather, cloth, fabrics, etc. However, a few species are parasites on plants and animals, including human beings.
2) The mycelium is well developed, profusely branched and septate.
3) The segments of the mycelium are uni-or multinucleate.
4) The pigments in the cytoplasm give a characteristic colour to the mycelium of various species (similarly coloured conidiophores and conidia would be present in the same species).
5) Conidiophores are erect, hyphal branches that extend from the vegetative hyphae. They are characterized by a stalk (stipe), a swollen apex (vesicle), and structures called metulae and phialides/sterigmata.
6) The vesicle supports the sterigmata, which are flask-shaped cells that produce the conidia.
7) Conidia are the asexual spores arranged in chains on the sterigmata. They are small, spherical, and green with a finely roughened surface.
8) Some of the hyphae spread superficially over the substratum while others penetrate deep into the substratum. The latter absorb food for the mycelium.



(A) **(B)**

***Aspergillus*- (A) Portion of mycelium (B) Mature conidiophore**

Penicillium (Blue Mold)

Kingdom: Mycota

Division: Eumycota

Sub-division: Ascomycotina

Class: Plectomycetes

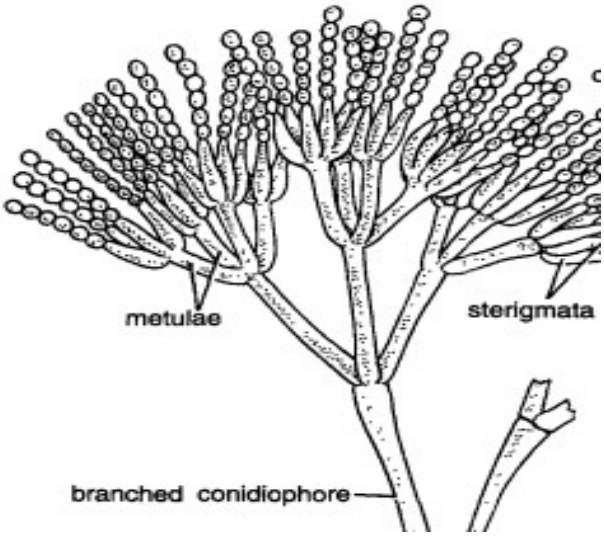
Order: Eurotiales

Family: Eurotiaceae

Genus: *Penicillium*

Important Features:

1) The fungus is a saprophyte and is commonly found on citrus and other fruits, jellies and other foodstuffs.
2) The mycelium is freely branched, septate and each cell is uni-or multinucleate.
3) The mycelium may grow superficially on the surface of substratum or may penetrate deeply.
4) The hyphae are generally coloured due to pigments on the surface of hyphal walls.
5) The conidia are the asexual spores borne on long, erect and branched conidiophores.
6) The branched conidiophore, with its conidia looks like a small 'Penicillus' (a brush in Latin).
7) Each conidiophore grows vertically from the mycelium and branches at its upper end. The ultimate branches are known as metulae.
8) Each branch of conidiophore ends in bottleshaped sterigmata bearing a group of conidia arranged basipetally.
9) The conidia are generally blue, sometimes green or -yellow and give characteristic colour to the colony.
10) The conidia are globose to ovoid in shape and appear as glass beads under the microscope.



Penicillium **mycelium bearing condiophores**

Peziza

Kingdom: Mycota

Division: Eumycota

Sub-division: Ascomycotina

Class: Discomycetes

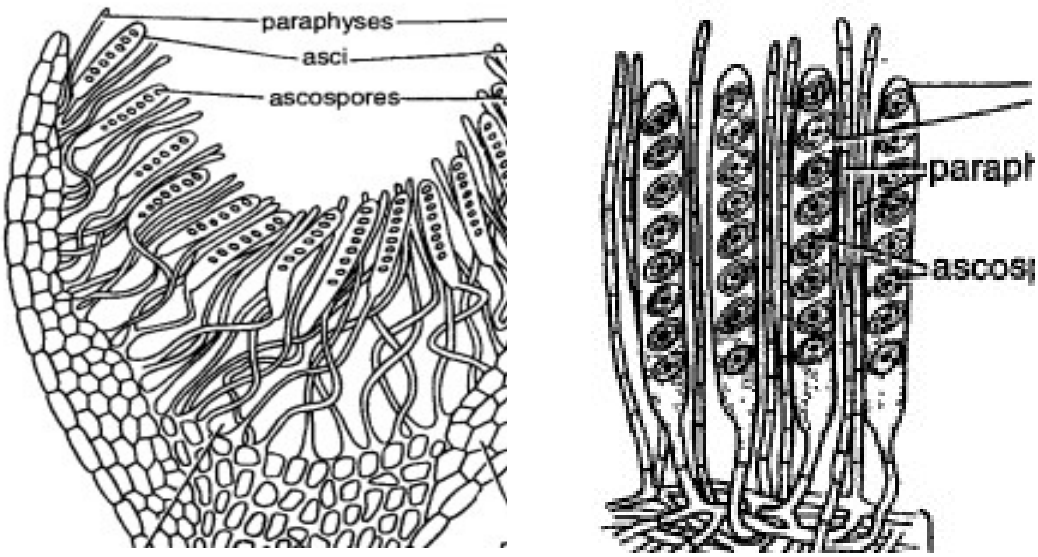
Order: Pezizales

Family: Pezizaceae

Genus: *Peziza*

Important Features:

1) It is a common saprophyte growing on rich humus soils and decaying woods. Sometimes it becomes coprophilous (grows on dung).
2) The mycelium is a complex system that penetrates the substratum.
3) The mycelium is profusely branched, septate and the cells are multinucleate.
4) The mycelium becomes visible only in the form of apothecial cups above the ground surface.
5) The ascocarp is an apothecium. It is fleshy, shortly stalked, about 5 cm in diameter with a bright red or bright grey lining.
6) A vertical section of ascocarp shows a cup shaped structure made up of mycelium. It shows 3 regions-hymenium, hypothecium and excipulum.
7) Hymenium consists of asci and paraphyses arranged vertically in organe-red-coloured palisade-like layer.
8) The hypothectum consists of thin and lightly coloured hyphae that run parallel to hymenium.
9) Excipulum forms a basal large part of loosely interwoven hyphae of apothecium.
10) The hymenium is encircled by densely interwoven hyphae forming the wall of the apothecium-the peridium.
11) Ascus is elongated with a single row of eight ascospores, arranged obliquely.
12) Each ascospore is uninucleate, hyaline or faintly coloured, elliptical, surface smooth or coarsely reticulate and ellipsoidal. It germinates to form new mycelium.



(A) **(B)**

Peziza **- (A) Ascocarp V.S (B) Ascocarp V.S magnified**

SUB-DIVISION 4: BASIDIOMYCOTINA (BASIDIOMYCETES)

Ustilago (Smuts)

Kingdom: Mycota

Division: Eumycota

Sub-division: Basidiomycotina

Class: Teliomycetes

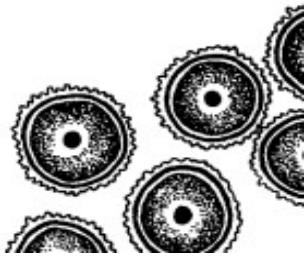
Order: Ustilaginales

Family: Ustilaginaceae

Genus: *Ustilago*

Important Features:

1) Various species of *Ustilago* are parasitic in their natural habitat but many of them grow as saprophytes also.
2) Most of the species infect members of the grass family (Poaceae) and cause enormous loss.
3) The cereal smuts are classified into loose smut and covered smut.
4) The mycelium is well developed. It is generally intercellular without haustoria but sometimes, it is intracellular also.
5) The chlamydospores are formed in the grains of the host by repeated partition of the mycelium.
6) The mature chlamydospores are black soot-like in colour.
7) Each chlamydospore at maturity is unicellular, uninucleate, diploid and globose.
8) The wall is thick with exospore and endospore. Exospore is thick and spiny while endospore is thin and smooth.
9) It germinates to form four basidiospores which in turn produce the monokaryotic (primary) mycelium.



***Ustilago* Chlamydospores**

Puccinia (Rusts)

Kingdom: Mycota

Division: Eumycota

Sub-division: Basidiomycotina

Class: Teliomycetes

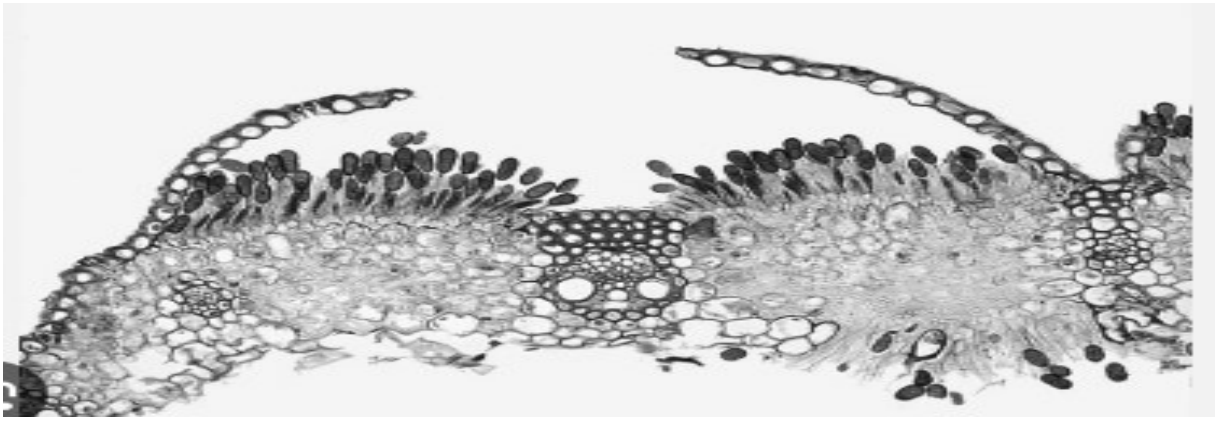
Order: Uredinales

Family: Puccinaceae

Genus: *Puccinia*

Important Features:

1) All the species of *Puccinia* are obligate parasites on some of the important cereals viz., wheat, maize and oat, on millets as bajra and jowar etc.
2) All the species of *Puccinia* are polymorphic.
3) The mycelium is well developed, branched and septate. It is generally intercellular and sometimes shows globular haustoria also.
4) The mycelium is called dikaryotic because it possesses two nuclei of different stains in each cell.
5) The uredosori and telutosori are developed on primary hosts.

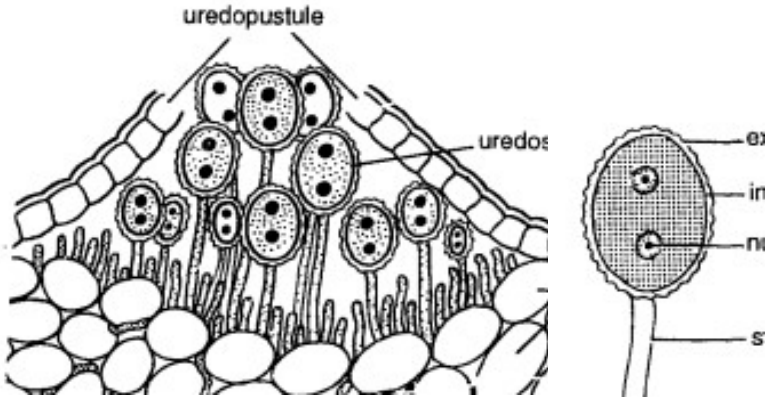


***Puccinia* mycelium**

Puccinia - Uredospores

Important Features:

1) The uredosori or uredopustules appear as red, oval or lemon shaped lesions on the leaves and leaf sheaths.
2) The uredosorus in section reveals the ruptured host epidermis due to the pressure of underlying uredospores.
3) The intercellular and branched mycelium is aggregated beneath the epidermis.
4) The uredospores are produced in massive groups from this mycelium.
5) Each uredospore is binucleate, stalked and rounded or oblong in shape.
6) It has an outer exine which is finely verrucose or echinulate and has inner smooth intine.
7) Each uredospore has four equatorial germ pores.
8) The uredospores get disseminated by wind and infect the fresh wheat plants.



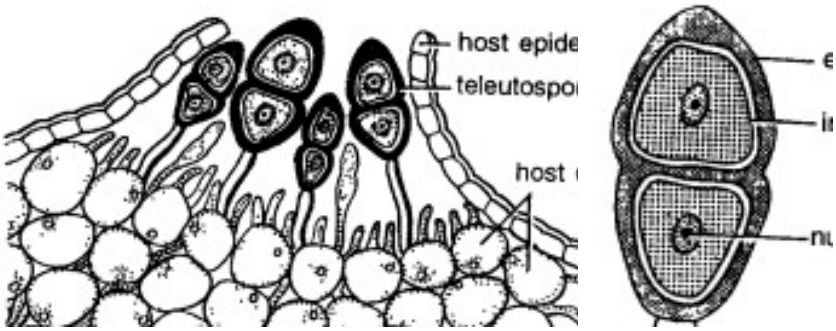
(A) (B)

***Puccinia*-(A) T.S of wheat through uredopustule (B) Uredospore**

Puccinia - Teleutospores

Important Features:

1) The teleutosori or teleutopustules appear on leaves, leaf sheaths and stem as black, oval pustules that fuse to form patches in case of severe infection.
2) A teleutosorus in a section reveals the intercellular, branched mycelium, a bunch of teleutospores and the ruptured host epidermisdue to the pressure of underlying teleutospores.
3) The teleutospores are formed by the same mycelium which earlier produced uredospores.
4) Each teleutospore is borne terminally by the mycelium. It is stalked, elongated and bicelled structure.
5) The apex of the teleutospore may be rounded or pointed as in *P. graminis* or it may be nearly flat as in *P. recondita* and *P. striiformis*.
6) The teleutospore has a very thick but smooth exine and delicate thin intine. The exine turns black at maturity.
7) At first, each of the two cells of the teleutospore is binucleate but later on, the nuclei fuse making each of them uninucleate.
8) Each cell of the bicelledteleutospore has a single germ pore.
9) The teleutospores are incapable of infecting the primary host (wheat plant). They germinate to form the basidiospores which infect the barberry plant or *Thalictrum*, etc., the alternate host.



(A) **(B)**

***Puccinia* (A) T.S of wheat leaf through teleutopustule (B) Teleutospore**

Agaricus (Mushroom) Button stage

Kingdom: Mycota

Division: Eumycota

Sub-division: Basidiomycotina

Class: Hymenomycetes

Sub-class: Holobasidiomycetidae

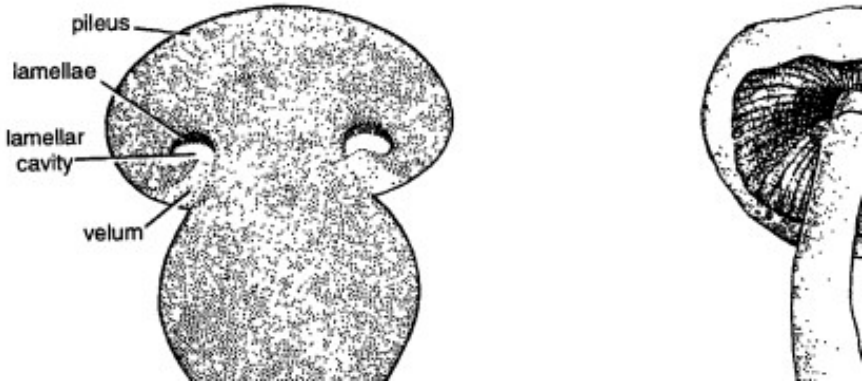
Order: Agaricales

Family: Agaricaceae

Genus: *Agaricus*

Important Features:

1) The mycelium is underground and consists of much branched hyphae, anastomosing at their points of contact, forming a network in the substratum.
2) Hyphae are septate, dikaryotic with granular protoplasm and prominent oil globules.
3) The aerial portion constitutes the fruiting body.
4) Button stage is a developmental stage of the basidiocarp.
5) It is formed above the ground in the form of a small, globose body.
6) In a longitudinal cut, it reveals a small stipe and the pileus.
7) In between pileus and stipe, there is a constriction.
8) At the level of this constriction are seen two lamellar cavities or chambers, one on either side. The lamellar cavities or chambers have small lamellae or gills.
9) The edge of the pileus is connected to the stipe by a thin sheet of tissue-the veil or velum.



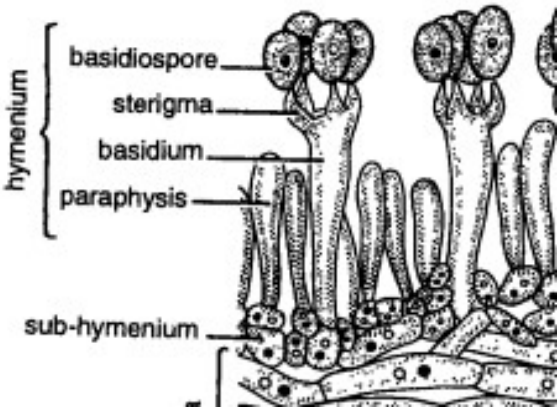
(A) **(B)**

***Agaricus* (A) Button stage (B) Basidiocarp**

Agaricus - Basidiocarp

Important Features:

1) The mature basidiocarp consists of a stalk or the stipe, having an expanded pileus at its top.
2) With the growth of the basidiocarp, the veil or velum ruptures and in mature basidiocarp it remains in the form of a ring (annulus) on the stipe, just below the pileus.
3) The upper surface of pileus is flesh coloured and tough.
4) The pileus, on the underside, bears many lamellae or gills which hang down vertically and extend almost radially from stipe to the margin of the pileus.
5) The gill in transverse section exhibits a trama, a sub-hymenium and a hymenium.
6) The trama forms a central core of elongated sterile hyphae.
7) The hyphal cells of trama curve outwards on either side of the gill forming a more or less compact tissue of cells, the sub-hymenium.
8) Finally the hyphae terminate in elongated, clubshaped cells, forming a superficial layer of the gill, known as the hymenium.
9) The hymenium at maturity, consists of the fertile cells, the basidia, intermingled with the sterile cells, the paraphyses.
10) Each basidium is a club-shaped structure, bearing at its top generally four but sometimes two basidiospores, on short slender stalks known as sterigmata.
11) Each basidiospore is oval in shape and uninucleate. On germination, it produces the new (monokaryotic) mycelium.



***Agaricus*- T.S. of Gills shwoing basidia and basidiocarp**

SUB-DIVISION 5: DEUTEROMYCOTINA (THE FUNGI IMPERFECTI)

Alternaria

Kingdom: Mycota

Division: Eumycota

Sub-division: Deuteromycotina

Class: Hyphomycetes

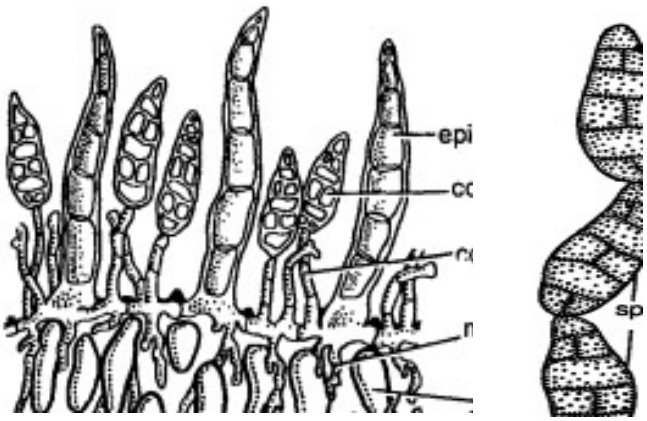
Order: Moniliales

Family: Dematiaceae

Genus: *Alternaria*

Important Features:

1) Mycelium is intercellular or sometimes intracellular and yellowish brown in colour.
2) Hyphae are multicellular,branched, septate and each cell is uninucleate.
3) Usually the conidia are also yellowish brown in colour.
4) The conidia may either be single or in chains. These are borne on conidiophores which are not much distinguishable from the vegetative hyphae emerging through stomata.
5) They are long, dark coloured, muriform (beaked), multicellular and dictyosporous i.e. spindle shaped or ovoid with both transverse and longitudinal septa.
6) The perfect stage of this form genus wherever known belongs of Loculoascomycetes-genus *Pleospora*.



(A) **(B)**

***Alternaria*- (A) T.S of infected leaf showing conidiophores (B) Conidia**

Cercospora

Kingdom: Mycota

Division: Eumycota

Sub-division: Deuteromycotina

Class: Hyphomycetes

Order: Moniliales

Family: Dematiaceae

Genus: *Cercospora*

Important Features:

1) Majority of the species are facultative parasites.
2) Most of these often turn out as destructive parasites commonly producing Leaf spot diseases.
3) Fungus produces pale green spots on the upper surface of the leaf. These gradually turn yellow and ultimately become brown.
4) The foliage finally dries up and is destroyed when disease is severe and destructive. Also, either the fruits are not formed or remain smaller.
5) Mycelium consists of multicellular, septate and branched hyphae.
6) Parasitic hyphae are slender and intracellular. Inside the host, it forms lobed haustoria which penetrate the cells.
7) The hyphal mass is aggregated beneath the epidermis as pseudoparenchymatousstroma.
8) A tuft of short, septate, geniculate, (knee-like) thin walled and unbranched conidiophores emerge through the epidermis.
9) Mature conidiophores are dark coloured, and somewhat thicker than the rest of the hyphae.
10) Conidium is produced at the tip of conidiophore. This conidium is pushed to a side and the tip of conidiophore resumes its growth. Later, a new conidium is produced at its apex.
11) At the places of attachment, conidia leave a scar after falling off.
12) Conidium is inversely clavate (rounded at base and tapering towards apex) and straight or slightly curved. It is generally 4-5 septate (at times 12-15 septate).
13) The colour of the conidium ranges from hyaline to ash-grey to light brown.

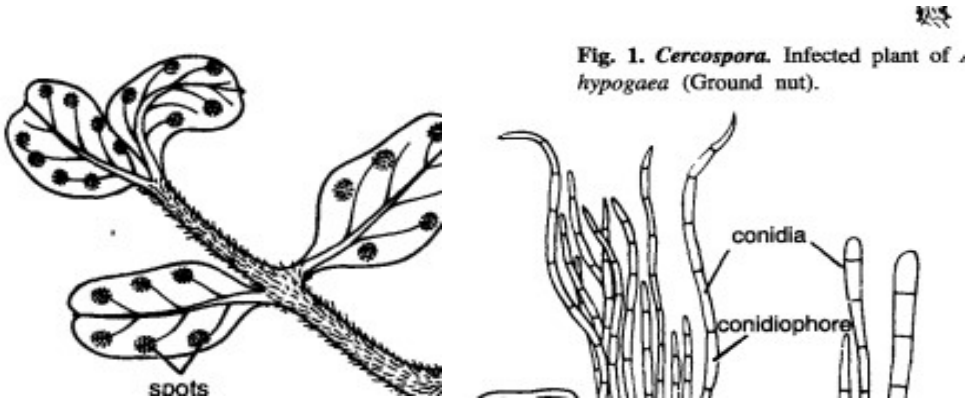
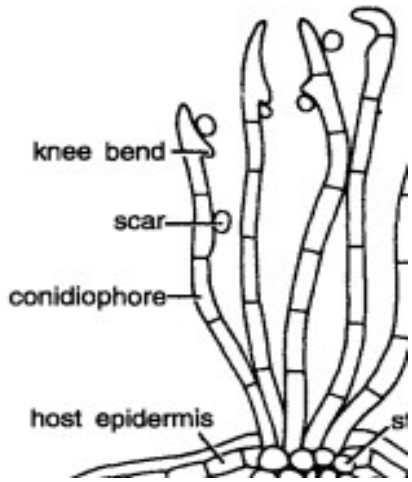


Fig. 1. *Cercospora.* Infected plant of *hypogaea* (Ground nut).

(A) **(B)**

Cercospora **(A) Infection on** ***Arachis hypogea*** **(B) T.S of host leaf and Conidia**



Cercospora **condiophores with geniculate branching and the scars**

Colletotrichum

Kingdom: Mycota

Division: Eumycota

Sub-division: Deuteromycotina

Class: Coelomycetes

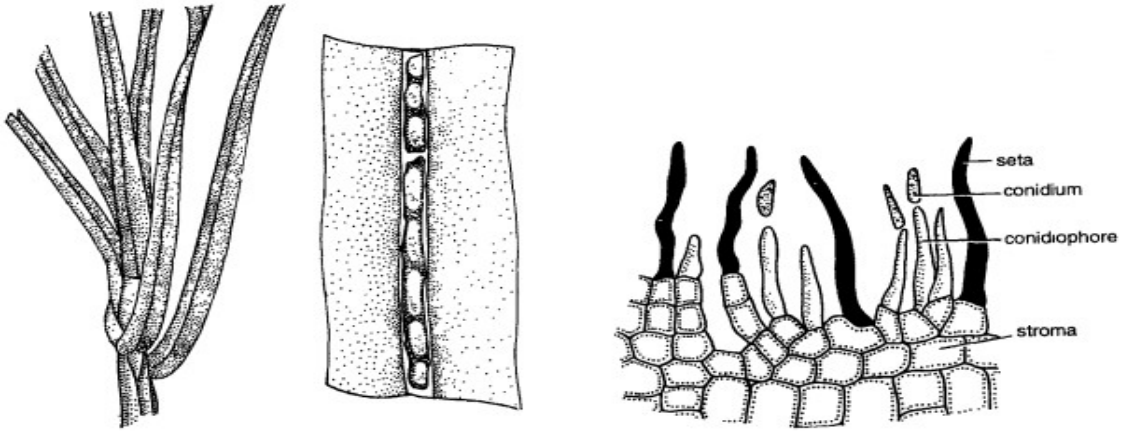
Order: Melanconiales

Family: Melanconiaceae

Genus: *Colletotrichum*

Important Features:

1) Most of the species of *Colletotrichum* are parasitic on higher plants, such as sugarcane, cotton, beans, onion, etc. while others are saprophytes.
2) *C. falcatum* infects sugarcane (*Saccharumofficinarum*) and causes red rot.
3) In red rot, the fungus generally infects the stem and midrib of the leaves.
4) The stem gets rotten within; the rind becomes dull in appearance and shrinks at the nodes.
5) The upper leaves turn paler; droop slightly and split open; show a red colour in the internodes.
6) On the midribs, the infection is seen in the form of dark-reddish areas, which elongate rapidly, forming blood red lesions with dark margins.
7) The mycelium is inter- and intracellular.
8) Hyphae are freely branched, septate, and colourless and contain characteristic oil droplets.
9) The conidia are always formed in acervuli and borne on conidiophores.
10) The acervulus is formed on the surface of the rind as minute black clusters, just above or below the nodes. These develop from the hyphalstroma just beneath the epidermis.
11) Each saucer-shaped acervulus has a layer of non-septate conidiophores arranged in a palisade like manner.
12) Intermixed with conidiophores are black, long, rigid, bristle-like and septate setae. Sometimes, setae form a fringe around the acervulus.
13) Each conidium is one celled, falcate and is typically elongated with rounded ends. It is hyaline and densely granular.



(A) **(B)**

Colletotrichumfalcatum **(A) Infection on sugarcane (A) Acervulus**

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Lesson Writer:

Prof. V. Umamaheswara Rao

OUTLINES OF BRYOPHYTES, PTERIDOPHYTES, GYMNOSPERMS AND PLANT FOSSILS

I. BRYOPHYTES:

Experiment 1: Transverse section of *Marchantia* Thallus

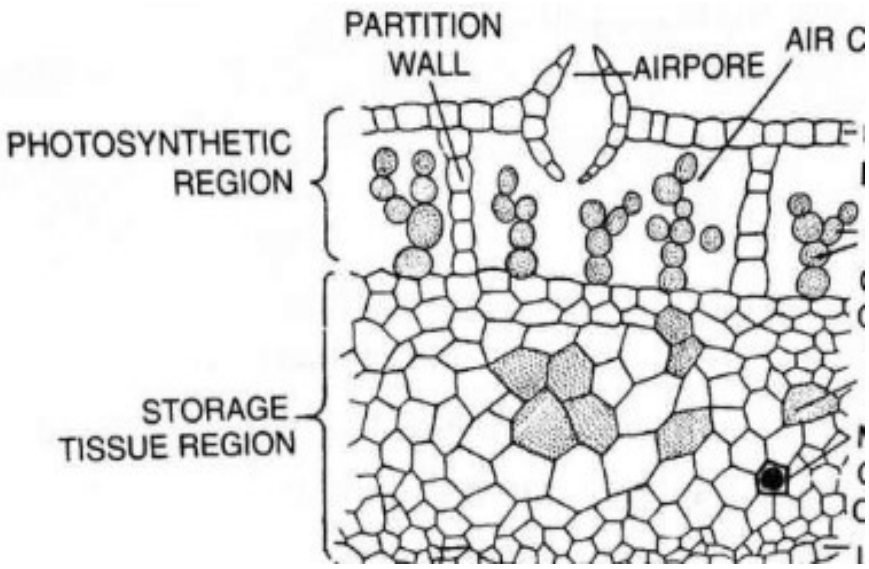
Aim: To make a section cutting of the given plant material and observe the anatomical structure.

Materials Required: Plant Sample, Compound microscope, slides, blades and brush, Glycerol and Safranin.

Procedure: Take fresh plant sample of *Marchantia* and make a thin section of the thallus. Observe the section of thallus under microscope for detailed features.

Salient features:

1) It has two regions (i) Dorsal photosynthetic region (ii) Ventralstorage region.
2) Photosynthetic region has upper epidermis with chimney like air pores which open in to lower air chambers.
3) The air pores help in gaseous exchange for respiration and photosynthesis.
4) The air chambers are separated by partition layer.
5) From floor of each chamber, arise short, simple or branched green filaments, called photosynthetic or assimilatory filaments.
6) Storage region has thin walled parenchymatous cells which contain oil cells and mucilage cells. Storage is the main function of this region.
7) The lower most portion of the storage region is single layer lower epidermis which bears unicellular rhizoids and multicellular scales.
8) There are two types of rhizoids, smooth walled rhizoids and tuberculated or pegged rhizoids.
9) Smooth walled rhizoids are colourless and thin walled.
10) The tuberculate rhizoids are thick walled with peg like in growths.



T.S of *Marchantia* Thallus

Experiment 2: Transverse section of *Anthoceros* thallus

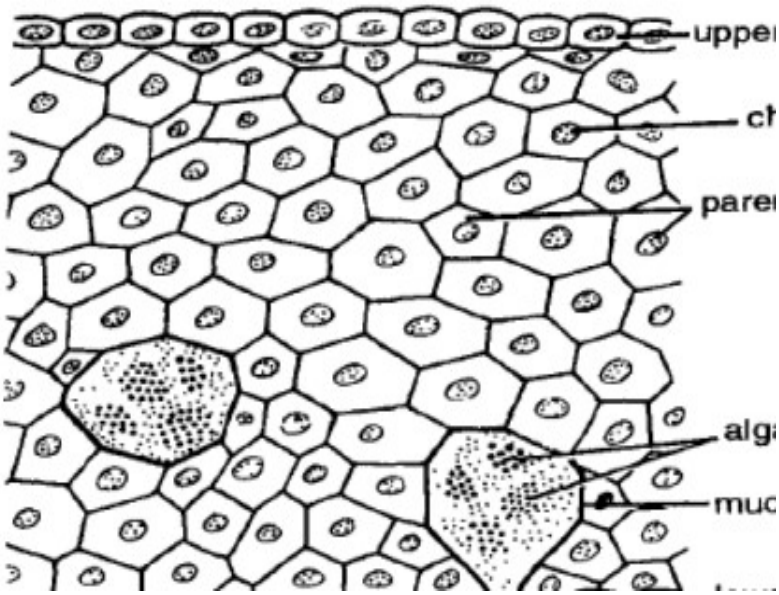
Aim: To make a section cutting of the given plant material and observe the anatomical structure.

Materials Required: Plant Sample, Compound microscope, slides, blades and brush, Glycerol and Safranin.

Procedure: Take fresh plant sample of *Anthoceros* and make a thin section of the thallus. Observe the section of thallus under microscope for detailed features.

Salient features:

1) The cross section of the thallus shows an upper epidermis, a lower epidermis and a middle parenchymatous tissue in between the two.
2) The upper epidermis is made up of compactly arranged thin-walled cells without stomata.
3) Below the upper epidermis, is a parenchymatous tissue of 4-38 cells in thickness.
4) The cells are compactly arranged without intercellular spaces and each cell has a big chloroplast and a pyrenoid.
5) Many round cavities, known as mucilage cavities filled with mucilage are embedded in the parenchyma tissue.
6) The mucilagecavities open in the lower epidermis by small pores called slime pores or slime slits.
7) Each slime pore is guarded by two guard cells. Many rhizoids arise from the cells of the lower epidermis.
8) Each cell of *Anthoceros* has a large nucleus and a discoid chloroplast in the cytoplasm.
9) Each chloroplast contains a single pyrenoid surrounded by starch plates. The chloroplast contains pigments like chlorophyll-a, chlorophyll-b, carotenes and xanthophylls.



Transverse Section of *Anthoceros* thallus

Experiment 3: Transverse section of *Polytrichum* Rhizome

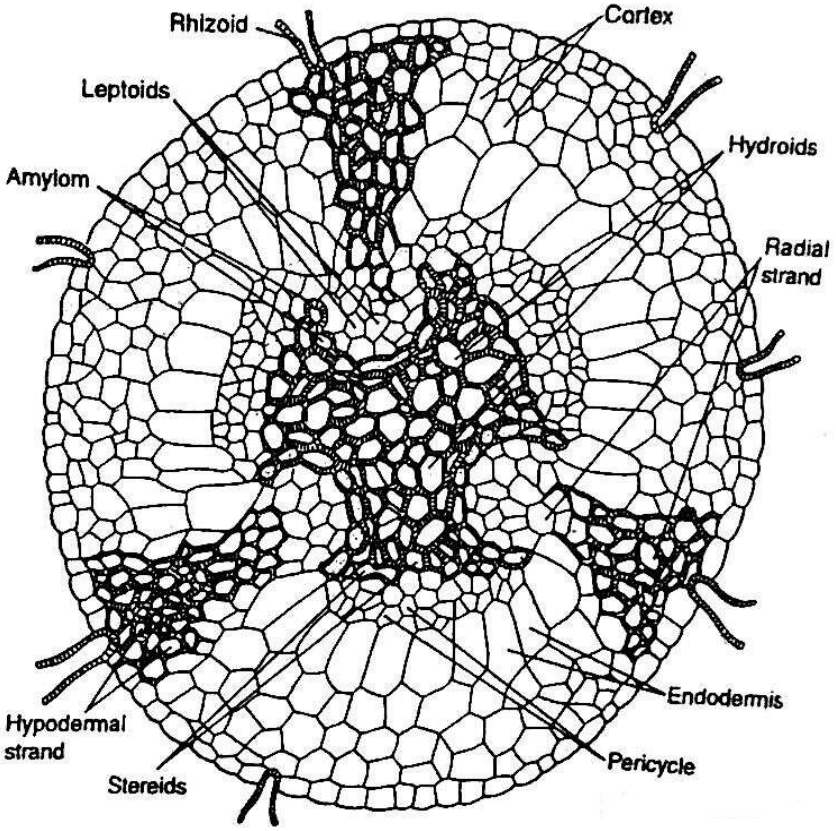
Aim: To make a section cutting of the given plant material and observe the anatomical structure.

Materials Required: Plant Sample, Compound microscope, slides, blades and brush, Glycerol and Safranin.

Procedure: Take fresh plant sample of *Polytrichum* rhizome and make a thin section. Observe the section of the rhizome under microscope for detailed features.

Salient features:

1) The rhizome is the horizontally growing underground portion of the gametophore. It bears scale leaves and numerous fluffy rhizoids.
2) The leaves are small, scale-like, brown or colourless and arranged in three vertical rows.
3) The rhizoids are long, branched, multicellular, thick-walled and characterised by the presence of oblique septa. They are interwoven to form a dense tangled mass.
4) Rhizoids are colourless and arise from the base of the rhizome.
5) Rhizoids attach the leafy shoot to the substratum and also help in absorbing water and mineral nutrients from the soil.



Polytrichum **rhizome transverse section**

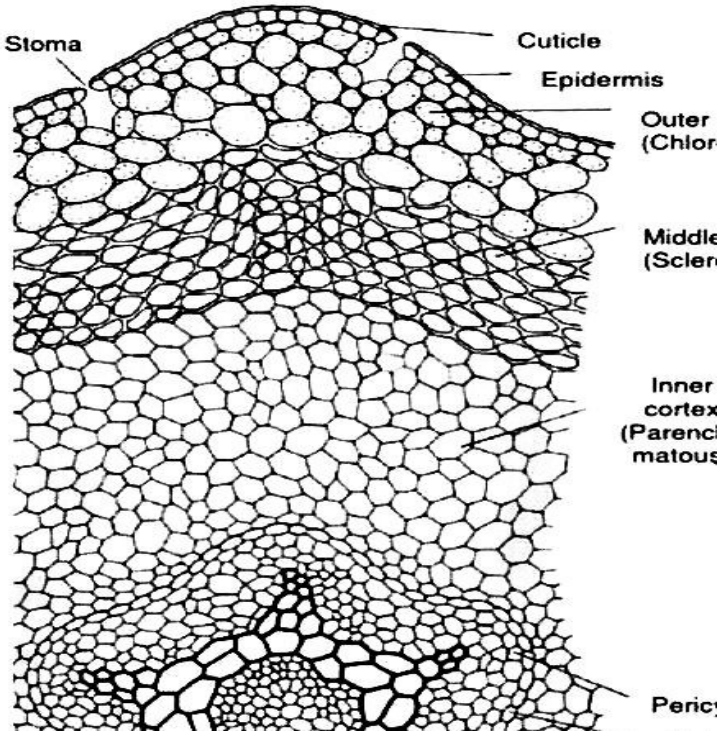
II. PTERIDOPHYTA

Experiment 4: Transverse section of aerial axis of *Psilotum*

1) **Aim:** To make a section cutting of the given plant material and observe the anatomical structure.
2) **Materials Required:** Plant Sample, Compound microscope, slides, blades and brush, Glycerol and Safranin.
3) **Procedure:** Take fresh plant sample of *Psilotum*aerial axis and make a thin section and observe it under microscope for detailed features.

Salient Features:

1) The T.S. of *Psilotum* aerial axis shows an outer epidermis, cortex, an endodermis and an inner stele.
2) Epidermis consists of thin-walled cells, covered over by a layer of cuticle and consists many small porescalled stomata.
3) Cortex is three layered - outer cortex, middle cortex and innercortex.
4) The outer cortex is made-up of thin-walled, chlorenchymatouscells.
5) The middle cortex consists of elongated, densely arranged, thick walled cells.
6) The inner cortex is multi-layered and it is composed of thin walled cells.
7) Endodermis is single-layered and is composed of elongated thin walled cells having casparian thickening.
8) The stele is actinostelicprotostele.
9) Pericycle is always single-layered.
10) Xylem is stellate (star-shaped) and exarch.
11) Phloem occurs between the lobes and the surrounding regions.



Internal structure of aerial axis of *Psilotum*

Experiment 5: Transverse section of *Lycopodium* Stem T.S

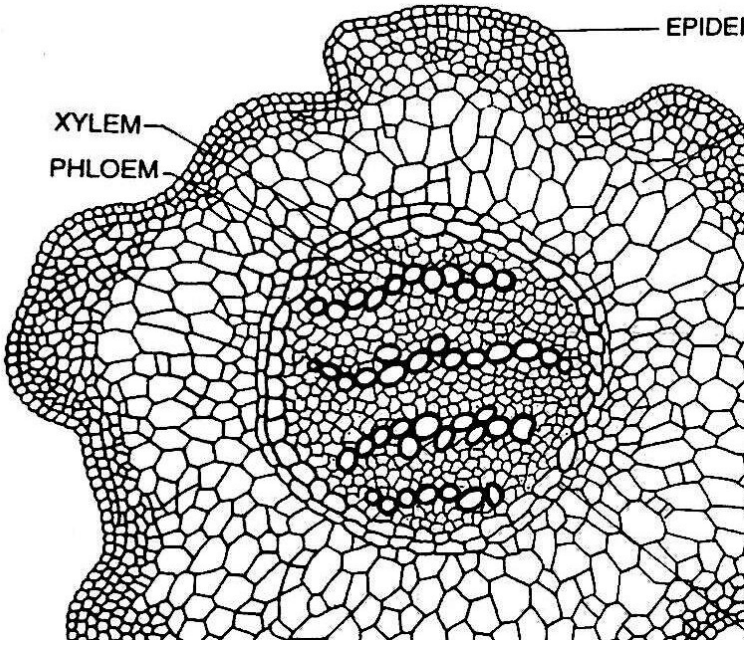
Aim: To make a section cutting of the given plant material and observe the anatomical structure.

Materials Required: Plant Sample, Compound microscope, slides, blades and brush, Glycerol and Safranin.

Procedure: Take fresh stem of *Lycopodium* and make a thin section and observe the section under microscope for detailed features.

Salient features:

1) The stem consists of a superficial epidermis, a broad cortex and a central stele or vascular cylinder.
2) Epidermis is the outermost layer, usually with the thick cutinized outer walls and possess stomata.
3) Cortex is broad, homogeneous throughout or divided into three concentric zones, i.e., outer and inner zones of elongated sclerenchymatous cells and middle zone of large thin-walled parenchymatous cells.
4) An ill-defined endodermis marks off the stele from the cortical region.
5) Inner to the endodermis, pericycle with one to three layers of thin-walled cells is present.
6) Next to the pericycle, stele is present which is generally a protostelebut it varies in different species as well as in different portions of the same plant.
7) The xylem consists of protoxylem and metaxylem, the former being exarch consisting of spiral or annular tracheids, and the latter consisting of scalariform tracheids.
8) Phloem consists of sieve tubes, sieve plates and phloem parenchyma with no companion cells.
9) Many leaf traces are present.
10) Cambium is absent and, therefore, the secondary tissues are absent.



T.S of *Lycopodium* stem

Experiment 6: Transverse section of *Selaginella* Stem

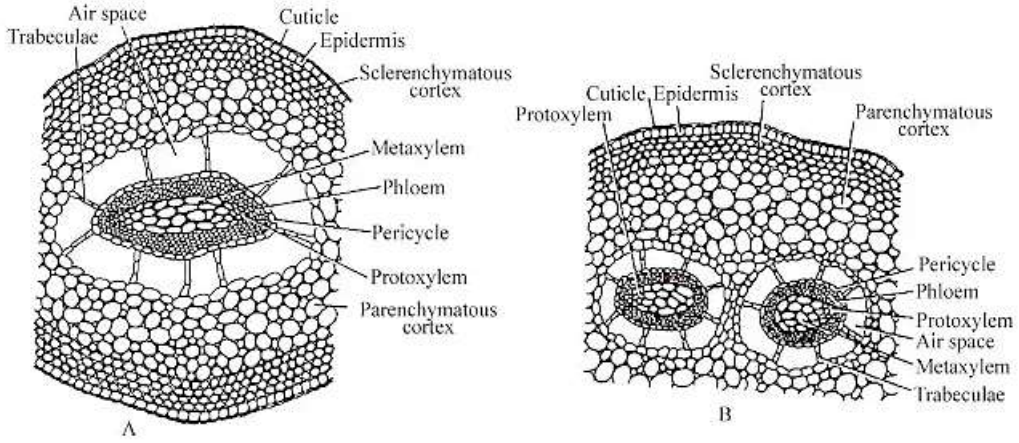
Aim: To make a section cutting of the given plant material and observe the anatomical structure.

Materials Required: Plant Sample, Compound microscope, slides, blades and brush, Glycerol and Safranin.

Procedure: Take fresh sample of *Selaginella* stem and make a thin section and observe the section under microscope for detailed features.

Salient features:

1) The transverse section (T.S.) of a *Selaginella* stem exhibits several distinctive anatomical features, characteristic of lycophytes.
2) Epidermis is a single layer of cells covered by a cuticle to minimize water loss.
3) Cortex is divided into two regions 1. Hypodermis- composed of sclerenchyma cells providing mechanical strength. 2. Inner cortex - **c**onsists of parenchyma cells for storage and possibly photosynthesis.
4) A central cavity, containing air spaces, separates the stele from the cortex.
5) The endodermis connects the cortex to the central tissue through radially elongated cells known as 'trabeculae'.
6) Endodermis a single cell layer surrounding the stele, featuring casparian strips (suberin deposits) in radial walls. It regulates water and nutrient entry into the stele.
7) Stele may be monostelic and distelic.
8) Pericyclelies immediately inside the endodermis. It may contribute to lateral root formation.
9) Vascular cylinder is protostele, specifically a plectostele in many *Selaginella* species.
10) Xylem is exarch, with protoxylem at the periphery and metaxylem centrally within plate-like bands.
11) Phloem is located between the xylem plates, surrounding them.
12) In T.S., the xylem and phloem form alternating parallel bands/plates, giving a "ribboned" appearance.
13) The centre of the stem is occupied entirely by vascular tissue (xylem and phloem), with no parenchymatous pith.
14) Lacks vascular cambium, so no secondary xylem/phloem. The stem remains herbaceous.



Selaginella **stem T.S- A. Monostelic condition B. Distelic condition**

Experiment 7: Transverse section of *Equisetum* stem

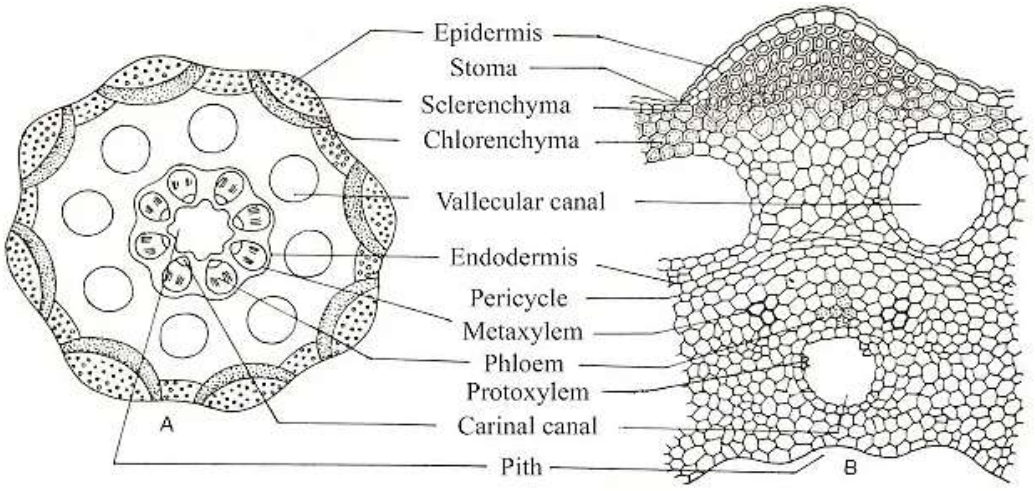
Aim: To make a section cutting of the given plant material and observe the anatomical structure.

Materials Required: Plant Sample, Compound microscope, slides, blades and brush, Glycerol and Safranin.

Procedure: Take fresh sample of *Equisetum* stemand make a thin section of the it. Observe the section of the stem under microscope for detailed features.

Salient features:

1) Stem is wavy in outline due to the presence of ridges and grooves.
2) It has epidermis, cortex, vascular bundles and a large pithcavity.
3) Epidermis is single layered with deposition of silica on theirouter and radial walls which provides mechanical strength.
4) Epidermis is interrupted by stomata.Stomata are confined togrooves- sunken.
5) Cortex is differentiated into outer and inner regions.
6) The outer cortex consists of sclerenchymatous which lies below the epidermis followed by a band of andchlorenchymatous cells.
7) The inner cortex is composed of thin walled parenchymatouscells. It has large schizolysigenous canals known as vallecularcanal below the furrow- aerating system.
8) Cortex is delimited from the stele by an endodermis.
9) The endodermis is followed by a single layer of parenchymatous pericycle.
10) The vascular bundle is a siphonostele. Vascular bundles are arranged in a ring around the large pith opposite to ridges alternating the vallecular canal.
11) Vascular bundles are conjoint, collateral and endarch.
12) Xylem of a bundle is in the form of two lateral and a median group of tracheids.
13) In the young vascular bundle, the protoxylem is represented bytracheids with annular or spiral thickening.
14) The metaxylem tracheids have scalariform, reticulate orpitted thickenings.
15) The phloem lies outside the xylem.
16) The central part of the internode of the aerial shoot has largepith cavity.



***Equisetum* stem T.S (A) Diagramatic (B) Cellular**

Experiment 8: Transverse section of *Marsilea* Rhizome

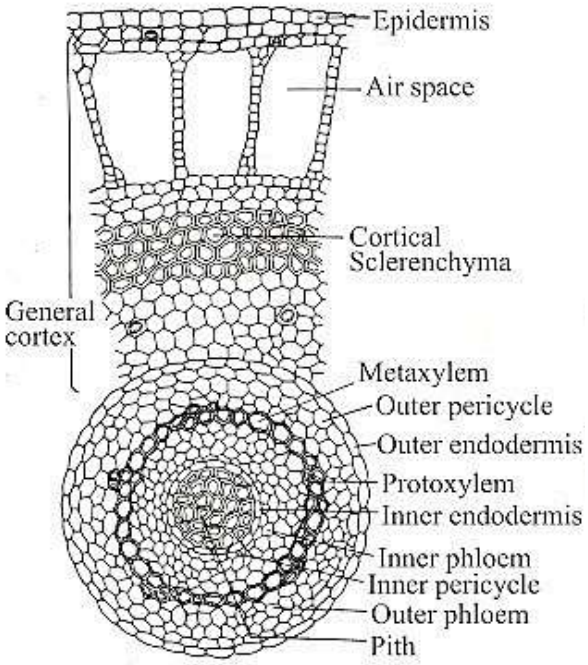
Aim: To make a section cutting of the given plant material and observe the anatomical structure.

Materials Required: Plant Sample, Compound microscope, slides, blades and brush, Glycerol and Safranin.

Procedure: Take fresh *Marsilea* stem and make a thin section of it. Observe the section of under microscope for detailed features.

Salient features:

1) A T. S. of the old stem is somewhat circular in outline and shows epidermis, cortex and stele.
2) Epidermis is the outermost limiting layer of single celled thick parenchymatous cells. The stomata are absent.
3) Cortex is differentiated into three regions – the outer cortex, middle cortex and inner cortex.
4) Outer cortexis present just below the epidermis (also called hypodermis). It is parenchymatous and may be one to several cells thick. Some of outer cortex cells contain tannin.
5) Middle cortexlies below the hypodermis and also called as aerenchyma. It consists of large air spaces (chambers) separated by one cell thick parenchymatous septa.
6) Inner cortexis a solid tissue of several cells thickness. The outer layers are thick walled (sclerenchymatous) while the inner layer of cells is thin walled (parenchymatous) and compactly arranged.
7) Stele is amphiphloicsiphonostele i.e., in the centre there is a pith which may be either parenchymatous (aquatic species) or sclerenchymatous (terrestrial muddy species).
8) Xylem is present in the form of a complete ring which is surrounded on both sides by a complete ring of inner and outer phloem, pericycle and endodermis.
9) The protoxylem may be well defined exarch (*M.vestita*) or mesarch (*M.aegyptiaca*) or ill defined (*M.quadrifolia*).



T.S of *Marselia* rhizome

Experiment 9: Transverse section of *Marsilea* Petiole

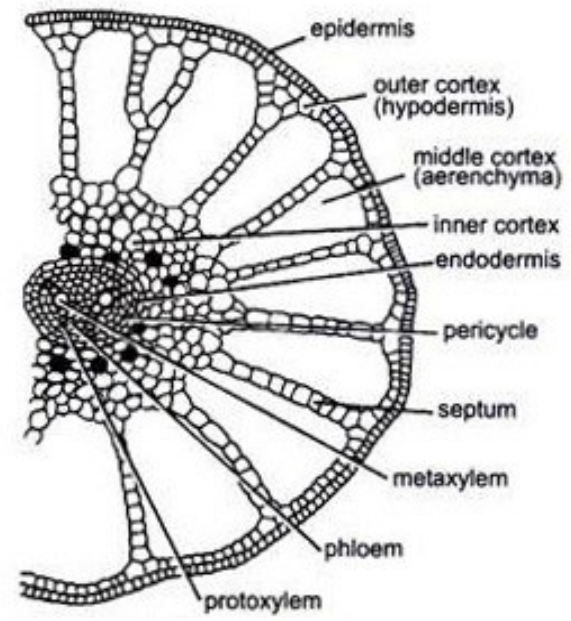
Aim: To make a section cutting of the given plant material and observe the anatomical structure.

Materials Required: Plant Sample, Compound microscope, slides, blades and brush, Glycerol and Safranin.

Procedure: Take fresh *Marsilea* petiole and make a thin section observe the section under microscope for detailed features.

Salient features:

1) The T.S. of the petiole is somewhat circular in outline and is differentiated into epidermis, cortex and stele.
2) Epidermis is the outermost layer of single cell thickness. The cells are parenchymatous and slightly elongated.
3) Cortexis differentiated into three regions: the outer cortex, middle cortex and inner cortex.
4) Outer cortexis present just below the epidermis, (also called hypodermis). It is made of thin walled cells (parenchymatous).
5) Middle cortexlies below the hypodermis and is called as aerenchyma. It consists a ring of air chambers.
6) The air chambers are separated by single layered partitions of thin-walled parenchymatous cells.
7) Inner cortexis a solid parenchymatous tissue of several cells thickness and contain starch and tannin filled cells.
8) Steleis somewhat triangular in outline and is of protostelic type i.e. pith is absent. Xylem is “V” shaped with 2 distinct arms.
9) Each arm is provided with metaxylem elements in the centre and protoxylem is situated at both the margins i. e., protoxylem is exarch.
10) The xylem is surrounded on all sides by phloem. Phloem is externally surrounded by a single layer of parenchymatouspericycle which, in turn, is bounded by a single layered endodermis.



T.S of *Marselia* petiole

III. GYMNOSPERMS

Experiment 10: Transverse section of *Cycas* Corolloid Root

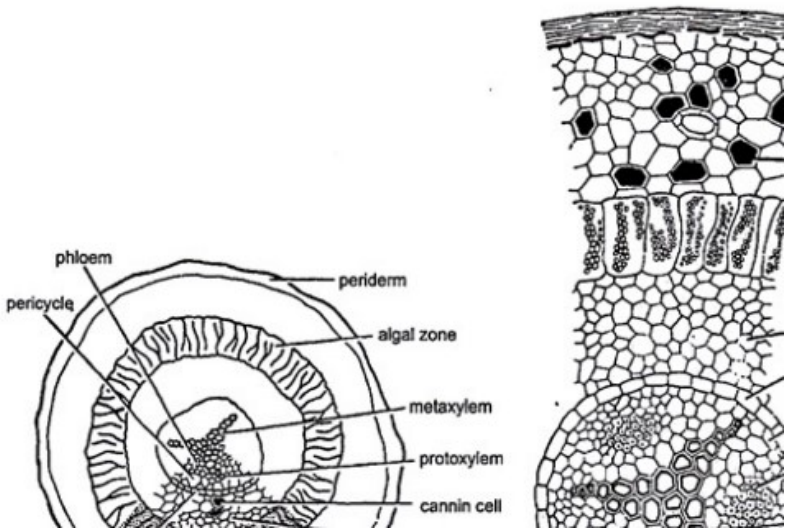
Aim: To make a section cutting of the given plant material and observe the anatomical structure.

Materials Required: Plant Sample, Compound microscope, slides, blades and brush, Glycerol and Safranin.

Procedure: Take fresh sample of *Cycas* corolloid rootand make a thin section and observe under microscope for detailed features.

Salient features:

1) Epidermis is the outermost layer composed of a single layer of thin-walled cells. May lack root hairs, adapted for symbiosis rather than absorption.
2) Cortex is divided into three distinct regions – Outer, Middle and Inner.
3) Outer cortex is parenchymatous cells with intercellular spaces, potentially involved in storage and gas exchange.
4) Middle cortex (algal zone – unique to corolloid roots) is characterized by irregular, labyrinthine intercellular spaces filled with mucilage.
5) Cells adjacent to these spaces facilitate nutrient exchange (plant provides carbohydrates; cyanobacteria fix atmospheric nitrogen).
6) Inner cortex is compact parenchyma cells with fewer intercellular spaces, transitioning to the endodermis.
7) Endodermis is single layer of cells with casparian strips (suberin deposits) on radial and transverse walls. Regulates selective transport of water and minerals into the vascular cylinder.
8) Pericycle is located just inside the endodermis and composed of meristematic cells capable of forming lateral roots.
9) Xylem is arranged in an exarch pattern (protoxylem toward the periphery, metaxylem inward) and typically diarch or tetrarch.
10) Phloemstrands alternate with xylem, responsible for organic nutrient transport.



***Cycas*(A) Corolloid root T.S diagrammatic (B) Corolloid root T.S (Cellular)**

Experiment 11: Transverse section of *Pinus* needle

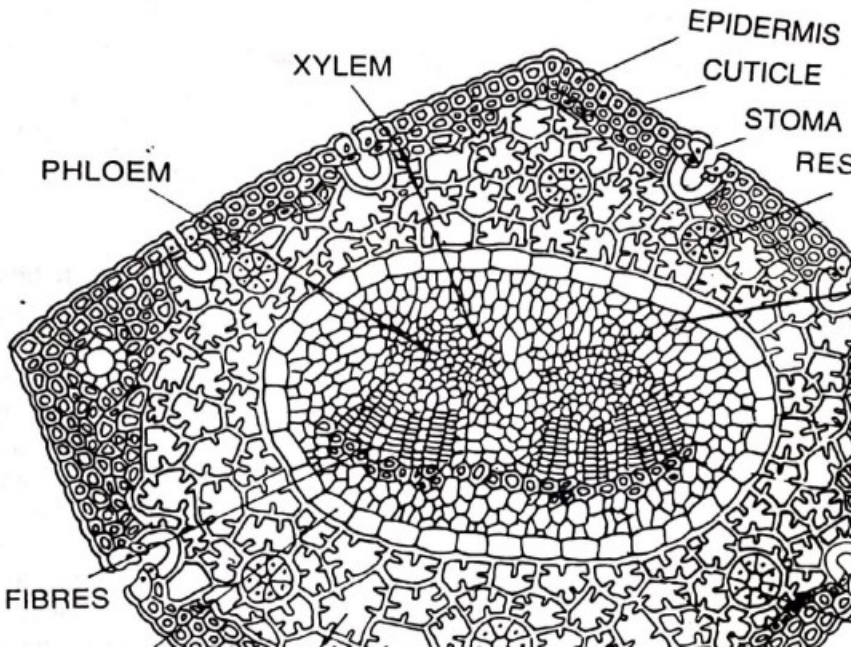
Aim: To make a section cutting of the given plant material and observe the anatomical structure.

Materials Required: Plant Sample, Compound microscope, slides, blades and brush, Glycerol and Safranin.

Procedure: Take fresh *Pinus* needle, make a thin section and observe the section under microscope for detailed features.

Salient Features:

1) The transverse section of a *Pinus* needle reveals specialized adaptations for xerophytic conditions.
2) Epidermis is a **s**ingle-layered, thick-walled cells with a heavy cuticle to minimize water loss.
3) Stomata are sunken in rows (stomatal crypts), each surrounded by subsidiary cells. This design reduces transpiration by trapping moist air.
4) Hypodermis is present beneath the epidermis and contains sclerenchyma cells that provide mechanical support and rigidity to the needle.
5) Mesophyll cells are parenchymatous with chloroplasts for photosynthesis. Unlike angiosperms, there are no distinct palisade/spongy layers, but cell walls may fold to increase surface area.
6) Resin canals are embedded in the mesophyll, lined with epithelial cells that secrete resin (defence against herbivores/pathogens).
7) Endodermis **s**urrounds the vascular region and acts as a selective barrier. Cells may contain casparian strips to regulate solute transport.
8) Transfusion tissue is composed of tracheids (meant for water conduction) and parenchyma (meant for nutrient storage).Facilitates exchange between the vascular bundle and mesophyll.
9) Vascular bundles typically arranged in 1–2 collateral bundles present in the centre with xylem inward and phloem outward.



T.S of *Pinus* needle

Experiment 12: Transverse section of *Pinus* stem

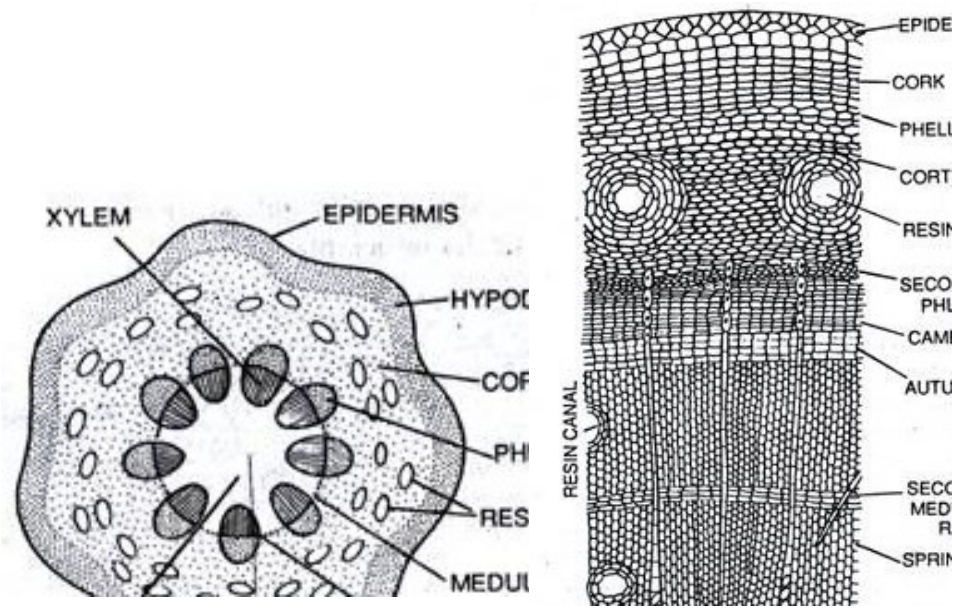
Aim: To make a section cutting of the given plant material and observe the anatomical structure.

Materials Required: Plant Sample, Compound microscope, slides, blades and brush, Glycerol and Safranin.

Procedure: Take fresh *Pinus* stemand make a thin section of it. Observe the section of under microscope for detailed features.

Salient features:

1) The transverse section of a *Pinus* stem exhibits distinct anatomical features, especially after secondary growth.
2) Periderm (Bark) in mature stems replaces the epidermis in older stems. Composed of cork (phellem), cork cambium (phellogen), and phelloderm.
3) Cortex is located beneath the periderm,composed of parenchyma cells with chloroplasts in young stems. Contains resin canals (schizogenous cavities lined with epithelial cells) that secrete resin for defence.
4) Secondary phloem contains sieve cells (elongated with sieve areas on lateral walls) and albuminous cells (support sieve cells, analogous to companion cells in angiosperms). Lacks companion cells and sieve tubes.
5) Vascular cambium is a meristematic layer between xylem and phloem responsible for secondary growth.
6) Secondary xylem (wood) is having tracheids. These are main conducting cells and lack vessels. Have bordered pits for lateral water movement.
7) Annual rings are formed by seasonal growth i.e. spring wood (large, thin-walled tracheids) and summer wood (small, thick-walled tracheids).
8) Medullary rays are uniseriate (single-cell-wide) parenchyma rows for radial transport.
9) Resin canals are vertical ducts in the wood, lined with epithelial cells.
10) Pith is composed of parenchyma cells and may contain resin canals in young stems.



***Pinus* stem T.S (A) Pinus T.S (Diagramatic) (B). Pinus T.S (Cellular)**

Experiment 13: Transverse section of *Gnetum* Stem

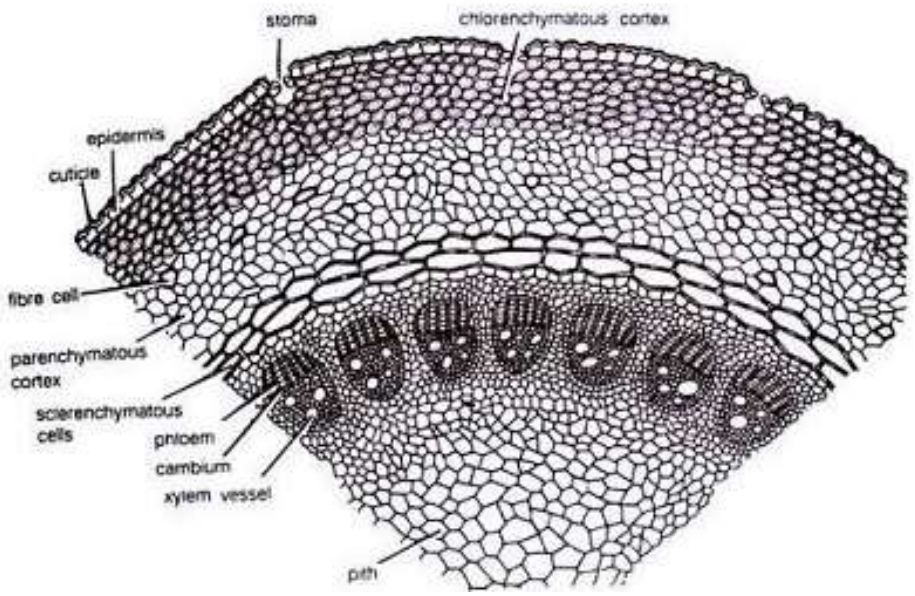
Aim: To make a section cutting of the given plant material and observe the anatomical structure.

Materials Required: Plant Sample, Compound microscope, slides, blades and brush, Glycerol and Safranin.

Procedure: Take fresh sample of *Gnetum* stemand make a thin section of it. Observe the section under microscope for detailed features.

Salient features:

1) The T.S of *Gnetum* stem shows an epidermis, cortex, endodermis and astele.
2) Epidermis is the outer layer made up of rectangular cells covered with cuticle. It has sunken stomata.
3) The cortex has three distinct zones. The outer cortex is chlorenchymatous, the middle cortex is parenchymatous andthe inner cortex is sclerenchymatous.
4) The endodermis and pericycle are not so distinct.
5) The stele is an ectophloic eustele. It consists of a ring of manyvascular bundles.
6) The vascular bundles are conjoint, collateral, endarchandopen.
7) Xylem is central and consists of tracheids and vessels.
8) The phloem consists of sieve cells, phloem pacenchma and companion cells.
9) Vascular bundles are separated by a broad parenchyma.
10) The pith is parenchymatous.



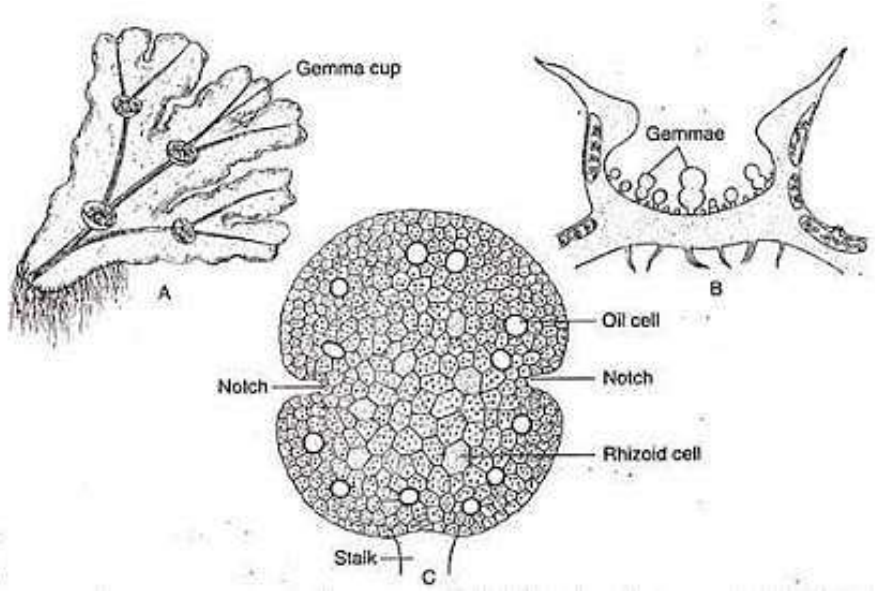
***Gnetum* stem T.S**

PERMANENT SLIDES

I. BRYOPHYTES

1. Gemma Cup:

1) Gemmae are asexual reproductive organisms that form cup-shaped structures termedas gemma cups on the dorsal surface of the thallus.
2) The gemma cup has a serrated and membranous edge, with many gemmae.
3) Gemmae are linked to the bottom of the cup by a tiny, single-celled stalk.
4) Multicellular glandular hairs are mixed with gemmae.
5) Mature gemmas are green, multicellular, and lens-shaped structures.
6) It features two deep lateral notches with developing tips.
7) Gemma cells are chlorenchymatous, with few oil and rhizoidal cells.
8) The mature gemma separates from the mother plant and grows into a new plant.

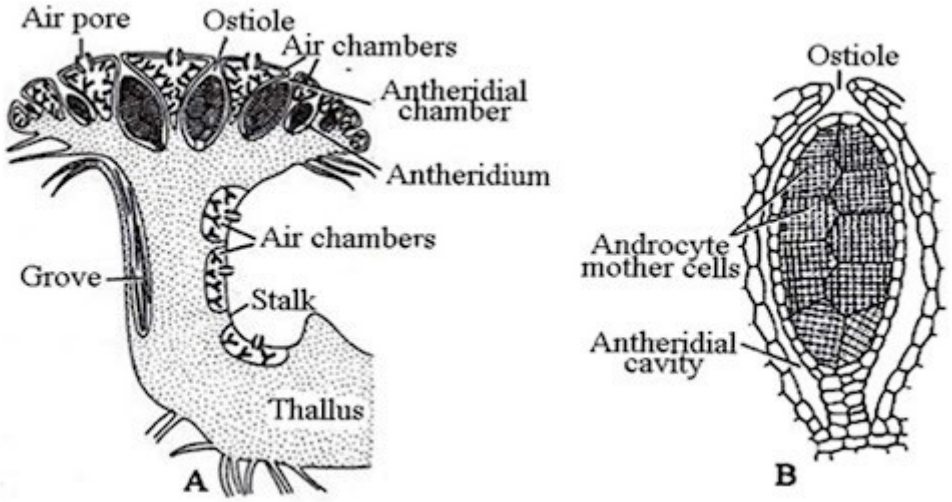


(A) *Marchantia* thallus with gemma cup (B) Vertical section of gemma cup

(C) Individual gemma cup

2. *Marchantia* - *A*ntheridiophore

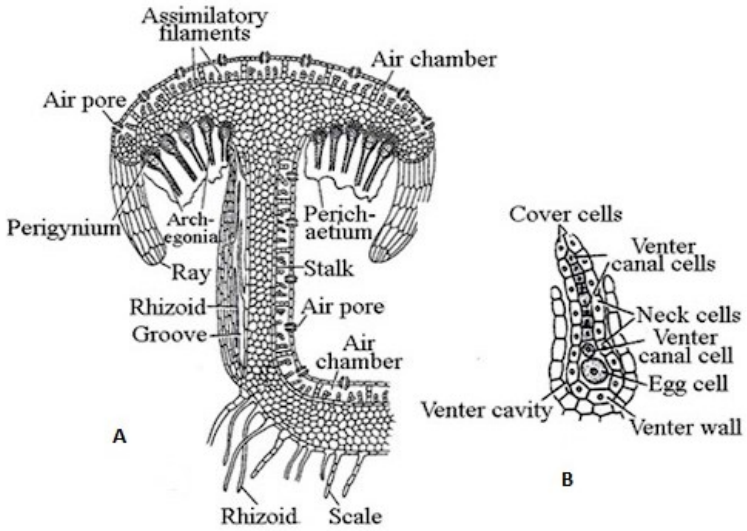
1) Antheridiophores have stalks and receptacles.
2) The stalk is cylindrical, with air chambers on the back and two vertical grooves on the front.
3) The receptacle disk has two regions: assimilatory and storage.
4) Assimilatory chambers alternate with flask-shaped voids known as antheridial chambers.
5) Each antheridial chamber has a single antheridium that opens through the ostiole.
6) The mature antheridium has a slender stalk and a spherical body called the capsule.
7) The antheridium is enclosed by a single, layered jacket called the antheridial wall.
8) The jacket contains androcyte mother cells.



***Marchantia* (A) Antheridiophore longitudinal section (B) Antheridium**

3. *Marchantia* - Archegoniophor1e

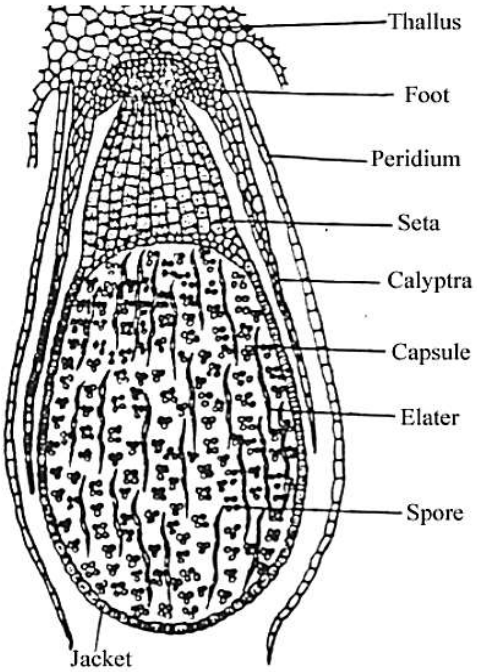
1) Archegoniophores have a stalk and disc-shaped receptacle.
2) The receptacle has eight lobes and each lobe has 12-14 archegonia grouped in acropetal order.
3) The adult archegonium is flask-shaped.
4) It has a basal stalk, venter, and neck.
5) The venter contains an egg and a venter canal cell.
6) The neck contains 4-8 neck canal cells and 4 lid cells.
7) In mature archegonium, the neck canals and venter canal cells disorganize, resulting in mucilaginous fluid.
8) This mucilage absorbs water and aids in opening lid cells.



***Marchantia* (A) Archegoniophore (B) Archegonium**

4. *Marchantia* - Sporophyte

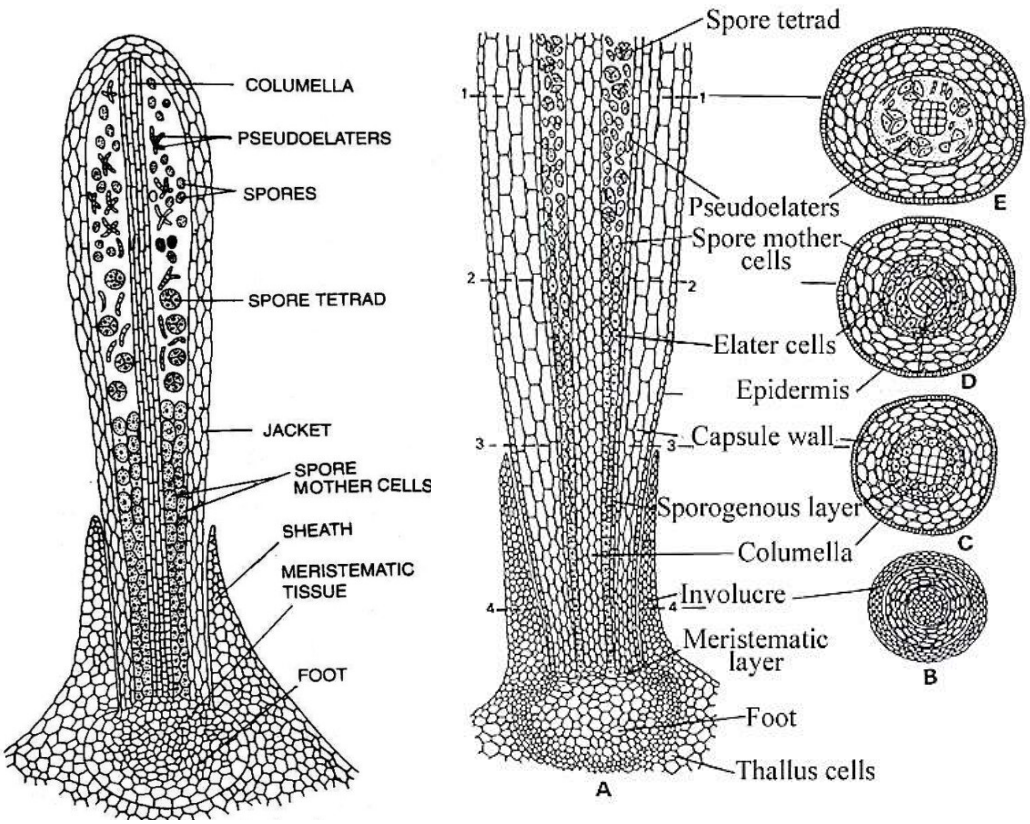
1) *Marchantia* produces sporophytes in female gametophytes.
2) The sporangium comprises three parts: (i) the foot, (ii) the seta, and (iii) the capsule.
3) The sporophyte's foot serves as its base, anchoring, and absorptive organ.
4) Seta is the middle section that connects the foot to the capsule.
5) The fruitful zone is the capsule. The outer layer of the capsule, known as the capsule wall, contains viable sporogenous tissue.
6) Sporogenous cells generate spore mother cells and elater mother cells.
7) Elater mother cells generate elaters.
8) Elaters are hygroscopic diploid, sterile, elongated, and have pointy ends. It exhibits spiral rings of thickening on the inner surface. It assists with capsule dehiscence.
9) Spore mother cells divide by meiosis to create tetrads.
10) The spores are haploid and develop in to gametophyte.



***Marchantia* sporophyte**

5. *Anthoceros* - Sporophyte

1. The sporophyte is elongated, cylindrical, and resembles a horn—hence the name "hornworts."
2. It grows upright and continuously from the gametophyte.
3. Unique among bryophytes, the sporophyte has a basal meristem (growth point at the base), allowing continuous growth and spore production over time.
4. The foot is embedded deep in the gametophyte tissue and absorbs nutrients and water.
5. Unlike mosses and liverworts, the seta is absent or very short.
6. The sporophyte elongates due to intercalary meristematic activity near the foot, not because of a seta.
7. True stomata are present on the capsule surface for gaseous exchange—another advanced feature.
8. The sporophyte is green and photosynthetic, containing chloroplasts, which partly reduce dependency on the gametophyte.
9. The capsule is long, narrow, and splits longitudinally from apex to base for spore release.
10. It contains pseudoelaters (spiral, sterile cells) that assist in spore dispersal.
11. Spores are haploid and formed via meiosis in the capsule.
12. Pseudoelaters are non-spiral or less spirally thickened compared to true elaters in liverworts.
13. No true xylem or phloem, but primitive conducting cells may be present in some species.
14. The gametophyte hosts cyanobacteria (e.g., *Nostoc*) in mucilage cavities, but the sporophyte benefits indirectly.

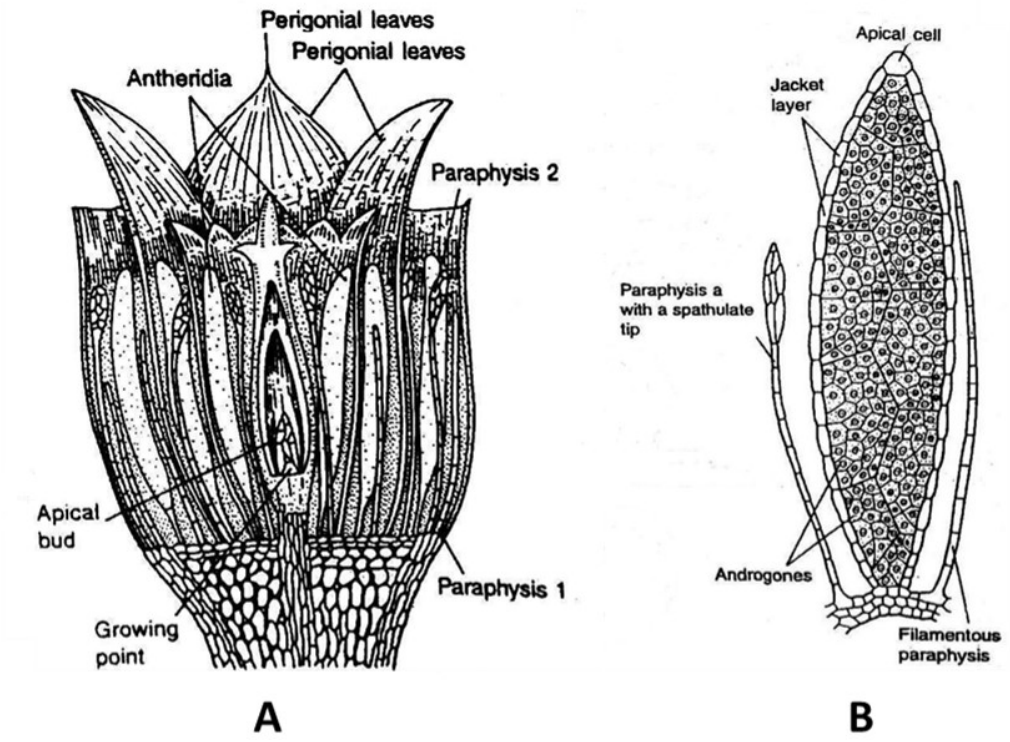


Anthoceros **sporophyte (A) L.S of sporophyte**

(B-E) Cross section of sporophyte

6. *Polytrichum* - *A*ntherediophore

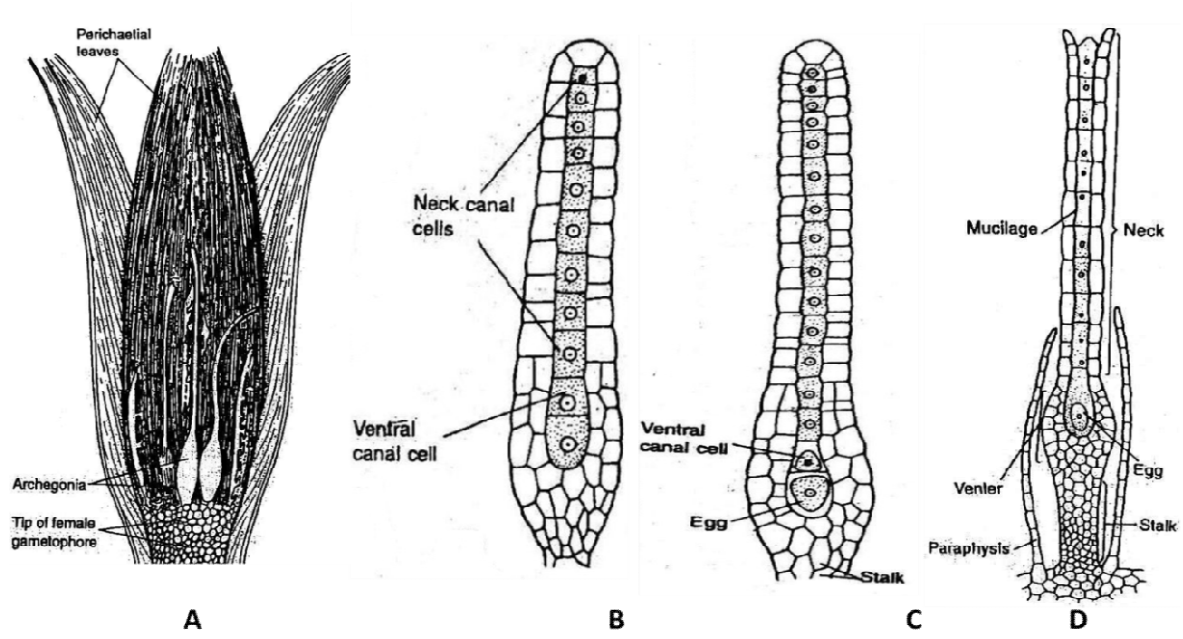
1) The antherediophore is a specialized structure found in the male gametophytes of *Polytrichum*, a genus of mosses.
2) It is essentially a modified stem apex that bears the antheridia, the male sex organs that produce sperm.
3) The antherediophore develops at the tip of the leafy male gametophyte stem.
4) The antheridia are surrounded by a distinctive rosette of modified leaves called perigonial leaves or bracts.
5) These leaves are typically shorter and broader than the vegetative leaves found elsewhere on the stem and often have a reddish or brownish tinge.
6) They are spirally arranged and overlap, forming a cup-like or bud-like structure.
7) The rosette of perigonial leaves forms a "splash cup." This is a crucial adaptation for sperm dispersal.
8) When raindrops fall into this cup, they dislodge the mature sperm from the antheridia.
9) The shape of the cup helps to splash the sperm-containing fluid outwards, facilitating their dispersal to nearby female plants (archegoniophores).
10) Within the splash cup, numerous club-shaped antheridia are produced in groups in the axils of the perigonial leaves.
11) Intermingled with the antheridia are sterile, hair-like filaments called paraphyses.
12) These paraphyses help to retain moisture within the antheridial head, preventing the antheridia from drying out prematurely. They may also aid in the dispersal process.
13) Each mature antheridium consists of a short stalk and a club-shaped body.
14) The body of the antheridium is enclosed by a sterile jacket layer of cells.
15) Inside the jacket layer are numerous androcyte mother cells, which undergo meiosis to produce biflagellate sperm.



Polytrichum **(A) Antheridiphore (B) Antheridium**

7. *Polytrichum* - Archegoniophore

1) The archegoniophore is a specialized stalked structure in the female gametophyte of *Polytrichum*, bearing the archegonia.
2) In *Polytrichum*, the archegoniophore develops at the apex of the female gametophyte shoot, replacing the vegetative growth.
3) The archegonia, borne on the archegoniophore, are typically surrounded by a cluster of specialized leaves called perichaetial leaves. These leaves are often larger than the ordinary foliage leaves and form a protective, bud-like structure around the archegonia.
4) The flask-shaped archegonia are located at the apex of the female shoot, often in a cluster of 3 to 6.
5) Each archegonium contains a single egg cell in its venter.
6) Unlike some other bryophytes, paraphyses (sterile filaments) are generally absent among the archegonia on the *Polytrichum* archegoniophore.
7) The archegoniophore elevates the archegonia, potentially aiding in the reception of sperm.
8) During fertilization, the neck canal cells and the ventral canal cell within the archegonium disintegrate, forming a mucilaginous substance that attracts the flagellated sperm released from the antheridia (borne on the male gametophytes).
9) The sperm then swim through the water film to reach and fertilize the egg within the venter.
10) After fertilization, the zygote develops into the sporophyte directly on the archegoniophore.
11) The young sporophyte remains attached to and dependent on the female gametophyte for nutrition and support.
12) The archegonial venter enlarges to form the calyptra, a protective cap that covers the developing sporophyte capsule.



Polytrichum **(A) Archegoniophore (B-C) Archegonium with egg and venter and neck canal cells (D) Mature archegonium**

8. *Polytrichum* - sporogonium

The mature sporogonium is clearly differentiated into three parts:

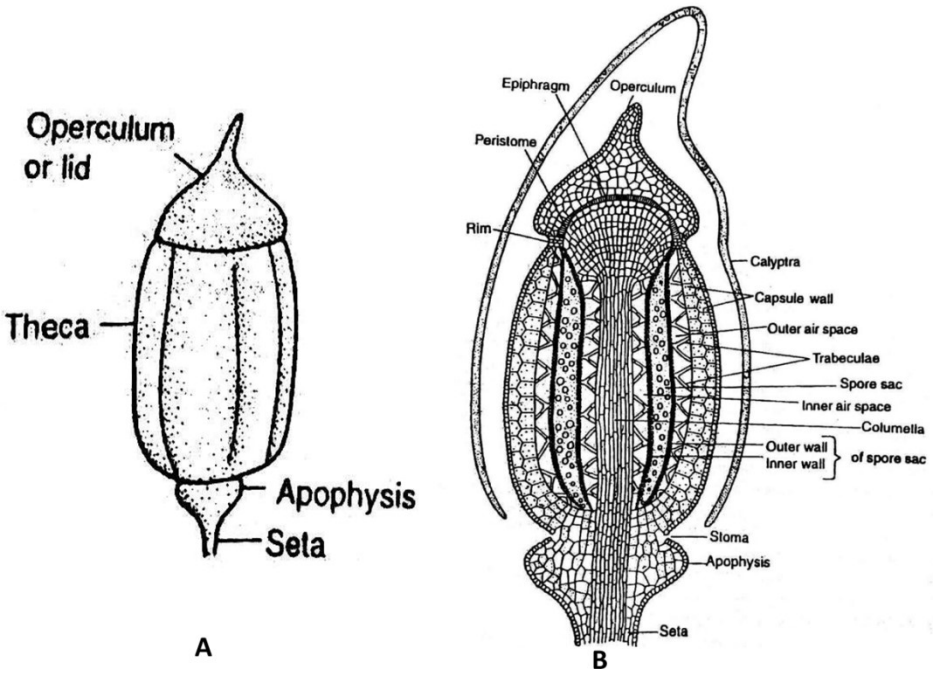
1) **Foot:** This basal part anchors the sporophyte firmly within the tissues of the gametophyte and is responsible for absorbing nutrients and water. It consists of thin-walled cells with dense cytoplasm, facilitating absorption.
2) **Seta:** A long, rigid stalk that extends upwards from the foot, elevating the capsule above the gametophyte. In *Polytrichum*, the seta can be quite long (up to 5-7 cm) and is structurally complex, with a well-differentiated outer cortex and a central conducting strand for transport. The elongation of the seta aids in spore dispersal by raising the capsule into air currents.
3) **Capsule:** The uppermost part, which is the site of spore production. It is further differentiated into:
   a) Apophysis: The lower, sterile part of the capsule, which in *Polytrichum* contains stomata and photosynthetic tissue, contributing to the sporophyte's nutrition for a longer period compared to some other bryophytes.

   b) Theca: The main spore-bearing region located above the apophysis. Inside, spore mother cells undergo meiosis to produce haploid spores. The central tissue of the theca, except for the developing spores, degenerates at maturity, leaving the spores free.

   c) Operculum: A lid-like structure at the apex of the capsule that covers the opening through which spores are released. In *Polytrichum*, the operculum is covered by a hairy calyptra, a remnant of the archegonium.

   d) Peristome: A ring of tooth-like structures located below the operculum. In *Polytrichum*, the peristome is complex and consists of 32 or 64 teeth, which play a crucial role in regulating spore release, often being hygroscopic and moving in response to changes in humidity.

   e) Epiphragm: A membrane-like structure attached to the tips of the peristome teeth, forming a diaphragm over the mouth of the capsule with pores that control spore dispersal.

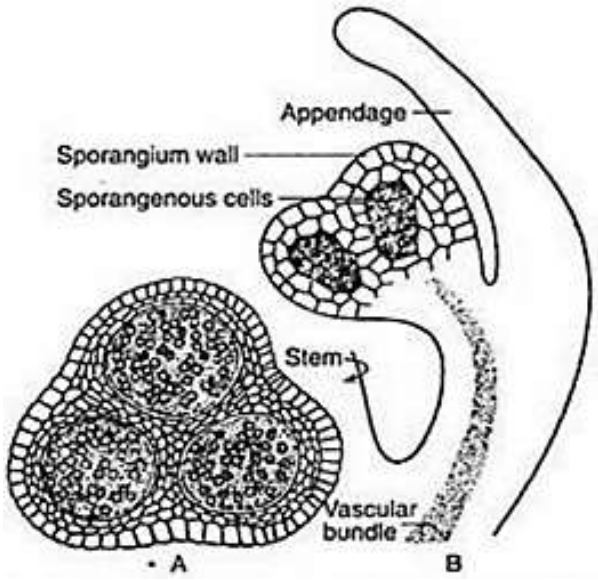


Polytrichum **(A) Sporogonium (B) Sporogonium L.S**

II. PTERIDOPHYTES

1. *Psilotum* Synangia

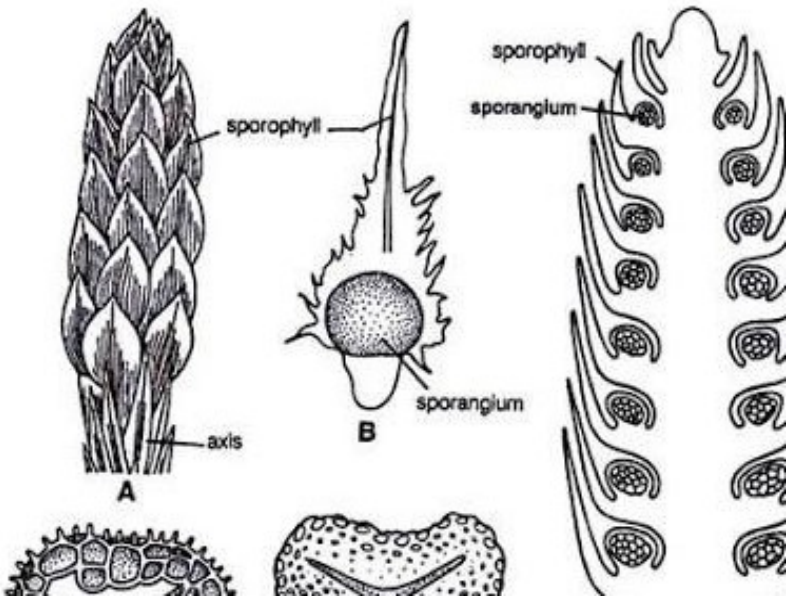
1) The synangia are key reproductive structures in *Psilotum*.
2) Each synangium is characteristically composed of three fused sporangia.
3) The synangia are borne in the axils of small, scale-like or bifid appendages (often referred to as leaves or enations) on the upper portions of the aerial branches.
4) The development of each sporangium within the synangium is of the eusporangiate type, originating from a group of superficial initial cells rather than a single cell.
5) The wall of the mature synangium is typically composed of 4-5 layers of cells.
6) The sporogenous tissue in the sporangial chamber forms the spore mother cell.
7) The spore mother cell undergoes meiosis and form tetrad of haploid spores.
8) The outermost layer is thick and forms the epidermis, while the inner layers separate the three spore-containing locules.
9) Each of the three locules within the synangium is filled with numerous homosporous spores.
10) At maturity, the synangium undergoes dehiscence along three lines on the epidermis, facilitating the release and dispersal of the spores.



Psilotum **(A) T.S of synangium (B) L.S of fertile axis through synangium**

2. *Lycopodium* Cone L.S.

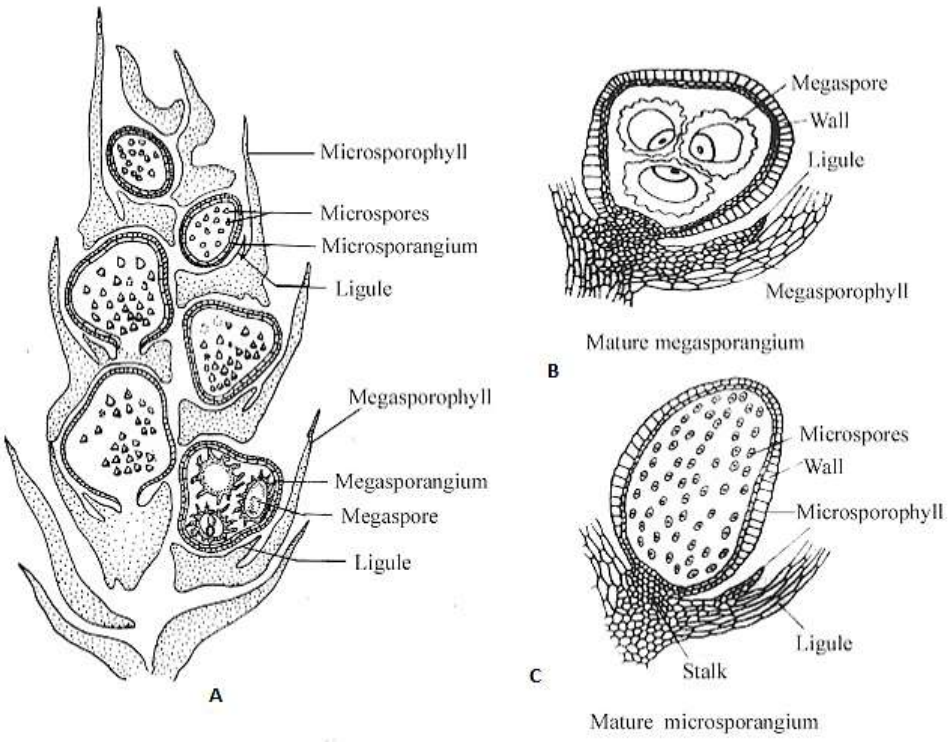
1) A *Lycopodium* cone, or strobilus, is the reproductive structure of a club moss.
2) The cone is located at the tip (apex) of the stem, forming a distinct reproductive structure.
3) A central vascularized axis runs longitudinally, supporting the sporophylls and connecting to the stem's vascular system.
4) Modified leaves (sporophylls) are arranged in a **spiral or whorled pattern** around the axis. These sporophylls are smaller and more densely packed than vegetative leaves.
5) Each sporophyll bears a single **kidney-shaped (reniform) sporangium** on its **adaxial (upper) surface.**
6) Sporangia are **eusporangiate**, developing from multiple initial cells, resulting in a thick, multi-layered wall. Attached to the sporophyll via a short **stalk (pedicel)**.
7) Produces **numerous haploid spores of uniform size** (homosporous). Spores are stored within the sporangium until maturity.
8) Sporangia dehisce along a **longitudinal slit** on the distal side to release spores, facilitated by differential cell wall thickening.
9) Sporangia mature **acropetally** (base to apex) or **basipetally** depending on species, with younger sporangia near the apex and mature ones toward the base.
10) *Lycopodium* sporophylls **lack ligules** (small flap-like structures).
11) The central axis contains vascular tissue that extends into each sporophyll, supplying the sporangium via a single vascular trace.
12) The cone consists **entirely of fertile sporophylls**; no sterile bracts or interspersed vegetative leaves are present.
13) Sporophylls shield developing sporangia until spore release, aiding in reproductive success.
14) Spores are highly flammable due to lipid content, a trait notable in some species (e.g., *Lycopodium clavatum*).



Lycopodium **cone L.S (A) Strobilus (B) Sporangia on sporophyll (C) L.S of cone (D-E) Spores**

3. L.S of *Selaginella* strobilus

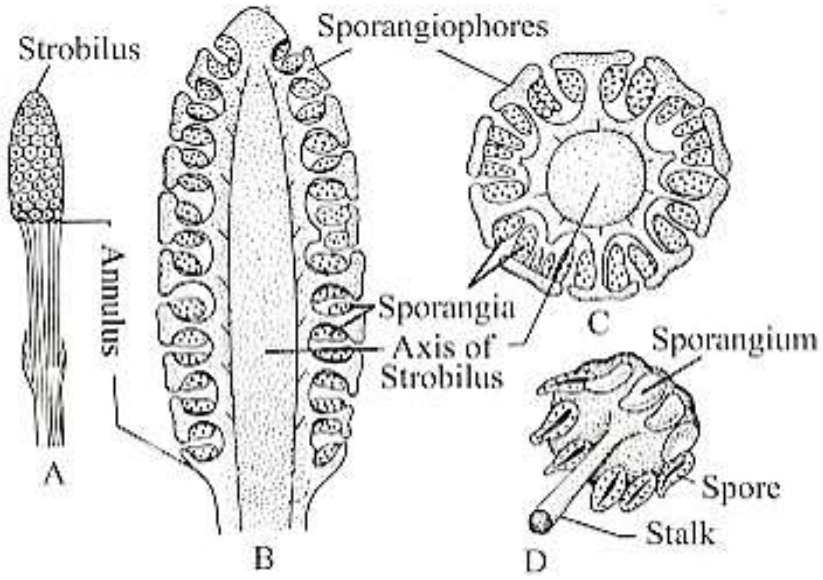
1) The Longitudinal Section (L.S.) of a *Selaginella* strobilus reveals the internal structure of this cone-like reproductive organ.
2) The axis of strobilus is a vertical core running through the strobilus, providing structural support. Contains vascular tissue to transport nutrients and water.
3) Sporophylls are modified leaves arranged in a spiral or alternating pattern along the axis.
4) Each sporophyll has a small, tongue-like ligule at its base (near the axis), a distinctive feature of Selaginella.
5) Sporangia are borne on the upper side (adaxial surface) of sporophylls, near their base.
6) Two types exist due to heterospory 1. Microsporangia: Produce numerous microspores (small, develop into male gametophytes). 2. Megasporangia: Produce fewer megaspores (large, develop into female gametophytes).
7) In some species, microsporangia and megasporangia are segregated (e.g., microsporangia at the top, megasporangia at the base of the strobilus).
8) Spores are two types 1. Microspores - Tiny, produced in masses within microsporangia. 2. Megaspores - Larger, fewer in number.
9) Ligule is a secretory structure on each sporophyll, possibly involved in sporangium development or protection.
10) Sporangia split open to release spores when mature.
11) In heterosporous species, sporangia may be zonated (microsporangia in upper regions, megasporangia in lower regions) or intermixed, depending on the species.



Selaginella **(A) L.S of strobilus (B) Megasporangium (C) Microsporangium**

4. *Equisetum* Cone L.S

1) Strobilus has a central strobilus axis and a large number of sporangiophores.
2) The sporangiophore is a stalked structure with a hexagonal peltate disc at its distal end.
3) On the underside of the sporangiophore disc 5 – 10 sac like sporangia are borne near its periphery in a ring.
4) In some species a whorl of scale-like outgrowths called annulus is present at the base of the strobilus.
5) The development of sporangium is eusporangiate.
6) The mature sporangia are sac-like structure attached to the underside of the peltate disc of the sporangiophore.
7) The wall of mature sporangium is only two layered. All spores are alike (homosporous)
8) As the sporangia mature, the strobilus axis elongates, consequently, the compactly arranged sporangiophores separate from each other and the sporangia are exposed.
9) As the sporangium dries the helicoid thickening bands present in the outer wall layer shrink and the sporangium ruptures.
10) Spores are spherical, uninucleate and green (contain numerous chloroplasts)
11) Spore wall is differentiated into 4 layers. The outermost perispore / epispore. The second middle layer. The third expspore and the innermost endospore.
12) The epispore splits into 4 strips which are separated from one another but attached to a common point on the spore.
13) These bands are wrapped around the spherical spore but as the spore dries, these bands are starched. These bands are called as elaters.
14) They have expanded spoon-like tips.
15) The elaters are hygroscopic and help in the dehiscence of the sporangium.



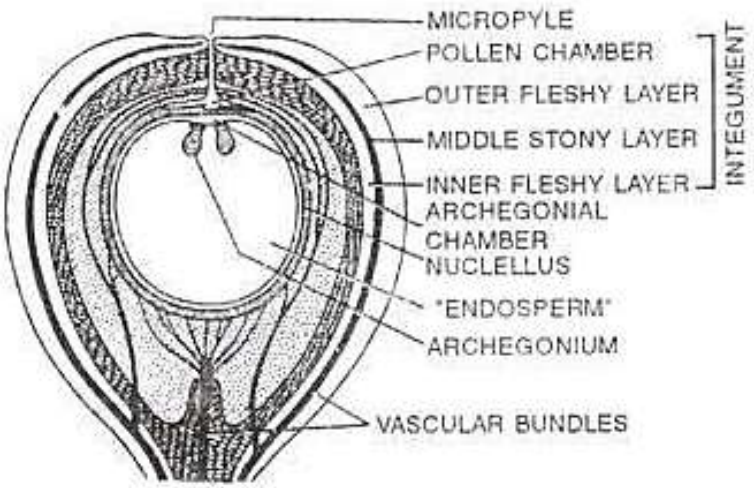
Equisetum **(A) Fertile shoot bearing strobilus (B) Strobilus L.S (C) Strobilus T.S**

(D) Individual sporangiophore

III. GYMNOSPERMS

1. *Cycas* ovule L.S

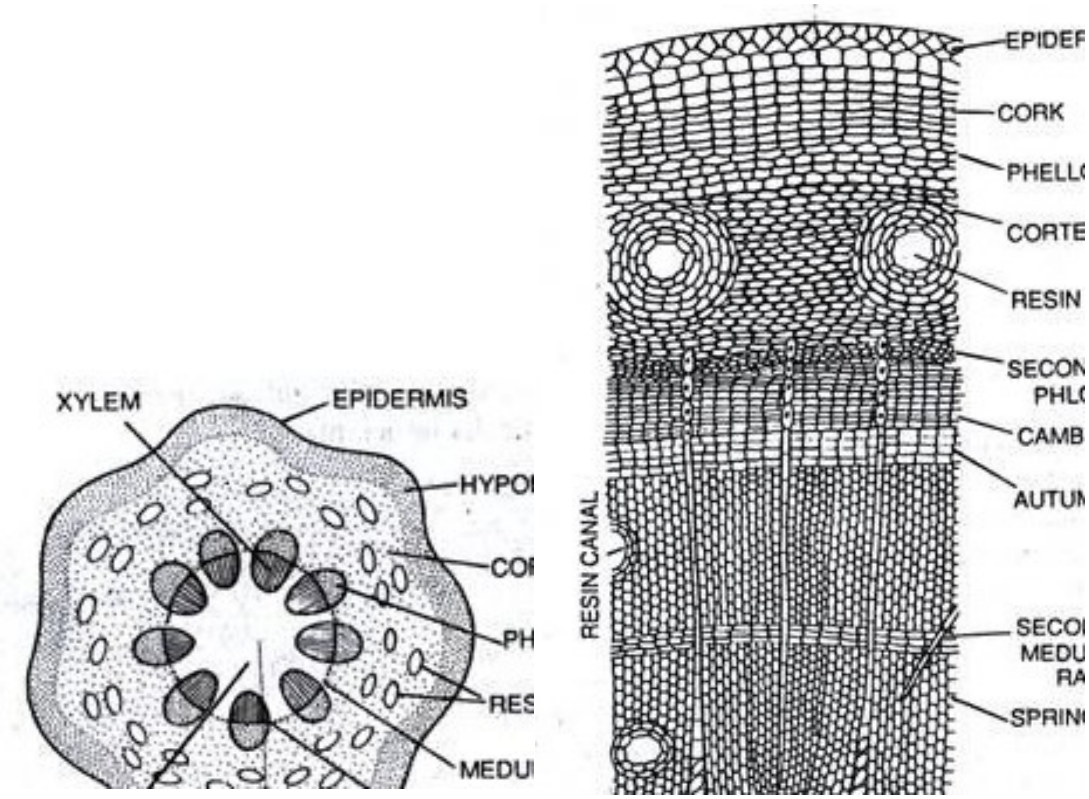
1) Largest ovule in the plant kingdom.
2) Ovules are orthotropous (straight, with micropyle, nucellus, and chalaza aligned).
3) They are borne singly on megasporophylls, arranged in a loose spiral on the female strobilus.
4) Integument is single, massive and fleshy, differentiated into three layers 1. Outer fleshy layer (sarcotesta) – rich in mucilage and may be colored. 2. Middle stony layer (sclerotesta) – hard and lignified, protective. 3. Inner fleshy layer – rich in nutrients.
5) Micropyle is present at the apex of the integument. Micropyle faces upward, facilitating pollen entry.
6) Nucellus is present at the centre, derived from the megasporangium.
7) Extends into the micropyle as a nucellar beak, which later forms the pollen chamber.
8) Pollen Chamber formed by the degeneration of the nucellar beak. Temporary chamber where pollen grains are retained before fertilization.
9) Female Gametophyte develops from the functional megaspore. It is haploid, multinucleate initially, and later cellular. Contains archegonia with a large egg cell and neck.
10) Archegonia are typically 2–3 per ovule. Located at the micropylar end of the female gametophyte. Each archegonium has a large egg cell, which is fertilized by the motile sperm.
11) Pollination is anemophilous (wind pollinated). Pollen grains reach the pollen chamber, where they germinate.
12) Motile sperm (largest in the plant kingdom) swim toward the archegonia for fertilization.
13) Ovule develops into a seed, with well-developed endosperm and embryo. Seeds are large, often reddish or orange when mature.



***Cycas* ovule L.S**

2. *Pinus* stem secondary growth

1) *Pinus* undergoes normal secondary growth, similar to dicotyledonous plants.
2) A cambial ring forms between the xylem and phloem. This ring originates from both intrafascicular and interfascicular cambium. It produces secondary xylem (wood) inward and secondary phloem outward.
3) Growth is seasonal, forming distinct annual rings. Each ring consists of a) spring wood (earlywood): light, less dense with larger cells. b) Autumn wood (latewood): dark, dense with smaller, thick-walled cells. Useful in dendrochronology (age estimation).
4) Wood is pycnoxylic (compact with abundant tracheids and little parenchyma). No vessels are present,tracheids are the main water-conducting elements. Resin canals are scattered in the secondary xylem.
5) Medullary rays are present as uniseriate or multiseriate structures. Composed of parenchyma cells. Aid in radial conduction and storage. Secondary phloem is composed of sieve cells, phloem parenchyma, and albuminous cells (no companion cells). Less amount of secondary phloem is formed compared to xylem.
6) Secondary protective tissue develops as periderm. Originates from a phellogen (cork cambium). Produces phellem (cork) externally and phelloderm internally.
7) Outer dead tissues are collectively termed bark. Rhytidome forms due to repeated periderm formation in older stems.
8) Schizogenous canals(resin canals) lined with epithelial cells secreting resin. Serve protective function against herbivores and pathogens.



Pinus **(A) Stem T.S diagrammatic (B) Stem T.S cellular**

SPECIMENS

1. Morphological Features of *Marchantia*

Classification

Division: Bryophyta

Class: Hepaticopsida (liverworts)

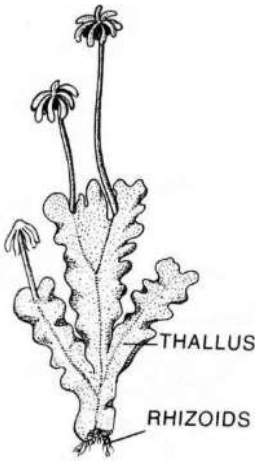
Order: Marchantiales

Family: Marchantiaceae

Genus: Marchantia

Salient Features:

1) *Marchantia* is a genus of liverworts.
2) The gametophyte is a prostrate, dorsiventral thallus with dichotomous branches.
3) The dorsal surface of the thallus contains several regular rhomboidal or polygonal patches. Each region contains a pore at the centre.
4) Each branch of the thallus has a distinct median groove (midrib) on the top (dorsal) surface and a corresponding ventral ridge.
5) The terminal groove (apical notch) contains a growth point that allows the branches to extend endlessly.
6) The ventral surface of the thallus has three to four rows of scales and rhizoids on each side of the midrib.
7) The scales are membranous, one-layered, and typically violet due to anthocyanin pigments. The scales come in two types: appendiculate and ligulate.
8) Beside from the scales, the ventral surface of the thallus contains rhizoids in between the scales. They are typically unicellular, colorless, and classified into two types: smooth walled and tuberculate.
9) Rhizoids anchor to the substrate and absorb water and nutrients from the soil.



***Marchantia* thallus**

2. Morphological Features of *Anthoceros*

Classification

Kingdom: Plantae (Plants).

Division: Anthocerotophyta

Class: Anthocerotopsida

Order: Anthocerotales

Family: Anthocerotaceae

Genus: *Anthoceros*

Salient Features:

1) *Anthocero s*is a genus of hornworts. Its name means 'flower horn', and refers to the characteristic horn-shaped sporophytes that all hornworts produce.
2) The gametophytic plant body is a small greasy dark-brown prostrate, dorsiventral thallus. The thallus is usually dichotomously lobed.
3) The middle part of the thallus is always without a definite midrib, although the thallus is thick.
4) The upper dorsal surface of the thallus may be smooth, velvety or rough with ridges.
5) The lower ventral surface bears numerous unicellular, smooth walled rhizoids along the median line.
6) Tuberculate rhizoids, scales or mucilage hairs are absent in Anthoceros.
7) The spores are dark gray, dark brown or black, this is the easiest way to identify *Anthoceros*.
8) The sporophytes of *Anthoceros* are larger differentiated into a foot, a constriction like intermediate zone and a capsule.
9) There is no seta. It arises in clusters from the dorsal surface of the thallus each surrounded at the base a tubular involucre.
10) *Anthoceros* species are host to species of *Nostoc*, a symbiotic relationship in which *Nostoc* provides nitrogen to its host through cells known as heterocysts, and which are able to carry out photosynthesis.
11) The *Nostoc* colonies are present on the lower ventral surface and are visible as blue green patches which open outwards by slime pores.

12) This hornwort grows in moist clay soils on hills, in ditches, and in damp hollows among rocks.

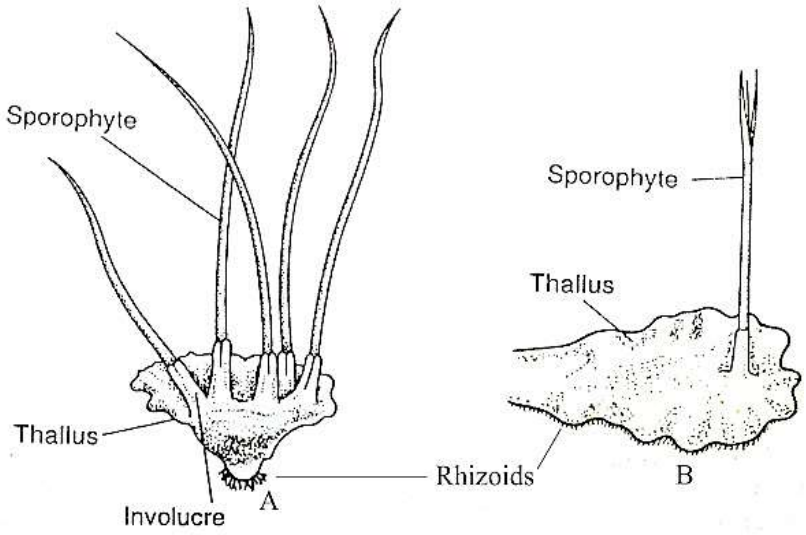
13) The adult plant body is a gametophyte. The thallus is translucent and sub-orbicular in outline.

14) *Anthoceros* reproduces by vegetative and sexual methods.

15) Vegetative reproduction takes place by the methods, i.e., by death and decay of the older portion of the thallus or fragmentation, tubers, Gemmae, persistent growing apices, apospory.

16) Sexual reproduction is oogamous.

17) Male reproductive bodies are known as antheridia and female as archegonia.



Anthoceros **(A) Thallus bearing sporophyte (B) Thallus with dehiscent sporophyte**

3. Morphological features of *Polytrichum*

Classification

Kingdom: Plantae

Division: Bryophyta

Class : Polytrichopsida

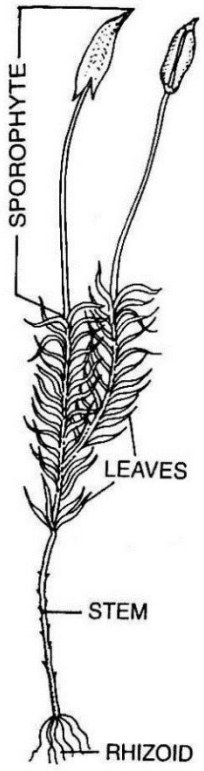
Order : Polytrichales

Family : Polytrichaceae

Genus : *Polytrichum*Hedw.

Salient Features:

1) *Polytrichum* is a genus of mosses, commonly called haircap moss or hair moss.
2) The main plant body is gametophyte. The adult plant consists of two parts, rhizome and upright leafy shoot.
3) Rhizome is horizontal portion and grows underground. It bears three rows of small brown or colourless leaves. It also bears rhizoids.
4) The cells are rich in protoplasm and oil globules.
5) Upright leafy shoots are much longer. It is the most conspicuous part of the plant. It arises from rhizome. These branches consist of central axis. These branches bear large leaves arranged spirally.
6) Leaves have broad bases. Leaves in the upper portion are green. But the lower ones are brown. Each leaf has a broad colourless sheathing leaf base and narrow distal limb.
7) In leaf, the mid-rib region is thick. But the margins are only one cell thick.
8) The central tissue of leaf is composed of thin-walled parenchymatous tissues. Above this are again sclerenchymatous cells.
9) The upper surface is formed of a layer of large cells from which arise numerous lamellae. This upper portion is the main photosynthetic region of the leaf.
10) Reproduction occur through vegetative reproduction as well as sexual reproduction.
11) Vegetative reproduction takes place by the methods, namely protoneme formation, through vegetative buds and fragmentation.
12) *Polytrichum*is dioecious. Antheridia and archegonia occur on different plants.



***Polytrichum* thallus**

4. Morphological features of *Psilotum*

Classification:

Kingdom: Plantae (Plants)

Division/Phylum: Psilophyta (Whisk-ferns)

Class: Psilopsida

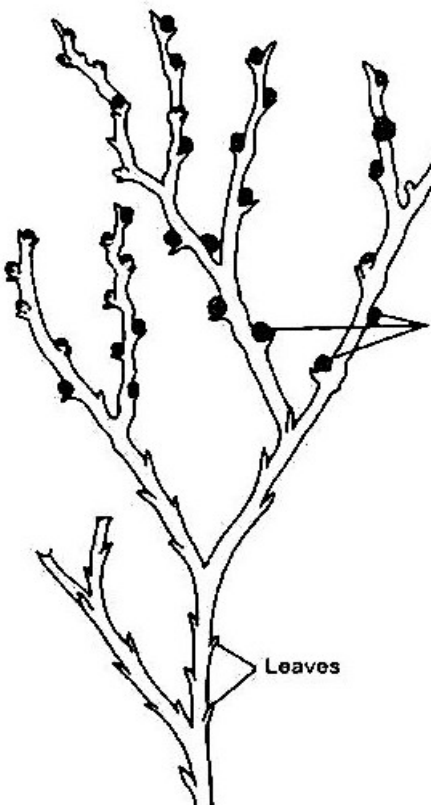
Order: Psilotales

Family: Psilotaceae

Genus: *Psilotum*

Salient Features:

1) The aerial stems display a characteristic forked branching pattern, dividing equally into two at each node. This repeated bifurcation is a prominent feature.
2) *Psilotum* lacks true roots. Instead, it possesses rhizoids, which are hair-like outgrowths from the underground rhizome that anchor the plant and absorb water and nutrients.
3) The aerial stems bear small, scale-like appendages known as enations. These enations lack vascular tissue and are not considered true leaves. They can be sterile or fertile.
4) The aerial stems are typically green, indicating the presence of chlorophyll and their role in photosynthesis.
5) The stems can be cylindrical at the base and may become more angular or ribbed towards the upper portions.
6) The scale-like leaves or enations are arranged spirally along the aerial stems.
7) The rhizome grows horizontally beneath the soil surface.
8) Numerous rhizoids emerge from the rhizome, facilitating anchorage and absorption.
9) In some species, the rhizome produces small, multicellular, oval structures called gemmae, which are involved in vegetative reproduction.
10) The sporangia (spore-producing structures) are fused into distinctive, three-lobed structures called synangia.
11) The synangia are typically borne in the axils of the fertile scale-like leaves (enations) on the upper parts of the aerial branches.
12) The synangia are attached to the stem by very short stalks.
13) The synangia produce only one type of spore (homosporous).



***Psilotum* thallus**

5. *Lycopodium* external morphology:

Classification

Kingdom: Plantae

Division/Phylum: Lycophyta

Class: Lycopodiopsida

Order: Lycopodiales

Family: Lycopodiaceae

Genus: *Lycopodium*

Salient Features:

1) The main stem can be either creeping along the ground or prostrate, meaning it lies flat.
2) The branching pattern is characteristic, with branches splitting into two at each point.
3) Some species have underground rhizomes that can spread horizontally.
4) Some *Lycopodium* species have erect or pendent aerial branches.
5) The leaves are simple, meaning they are not divided into leaflets, and they lack a stalk (sessile).
6) The leaves are small and resemble scales or needles, densely covering the stem and branches.
7) Each leaf has a single central vein.
8) The leaves can be arranged in various ways, such as spirally, whorled, or decussate (opposite pairs).
9) The roots arise from the stem, rather than from the seed. Like the stem, the roots can also be dichotomously branched.
10) The roots are often located on the underside of the creeping or prostrate stems.
11) Strobili (spore-bearing structures)) can be located at the tips of branches or sometimes laterally along the stem.
12) The strobili contain spores, which are the reproductive units of *Lycopodium*.

***Lycopodium* thallus**

6. *Selaginella* External Morphology

Classification

Kingdom: Plantae

Phylum: Tracheophyta

Class: Lycopodiopsida

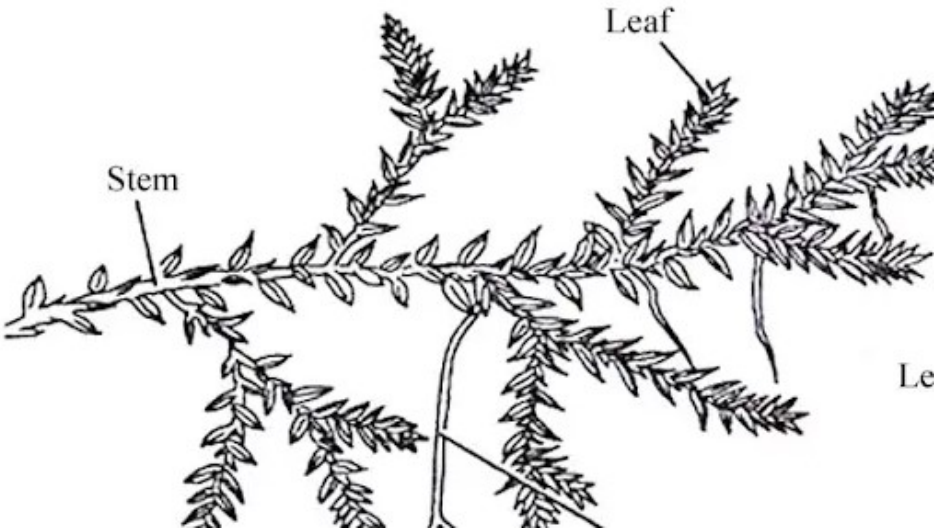
Order: Selaginellales

Family: Selaginellaceae

Genus: *Selaginella*

Salient Features:

1) Structure varies from mat-forming (prostrate) to upright, depending on the species.
2) Exhibits creeping, erect, or climbing habits. Stems are branched (dichotomous or monopodial) and may be dorsiventrally flattened, giving a fern-like appearance in some species.
3) Leaves are microphylls i.e. small, sessile leaves with a single unbranched vein.
4) Leaves are typically arranged in four distinct rows (quadrifoliate) – two rows of smaller dorsal leaves and two rows of larger ventral leaves, contributing to a flattened stem appearance.
5) Tiny, tongue-like structures called ligule is present at the base of each leaf, involved in water secretion or absorption.
6) Leaves are heterophyllous and many species show leaf dimorphism, with dorsal leaves smaller and ventral leaves larger, aiding in species identification.
7) Root System contains rhizophores which are unique, leafless, geotropic structures originating from stem nodes. They grow downward and develop adventitiousroots upon soil contact, serving as a distinguishing feature from other lycophytes.
8) Reproductive Structures contains strobili. These are terminal, cone-like structures composed of sporophylls (modified leaves). Each sporophyll bears a single sporangium.
9) *Selaginella* shows heterospory and produces two spore types- microspores (male gametophytes) in microsporangia and megaspores (female gametophytes) in megasporangia, a key evolutionary trait.
10) Stems may exhibit ridges or grooves, and leaves are often glossy or textured, though these traits vary by species.



***Selaginella* thallus**

7. *Equisetum* external morphology

Classification

Kingdom: Plantae

Division: Pteridophyta

Class: Equisetopsida (formerly Sphenopsida)

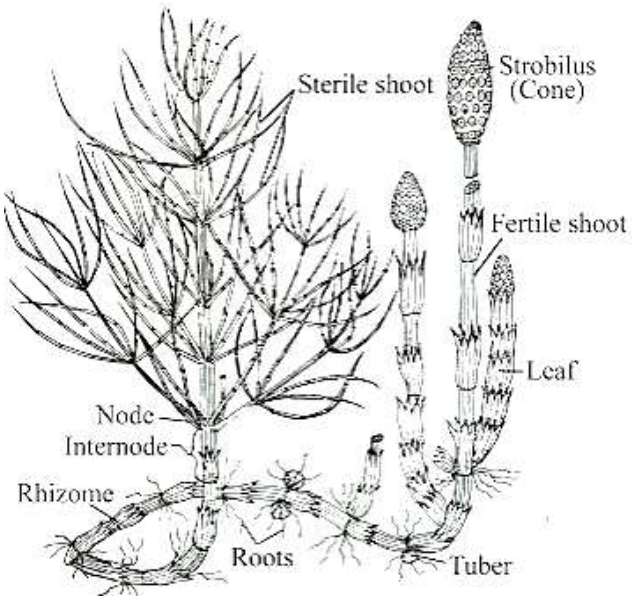
Order: Equisetales

Family: Equisetaceae

Genus: *Equisetum*

Salient Features:

1) *Equisetum* externally divides into rhizome which is a horizontal, underground stem that anchors the plant and facilitates vegetative propagation. It gives rise to erect aerial shoots and roots at nodes.
2) Aerial shoots are erect, jointed stems that emerge from the rhizome. These can be fertile (reproductive) or sterile (photosynthetic).
3) Stems are distinctly segmented into nodes (swollen joints) and internodes (hollow segments between nodes).
4) Longitudinal ridges run along the stem, corresponding to underlying vascular bundles. Grooves between ridges may house stomata.
5) Epidermal cells are reinforced with silica, giving stems a rough, abrasive texture (historically used for scouring).
6) Green stems perform most photosynthesis, as leaves are vestigial.
7) Leaves are scale-like and whorled, these are small, non-photosynthetic leaves form a sheath at each node, fused into a collar-like structure with tooth-like tips.
8) Fertile stems are often unbranched and non-photosynthetic, these bear a terminal strobilus (cone-like structure) composed of sporangiophores.
9) Strobilus is hexagonal sporangiophores bear sac-like sporangia that release spores.
10) Spores possess hygroscopic, ribbon-like elaters that aid dispersal by coiling/uncoiling with humidity changes.
11) The equisetum **s**tomata are aligned in rows within the grooves of the stem, minimizing water loss.



***Equisetum*s - porophytic plant body**

8. *Marsilea* external morphology

Classification

Kingdom: Plantae

Division: Pteridophyta

Class: Polypodiopsida

Order: Salviniales (Water Ferns)

Family: Marsileaceae (Water-clover family)

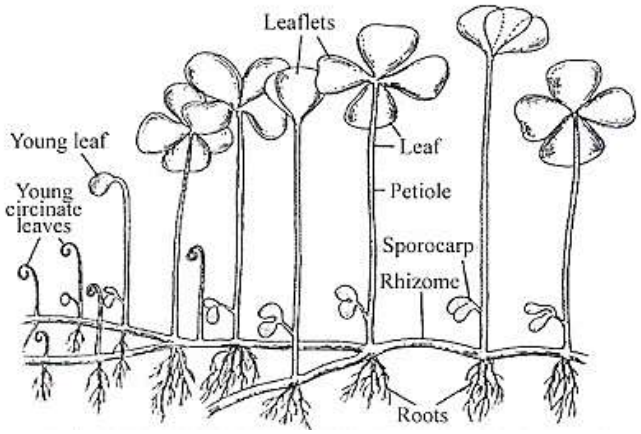
Genus: *Marsilea*

Salient Features:

1) The mature sporophyte is an herbaceous plant. Its underground rhizome spreads in a diameter of 25 meter or more.
2) The plant body is distinctly differentiated into rhizome, leaves and roots.
3) All the species possess a rhizome which creeps on or just beneath the soil surface. It is slender, dichotomously branched with distinct nodes and internodes and is capable of indefinite growth in all directions as a result of which it occupies an area of 25 metre or more in diameter.
4) In aquatic species the internodes are long while in sub-terrestrial species they are short.
5) Usually from the upper side at nodes, the leaves are given out while from their lower side, the roots. They are borne alternately on upper side of rhizome at nodes, in two rows.
6) Young leaves show circinate vernation (like ferns).
7) The leaves are compound, with basal petiole and terminal lamina.
8) In submerged plants the petiole is a long and flexible structure and the lamina floats over the surface of water but in muddy or marshy plants the petiole of the leaf is short and rigid with short lamina spreading in the air.
9) The lamina consists of 4 leaflets (pinnae) which are present at the apex of petiole, 2 leaflets arise slightly higher than other two.
10) The leaf consists of single pinna consisting of 4 pinnules.
11) The shape of pinna varies from obovate to obcuneate and margin also varies from entire to crenate or crenate to lobed.

12) Near the base of petiole the stalked bean-shaped sporocarps are borne.

13) The roots are adventitious, arising from the underside of the node of rhizome, either singly or in groups.



***Marsilea* sporophytic plant body**

9. *Adiantum* external morphology

Classification

Kingdom: Plantae

Phylum: Pteridophyta

Class: Pteropsida

Order: Pteridales

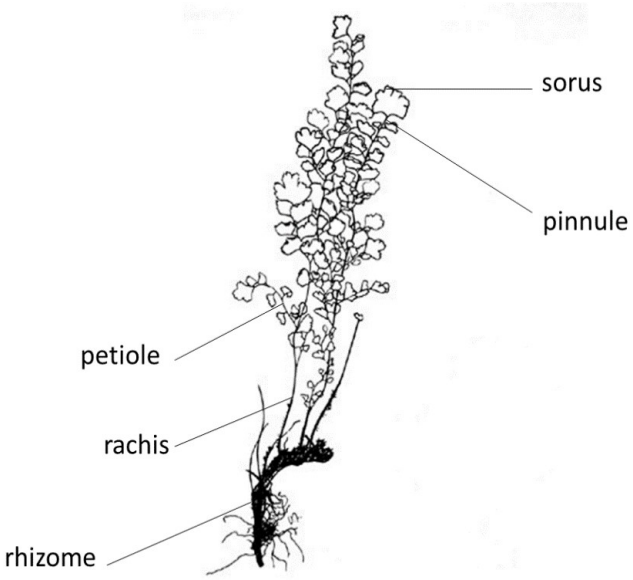
Family: Pteridaceae

Subfamily: Vittarioideae

Genus: *Adiantum*

Salient Features:

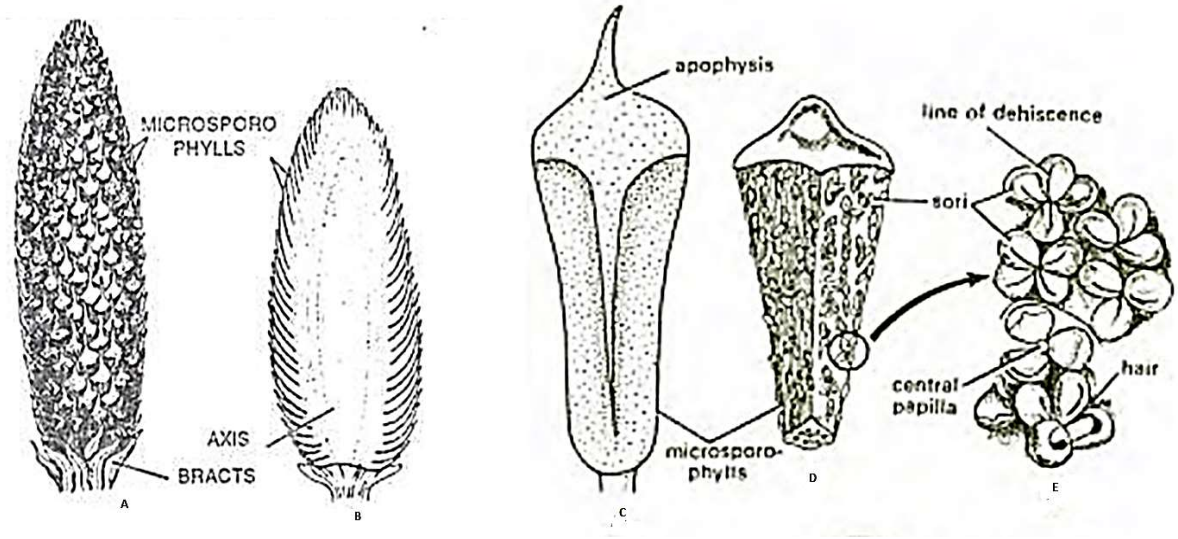
1) Rhizome is **s**hort, creeping, and horizontally growing underground stem,covered with dark brown to black scales (ramenta), providing protection and aiding in moisture retention.
2) Fronds (Leaves) arise from the rhizome, often in a spreading or arching manner, giving a delicate, feathery appearance.
3) Petiole/Stipe is **s**lender, wiry, and glossy black or dark brown, contrasting with the green foliage.
4) Typically pinnate or bipinnate (occasionally tripinnate), with a central rachis bearing smaller leaflets (pinnae).
5) Pinnae (Leaflets) are fan-shaped or wedge-shaped, with rounded, lobed, or incised margins. Connected to the rachis by delicate, hair-like stalks. Free dichotomous venation (veins fork repeatedly without forming a network).
6) Clusters of sporangia (sori) form along the undersides of pinnae margins. Sori are linear or oblong, following the vein pattern.
7) Roots are fibrous adventitious roots emerging from the rhizome, aiding in anchorage and nutrient absorption.



***Adiantum* thallus**

10. *Cycas* male cone

1) Male cone is terminal, stalked, large and conical
2) Consists of central cone axis and numerous micro sporophylls.
3) Microsporophylls are spirally arranged around the cone axis.
4) Microsporophyll- leaf like, woody, wedge shaped and brown in colour.
5) Lower expanded fertile region with sori and upper sterile region called apophysis.
6) Sorus has 5 to 6 microsporangia with soral hairs.
7) Microsporangium - oval in shape with sporangial wall. It encloses many unicellular, uninucleate, haploid microspores or pollen grains.
8) Microspores hasinner intine, outer exine, cytoplasm, and haploid nucleus.



***Cycas* (A) Entire male cone (B) Male cone L.S (C) Adaxial surface (D) Abaxial surface (E) Dehisced microsporangia**

11. *Cycas* megasporophyll

1) Arises at the stem apex among the crown of leaves.
2) The megasporophyll is large, 6-8 inch long.
3) Loosely arranged, not forming a true cone (female strobilus absent).
4) Its upper portion is broadly pinnate and tappers to a point.
5) The whole sporophyll is covered with dense brownish, woolly hairs.
6) Leaf-like structure with three distinct parts 1. Basal stalk 2. Middle ovule-bearing region 3. Terminal pinnate or dissected lobe.
7) The stalk like lower portion bears orthotropous ovules in two distichous, lateral rows.
8) Bears 2–6 large, naked ovules on the lateral margins of the middle region.
9) Ovules are orthotropous and upright, with the micropyle facing upward.
10) Largest ovules among seed plants (can reach up to 6 cm in length).
11) Ovules are sessile and exposed.
12) Integument is three-layered and forms a long micropyle tube.
13) The structure is morphologically similar to foliage leaves, unlike scale-like megasporophylls in other gymnosperms.
14) Fertilization leads to the development of a large seed.

***Cycas* megasporophyll**

12. *Pinus* external morphology

Classification

Kingdom: Plantae

Division: Pinophyta (Coniferophyta)

Class: Pinopsida

Order: Pinales

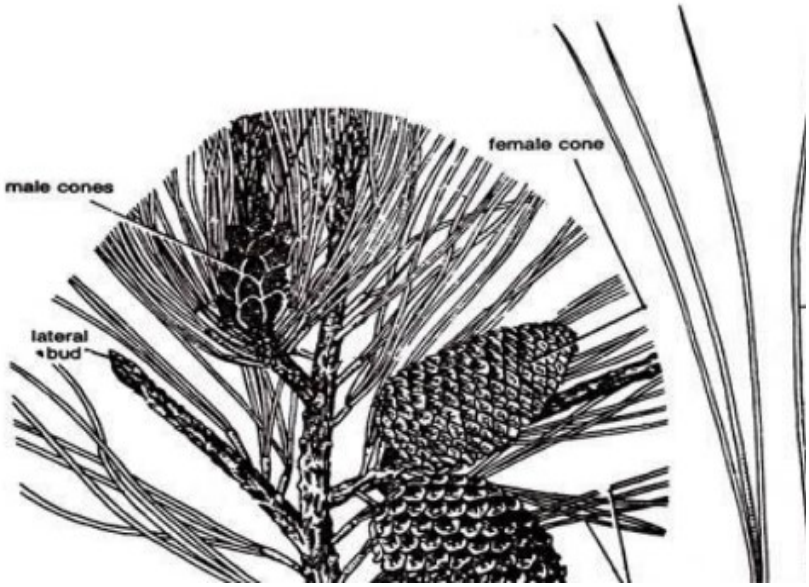
Family: Pinaceae

Genus: *Pinus*

Salient Features:

1) Plants are tall, evergreen trees.
2) Height ranges from medium (10–20 m) to very tall (up to 80 m in *P. lambertiana*).
3) Conical or pyramidal shape.
4) Monoecious (male and female cones on the same plant).
5) Root System Taproot system. Well developed and deep penetrating. Lateral roots with mycorrhizal associations.
6) Stem is woody, erect, cylindrical, covered with thick, scaly bark. Branches show *excurrent branching* (central leader with lateral branches).
7) Growth is dimorphic with Long shoots (branches of unlimited growth) and Dwarf shoots (spur shoots with limited growth)
8) Leaves are of two types 1. 1. Scale Leaves - Small, brown, membranous. Non-photosynthetic, protective in function. 2. Foliage Leaves (Needles) - Green, slender, needle-like. Present in clusters (fascicles) of 2, 3, or 5 depending on species (*P. sylvestris* – 2, *P. roxburghii* – 3, *P. wallichiana* – 5). Photosynthetic and long-lived (persist for 2–5 years). Adapted to xeric conditions (sunken stomata, thick cuticle, reduced surface area).
9) *Pinus* is monoecious plant, both male and female cones on the same tree but on different branches.

10) Male cones (staminate strobili) are small, catkin-like, found in clusters, located on lower branches. Female cones (ovulate strobili) are larger, woody, and more conspicuous, develop on upper branches and takes 2–3 years to mature.



Pinus **(A) Branch of mature plant (B) Stem with two types of shoots**

13. *Ginko biloba* external morphology

Classification

Kingdom: Plantae

Division: Ginkgophyta

Class: Ginkgoopsida

Order: Ginkgoales

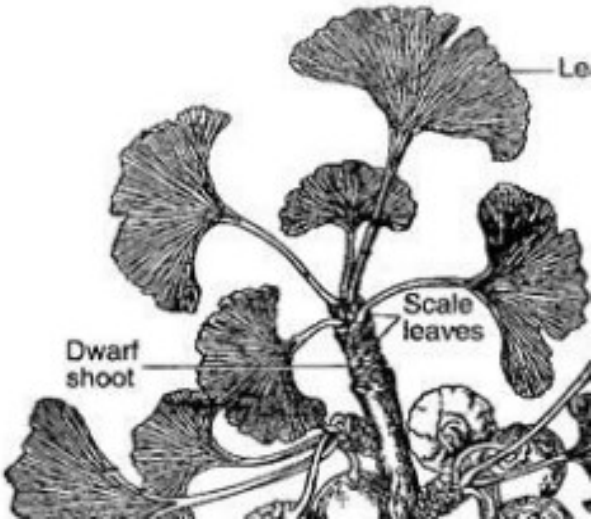
Family: Ginkgoaceae

Genus: *Ginkgo*

Species: *Ginkgo biloba*

Salient Features:

1) A medium to large deciduous tree, typically 20–35 meters tall (can reach up to 50 m).
2) Pyramidal to broadly spreading crown in older trees.
3) Woody stem with a rough, fissured bark. Branching is dimorphic with Long shoots - grow rapidly, bear scattered leaves and reproductive structures. Short shoots (spur shoots) - grow slowly, with dense clusters of leaves.
4) Leaves are simple, fan-shaped (flabellate), and bilobed – hence the name *biloba*. Have parallel dichotomous venation (veins repeatedly fork).
5) Leaves are petiolate (long petiole), giving the leaf a fluttering appearance and deciduous.
6) Root System is taproot system, strong and deeply penetrating. Produces mycorrhizal associations, aiding in nutrient uptake.
7) Plant is dioecious, male trees produce small, pendulous catkin-like strobili (cone-like structures) on short shoots. Each strobilus bears numerous microsporophylls with two microsporangia.
8) Female trees do not produce true cones. Ovules are borne in pairs on stalks (peduncles), usually only one matures. After fertilization, develop into plum-like seeds with a fleshy outer coat (smelly due to butyric acid).
9) Seeds are large, ovoid seed, ~2–3 cm long with three layers Outer fleshy layer (sarcotesta) – yellowish, malodorous when mature. Middle hard layer (sclerotesta) – stony. Inner layer (endosperm) – nourishing tissue.
10) No true fruit – seeds are naked as in gymnosperms.



***Ginko biloba* shoot with dwarf shoots**

IV. PALEOBOTANY

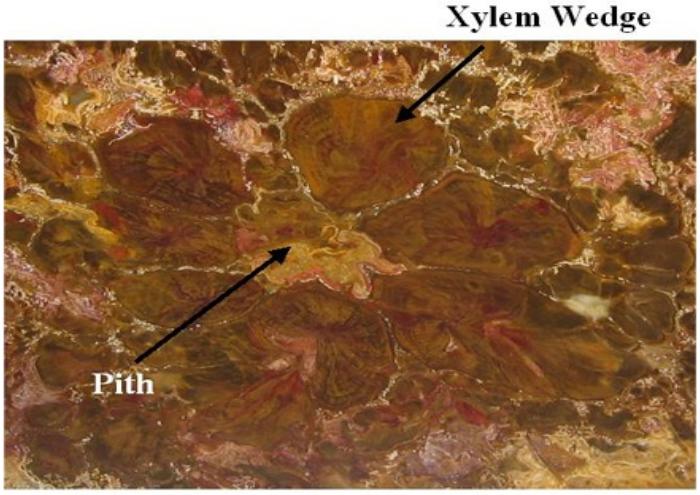
1. Petrified Wood:

1) It is formed through permineralization is a process through which the plant material becomes impregnated or permeated by mineral rich liquid before the plant matter decays.
2) The minerals seep into the plant and then harden, forming the three-dimensional fossil.
3) These fossils yield highly detailed information about the plant's internal structure.
4) Preserves fine internal structures, even cellular details.
5) Typically involves silica (SiO_2), calcite ($CaCO_3$), or iron compounds.
6) Requires rapid burial to limit decay and allow mineral-rich water to infiltrate.
7) Mostly occurs in bones, wood, and shells — parts with natural porosity.
8) Takes thousands to millions of years under stable geological conditions.

Petrified wood fossil

2. Pentaxylon Stem:

1) The most prominent feature is the preservation of multiple discrete vascular bundles (steles) arranged in a ring within the fossilized stem's cross-section. This confirms the polystelic nature of the stem.
2) The fossils often show exocentric secondary growth within each stele.
3) The dense and compact nature of the pycnoxylic secondary xylem is usually well-preserved in fossils.
4) The tracheids are closely packed, lacking significant amounts of parenchyma.
5) Details of the bordered pits on the tracheid walls can often be observed under a microscope in thin sections of the fossil.
6) The uniseriate medullary rays in the secondary xylem are typically discernible in radial and tangential sections of the fossilized wood.
7) The absence of ray tracheids or other specialized ray cells is also noted.
8) The presence of smaller vascular bundles in the cortex, alternating with the main steles, is sometimes preserved in fossils, providing evidence for their arrangement and potential connection to leaves or lateral shoots.
9) The surfaces of fossilized long shoots may exhibit rhomboidal leaf scars, similar to those seen in extant material, indicating the spiral arrangement and shape of the leaves.
10) In some older stem fossils, a preserved periderm layer can be identified in the outer cortical region.



Pentaxylon stem fossil

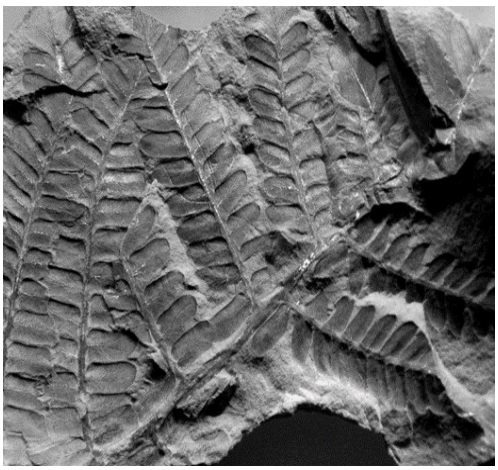
3. Compression Fossils:

1) Formed by the burial of plant material under sediment where it undergoes compression (pressure from overlying sediments) and partial chemical alteration.
2) Organic material is flattened and preserved mainly as a thin, carbonaceous film.
3) Usually appear as flattened, two-dimensional impressions or outlines of leaves, stems, or other plant parts.
4) Often dark or black carbon films on a lighter rock matrix.
5) Retain surface features like leaf venation, shape, margin, and sometimes even cellular details.
6) Fine details of epidermis or cuticle may be preserved if conditions are right.
7) Consist mostly of compressed organic matter (carbonaceous residue), not mineralized tissues.
8) Commonly leaves, stems, sometimes reproductive organs (cones, seeds).
9) Usually formed in low-oxygen, fine sediment environments such as lake beds, floodplains, or swamps where plant debris accumulates rapidly.

Compression Fossils

4. Impression Fossils:

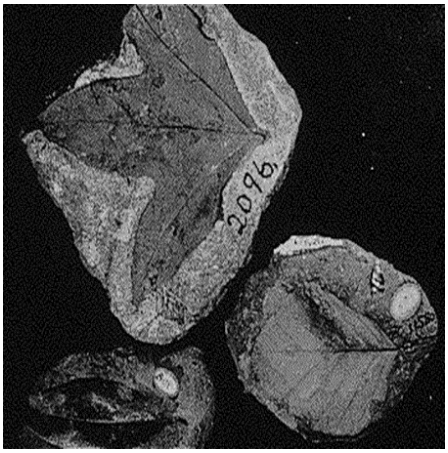
1) Impression fossils are formed when an organism leaves an imprint or outline on a substrate, such as mud or clay, which then hardens and preserves the external shape or surface details.
2) These are a type of trace fossil (not actual body parts), representing the external features of the organism rather than the organism itself.
3) Impression fossils are generally flat and two-dimensional, showing the surface texture or shape.
4) The organism (like leaves, insects, or fish) gets pressed into soft sediment, leaving a negative imprint, and the sediment hardens over time.
5) These often preserve fine details such as skin texture, veins of leaves, or the pattern of scales.
6) Unlike molds or casts, impression fossils typically do not contain organic material or three-dimensional shape.
7) Frequently found in plant leaves, feathers, or soft-bodied animals which do not fossilize easily as bones or shells.
8) Usually formed in fine-grained sedimentary rocks like shale, siltstone, or mudstone.



Impression fossils

5. Compaction Fossils:

1) Compaction fossils are formed when plant remains (usually leaves, stems, or other soft parts) are buried under sediments and subjected to pressure over time, which compresses the material into thin, carbonaceous films.
2) These fossils often retain a thin, black carbon film outline of the original plant part, preserving the external shape and surface details.
3) These are generally flattened and two-dimensional because of the pressure during sediment compaction, lacking three-dimensional structure.
4) Compaction fossils are mainly seen in plant fossils, particularly in coal-bearing strata, where delicate plant parts like leaves, ferns, and stems are preserved.
5) Surface venation and epidermal features can sometimes be observed clearly in compaction fossils, aiding identification.
6) These fossils are commonly found in fine-grained sedimentary rocks like shale or coal seams.
7) Internal cellular details are usually not preserved due to the flattening and compression process.



Compaction Fossils

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