Comments

1. *Carica papaya* acts as a host.
2. Leaves get rolled downward and inward, become deformed and leathery.
3. It is accompanied with vein clearing and reduction in the size of leaves.
4. The petioles are twisted in zigzag manner.
5. During severe infection, growth of the plants is checked, plants remain stunted and fruit bearing is reduced.
6. The causal virus is tobacco virus 16 or *Nicotiana* virus 10.
7. The most important agent of transmission is the white fly *Bemisia tabaci*.

Yellow Vein Mosaic of Bhindi

Exercise 1

***Object* : Study the symptoms of yellow vein mosaic of bhindi.**

Work procedure

Study the symptoms shown by the diseased *bhindi* plant.

Comments

1. Yellow vein mosaic of bhindi (*Abelmoschus esculentus*) is a serious problem all over India wherever the crop is grown.

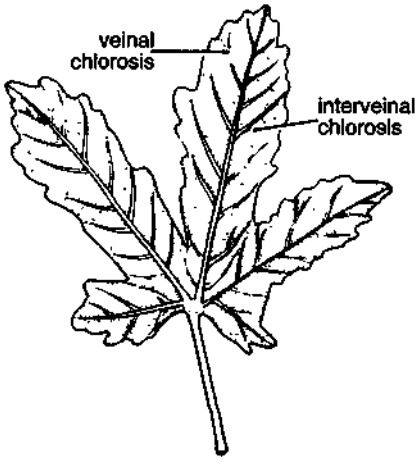


Fig. 1. Yellow vein mosaic of bhindi. A leaf showing symptoms.

2. The major symptoms include vein clearing followed by veinal chlorosis of the leaves.
3. A conspicuous yellow network of veins is formed. The veins and veinlets become thick.
4. In severe cases, chlorosis extends to interveinal areas and results in complete yellowing of leaves.
5. Fruits are dwarfed, malformed and are yellowish green in colour.
6. The causal virus is *Hibiscus* virus I.

Little Leaf of Brinjal

Exercise 1

***Object* : Study the symptoms of little leaf of brinjal.**

Work procedure

Study the infected brinjal plant and note the symptoms.

Comments

1. This disease of brinjal (*Solanum melongena*; vern. baingan; fam. Solanaceae) is caused by MLB (mycoplasma-like bodies).
2. The infected plants show extremely reduced leaves and nodes. The plants thus become bushy.
3. The heavily infected plants flowering and fruit setting is negligible. Virescent and phylloid flowers are very common.
4. The disease is transmitted by *Cestius phycitis*.
5. The disease is graft transmissible.
6. Control methods include tetracycline therapy, eradication of weed hosts and use of insecticides for the control of insect vectors.

Root Knot of Vegetables

Exercise 1

***Object* : Study the symptoms of root knot of vegetables.**

Work procedure

Study the infected plant parts and note down symptoms.

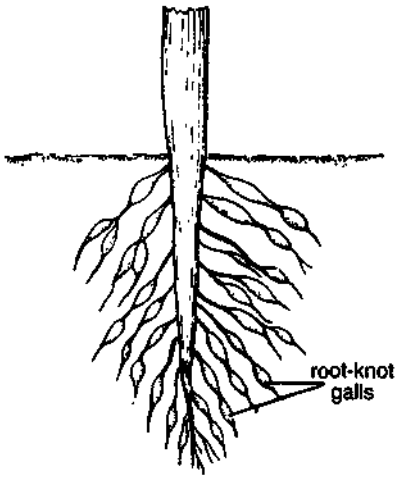


Fig. 1. Root knot of vegetables.

Comments

1. The disease is caused by root-knot nematodes *Meloidogyne*, the commonest species being *M. arneria, M. incognita* and *M. javanica.*
2. The common hosts include cucurbits, potato, tomato, brinjal, chillies, lady's finger, groundnut, carrot, radish, Colocasia, etc.
3. Since the symptoms are often not developed on the above ground parts, disease can not be easily recognised.
4. The diseased plants generally remain stunted, sickly and may dry suddenly and prematurely.
5. The roots show gall formation due to stimulation of excessive cell division.
6. Numerous female nematodes are present in the root galls.
7. Disease is controlled by fallowing or simple plowing, early or very late planting, application of DBCP, phorate, carbofuran, etc. and production of resistant varieties.

Exercise 2

***Object* : Study of causal organism.**

Work procedure

Since the organism is present in the root galls, these are dissected and nematodes separated. The dissected galls are studied under the microscope.

Comments

1. The disease is caused by a nematode, *Meloidogyne.*
2. The adult males are worm-like while the adult females appear pear-shaped.
3. The female lays eggs in gelatinous substance. Egg develops into larva.
4. II stage larva emerges from the egg in the soil and enters the host root. These enter behind the root tip and become established.
5. It is only at the IV stage larva that male and female can be distinguished.

Important Plants and Their Bacterial Diseases

Host	Diseases	Causal organism	Symptoms
1. Alfala (*Medicago sativa*)	Bacterial disease	*Xanthomonas alfalfae*	Small, water soaked spots, surrounded by straw coloured spots on leaves, later turn brown.
2. Brinjal (*Solanum melongena*)	Bacterial wilt	*Pseudomonas solanacearum*	Lower leaves droop, before wilting.
3. Cabbage (*Brassica oleracea* var. *capitata*)	Bacterial leaf spot	*Xanthomonas campestris* var. *armoriaceae*	Water-soaked leaf spots of minute size, increase. with age, leaves dry up.
4. Chillies (*Capsicum annuum*)	Bacrterial leaf spot	*Xanthomonas vesicatoria*	Small, water soaked spots, surrounded by straw coloured spots on leaves, later turn brown.
5. Cotton (*Gossypium* spp.)	Black arm or angular leaf spot	*Xanthomonas malvacearum*	Angular lesions on leaf and boll, watery and necrotic at maturity.
6. Mango (*Mangifera indica*)	Bacterial leaf spot	*Pseudomanas mangiferae-indicae*	Small water soaked lesions by veins on leaf, lesions turn dark brown.

Contd...

7. Moong, Urd (*Phaseolus* spp.)	Bacterial bean blight	*Xanthomonas phaseoli indicus*	Large, irregular, dry, sunken areas, red or brown in colour.
8. Potato (*Solanum tuberosum*)	Blackleg and soft rot	*Erwinia carotovora*	Affected plants turn pale green or yellow, wilt and die. Affected haulms are jet black at soil level. Diseased tubers rot in storage.
9. Sugarcane (*Saccharum officinarum*)	Red stripe	*Pseudomonas rubrilinaeus*	Long, narrow red streaks on leaves and top shoots affected.
	Gummosis	*Xanthomonas vasculorum*	Pale yellow stripes on leaves, later turning brown, canes become thin, short internodes, vascular bundles red.
10. Tomato (*Lycopersicum esculentum*)	Bacterial wilt	*Pseudomonas solanacearum*	Lower leaves droop before wilting, vascular system becomes brown.

Important Plants and Their Viral Diseases

Host	Diseases	Symptoms
1. Apple (*Pyrus malus*)	Mosaic	Mottling of leaves, white and yellow spots, chlorosis.
2. Banana (*Musa* spp.)	Bunchy top	Dark green streaks on petioles and along veins, shortening of crown and stunted growth.
3. Brinjal (*Solanum melongena*)	Little leaf	Production of tiny yellow or pink discolouration.
4. Cardamom (*Elattaria cardamom*)	Chirke	Light and dark green patches on leaves.
5. Citrus (*Citrus* spp.)	Tristeza	Profuse flowering, heavy fruit setting, yellowing of leaves, defoliation and die back of twigs.
6. Coconut (*Cocos nucifera*)	Wilt	Wilting of leaves, necrosis of leaf tips, yellowing of leaves, crown smaller.
7. Cotton (*Gossypium* spp.)	Stenosis	Leaves crinkled, deformed, yellow or pink discolouration.
8. Cow pea (*Vigna sinensis*)	Mosaic	Yellow and green patches on leaves, mottling and stunting.
9. Ground nut (*Arachis hypogaea*)	Rosette disease	Dwarf shoot forms dense clump, yellow leaves.
10. Potato (*Solanum tuberosum*)	Leaf roll	Upwards rolling of leaves, tissue becomes rigid and leathery, Necrosis of phloem, retarded growth, tubers small.
	Mosaic	Symptoms differ with infection of virus X, virus Y, and virus A.
11. Sugarcance (*Saccharum officinarum*)	Grassy shoot	Profuse tillering, sprouting of lateral buds, poor cane formation.
12. Tobacco (*Nicotiana* spp.)	Mosaic	Mottling of leaves, dark and light green streaks.

Bryophyta

7 *Chapter*

Preamble

Bryophyta includes mosses, liverworts and hornworts — both living as well as fossils, and numbering about 24,000, distributed in approximately 900 genera. They are fundamentally terrestrial plants, growing in tufts and usually, occupying moist shady places such as grounds, walls, rocks and their crevices. Apart from this terrestrial habit, some plants have secondarily, acquired the aquatic habit (*Riella, Ricciocarpus natans, Riccia fluitans*) whereas the others show epiphytic habit (some mosses and Jungermanniales) and still others a saprophytic habit (as *Buxbaumia*-moss and *Cryptothallus mirabilis*-liverwort).

The, largest Bryophyte is probably an Australian genus *Dawsonia* which attains a length of about 40-70 cms, otherwise as a whole, bryophytes are small and many are indeed microscopic, e.g. *Zoopsis*. This group stands between Algae and Pteridophyta and shows a sharply defined heteromorphic alternation of generations. A noteworthy point about Bryophytes is, that the gametophyte bearing the sex organs is an independent plant and long lived, whereas the sporophyte, bearing the spores, is dependent on the gametophyte and is short lived. The gametophyte, though small, is highly developed and differentiated, and is nutritionally self-sufficient because of the presence of chloroplasts. The gametophyte is either thallose (not differentiated into stem and leaf) or foliose (differentiated into stem and leaf). The true roots are absent and their function has been taken up by rhizoids which are unicellular and unbranched (liverworts) or multicellular and branched (mosses).

Reproduction is oogamous and gametes are produced in multicellular sex organs provided with an outer jacket. The antheridium (male sex organ) consists of stalk and a club-shaped or spherical body, the latter produces the antherozoids. The archegonium (female sex organ) is also stalked and a flask-shaped organ, with a swollen basal venter and slender elongated neck. The former is occupied by a large basal egg cell and a small upper venter canal cell, whereas the latter contains many neck canal cells. Water is essential for fertilization and the embryo is retained within the archegonium whose basal portion enlarges to form calyptra, a protective covering. The simple sporophyte is not differentiated into stem, leaves and roots but usually consists of foot, seta and spore producing terminal capsule. The haploid spores are produced by a reduction division of spore mother cells which represent the last stage of sporophytic generation. The spores germinate to form a filamentous germ tube which later forms the thallus as in liverworts or they germinate into filamentous or thallose protonema from which many erect gametophores arise as in mosses.

Bryophytes have been variously classified many times. No single classification has yet been considered satisfactory, though the classification proposed by Campbell (1936) is generally useful. Classification given below is a modified version of Campbell's scheme. Only those taxa have been mentioned which are later described in the book.

The Distinguishing Characters of Taxa

DIVISION **BRYOPHYTA**

(1) True roots absent
(2) Presence of antheridia and archegonia
(3) True vascular tissues absent

CLASS **1. HEPATICOPSIDA**

(1) Rhizoids without septa
(2) Chloroplasts without pyrenoids
(3) Capsule lacks columella

Order **1. Marchantiales**

(1) Presence of scales
(2) Two types of rhizoids

Family **1. Ricciaceae**

(1) Air pores single
(2) Sex organs in mid-dorsal groove
(3) Sporophyte differentiated into capsule and foot; seta absent

Example. ***Riccia***

Family **2. Marchantiaceae**

(1) Sex organs borne on stalked receptacles
(2) Barrel-shaped air pores
(3) Elaters present in the capsule

Examples. ***Marchantia, Plagiochasma***

Order **2. Jungermanniales**

(1) Scales absent
(2) Rhizoids smooth walled
(3) Antheridia and archegonia borne at apices
(4) Archegonial neck consists of 5 vertical rows of cells

Sub-order **1. Metzgerineae**
(Jungermanniales Anacrogynae)

(1) Gametophyte usually thallus, rarely stem with leaves.
(2) Archegonia develop from segments of apical cell; apical cell not completely used in archegonia formation
(3) Capsule wall 2-5 layers thick

Family **1. Pelliaceae**

(1) Sex organs scattered on the thallus surface
(2) The capsule has a basal elaterophore

Example. ***Pellia***

Sub-order **2. Jungermannineae**
(Jungermanniales Acrogynae)

(1) Gametophyte with stem and two rows of dorsal and a third, ventral row of leaves
(2) Archegonia in terminal cluster and the last archegonium is formed by the apical cell

Family **1. Porellaceae**

(1) Rhizoids less in number, form tufts at the bases of amphigastria
(2) Leaves incubously arranged
(3) Lobule (postical lobe) is distinct
(4) Perianth large, inflated with compressed mouth and bilabiate

Example. ***Porella***

Family **2. Frullaniaceae**

(1) The stems usually pinnately branched
(2) The rhizoids form a tuft at the base or middle of the under leaf
(3) Lateral leaves complicate-bilobed
(4) Perianth compressed and obtusely triangular in cross section

Example. ***Frullania***

CLASS **II. ANTHOCEROTOPSIDA**

(1) Plant body thalloid
(2) Rhizoids without septa
(3) Each cell of the thallus has generally a single, large chloroplast with a pyrenoid

Order **1. Anthocerotales**

(1) Thallus homogeneous
(2) Only smooth walled rhizoids present
(3) Scales and tuberculate rhizoids absent

Family **Anthocerotaceae**

(1) Sporophyte indeterminate in growth
(2) Presence of meristematic zone
(3) Capsule with central columella

Example. ***Anthoceros, Notothylas***

CLASS **III. BRYOPSIDA**

(1) Gametophores erect and leafy
(2) Rhizoids multicellular with oblique septa

Sub-class **1. Sphagnidae**

(1) Protonema thallose
(2) Leaves without midrib, composed of two types of cells
(3) Antheridia lateral and archegonia terminal
(4) Archesporium formed from amphithecium
(5) Capsule elevated by elongation of apex of gametophore called pseudopodium
(6) Peristome absent

Order **1. Sphagnales**

Characters same as sub-class

Family **1. Sphagnales**

Single family, characters same as sub-class

Example. ***Sphagnum***

Sub-class **2. Bryidae**

(1) Leaves with distinct midrib
(2) Seta long
(3) Spore sac usually separated from the capsule wall by air space

Order **1. Funariales**

(1) Leaves ovate or spathulate
(2) Peristome usually double
(3) Calyptra usually distended

Family **1. Funariaceae**

(1) Calyptra with a long beak
(2) Capsule pyriform and somewhat drooping

Example. ***Funaria***

Order **2. Polytrichales**

(1) Gametophores tall and perennial
(2) Leaves narrow with lamellae on the upper surface of midrib
(3) Peristome teeth 32 or 64
(4) Calyptra cucullate; either smooth, spinulose or hairy

Family **1. Polytrichaceae**

Single Family, Characters same as those of order

Examples. ***Polytrichum, Pogonatum***

DIVISION **BRYOPHYTA**

CLASS I **HEPTICOPSIDA** (Hepaticae) Liverworts	CLASS II **ANTHOCEROTOPSIDA** (Anthocerotae) Hornworts	CLASS III **BRYOPSIDA** (Musci) Mossess
Order 1. Marchantiales Family 1. Ricciaceae *Riccia* Family 2. Marchantiaceae *Marchantia* *Plagiochasma* Order 2. **Jungermanniales** Sub-Order 1. Metzgerineae (Jungermanniales Anacrogynae) Family Pelliaceae *Pellia* Sub-order 2. Jungermannineae (Jungermanniales Acrogynae) Family 1. Porellaceae *Porella* Family 2. Frullaniaceae *Frullania*	Order Anthocerotales Family Anthocerotaceae *Anthoceros* *Notothylas*	Sub-class 1. Sphagnidae Order **Sphagnales** Family Sphagnaceae *Sphagnum* Sub-class 2. Bryidae Order 1. Funariales Family Funariaceae *Funaria* Order 2. Polytrichales Family Polytrichaceae *Polytrichum* *Pogonatum*

Riccia

Classification

Division	—	**Bryophyta**
Class	—	**Hepaticopsida**
Order	—	**Marchantiales**
Family	—	**Ricciaceae**
Genus	—	***Riccia***

Exercise 1

***Object* : Study of external features of gametophyte.**

Work procedure

Study the external features of the gametophyte, both from dorsal and ventral surfaces. Observe the two types of rhizoids and violet coloured scales.

Comments

1. The plant body is thalloid, dorsiventral, prostrate and ribbon-like.
2. A rosette is formed due to repeated dichotomies of the thalli.
3. The thallus is linear to wedge shaped with an apical notch at the apex and thickened midrib in the sagittal axis. On the dorsal side, the midrib is traversed by a mid-dorsal groove.
4. On the ventral side, scales and rhizoids are present. The scales are present at the margins. The rhizoids arise from the midrib region.
5. Each scale is violet coloured, multicellular and one celled thick.
6. Rhizoids are of two types—(i) smooth walled and (ii) tuberculate. The smooth walled rhizoids have inner smooth walls whereas tuberculate rhizoids produce tuber-like or peg-like ingrowths of their inner wall which project into the lumen of the rhizoids.
7. Sex organs are present in the mid-dorsal groove and are embedded in the thallus. The sporophytes, however, may be seen as black dots, when mature, under the dissecting microscope.

Exercise 2

***Object* : Study of anatomy of thallus.**

Work procedure

Place the thallus in pith. Cut T.s. and stain either in safranin or fast green. Mount in glycerine and study.

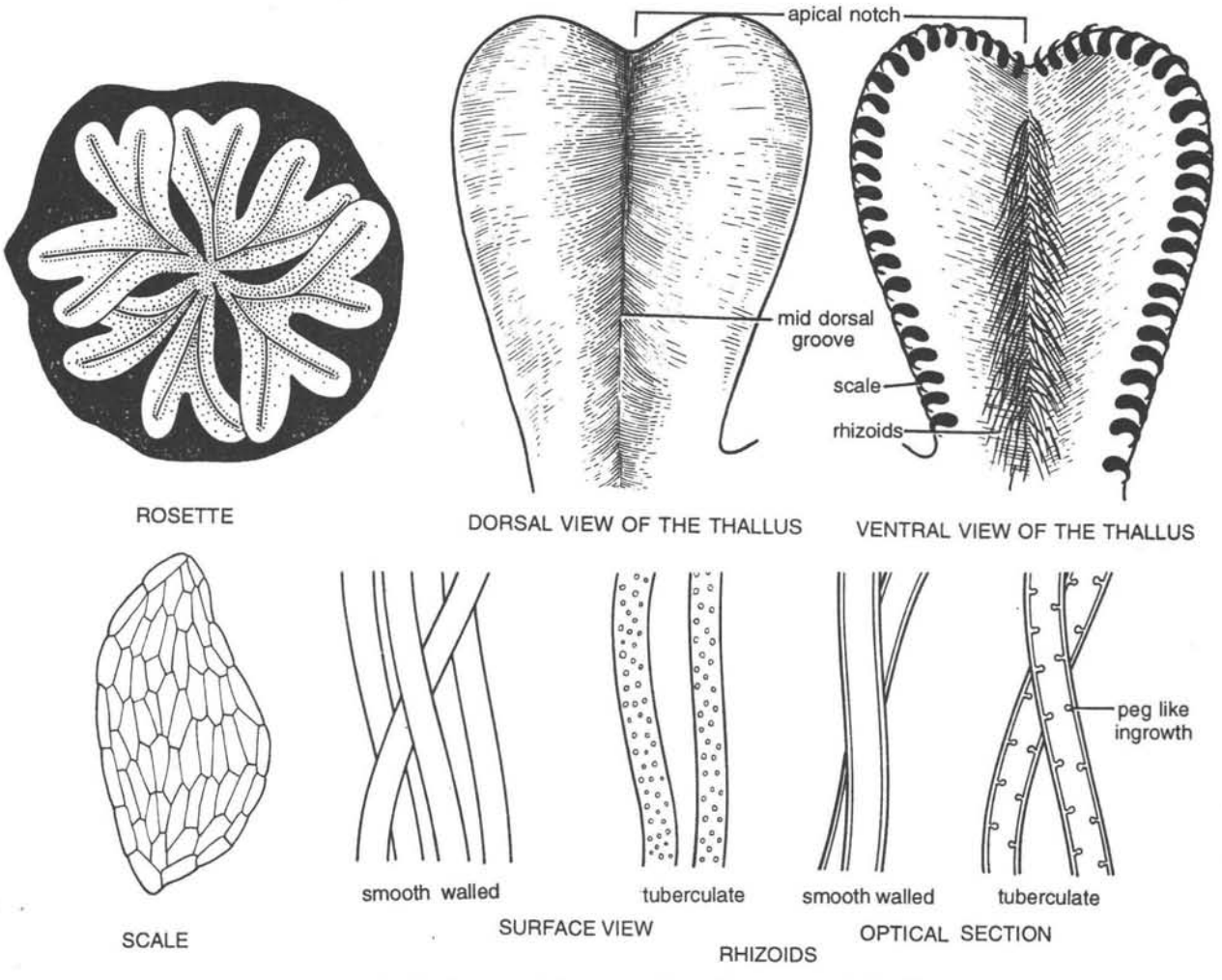


Fig. 1. ***Riccia.*** External features, scales and two types of rhizoids.

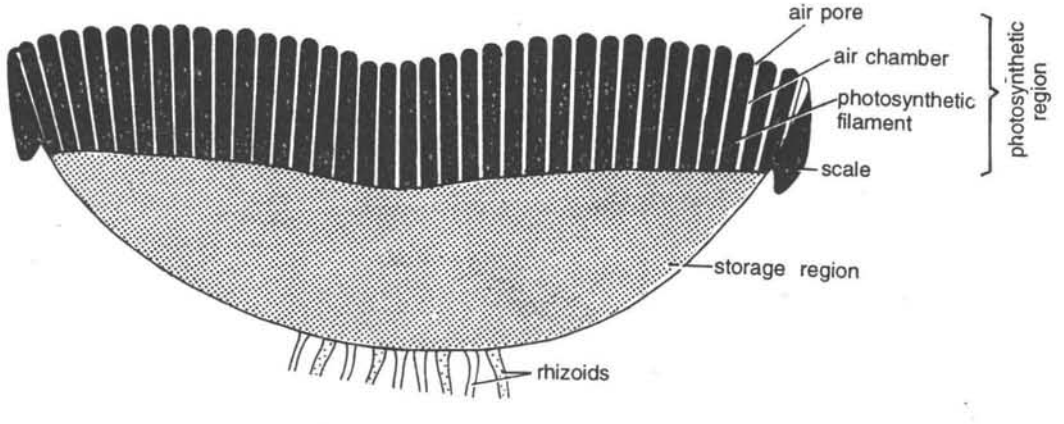


Fig. 2. ***Riccia.*** V.t.s. thallus (diagrammatic).

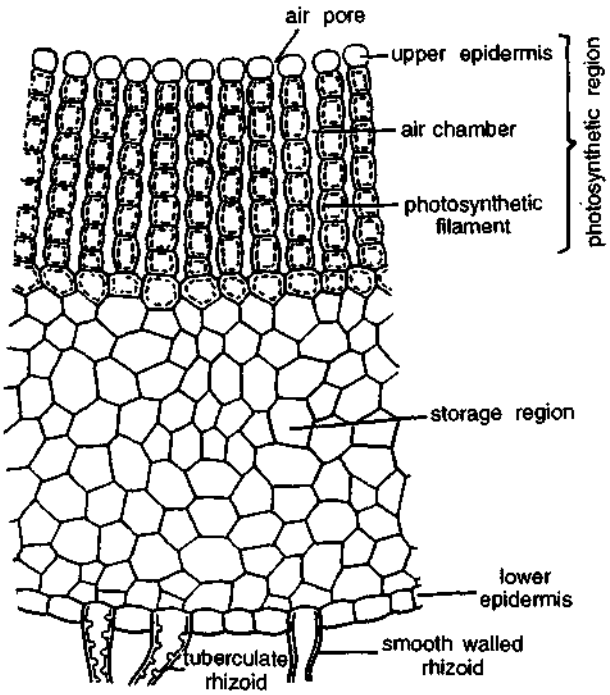


Fig. 3. ***Riccia.*** V.t.s. thallus (a part cellular).

Comments

1. The thallus is boat-shaped in a vertical transverse section.
2. It is thick in the midrib region and gradually thins out towards the margins.
3. The thallus is dorsiventrally differentiated into an upper green photosynthetic region and a lower colourless storage region.
4. The lower epidermis bounds the storage region on the lower side and bears the usual two types of rhizoids (smooth walled and tuberculate) in the centre.
5. The storage region consists of compactly arranged parenchyma. These cells contain starch.
6. The photosynthetic region consists of vertical rows of unbranched assimilatory filaments, separated by narrow air chambers. The cells of the filaments are barrel-shaped and each possesses numerous chloroplasts.
7. The air chambers open to the outside through simple air pores which are the intercellular spaces between the upper epidermal cells.
8. The uppermost cells of the assimilatory filaments are somewhat large. They lack chloroplasts and are thus colourless. These form an ill-defined upper epidermis.
9. On the two margins of the boat shaped section, violet coloured scales are present.

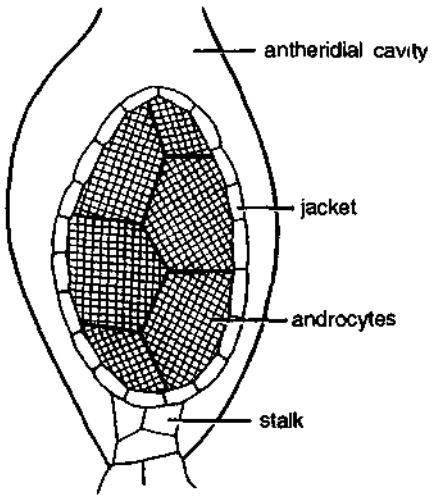


Fig. 4. ***Riccia.*** An antheridium.

Exercise 3

***Object* : Study of antheridium.**

Work procedure

Cut L.s. of thallus through mid-dorsal groove. Stain in fast green, mount in glycerine and study the antheridia.

Comments

1. The thallus is monoecious, both the sex organs being situated in the mid-dorsal groove. (*R. bischoffi* and *R. curtisii* are dioecious).
2. The antheridium is present inside a cavity called antheridial chamber which opens outside by antheridial pore.
3. The antheridial chamber with antheridium, lies embedded partly in the tissue of the photosynthetic region and partly in the tissue of the storage region.
4. A mature antheridium consists of a small stalk and a globular or club-shaped body.
5. The stalk is short and few celled. The body is composed of a central mass of either androcytes or antherozoids, surrounded by a single layer

of sterile jacket. The cells of the jacket are tangentially elongated.

Exercise 4

***Object* : Study of archegonium.**

Work procedure

Cut L.s. of thallus through mid-dorsal groove, stain the section in fast green, mount in glycerine and study the archegonium.

Comments

1. The thallus is monoecious and both the sex organs are situated in the mid-dorsal grrove.
2. A nearly mature archegonium is flask-shaped.
3. Archegonium is shortly stalked and consists of a broad venter and a long neck.
4. Wall of the venter is one celled. The venter has one venter canal cell and an egg cell.
5. The neck consists of 6 vertical rows of cells and is 6-9 cells in height. It possesses 4 neck canal cells.
6. The neck is surmounted by four cover cells.
7. Before fertilization, all the axial cells except the egg cell degenerate and the cover cells spread open to facilitate the entry of antherozoids.

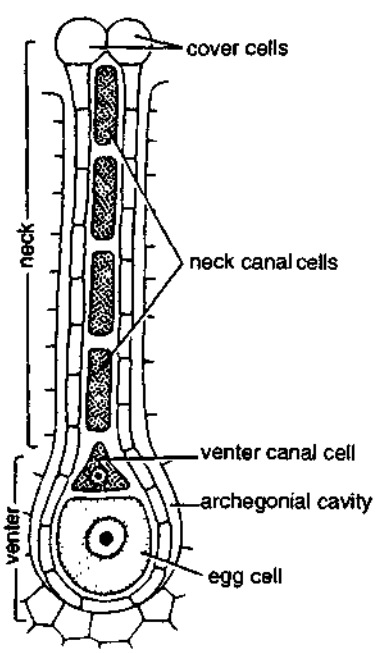


Fig. 5. ***Riccia.*** An archegonium.

Exercise 5

***Object* : Study the structure of sporophyte.**

Work procedure

Cut L.s. of the thallus through mid-dorsal groove, stain in safranin or fast green, mount in glycerine and study the sporophyte.

Comments

1. The sporophyte is embedded in the tissue of the thallus. It is present in the venter of fertilized archegonium.
2. Sporophyte is represented only by the capsule, foot and seta being absent.
3. The young capsule has a jacket layer and a 2-layered calyptra, derived from venter.

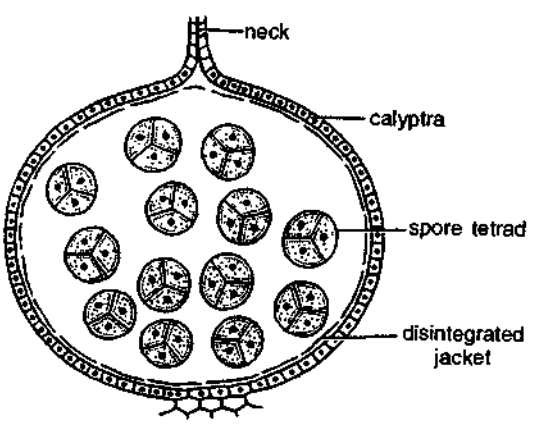


Fig. 6. ***Riccia.*** V.t.s. sporophyte.

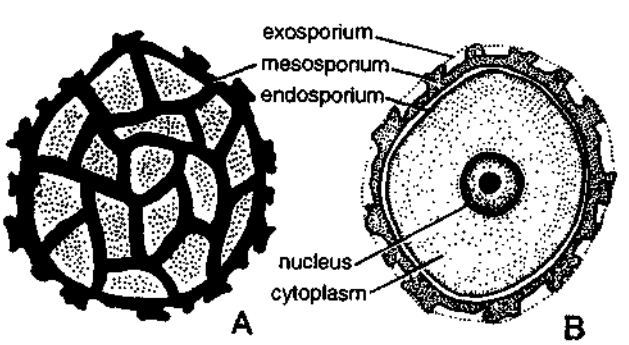


Fig. 7. ***Riccia.*** Spores **A.** Surface view. **B.** Optical view.

4. The mature sporophyte has spore tetrads arranged tetrahedrally (except *R. pearsonii*) or spores. These remain surrounded only by outer layer of calyptra, the inner layer of calyptra and the jacket disintegrates.
5. The spores are discharged only after the disintegration of the thallus.
6. Each spore ranges from 0.05 to 0.012 mm in diameter and consists of spore wall, enclosing within a rich cytoplasm and a nucleus.
7. The spore wall is three layered. The outermost layer is the exosporium which is thin and cutinized. The middle mesosporium is thick and the innermost endosporium is thin and homogenous. The entire spore wall is irregularly thickened and folded.

Identification

Division—**Bryophyta**. (1) True roots absent, (2) True vascular strands absent.

Class—**Hepaticopsida**. (1) Mostly thalloid, (2) Rhizoids without septa, (3) Chloroplasts without pyrenoids, (4) No columella in capsule.

Order—**Marchantiales**. (1) Scales present, (2) Two types of rhizoids present, (3) Air chambers and air pores present.

Family—**Ricciaceae**. (1) Air pores are simple, (2) Sex organs in the mid-dorsal groove, (3) Sporophyte composed only of capsule, foot and seta being absent.

Genus—***Riccia***. (1) Scales on the margins, (2) Assimilatory filaments are unbranched and vertical.

Hints for Collection

Riccia is very common in both hills as well as in plains. All the species grow on damp soil and rock. In plains *Riccia* can be seen growing amongst brick work or unused soil just after a few heavy showers.

Riccia fluitans

Comments

1. It is the only aquatic and free floating species of *Riccia*.
2. It is much dichotomously branched and thalloid.
3. The thallus is linear, elongated, ribbon-like, thin and lacks rhizoids and scales.
4. Vegetative reproduction takes place by adventitious branches.
5. It is sterile when free floating, but if water recedes, sex organs are formed. Therefore, fertile forms are terrestrial.

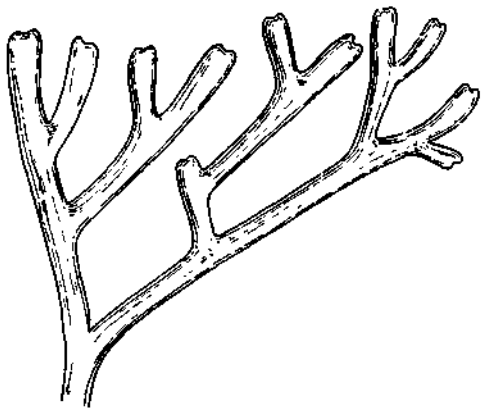


Fig. 1. ***Riccia fluitans***. External features.

Marchantia

Classification

Division	—	**Bryophyta**
Class	—	**Hepaticopsida**
Order	—	**Marchantiales**
Family	—	**Marchantiaceae**
Genus	—	***Marchantia***

Exercise 1

Object **: Study of external morphology of thallus.**

Work procedure

Study the external features of gametophyte. Observe the thallus from dorsal and ventral surfaces. Remove the rhizoids, stain in safranin and study. Also remove the scales from ventral side from the mid ventral region and margins. Mount in glycerine and study.

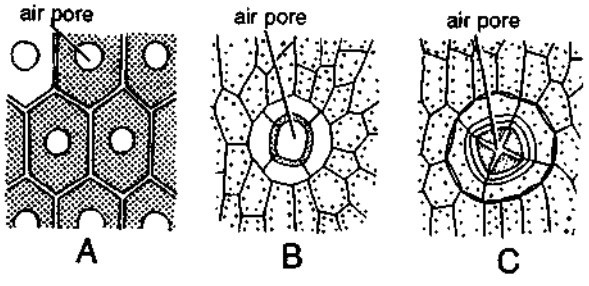


Fig. 2. ***Marchantia***. **A.** Polygonal area, **B.** and **C.** Air pores in surface view.

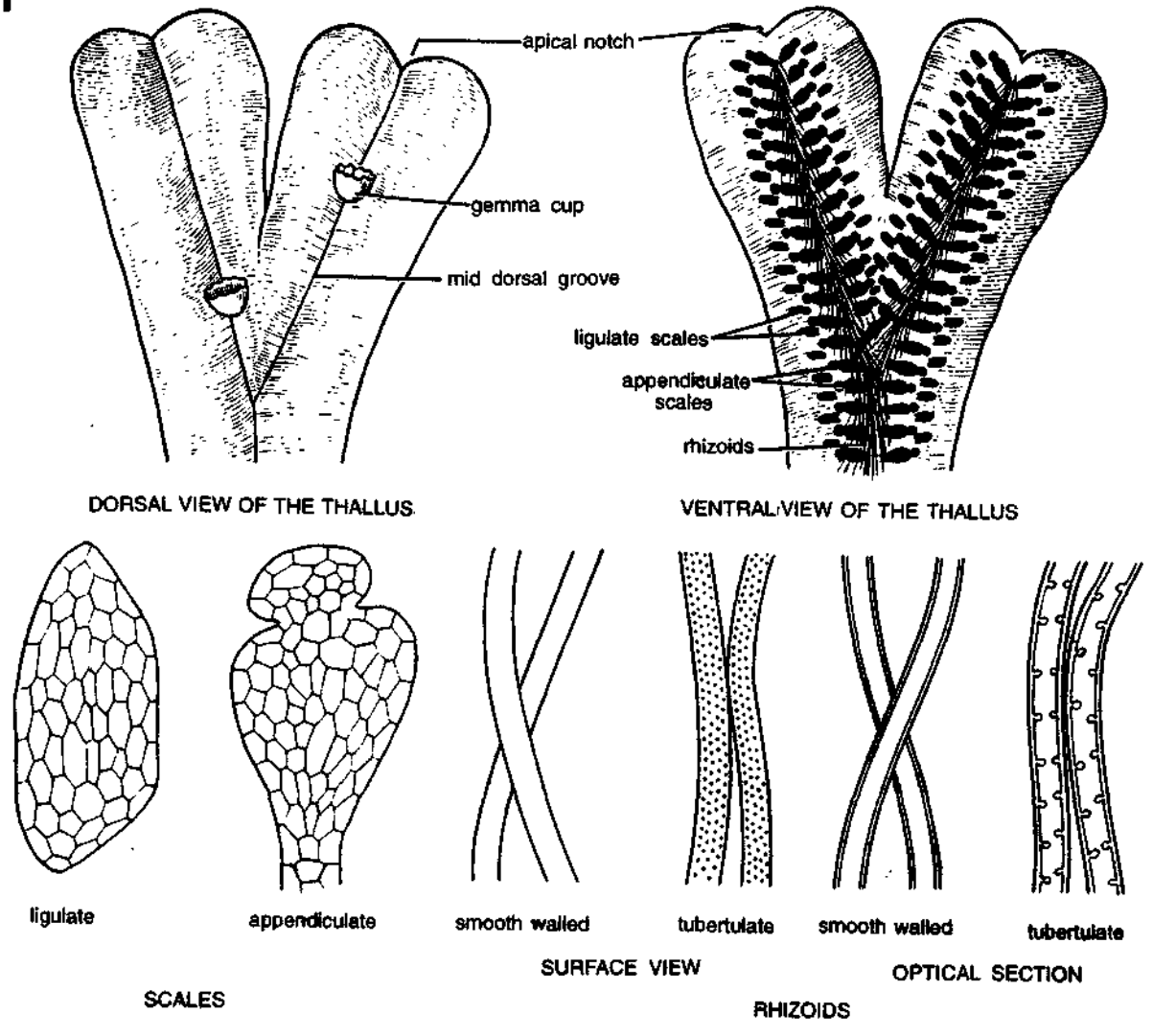


Fig. 1. ***Marchantia.*** External features; dorsal and ventral views, scales and rhizoids.

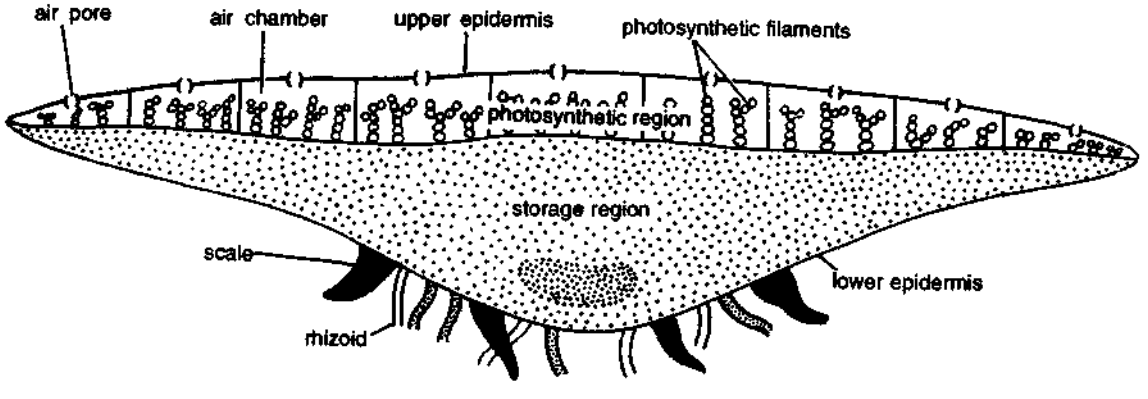


Fig. 2. ***Marchantia.*** V.t.s. thallus (diagrammatic).

Comments

1. Plants are thalloid, dorsi-ventral and prostrate.
2. Thallus is dichotomously branched and the apex of each branch is notched.
3. The dorsal side has a conspicuous midrib and many polygonal areas. These represent the underlying air chambers, each of which opens by a central air pore.
4. Each air pore is compound being made of 4-8 superimposed tiers of 3-4 cells each.
5. Certain cup-like structures present along the midrib are known as gemma cups. These contain gemmae, the vegetative reproductive bodies.
6. The ventral surface bears scales and rhizoids along the midrib.
7. Scales are arranged in two to four rows on either side of the midrib. Scales are of two types—(i) the simple or ligulate and (ii) the appendiculate. The appendiculate scales have a sub-rotund appendage at their tips.
8. The rhizoids are of two types—(i) smooth walled and (ii) tuberculate. The inner wall of the smooth walled rhizoid is smooth, while that of the tuberculate rhizoid has tuber-like or peg-like ingrowths. These appear just like circular dots in surface view.
9. The genus is dioecious, male and female thalli being different.
10. The sex organs are present on the stalked male and female receptacles. The male receptacle is known as antheridiophore and the female as archegoniophore. These structures arise from the growing apices of the thallus.

Exercise 2

***Object* : Study of anatomy of thallus.**

Work procedure

Cut V.T.s. of thallus by placing it in pith. Stain in safranin or fast green. Mount in glycerine and study.

Comments

1. Thallus is dorsiventrally differentiated into an upper photosynthetic or assimilatory region and a lower storage region.
2. Photosynthetic region is differentiated into upper epidemis and air chambers.
3. Upper epidermis is interrupted by compound, barrel-shaped air pores which open below into air chambers.
4. Air pore is made of 4-8 superimposed tiers of cells.
5. Each air chamber is filled with many branched assimilatory or photosynthetic filaments. The cell of these filaments and epidermis possess many chloroplasts.
6. Storage region is thick in the centre and gradually narrows towards margins.
7. Storage region consists of compactly arranged parenchymatous cells. A few cells are filled with oil bodies and mucilage.
8. The cells in the midrib or centre are slightly thickened to serve for conduction.
9. The lower surface of the thallus is bound by the lower epidermis, which bears scales (two types) and rhizoids (two types) in the middle region.

Exercise 3

***Object* : Study of vegetative reproductive structure : the gemma cup.**

Work procedure

Gemma cups are found on the upper side of thallus. Cut V.T.s. after placing the thallus in pith. Stain in safranin or fast green and mount in glycerine.

Comments

1. Outline is goblet-shaped with an outer wall and central cavity.
2. The outer wall shows outer photosynthetic region and inner storage region.
3. The internal structure of photosynthetic region and storage region is similar to that of thallus.
4. From the floor of the central cavity arise numerous discoid gemmae.
5. Intermingled with gemmae are many mucilage hairs or cells.
6. The gemma cup arises as a part of the thallus. It remains attached with the thallus by its base.

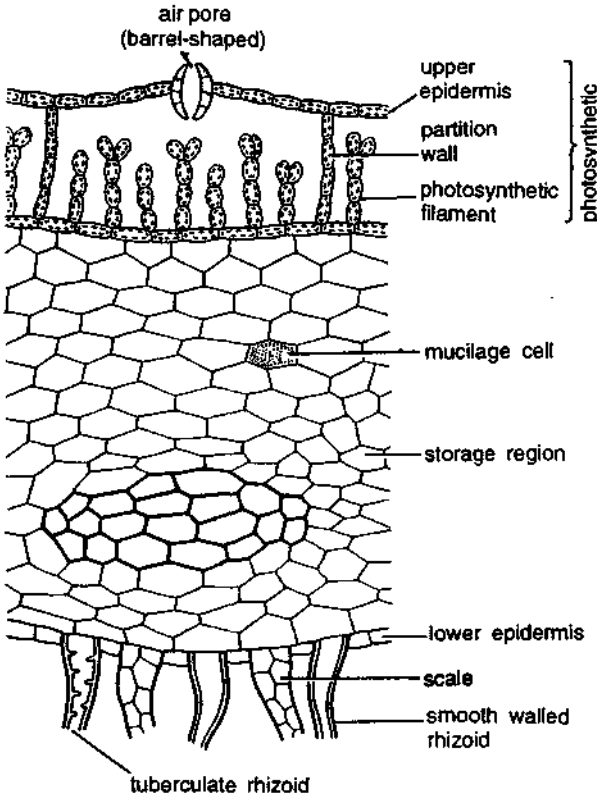


Fig. 4. ***Marchantia.*** V.t.s. thallus (a part cellular).

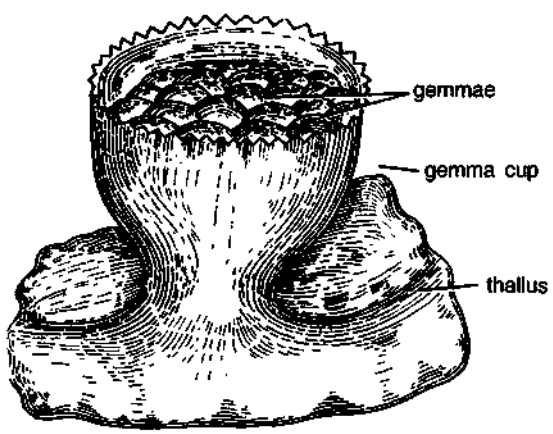


Fig. 5. ***Marchantia.*** A gemma cup.

7. Gemmae is one-celled, stalked structure. The stalk keeps gemma attached to the base of the gemma cup.
8. The disciform gemma has two shallow notches on both the lateral sides. Each notch possesses a row of apical cells.

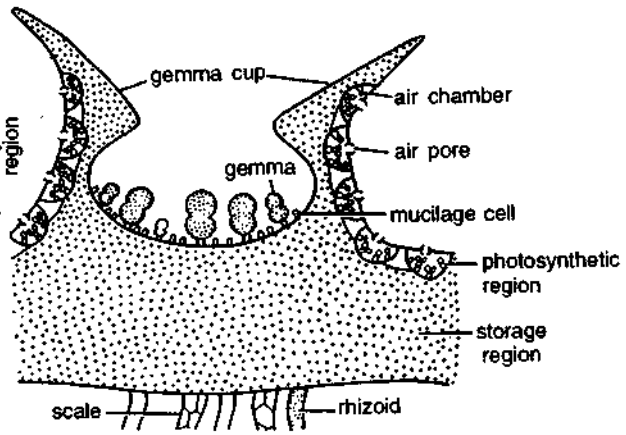


Fig. 6. ***Marchantia.*** V.t.s. of thallus through gemma cup.

9. Towards the periphery of the gemma colourless oil cells are present. Inner to them are the rhizoidal cells.
10. All the cells of gemma except the oil cells and rhizoidal cells contain chloroplast.

Exercise 4

***Object* : Study of stalk of the receptacle.**

Work procedure

Sex organs are found on stalked receptacles known as antheridiophores (male) and archegoniophores (female). T.s. of stalks of any one of the receptacles is cut. It is stained in safranin or fast green and mounted in glycerine.

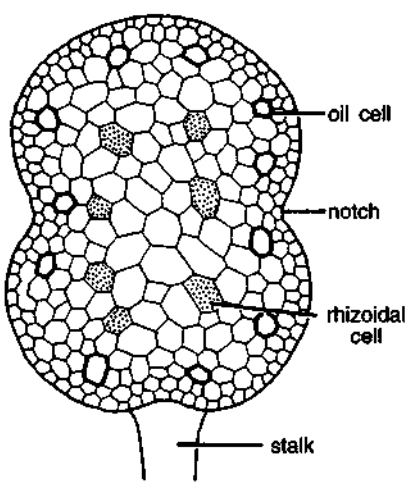


Fig. 7. ***Marchantia.*** A gemma.

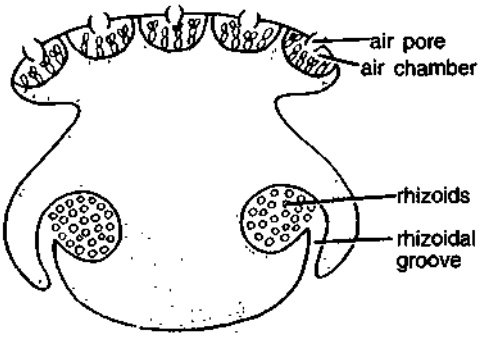


Fig. 8. ***Marchantia.*** T.s. of the stalk.

Comments

1. The stalk is dorsiventrally symmetrical.
2. It shows 2 rhizoidal grooves on the lower side, situated one on either side. It contains two types of rhizoids.
3. Upper side has photosynthetic region divided into many air chambers. It is similar to photosynthetic region of the thallus.
4. Stalks of both male and female receptacles are similar in structure.

Exercise 5

***Object* : Study of male sex organs.**

Work procedure

Cut a L.s. through antheridiophore, stain in safranin or fast green and mount in glycerine.

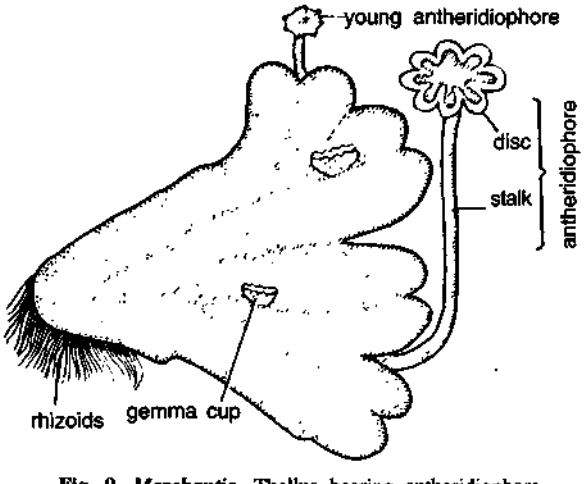


Fig. 9. ***Marchantia.*** Thallus bearing antheridiophore.

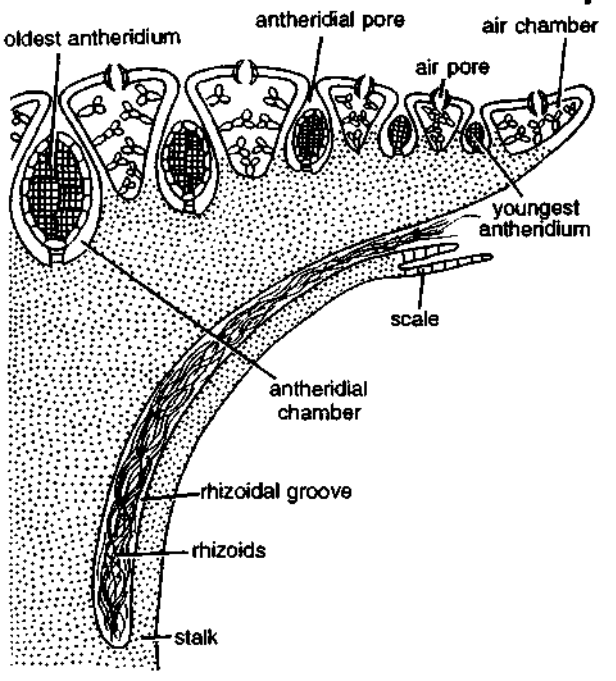


Fig. 10. ***Marchantia.*** A part of L.s. of antheridiophore.

Comments

1. The antheridiophore consists of 0.5 to 2.0 cms long stalk, bearing at its apex one eight lobed disc.
2. The peltate disc is slightly convex. The internal structure resembles with that of the thallus.
3. Epidermis is interrupted below by barrel-shaped air pores, each opening below, into an air chamber with branched assimilatory filaments.

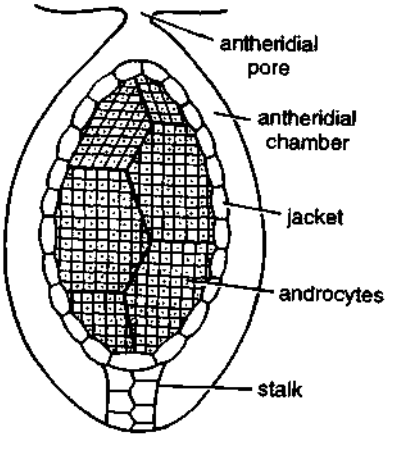


Fig. 11. ***Marchantia.*** An antheridium in anteridial cavity.

4. Alternating with air chambers, are antheridial cavities. Each antheridial cavity, that opens by an antheridial pore, has a single globular antheridium.
5. The antheridia are acropetally arranged i.e. oldest is nearest the centre and youngest nearest the margins.
6. It has a multicellular stalk attached to the base of the antheridial cavity.
7. The globular body has a single sterile jacket layer. Many androcytes or antherozoids occupy the space inside the jacket.

Exercise 6

***Object* : Study of female sex organs.**

Work procedure

Cut L.s. through archegoniophore, stain in safranin or fast green and mount in glycerine.

Comments

1. It is a stalked structure, (stalk 1 to 5 cms long) possessing a nine-rayed stellate disc at the apex. Groups of archegonia are found in between the rays. In each archegonial group, the archegonia are borne in radial rows.
2. After fertilization, sporophyte is formed in the same archegonium.
3. The peltate disc is convex. The internal structure is similar to that of thallus.

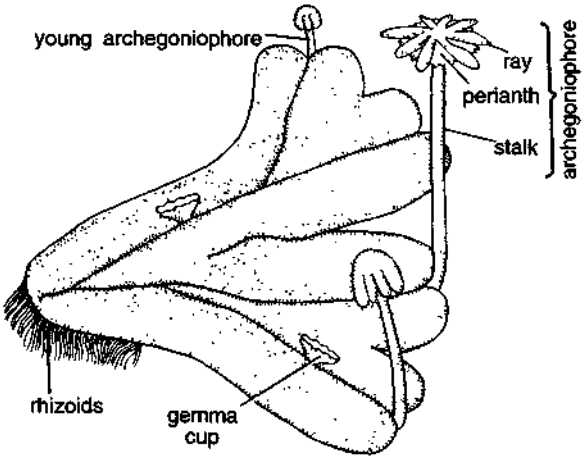


Fig. 12. ***Marchantia.*** Thallus with archegoniophores.

4. Outermost is the epidermis, interrupted by air pores. These open into air chambers with branched photosynthetic filaments.
5. In a young receptacle, archegonia are acropetally arranged on the upper side of the disc.
6. Due to the growth in the centre of the disc (which happens only after fertilization),

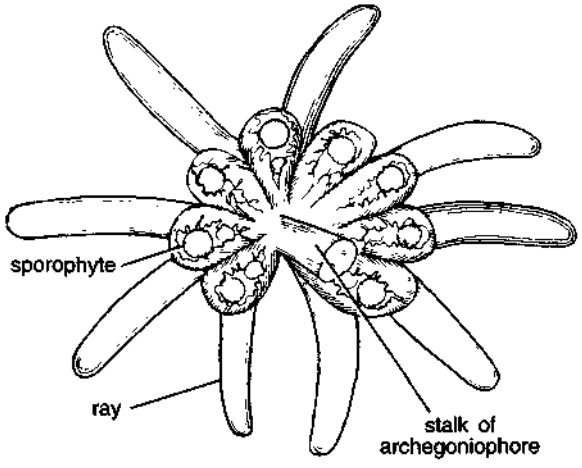


Fig. 13. ***Marchantia.*** Disc of archegoniophore as seen from lower side.

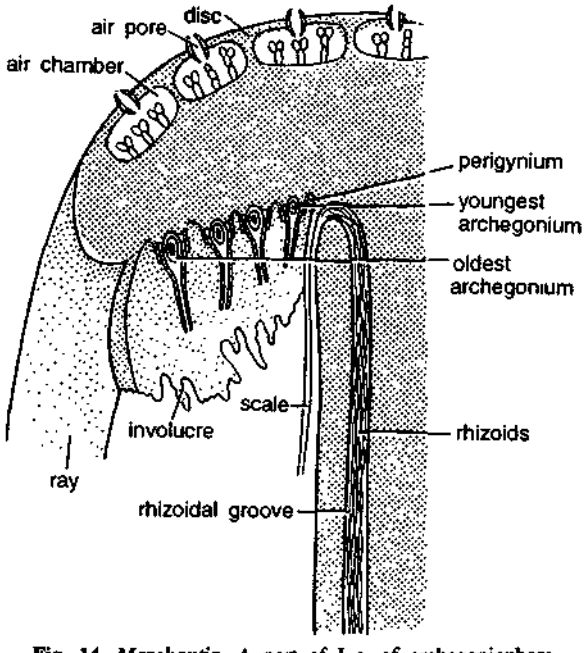


Fig. 14. ***Marchantia.*** A part of L.s. of archegoniophore.

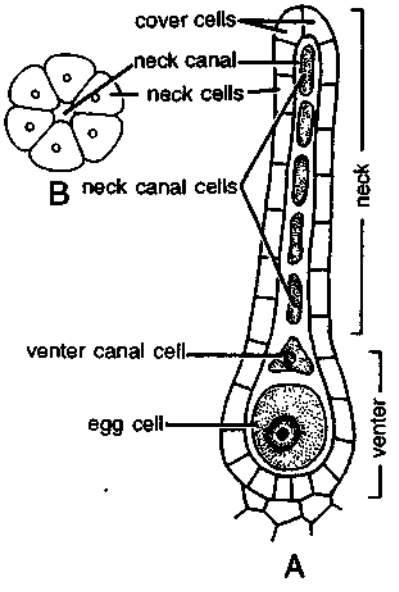


Fig. 15. ***Marchantia.*** **A.** An archegonium. **B.** T.s. through the neck.

archegonia finally become shifted towards the lower side.

7. The nearly mature archegonium has swollen venter and a long neck.
8. The venter encloses an egg cell and a venter canal cell, while the neck has 4-8 neck canal cells surrounded by six vertical rows of jacket cells.
9. The cover cells are not much distinct.
10. After fertilization perianth and involucre are developed.

Exercise 7

Object **: Study of sporophyte.**

Work procedure

Cut L.s. through disc of mature archegoniophore, stain in safranin and mount in glycerine.

Comments

1. Sporophyte develops in the same place as archegonium after its fertilization. Therefore, capsules are seen in a disc of mature archegoniophore, on the lower side. Only one sporophyte develops in one involucre.

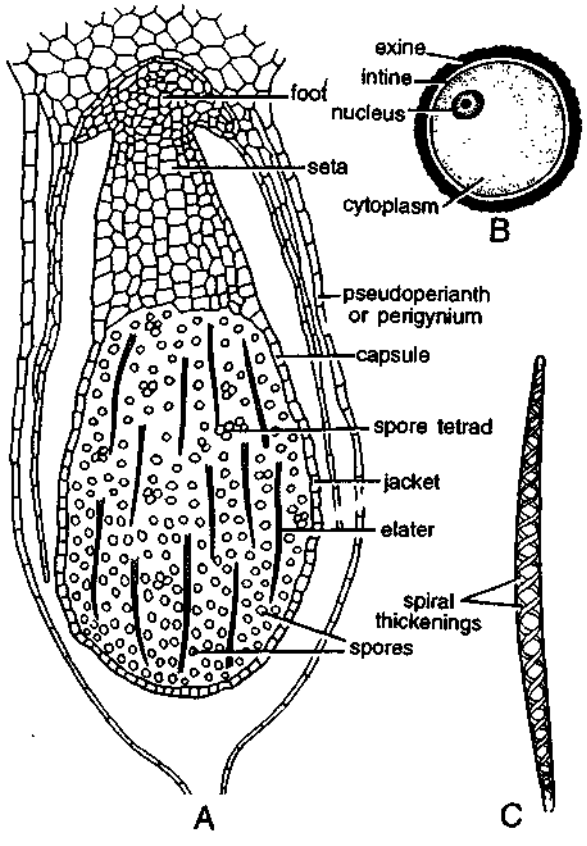


Fig. 16. ***Marchantia.*** **A.** L.s. of nearly mature sporophyte. **B.** Spore. **C.** An elater.

2. The sporophyte is enclosed by three coverings (i) calyptra, (ii) perigynium (perianth) and (iii) perichaetium (involucre). It is differentiated into a foot, seta and capsule.
3. Foot is basal and bulbous. Seta is middle and short and the capsule is spherical, occupying the distal end of the sporophyte.
4. Capsule has a single layered jacket, inside which lie many spores and elaters. Spores are arranged in tetrahedral tetrads.
5. A spore has an outer thick sculptured exine and a thin uniform intine. Every spore is uninucleate with rich cytoplasm.
6. The spores are very small in size.
7. Elaters are spindle-shaped and each possesses 2 spiral thickening bands. These are hygroscopic and help in the dispersal of spores.

Identification

Division—**Bryophyta**. (1) True roots absent and instead are present rhizoids, (2) No true vascular strand.

Class—**Hepaticopsida**. (1) Mostly thalloid, (2) Rhizoids without septa, (3) Chloroplasts without pyrenoids, (4) Columella absent from capsule.

Order—**Marchantiales**. (1) Scales present, (2) Two types of rhizoids.

Family—**Marchantiaceae**. (1) Sex organs borne on stalked receptacles, (2) Air pores barrel-shaped, (3) Elaters in capsule.

Genus—***Marchantia***. (1) Assimilatory filaments branched, (2) Scales ligulate and appendiculate both, (3) Gemma cup not crescent-shaped.

Hints for Collection

All the species of *Marchantia* found in India grow mainly in the Himalayas. Plants usually grow in moist places, either in wet open woodland or near the banks of streams. The best development is, however, seen in damp burnt soil.

Pellia

Classification

Division	—	**Bryophyta**
Class	—	**Hepaticopsida**
Order	—	**Jungermanniales**
Sub-order	—	**Metzgerineae**
Family	—	**Pelliaceae**
Genus	—	***Pellia***

Exercise 1

***Object* : Study of external morphology.**

Work procedure

Study the external features of gametophyte. Observe the thallus from dorsal and ventral sides. Remove the rhizoids and study.

Comments

1. The plants are thalloid, prostrate, drosiventral and dichotomously branched.
2. On the dorsal side there is an indistinct midrib and one celled thick lateral wings, with somewhat wavy margins.
3. At the apex is a notch in which growing point is situated. Club-shaped mucilaginous hairs are also present at the apex.
4. The shape of the thallus depends upon moisture conditions. If the thalli grow near water, they are narrow, ribbon-like, delicate and with distinct midrib. If the thalli happen to grow on dry soil, they become shorter, thick and bear an indistinct midrib.
5. Only smooth walled rhizoids are present on the ventral side towards the midrib portion. The tuberculated rhizoids and scales being altogether absent.

Exercise 2

***Object* : Study of anatomy of thallus.**

Work procedure

Cut V.T.s. of thallus, stain in safranin or fast green, mount in glycerine and study.

Comments

1. The section of the thallus shows homogeneous internal structure. Only the surface layers are little different while cells forming the rest of the tissues are all similar.
2. The section shows ventral projected midrib and wings. The midrib is 8-14 cells in thickness passing gradually on either sides into one celled wings.
3. The epidermal cells are smaller and contain more chloroplasts, than the other cells which have distinct starch grains and oil bodies.
4. In *P. epiphylla* and *P. neesiana* there are some thick-walled cells in the midrib portion which travel longitudinally from posterior to anterior end.
5. Rhizoids arise from the lower epidermis in the midrib region.
6. Vegetative reproduction takes place by adventitious shoots arising either from the midrib or from margins of the dorsal side. These branch on their separation from the parent plants and grow into new plants.

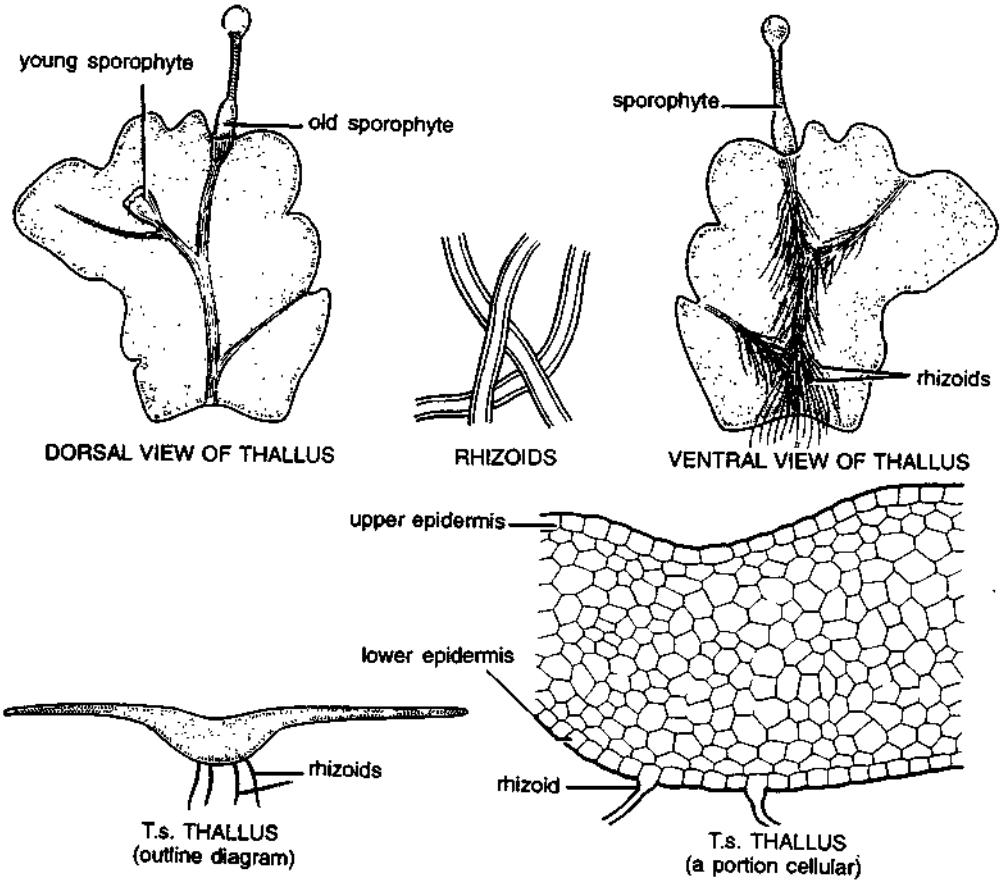


Fig. 1. ***Pellia.*** External features and anatomy of the gametophyte.

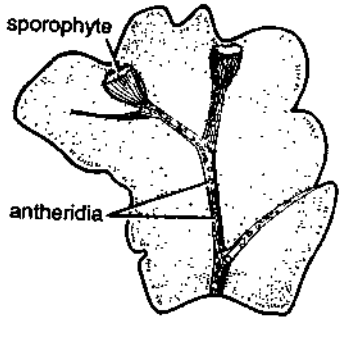


Fig. 2. ***Pellia.*** Fertile thalli of *P. calycina.*

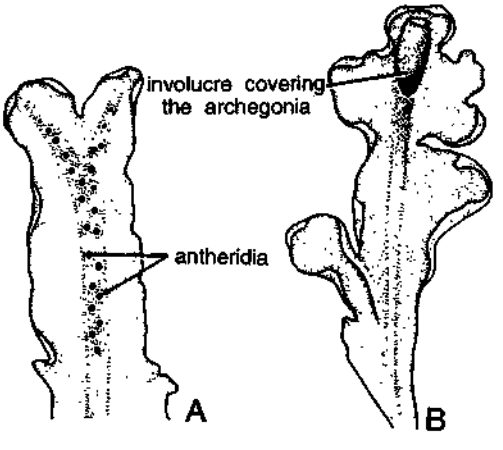


Fig. 3. ***Pellia.*** Fertile thallus of *P. epiphylla.*

Exercise 3

***Object* : Study of male sex organs—the antheridia.**

Work procedure

Cut V.T.s. of thallus passing through midrib. Stain in safranin or fast green, mount in glycerine and study

Comments

1. All the species are dioecious except *P. epiphylla* which is monoecious and protandrous.
2. The antheridia are found just behind the growing points in two to three irregular rows in the midrib portion on the dorsal side.
3. Externally antheridia appear as wart-like projections.

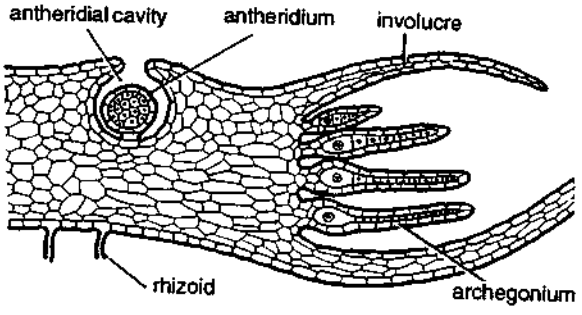


Fig. 4. ***Pellia.*** L.s. of thallus through sex organs.

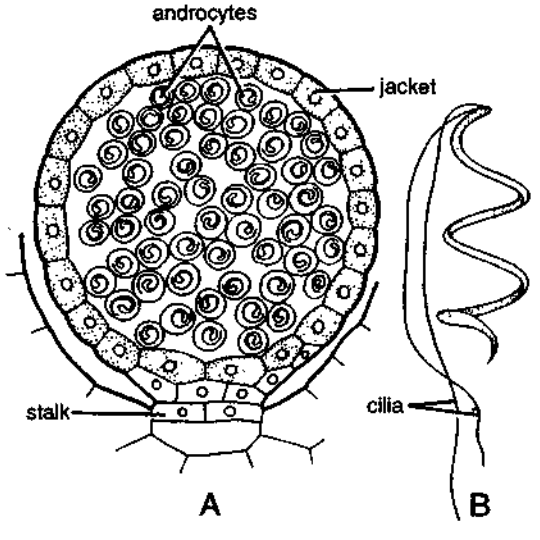


Fig. 5. ***Pellia.*** **A.** An antheridium. **B.** An antherozoid.

4. Each antheridium is present in the antheridial cavity that opens on the dorsal side by a narrow pore known as the antheridial pore.
5. Each antheridium consists of a short multicellular stalk and a nearly spherical body.
6. The body of the antheridium has a single-layered jacket enclosing many androcytes or antherozoids.
7. Each antherozoid is a spirally coiled, biciliate structure.

Exercise 4

***Object* : Study of female sex organs—the archegonia.**

Work procedure

Cut L.s. of the thallus passing through growing point. Stain with safranin or fast green, mount in glycerine and study.

Comments

1. The archegonia are found in groups of 4 to 12, just near the apical cell.
2. Each archegonial group is surrounded by an involucre which may either be tubular, cylindrical or flap-like.

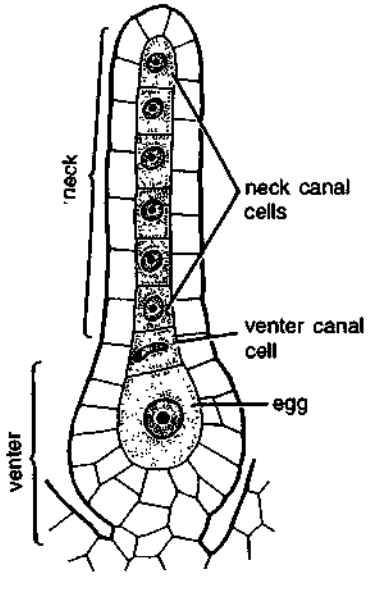


Fig. 6. ***Pellia.*** A nearly mature archegonium.

3. Archegonia are intermingled with each other without definite arrangement of older and younger archegonia.
4. A nearly mature archegonium has a short multicellular stalk, a broad venter and a long neck.
5. The jacket of a neck consists of five vertical rows of cells and encloses usually 6-8 neck canal cells.
6. The venter is two-layered thick and encloses a single venter canal cell and an egg cell.
7. The cover cells are 4 in number but are not very much distinct.

Exercise 5

***Object* : Study of sporophyte.**

Work procedure

Study the external features and also cut L.s. Stain with safranin or fast green, mount in glycerine and study.

Comments

1. The mature sporophyte consists of foot, seta and capsule.
2. The foot is very prominent with its edges overlapping the basal portion of seta, thus assuming a collar-shape.
3. The seta is short when young but becomes very much elongated at maturity.
4. The capsule is covered by calyptra and involucre respectively.
5. The capsule is nearly spherical and consists of an outer jacket composed of 2 or 3 layers.
6. The jacket layers of capsule have radial thickenings except at 4 places at the top wherefrom the dehiscence takes place.
7. Inside the jacket at the base of the capsule is present a sterile tissue, known as elaterophore. On this elaterophore are attached some 20 to 100 elaters, radiating into the cavity of capsule.
8. In the remaining cavity of the capsule are present spores and elaters.
9. The spores are arranged in tetrahedral tetrads and are formed by lobing of spore mother cell.
10. Each spore is unicellular. The elater is a long, slender, spindle-shaped, structure with generally 2 but sometimes 3-4 spiral thickening bands.

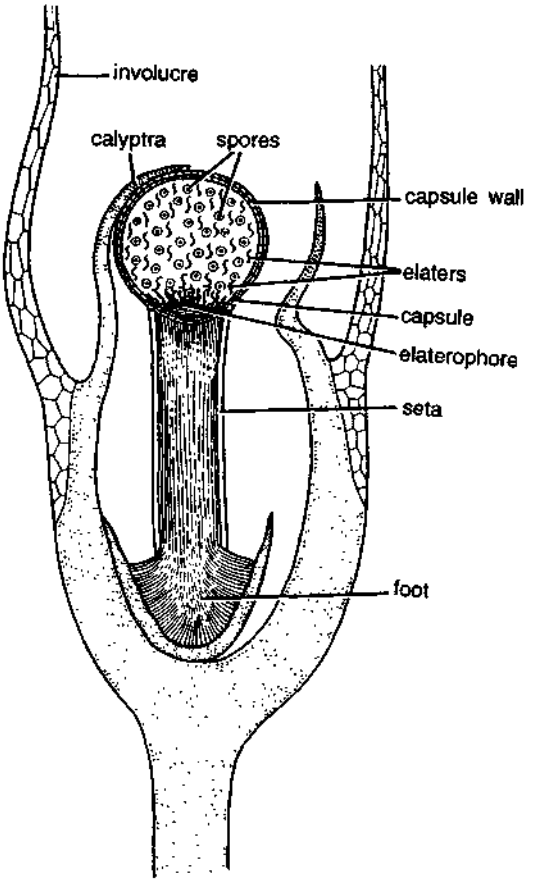


Fig. 7. ***Pellia.*** L.s. through the mature sporophyte.

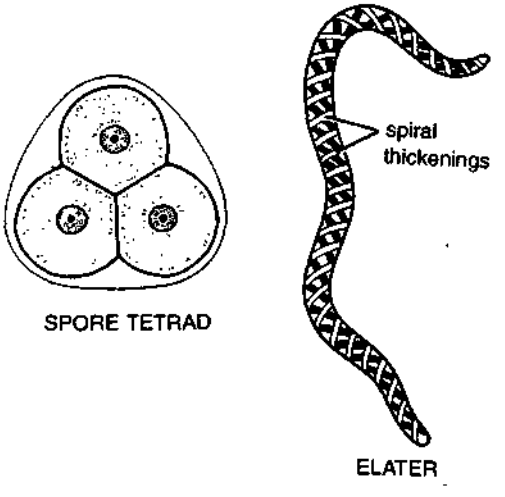


Fig. 8. ***Pellia.*** A spore tetrad and an elater.

Identification

Division—**Bryophyta**. (1) True roots absent and instead are present the rhizoids, (2) No true vascular strand.

Class—**Hepaticopsida**. (1) Rhizoids without septa, (2) Chloroplasts without pyrenoids, (3) Columella absent from capsule and there are stomata on capsule wall.

Order—**Jungermanniales**. (1) Scales absent, (2) Rhizoids smooth walled, (3) Antheridia and archegonia are borne at the apices, (4) Archegonial neck consists of 5 vertical rows of cells.

Sub-order—**Metzgerineae**. (Jungermanniales Anacrogynae) (1) Gametophyte usually a thallus, very rarely a stem with leaves, (2) Archegonia arise from the segments of apical cell. The apical cell is not consumed in the formation of archegonium, (3) Jacket of the capsule is 2 to 5 layers thick.

Family—**Pelliaceae**. (1) Sex organs are scattered on the dorsal surface of thallus, (2) The capsule has a basal elaterophore.

Genus—***Pellia***. (1) Thallus often lobed by irregular incisions, (2) Archegonia are present just behind the apical cell in groups of 4 to 12, (3) Capsule dehisces by 4 valves.

Hints for Collection

Two species of *Pellia* found in India are *P. calycina* and *P. epiphylla*. The former is chiefly found in western Himalayas and Kumaon, whereas the latter is common in eastern Himalayas and Skikkim. These very commonly grow in moist, shady places especially by the sides of ditches, streams and moist rocks, etc.

Porella *(Madotheca)*

Classification

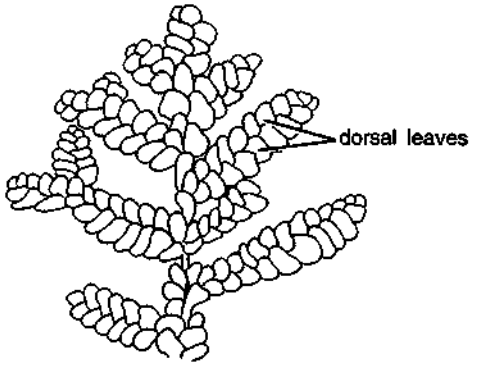
Division	—	**Bryophyta**
Class	—	**Hepaticopsida**
Order	—	**Jungermanniales**
Sub-order	—	**Jungermannineae**
Family	—	**Porellaceae**
Genus	—	***Porella***

Exercise 1

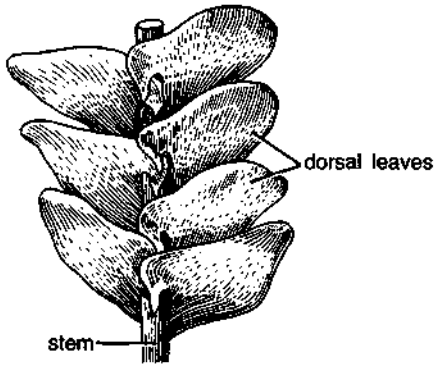
***Object* : Study of external features.**

Work procedure

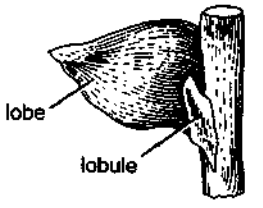
Study the gametophytic thallus and note down the characters.



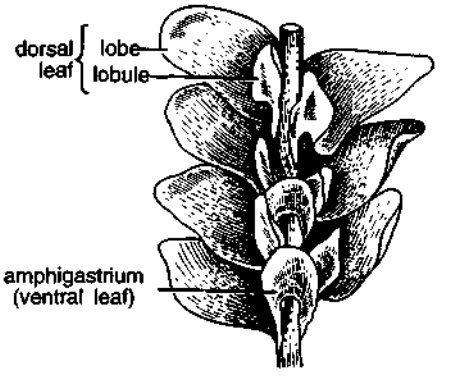
A PLANT FROM DORSAL SIDE



A PORTION OF BRANCH (dorsal view)



DORSAL LEAF



A PORTION OF BRANCH (ventral view)

Fig. 1. ***Porella***. External features of gametophyte.

Comments

1. The plants are large, prostrate, dorsiventral and grow in compact greenish patches.
2. Thallus is differentiated into a branched stem and leaves, arranged in 3 rows.
3. Out of the three rows of leaves, the two are dorsal and one is ventral. These ventral smaller leaves are known as the amphigastria.
4. The dorsal leaves are incubously arranged (*the anterior margin of the lower leaf is covered by the posterior margin of the leaf next above it, when seen from above*) and each is divided into a larger (antical) lobe and a smaller (postical) lobule.
5. The lobe is usually ovate with rounded apex while the lobule is narrower with acute apex.
6. Many rhizoids are present on the lower side of the stem.

Exercise 2

***Object* : Study of anatomy of axis.**

Work procedure

Place the thallus in pith. Cut T.s. and stain either in safranin or fast green. Mount in glycerine and study.

Comments

1. The axis is differentiated into an epidermis, cortex and medulla.

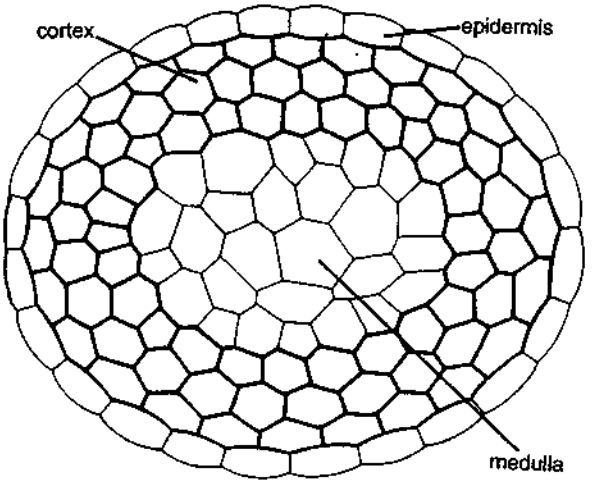


Fig. 2. *Porella*. T.s. axis (cellular).

2. The cortical cells are usually small and thick-walled, in comparison to the large, thin-walled medullary cells.

Exercise 3

***Object* : Study of antheridial branch and antheridium.**

Work procedure

Tease out the bracts and expose the antheridia, from antheridial branches. Stain in safranin, mount in glycerine and study.

Comments

1. The genus is dioecious and the male and female plants can be externally differentiated.
2. The male plants are usually smaller with the antheridial branches projecting nearly at right angles from the main axis.
3. The antheridial branch has many closely arranged bracts.
4. In the axil of each bract, antheridium is present.
5. Each antheridium consists of a long stalk, composed of two rows of cells subtending at its apex a globular body.
6. The body has a jacket layer composed of 2-3 layers in the basal part and one layer in the upper part.
7. Within the jacket are present many androcytes which ultimately go to form the biciliate antherozoids.

Exercise 4

***Object* : Study of archegonial branch and the archegonium.**

Work procedure

Tease the apex of archegonial branch. The archegonia appear between the leaves. Stain with safranin or fast green, mount in glycerine and study.

Comments

1. The genus is dioecious. The female plants are distinct from the male plants.
2. Female plants are usually larger though archegonial branches are shorter than the antheridial branches.

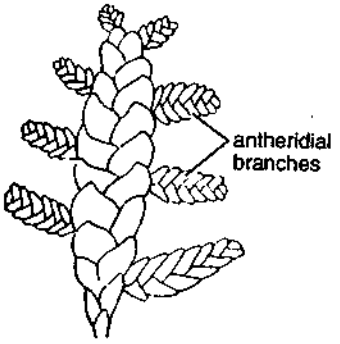


Fig. 3. *Porella.* A male plant with antheridial branches.

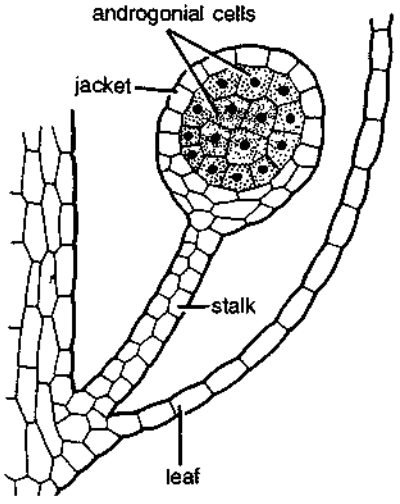


Fig. 4. *Porella.* A portion of an antheridial branch bearing antheridium in the axil of leaf.

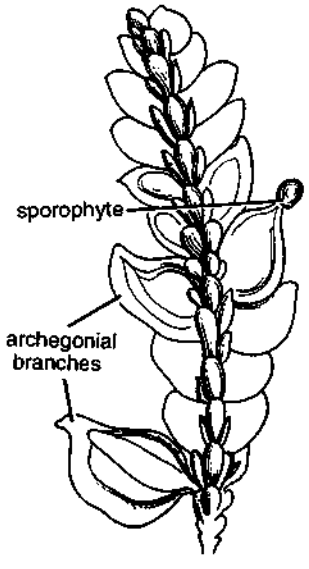


Fig. 5. *Porella.* A female plant with archegonial branches and a sporophyte.

3. The archegonia are found at the apex of archegonial branch.
4. The first few archegonia are arranged acropetally and the last archegonium is formed by the apical cell itself, thus checking the further growth of archegonial branch.
5. The archegonium consists of a broad neck and the venter.
6. The neck consists of five vertical rows of cells, typical of jungermanniales, and encloses 6-8 neck canal cells.
7. The venter wall is two layered. It encloses a venter canal cell and an egg cell.

Exercise 5

***Object* : Study of L.s. sporophyte.**

Work procedure

Cut a thin L.s. of the capsule. Stain in fast green, mount in glycerine and study.

Comments

1. The sporophyte consists of a small foot, a short seta and a globose capsule.

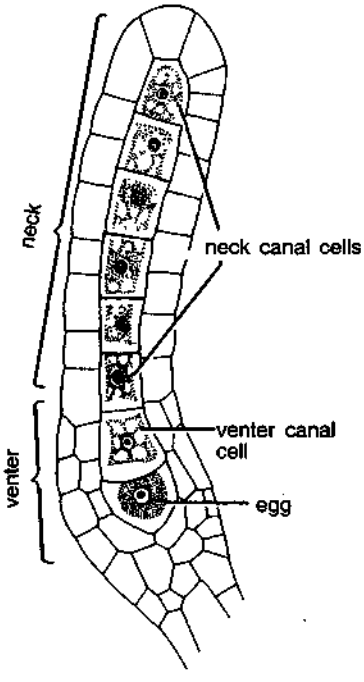


Fig. 6. *Porella.* A nearly mature archegonium.

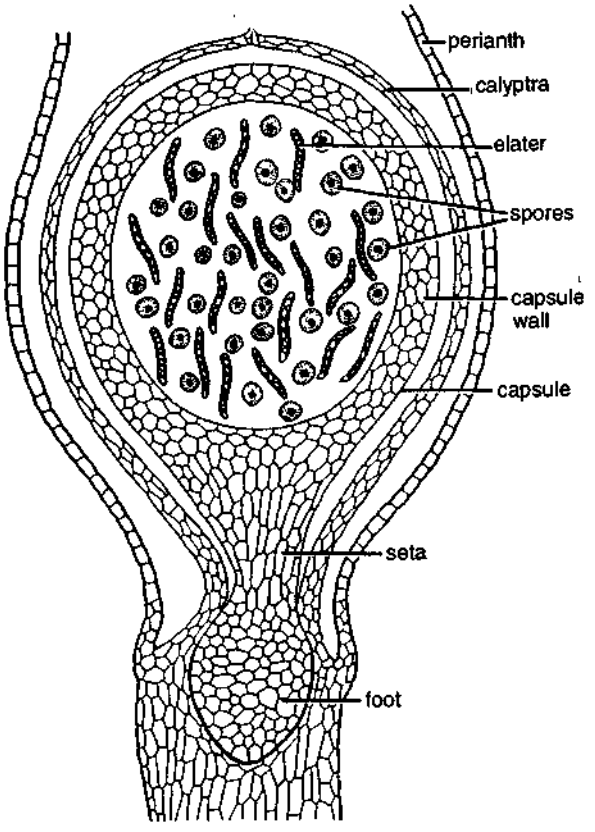


Fig. 7. ***Porella.*** L.s. mature sporophyte.

2. The young sporophyte is covered by calyptra and perianth.
3. The calyptra developed from venter of archegonium is more than one layered thick. It surrounds the sporophyte until its maturity.
4. The perianth is formed by the fusion of two uppermost perichaetial bracts and is more or less dorsiventrally compressed, in the anterior region.
5. The capsule is globose and consists of a jacket layer, two or six cells in thickness.
6. Enclosed within the jacket are many spores and elaters, the latter help in dispersal of spores.

Exercise 6

***Object* : Study of a spore and an elater.**

Work procedure

Break the sporophyte open to release spores and elaters. Stain in safranin and mount in glycerine.

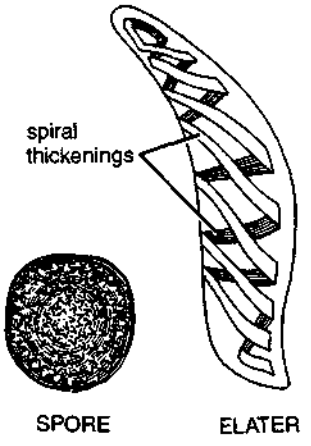


Fig. 8. ***Porella.*** A spore and elater.

Comments

1. A spore measures from 40 to 55 microns in diameter.
2. Each spore has an outer, smooth or papillose exospore and an inner, smooth endospore. Sometimes a third layer may also be present. It is known as outer exospore or perinuium.
3. Inside the wall layers, is a single nucleus embedded in rich cytoplasm.
4. An elater is a longitudinally stretched and coiled structure with 2-3 spiral thickening bands.

Identification

Division—**Bryophyta**. (1) True roots absent and instead are present the rhizoids, (2) No true vascular strand.

Class—**Hepaticopsida**. (1) Rhizoids without septa, (2) Chloroplasts without pyrenoids, (3) Columella absent from capsule and there are no stomata on capsule wall.

Order—**Jungermanniales**. (1) Scales absent, (2) Rhizoids smooth walled, (3) Antheridia and archegonia are borne at the apices, (4) Archegonial neck consists of 5 vertical rows of cells.

Sub-order—**Jungermannineae**. (Jungermanniales Acrogynae) (1) Gametophyte with stem and two rows of dorsal, and a third ventral row of leaves, (2) Archegonia in a terminal cluster and the last archegonium is formed by the apical cell.

Family—**Porellaceae**. (1) Rhizoids are scarce and form tufts at the bases of amphigastria, (2) Leaves incubously arranged, (3) Locule (postical lobe) is distinct, (4) Perianth large, inflated with compressed mouth and is bilabiate.

Genus—***Porella***. Characters same as those of Porellaceae.

Hints for Collection

Out of the 34 species so far recorded from India, only a few are found in South India, others have

been collected from the Himalayas. The genus usually grows on shaded, moist rocks, stones or on the bark of trees particularly at the base and rarely on the soil.

Frullania

Classification

Division	—	**Bryophyta**
Class	—	**Hepaticopsida**
Order	—	**Jungermanniales**
Sub-order	—	**Jungermannineae**
Family	—	**Frullaniaceae**
Genus	—	***Frullania***

Exercise 1

***Object* : Study of external morphology.**

Work procedure

Study the external features of the gametophyte, observe the arrangement and structure of leaves.

Comments

1. The plants are large or medium sized but rarely small. These are reddish-brown or nearly black in colour.
2. The plant body is a gametophyte. It is differentiated into a branched, prostrate, central, stem-like axis and the leaves.
3. The thallus is attached to the substratum by unicellular, smooth walled rhizoids which arise in tufts from the bases or middle of the amphigastria.
4. The prostrate stem is pinnately or bipinnately branched.
5. The leaves on the stem are arranged in three rows—two rows of lateral leaves and a row of underleaves or amphigastria. Each lateral leaf is bipartite forming a large expanded antical lobe and a small postical lobe.
6. The antical lobe is obliquely ovate or sub-orbicular and almost always entire.
7. The postical lobe, also called lobule is cucullate, galeate or saccate. It may either form a water sac or may remain open.
8. The postical lobe usually bears a short subulate process, the stylus near its attachment between the postical lobe and the stem.
9. Underleaves or amphigastria are usually smaller. These are rounded, notched or deeply lobed.

Exercise 2

***Object* : Study of anatomy of the stem.**

Work procedure

Cut a T.s. of the axis, stain in safranin, mount in glycerine and study.

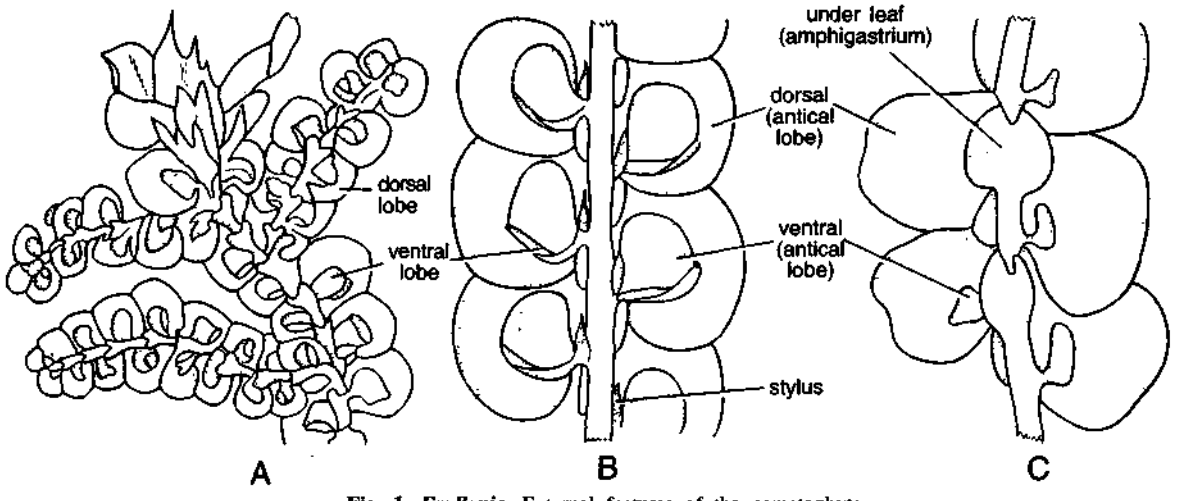


Fig. 1. ***Frullania.*** External features of the gametophyte.

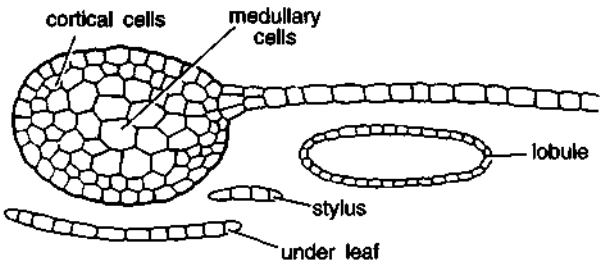


Fig. 2. ***Frullania.*** Anatomy of the stem.

Comments

1. T.s. of the stem is almost circular in outline.
2. Well defined epidermis is absent.
3. The section shows cortical and medullary regions.
4. The cortex is 2 to 3 cells deep. It consists of small cells with distinct thickened pigmented walls.
5. The central part is called medullary region. It is made of large and elongated cells with thin colourless walls.

Exercise 3

Object **: Study of the antheridial branches and antheridia.**

Work procedure

Antheridia are found on short lateral branches. These could be seen by carefully removing the leaves, staining of antheridia with safranin and then by mounting in glycerine.

Comments

1. The species of this genus are dioecious as well as monoecious.
2. Monoecious species are autoicous i.e. antheridia and archegonia are borne by different branches.
3. The antheridia occur in the axils of bracts (perigonial bracts) borne on short laterals.
4. The perigonial bracts are densely imbricate and are divided into two almost equal lobes, large in size.
5. There are usually two antheridia in the axil of each bract.

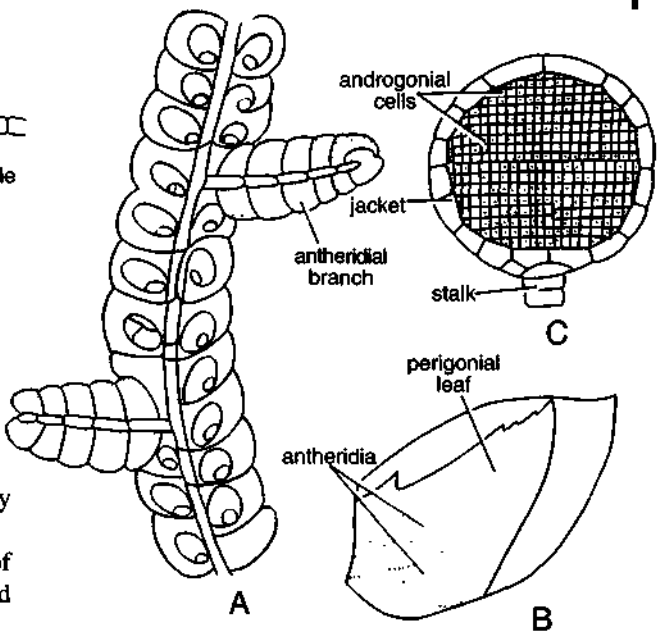


Fig. 3. ***Frullania.*** **A.** Antheridial branch, **B.** Perigonial leaf from ventral surface showing two antheridia. **C.** Single antheridium.

6. A mature antheridium consists of a stalk and a body.
7. The stalk is slender and multicellular being composed of two rows of cells.
8. The body of the antheridium is globose. It consists of a central mass of androcyte mother cells and one-celled wall or jacket.
9. Androcyte mother cell divides, each forming two biflagellate antherozoids.

Exercise 4

Object **: Study of the archegonial branch and archegonium.**

Work procedure

Tease out the apices of short lateral branches of the female plant or female branch. Locate the groups of archegonia, stain with safranin, mount in glycerine and study.

Comments

1. The archegonia occur in groups at the apices of short lateral branches.
2. Each group has two to four archegonia.

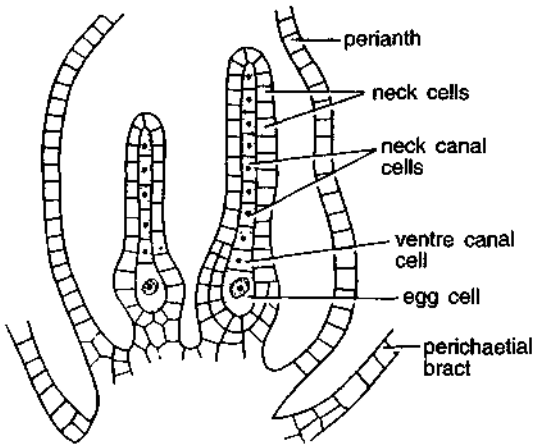


Fig. 4. ***Frullania.*** L.s. of archegonial branch showing two nearly mature archegonia.

3. A group of archegonia is surrounded by 2 to 5 pairs of perichaetial bracts which are dentate or lobed and larger than foliage leaves.
4. The inner pairs of bracts are connate with each other.
5. The uppermost bracts are laterally fused to form perianth.
6. The perianth is inversely heart shaped and much contracted to form a small, tubular mouth.
7. A mature archegonium is a flask shaped structure consisting of a basal ventre and the upper neck.
8. The venter has two layered wall that surrounds a small egg cell and a venter canal cell situated just above it.
9. The neck consists of five vertical rows of neck cells which surround an axial row of eight neck canal cells.

Exercise 5

***Object* : Study of the sporophyte.**

Work procedure

Study the sporophyte externally. Also study the L.s. of the sporophyte.

Comments

1. A mature sporophyte consists of foot, seta and capsule.
2. The foot remains embedded in the tissue of the female branch.
3. The seta is very short and only 8-9 cells thick. It is not very distinct from the capsule because of the mass of thin walled tissue at the base of the capsule (resembling apophysis of moss sporogonium).
4. The capsule wall is made of two layers of cells.

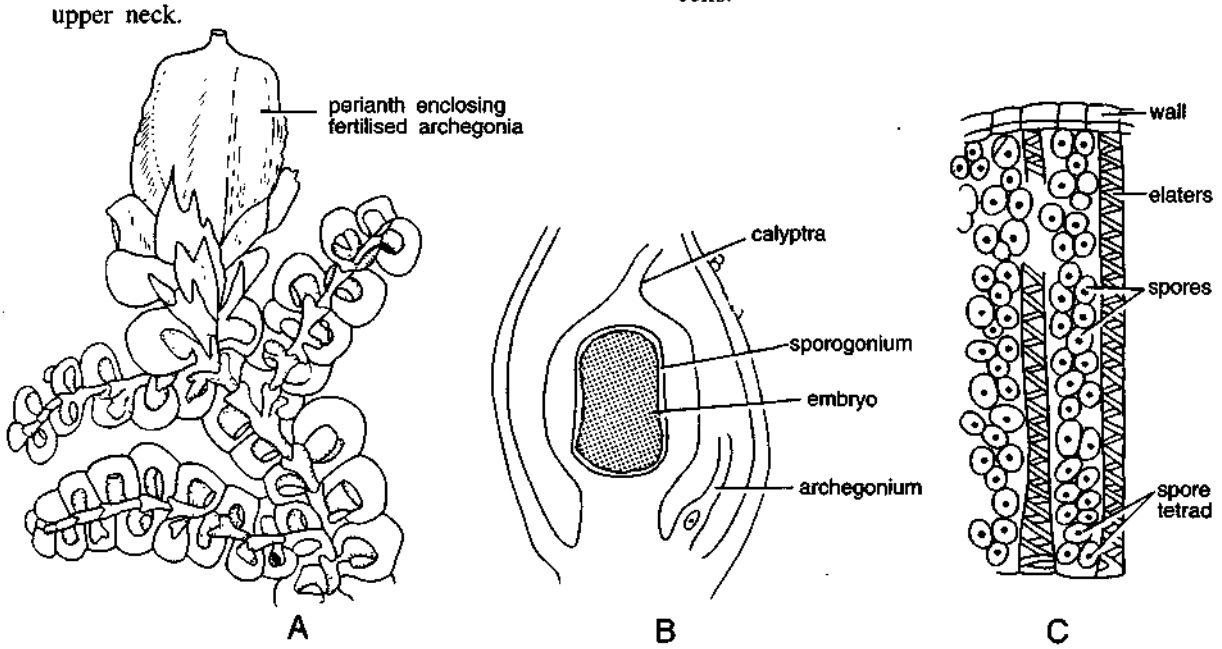


Fig. 5. ***Frullania.*** The sporophyte. **A.** External features, **B.** L.s. of young sporophyte, C. L.s. of nearly mature capsule.

5. The cells of the outer layer have thick rod-like fibres on their lateral walls especially at the corners.
6. The cells of the inner layers have walls with irregular network of thickening fibres.
7. Inside the wall there are about 80 elaters and large number of spores.
8. The elaters run from the roof to the floor of the capsule. These alternate with vertical rows of spores. Each elater is flattened. It has a single broad spiral band of thickening. The lower end of the elater is trumpet shaped.
9. The spores are large, oblong to roundish. The wall is two layered, the exospore and the endospore. The exospore is rough, tuberculate and verrucose. The cytoplasm has a nucleus and a chloroplast.

Identification

Division—**Bryophyta**. (1) The roots absent, but rhizoids present, (2) True vascular strand lacking.

Class—**Hepaticopsida**. (1) Rhizoids without septa, (2) Chloroplasts without pyrenoids, (3) Columella absent from capsule and there are no stomata on capsule wall.

Order—**Jungermanniales**. (Jungermanniales Acrogynae). (1) Gametophyte with stem and two rows of dorsal and a third ventral row of leaves, (2) Archegonia in terminal cluster and the last archegonium is formed by the apical cell.

Family—**Frullaniaceae**. (1) Stems usually pinnately branched, (2) Rhizoids form a tuft at the base or middle of the under leaf, (3) Lateral leaves complicate-bilobed, (4) Perianth compressed and obtrusely triangular in cross section.

Genus—***Frullania***. (1) Branch develops from the ventral half of a lateral segment replacing lobule of the leaf, (2) Presence of stylus.

Hints for Collection

Frullania is represented by about 700 species, of which about 39 are reported from India. The species can be collected from wet shady rocks or trunks of tree. It usually forms flat patches or extensive mats on the rocks or on tree trunks.

Anthoceros (Horn Wort)

Classification

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

Exercise 1

***Object* : Study of external features.**

Work procedure

Study the external features of the gametophyte from dorsal and ventral sides. Note the absence of scales and presence of only smooth walled rhizoids.

Comments

1. Plant body is thalloid, somewhat lobed or radially dissected and generally suborbicular.
2. The thallus is less often dichotomously branched and lack a definite midrib.

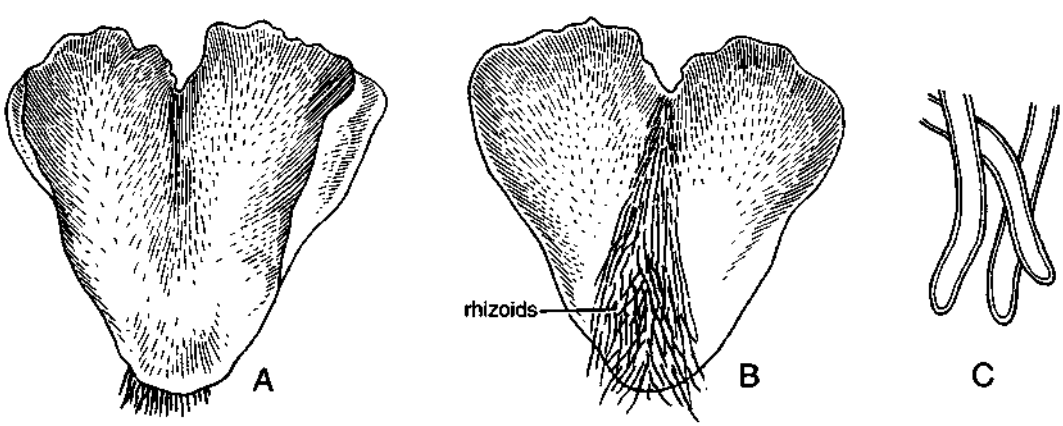


Fig. 1. ***Anthoceros***. External features of gametophyte. **A.** Dorsal surface. **B.** Ventral surface. **C.** Rhizoids.

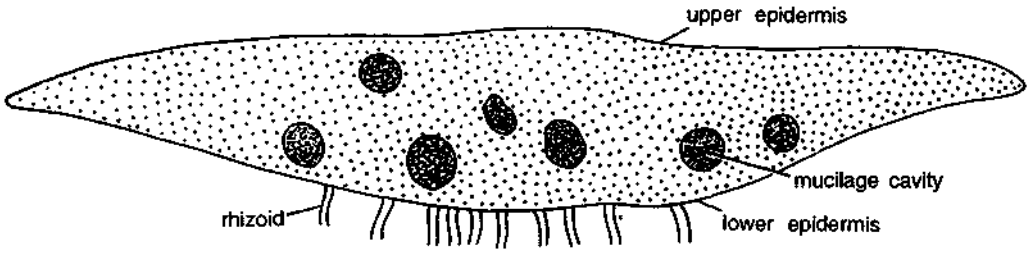


Fig. 2. ***Anthoceros.*** V.t.s. thallus (diagrammatic).

3. The dorsal surface of the thallus is generally smooth, velvety or rough.
4. The ventral surface bears smooth walled rhizoids only.
5. On the ventral side, a few bluish spots are seen indicating the presence of filaments of blue-green-alga (viz. *Nostoc* or *Anabaena*).
6. Sex organs are situated on the dorsal side and are embedded in the tissue of the thallus.
7. The sporophyte, however, is linear and elongated structure, arising from the dorsal side.

Exercise 2

***Object* : Study of anatomy of thallus.**

Work procedure

Place the thallus in pith. Cut V.t.s. and stain in fast green. Mount in the glycerine and study.

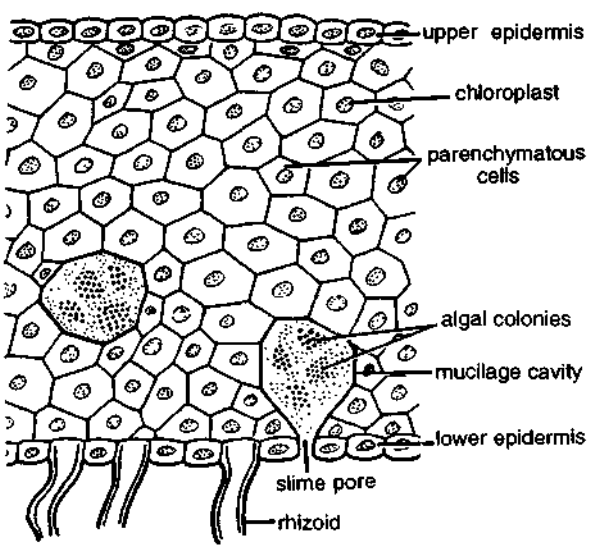


Fig. 3. ***Anthoceros.*** A part of V.t.s. of thallus (cellular).

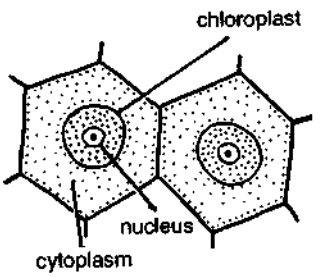


Fig. 4. ***Anthoceros.*** Cells of thallus with chloroplast.

Comments

1. Thallus is few cells in thickness in the middle and becomes thinner towards the margins.
2. Internal structure is homogeneous (i.e. all cells are alike). Air pores and air chambers are absent.
3. On upper side is present upper epidermis and lower epidermis on the lower side.
4. Parenchymatous tissue lies between these two layers.
5. Each parenchymatous cell has a distinct nucleus and a chloroplast.
6. Each of the cells has a large chloroplast with a single pyrenoid except the cells of lower epidermis producing rhizoids. There are two chloroplasts in the cells of *A. pearsonii* and four in *A. hallii.*
7. On the ventral side there are certain mucilage-filled cavities which open by slime pores, through the ventral epidermis.
8. The endophytic algae *Nostoc* or *Anabaena* present in he mucilage cavities, enter through these slime pores.
9. Rhizoids are smooth-walled and arise in the middle region of the thallus from the lower epidermis.

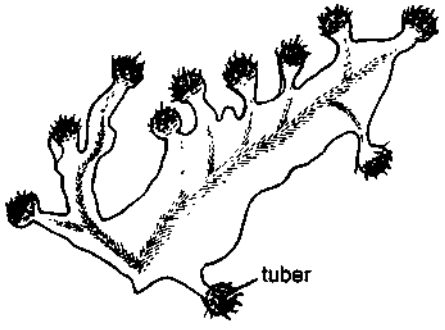


Fig. 5. ***Anthoceros.*** Thallus showing tubers.

Exercise 3

***Object* : Study of tuber.**

Work procedure

Study a thallus with tubers. It can be stained with safranin and mounted in glycerine.

Comments

1. The tubers are the vegetative reproductive structures.
2. Tubers are formed under unfavourable conditions, on the dorsal side along the margins of the thallus.
3. A tuber in section shows outer 2-3 corky layers, protecting the inner tissue, containing the reserve food material.
4. On return of the favourable conditions, tubers develop into new thalli.

Exercise 4

***Object* : Study of antheridium.**

Work procedure

Cut L.s. of thallus, select a section showing antheridia, stain in fast green, mount in glycerine and study the antheridia.

Comments

1. Both antheridia and archegonia remain embedded in the dorsal region of the thallus and are acropetally arranged.

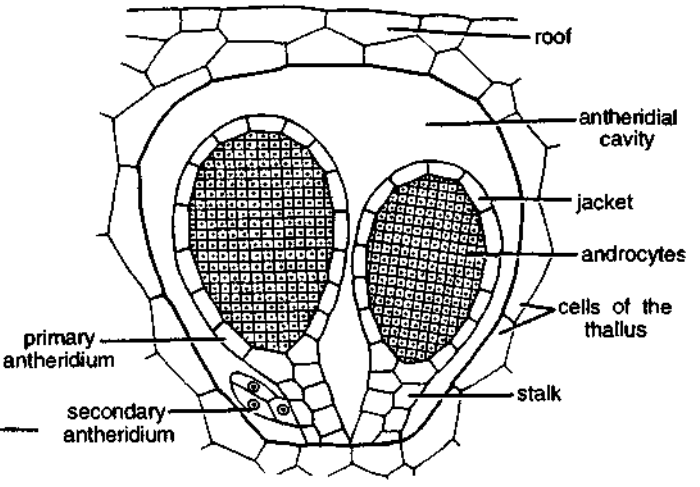


Fig. 6. ***Anthoceros.*** Antheridial cavity with primary and secondary antheridia.

2. Few species are monoecious (homothallic), but some are dioecious (heterothallic).
3. Monoecious species are frequently protandrous (antheridia maturing first).
4. The antheridia are present in the antheridial cavity or antheridial chamber with a sterile roof of 2-3 layers.
5. Each antheridial cavity contains about 1-4 or more primary antheridia. Secondary antheridia arise from the stalks of primary antheridia and ultimately there may be as many as 25 in each antheridial cavity.
6. The mature antheridium is a stalked, club-shaped structure with single layered jacket. Each cell possesses a prominent plastid.
7. Inside the jacket, there are large number of androcytes.

Exercise 5

***Object* : Study of archegonium.**

Work procedure

Cut L.s. of thallus, select a section that shows archegonia, stain in fast green, mount in glycerine and study archegonia.

Comments

1. The thalli are generally monoecious and protandrous (antheridia maturing first).

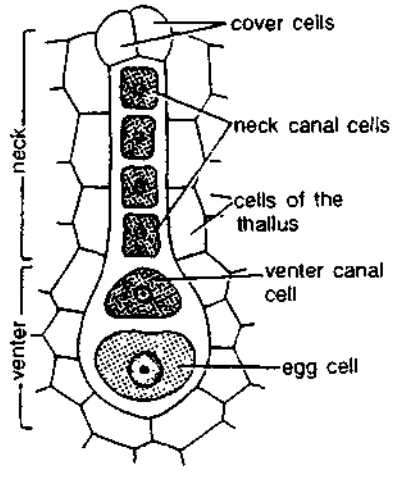


Fig. 7. ***Anthoceros.*** An archegonium.

2. The archegonia are embedded in the thallus and only the cover cells project beyond the general surface of the thallus.
3. They are in direct contact with the vegetative cells, lateral to them.
4. Archegonium consists of a neck and a swollen venter.
5. The nearly mature archegonium has 4 cover cells, 4-6 neck canal cells, one venter canal cell and one egg cell.

Exercise 6

***Object* : Study of sporophyte.**

Work procedure

Study the external features of the sporophyte. Cut a L.s., stain in safranin and fast green, mount in glycerine and study the internal structure.

Comments

1. The sporophytes are linear, 2-3 cms long, elongated structure, arising from the dorsal side of the thallus.
2. The base of each sporophyte is enclosed by an involucre, made of gametophytic tissue.
   (The internal structure of the sporophyte can be understood by studying the transverse and longitudinal sections).

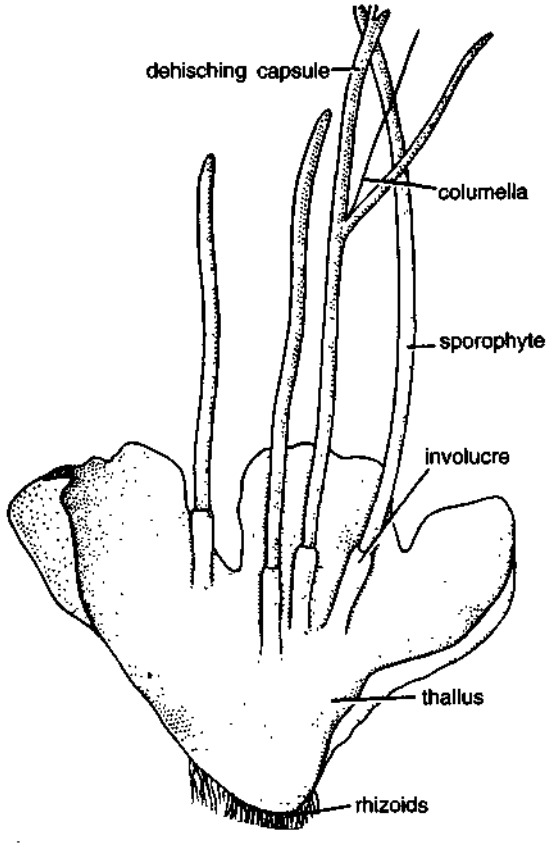
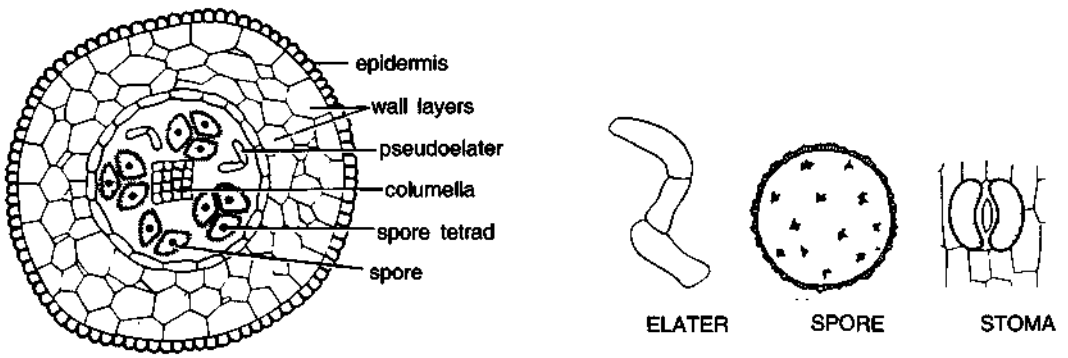


Fig. 8. ***Anthoceros.*** Gametophytic thallus bearing sporophytes.

L.s. of the sporophyte shows following characters:

3. The mature sporophyte is made of a lower foot, middle meristematic zone and upper capsule.
4. The foot is bulbous and is deeply rooted in the gametophytic tissue.
5. The seta is absent and instead is present the meristematic zone.
6. In the centre is columella, composed of 16 vertical rows of cells, extending from the base to the tip of the capsule.
7. Surrounding the columella is a cylinder of sporogenous tissue which extends from the base to the tip of the capsule where it over-arches the central columella. It reveals sporogenous series, from one layered archesporium at the base, to mature spores and pseudo-elaters at the tip.



T.S. CAPSULE **Fig. 9.** ***Anthoceros.*** T.s. capsule, elater, spore and stoma on the capsule wall.

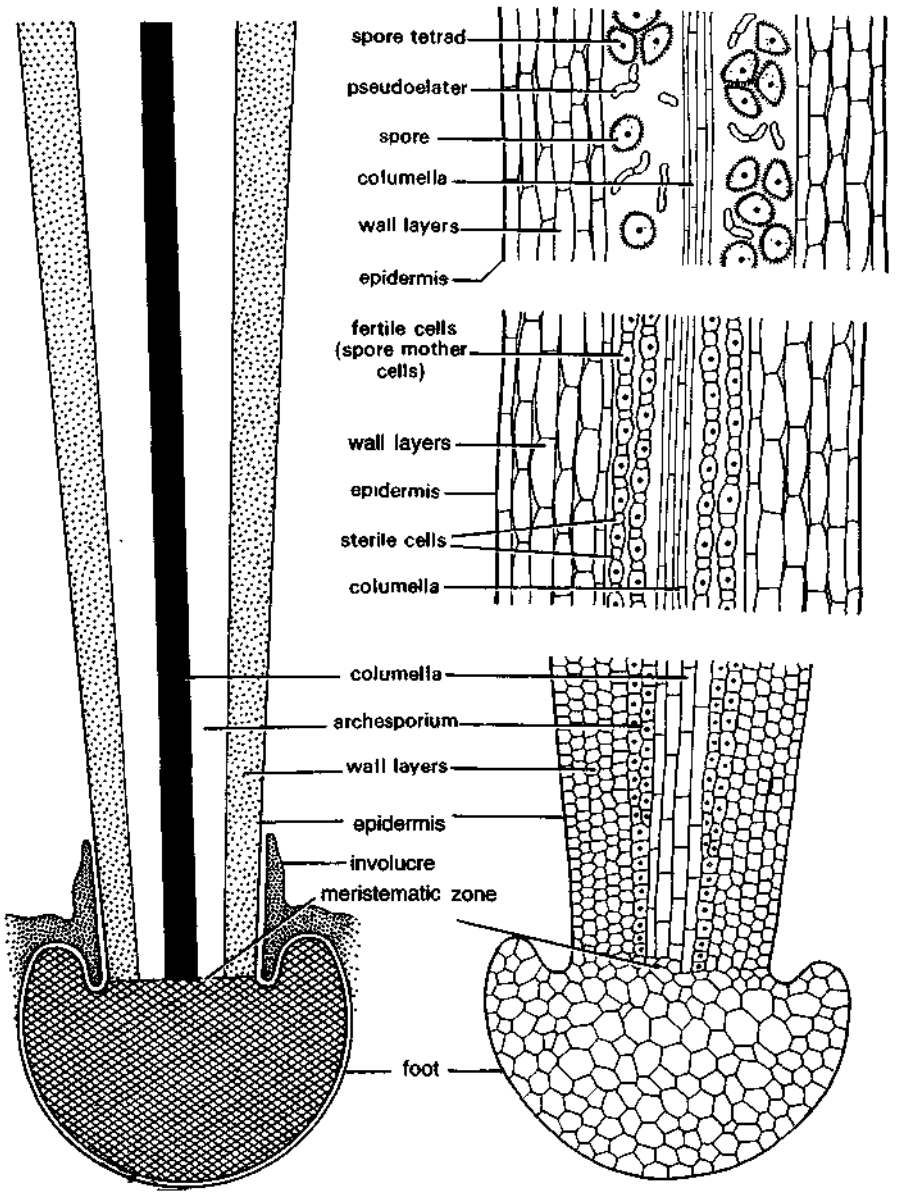


Fig. 10. ***Anthoceros.*** L.s. through sporophyte (diagrammatic and parts cellular).

8. At the base of the capsule is a single to double layered archesporium, while little higher up, archesporium is differentiated into alternately placed fertile cells (spore mother cells) and sterile cells (which form pseudo-elaters). A part of sporogenous tissue, upper to this region shows tetrahedral tetrads of spores and many pseudo-elaters. In the upper most region of the capsule are present the separated spores and pseudo-elaters.
9. The wall of the capsule is 4-6 layered.
10. The outermost layer forms a well defined epidermis, ventilated with stomata.
11. The cells of the layers beneath the epidermis possess generally two chloroplasts each and these chloroplasts make the sporophyte partially self-sufficient with regard to food.
12. Each spore is uninucleate and has a thick ornamented exospore and a thin endospore.
13. Pseudo-elaters consist of 2-3 cells, joined end to end, in a simple or branched structure. (These do not possess characteristic spiral thickenings of true elaters and, therefore, are called pseudo-elaters).

Identification

Division—**Bryophyta**. (1) True roots absent and instead are present the rhizoids, (2) No vascular strand.

Class—**Anthocerotopsida**. (1) Thalloid, (2) Rhizoids without septa, (3) Each cell of the thallus has generally a single large chloroplast, with pyrenoid.

Order—**Anthocerotales**. (1) thallus homogeneous, (2) Only smooth walled rhizoids present, scales and tuberculated rhizoids absent.

Family—**Anthocerotaceae**. (1) Sporophyte indeterminate in growth, (2) Presence of meristematic zone, (3) Capsule with central columella.

Genus—***Anthoceros***. (1) Capsule partly covered with involucre, only at the base, (2) Capsule wall ventilated, (3) *Nostoc* colonies inside the thallus.

Hints for Collection

Anthoceros is common in both hills and plains. Plants grow, as a rule, in moist, shady places on the sides of ditches or in moist hollows among rocks.

Sphagnum (Peat Moss or Bog Moss)

Classification

Division	—	**Bryophyta**
Class	—	**Bryopsida**
Sub-class	—	**Sphagnidae**
Order	—	**Sphagnales**
Family	—	**Sphagnaceae**
Genus	—	***Sphagnum***

Exercise 1

***Object* : Study of external features of thallus.**

Work procedure

Study the branching, the branches and arrangement of leaves on the axis.

Comments

1. The plants are aquatic, growing about the margins of small lakes and ponds or growing on dripping rocky banks.
2. The pH of water in which *Sphagnum* grows ranges from 3.7 to 4.9. Since this water accumulates year after year to form peat and hence the name peat moss.
3. The size of the plant varies from a few inches to a maximum of 7 inches.
4. The plant is erect, branched and differentiated into stem and the leaves. The colourless rhizoids are formed at the base but soon disappear. Hence, there are no rhizoids on mature gametophores.
5. At the apex of the gametophore there are a number of short branches densely crowded in a cluster, called coma.
6. In the posterior part of the stem, the branches arise in tufts in the axil of every fourth leaf and in each tuft there are 3-8 branches.
7. These branches are of two types—(i) diverging branches which are stout, short, growing

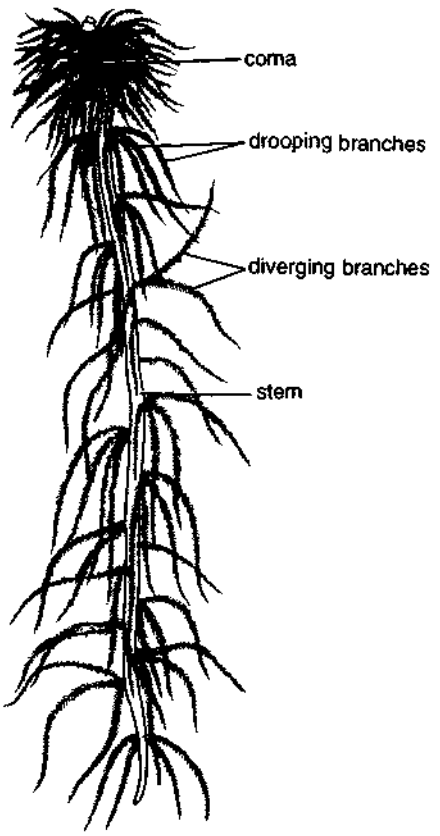


Fig. 1. ***Sphagnum.*** A part of gametophore.

outward and upward and (ii) drooping or flagelliform branches which hang downward, around and close to main stem. These are absent from submerged forms.

8. At intervals, one of the branches in the tuft grows and forms an apical cluster of branches like the main stem. This is called an innovation. It helps in vegetative propagation by separating from the main branch.
9. When first formed, the leaves are in three vertical rows or three ranked. Later the arrangement changes to 2/5.
10. The leaves lack a midrib an exception to mosses.

Exercise 2

***Object* : Study of anatomy of axis.**

Work procedure

Cut a T.s. of the axis, stain in safranin and fast green, mount in glycerine and study.

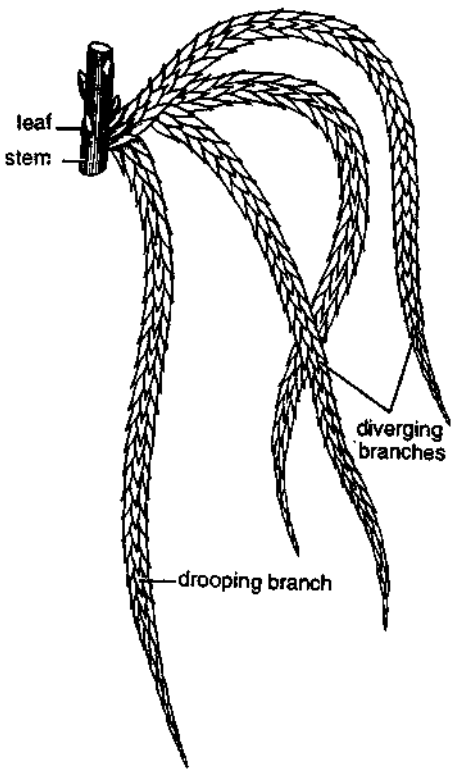


Fig. 2. ***Sphagnum.*** Portion of a plant showing tuft of branches.

Comments

1. The outermost layer is cortex, made of compactly arranged cells.
2. In some species, as *S. subsecundum*, it remains one cell thick throughout its life but in some others, it becomes 3-5 cells thick.
3. At maturity these cortical cells lack protoplast, become hyaline and dead.
4. In some species viz. *S. cymbifolium*, they develop spiral thickenings and develop even the pores. These cortical cells contain air and water.
5. In some species as *S. molluscum* and *S. tenellum*, some of the cortical cells become greatly enlarged and become flask shaped. The cells also accumulate water and are known as retort cells. Such type of cortex is also known as hyalodermis.
6. The cells inner to cortex are prosenchymatous. These give mechanical support to the stem. The region is also known as hadrome.
7. The innermost region is known as medulla. The cells are colourless, parenchymatous and somewhat vertically elongated.

Exercise 3

***Object* : Study of leaf : external features.**

Work procedure

Take out a few leaves, stain in safranin, mount in glycerine and study.

Comments

1. The mature leaf is sessile, entire, acute and one-celled thick.
2. The leaf lacks a midrib and the surface view shows two kinds of cells (i) the narrow, chlorophyll containing assimilatory cells, and (ii) the large, dead, rhomboidal hyaline cells with spiral thickenings and pores.
3. The spiral thickenings provide mechanical support and keep the hyaline cells from collapsing when they are empty.
4. The pores help in rapid intake of water.
5. The green assimilatory cells of the leaf are joined together and form a network with sinuous walls.
6. At the base of very young leaf there are one or more glandular hairs but these disappear as the leaf matures.

Exercise 4

***Object* : Study of leaf anatomy.**

Work procedure

Cut a T.s. of the leaf stain in safranin, mount in glycerine and study.

Comments

1. In a cross section, the leaf appears like a beaded structure with hyaline and chlorophyllous cells alternating with each other.
2. The chlorophyllous cells are triangular and the base of triangle is towards the upper side e.g. *S. acutifolium*. In *S. tenellum* the condition is just reverse i.e. the base of the triangle is towards the lowerside. In *S. squarrosum* the chlorophyllous cells are not triangular but appear spindle-shaped and are hemmed in, above and below, by the hyaline cells.

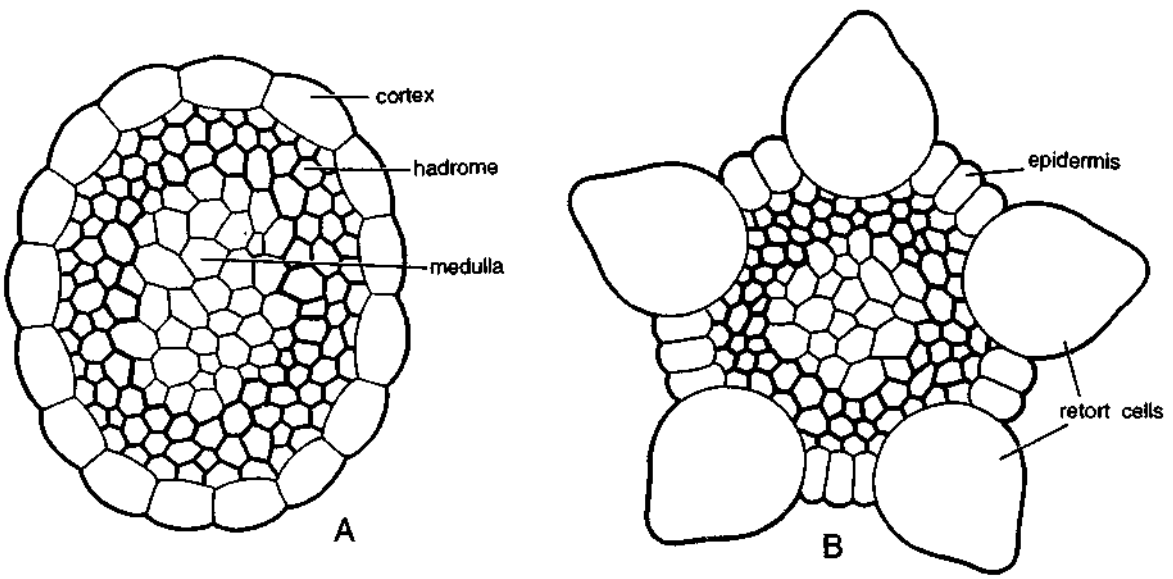


Fig. 3. *Sphagnum*. A. T.s. stem in most species. **B.** T.s. of stem of *S. molluscum*.

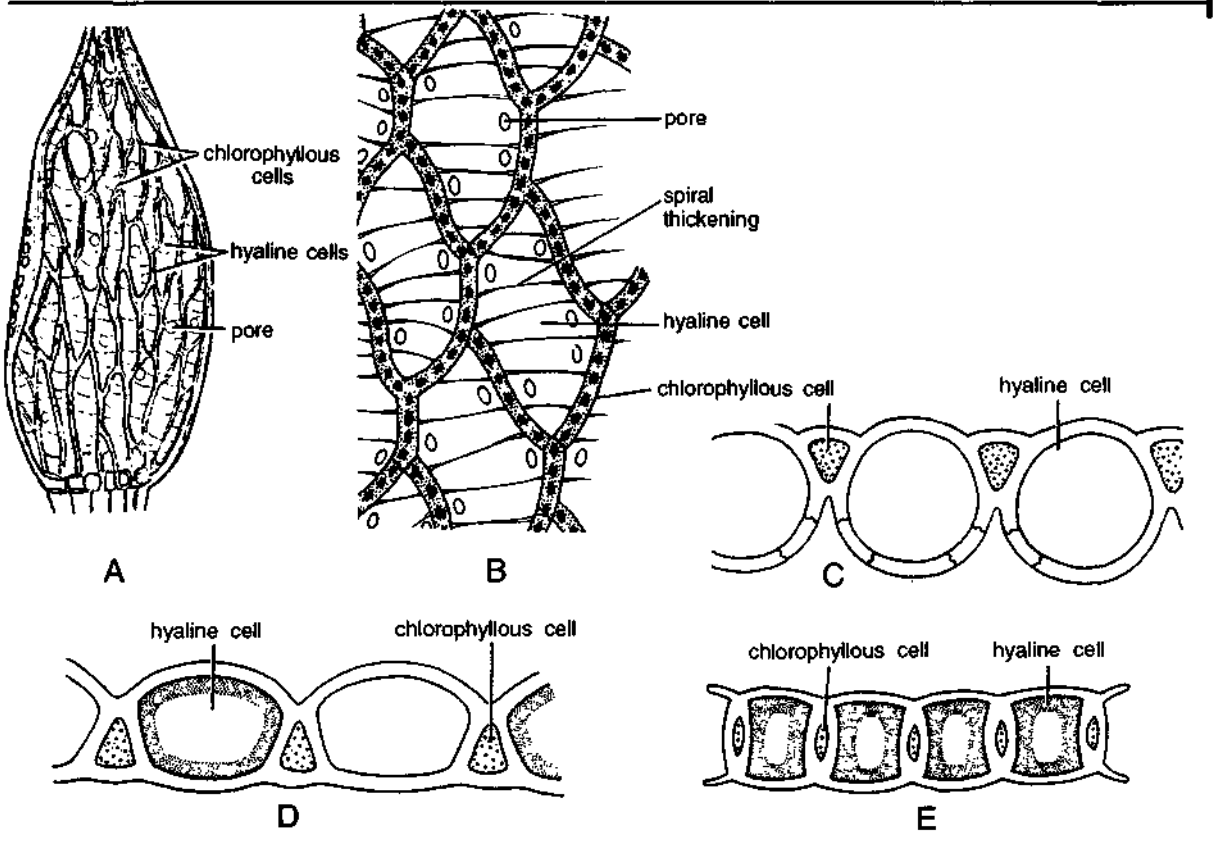


Fig. 4. ***Sphagnum.*** **A.** Leaf in surface view. **B.** A part of leaf surface magnified. **C,D,E.** Portions of transverse sections of leaves of **C.** *S. acutifolium*, **D.** *S. tenellum*, **E.** *S. squarrosum*.

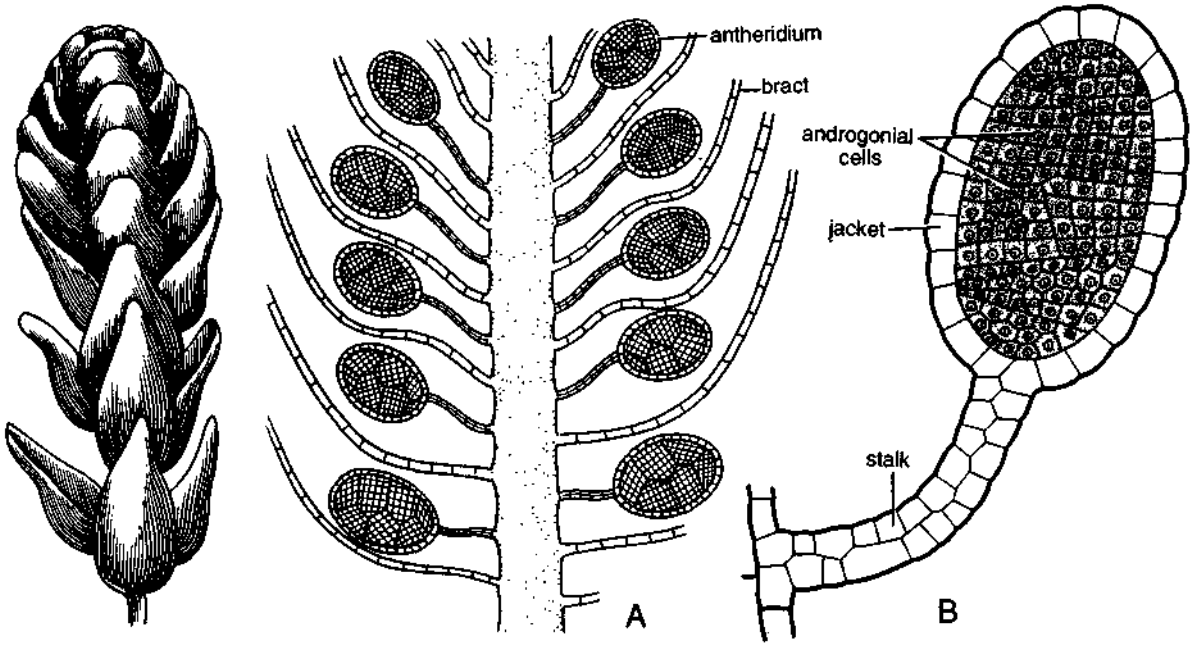


Fig. 5. ***Sphagnum.*** External features of antheridial branch.

Fig. 6. ***Sphagnum.*** **A.** Portion of antheridial branch to show position of antheridia. **B.** Single antheridium.

Exercise 5

***Object* : Study of antheridial branch and antheridium.**

Work procedure

Select antheridial branch by its catkin-like appearance at the tip of the branch. Tease out antheridia or else cut a longitudinal section, stain in safranin and mount in glycerine to study.

Comments

1. The plants are either monoecious or dioecious and both antheridial and archegonial branches occur at the apices of the gametophores.
2. The catkin-like antheridial branches are either red, brown or yellow in colour with club-shaped appearance.
3. The antheridia present in the axil of leaf are arranged acropetally.
4. The mature antheridium has a long stalk, 2 cells in breadth and a globular body.
5. The body of the antheridium consists of single-layered jacket surrounding number of androgonial cells.
6. The androgonial cells ultimately form the biciliate antherozoids.

Exercise 6

***Object* : Study of archegonial branch and archegonium.**

Work procedure

Select archegonial head, tease out to observe archegonia or cut a longitudinal section, stain in fast green and mount in glycerine to study.

Comments

1. The archegonial branches are purple coloured. These bear large leaves known as perichaetial leaves.
2. Each archegonial branch has usually 3 archegonia (sometimes 1 or 5 also). Paraphyses are absent.
3. The position of the archegonium is acrogynous i.e. the first archegonium is formed by the apical cell and is known as the primary archegonium, whereas the other two archegonia are developed from the last two segments cut off by the apical cell and are known as secondary archegonia.
4. The structure of both types of archegonia is similar. A mature archegonium is a stalked structure with a broad venter and a long twisted neck.

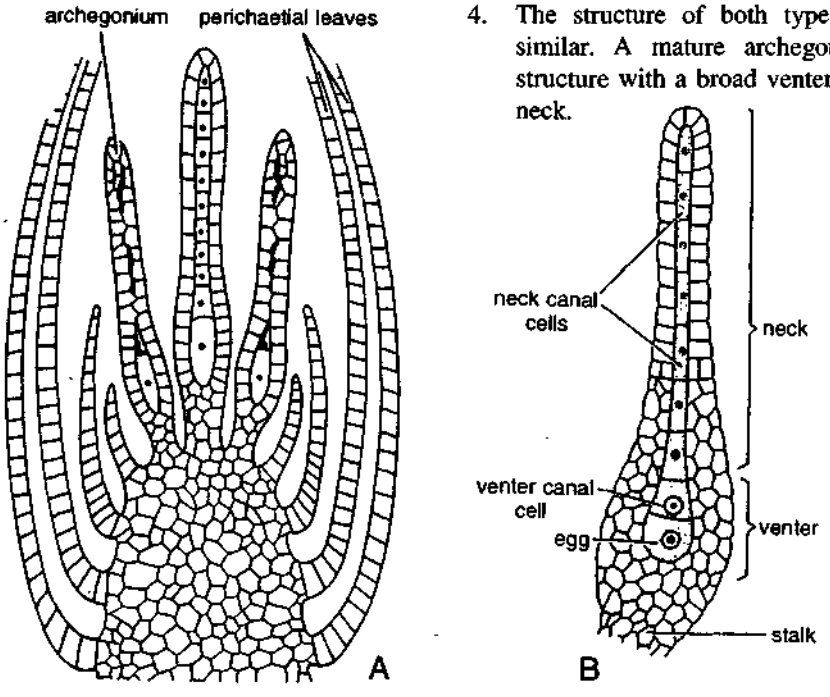


Fig. 7. *Sphagnum*. A. L.s. archegonial branch, **B.** A single archegonium.

5. The venter as well as lower portion of neck are 2-4 cells in thickness.
6. The cover cells are not distinct and in the axial row are found 8-9 neck canal cells, one venter canal cell and one egg cell.

Exercise 7

***Object* : Study of sporophyte.**

Work procedure

Study the external features of the sporophyte. Cut longitudinal section, stain with safranin and fast green, mount in glycerine and study.

Comments

1. It consists of a large bulbous foot and a nearly spherical, black coloured capsule. Seta is absent and occurs as a small constriction between foot and capsule.
2. At maturity the apex of the archegonial branch elongates to form stalk-like portion called pseudopodium.
3. The calyptra covers the upper part of the mature capsule.
4. Longitudinal section of the sporophyte shows following characters.
5. Sporophyte consists of a bulbous foot and a spherical capsule connected by a neck-like suppressed seta.
6. The jacket of the capsule is 4-6 layered. The outermost layer is differentiated into an epidermis with rudimentary, non-functional stomata.
7. All cells of the capsule wall contain chloroplasts, hence the sporophyte is not completely dependent on the gametophyte.
8. At the top of the capsule there is a convex operculum separated from the remainder of the thallus by a thin-walled transverse ring of cells called the annulus.
9. Over the operculum is the calyptra which arises from the venter of the archegonium and completely covers the sporophyte.
10. The central region of the capsule is occupied by the columella. It is overarched by dome-shaped spore sac.

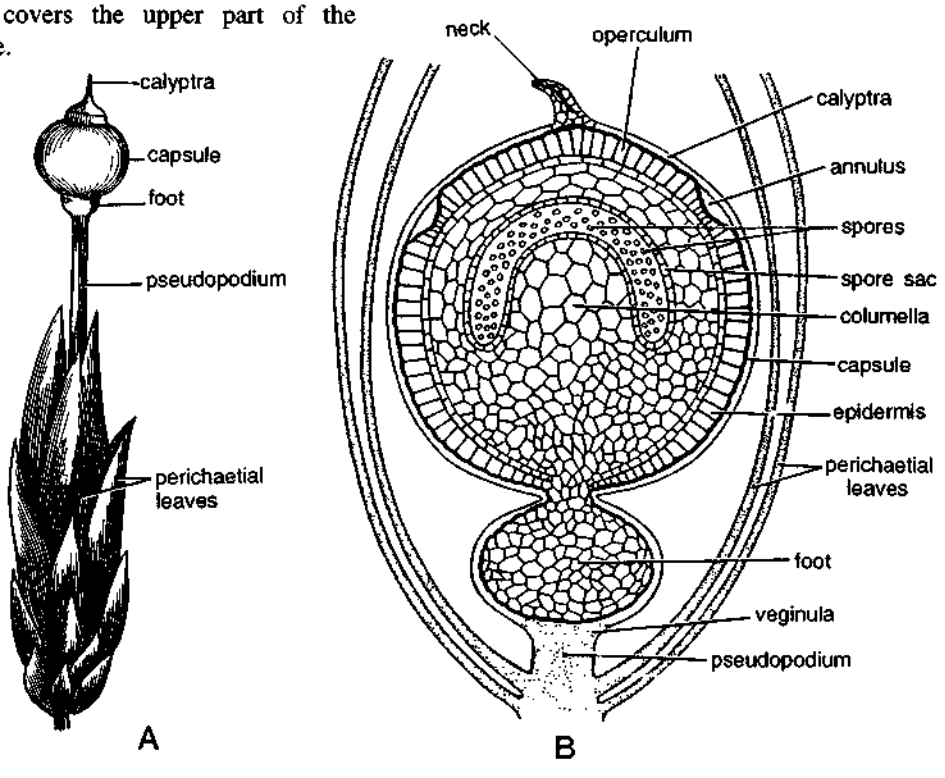


Fig. 8. ***Sphagnum.*** **A.** External features of sporophyte. **B.** L.s. sporophyte.

11. The spore sac is filled only with spores, elaters being altogether absent. Each spore has an outer exine and inner intine.
12. A mature saprophyte is situated at the top of an elongated archegonial branch, the pseudopodium.
13. The apex of the pseudopodium is enlarged which together with the basal portion of calyptra is known as veginula.
14. Veginula is a sac-like structure into which the foot of the sporophyte is embedded.
15. When the spores mature, the operculum breaks away at the place of annulus thus releasing the spores.

Exercise 8

***Object* : Study of protonema.**

Work procedure

Collect the protonema from the soil or allow the spore to germinate into protonema. Stain in fast green and mount in glycerine.

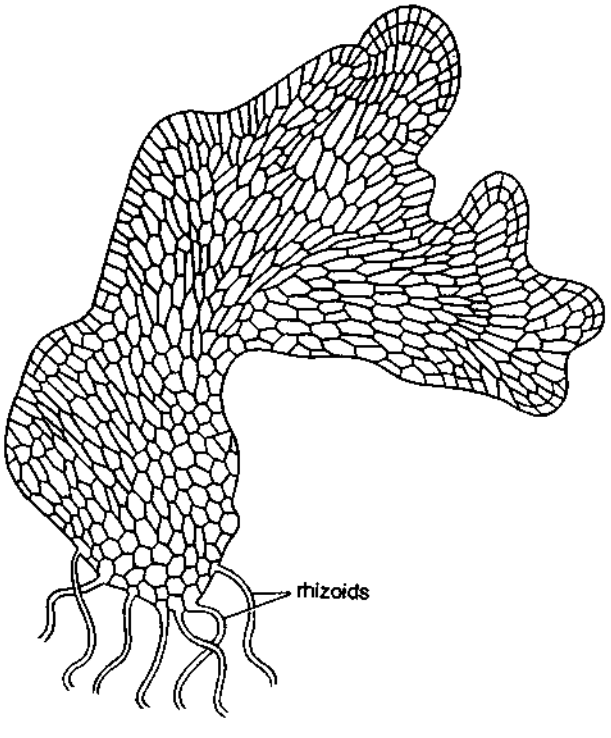


Fig. 9. *Sphagnum.* Thalloid lobed protonema.

Comments

1. The spore germinates to form a thalloid protonema.
2. At the posterior end of the thalloid protonema are borne the rhizoids which are multicellular with oblique septa.
3. Secondary protonema may arise from the primary protonema
4. Later, at the base of the protonema a single bud is differentiated with a 3-sided apical cell. This bud develops into the leafy gametophore. Thus, only one gametophore is developed from one protonema.

Identification

Division—**Bryophyta**. (1) True roots absent and instead are present the rhizoids, (2) No true vascular strand.

Class—**Bryopsida**. (1) Gametophore erect and leafy, (2) Rhizoids multicellular with oblique septa.

Sub-class—**Sphagnidae**. (1) Protonema thallose, (2) Archesporium from amphithecium, (3) Seta is very small but the capsule is elevated by the elongation of the gametophore apex known as pseudopodium, (4) Peristome teeth absent.

Order—**Sphagnales**. Character same as sub-class.

Family—**Sphagnaceae**. Characters same as those of Sphagnidae.

Genus—***Sphagnum***. Characters same as Sphagnidae.

Hints for Collection

All the 11 species of *Sphagnum* found in India are restricted to the Himalayas. The plants are aquatic or semi-aquatic forming dense cushions commonly seen in swamps, ponds and lake margins, moorelands and wet hill sides.

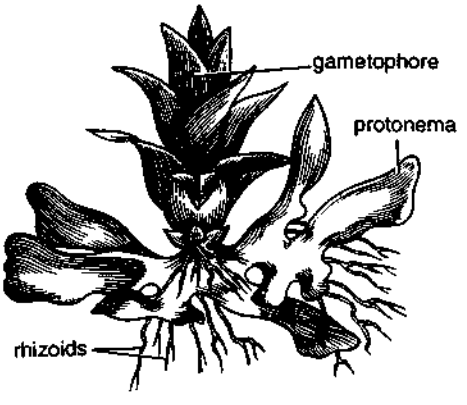


Fig 10. *Sphagnum.* Mature protonema producing a leafy gametophore.

Funaria (Cord Moss)

Classification

Division	—	**Bryophyta**
Class	—	**Bryopsida**
Sub-class	—	**Bryidae**
Order	—	**Funariales**
Family	—	**Funariaceae**
Genus	—	***Funaria***

Exercise I

***Object* : Study of external features of gametophyte.**

Work procedure

Observe the branching, arrangement of leaves, midrib of the leaf, branched and multicellular rhizoids. Pick up a few rhizoids, stain in safranin and observe oblique septa.

Comments

1. The gametophyte shows a prostrate underground protonema and an erect leafy gametophore.
2. The gametophore that arises from protonema is differentiated into (i) rhizoids, (ii) axis or 'stem' and (iii) leaves.
3. Many rhizoids are present at the base. These are slender, branched, and multicellular. The septa are oblique.
4. Young rhizoids are colourless while mature are coloured brown. They also develop chloroplast and become green if exposed to sunlight.
5. The axis is erect and branched. It is 1-3 cms high. The branches arise below a leaf and are thus extra-axillary.
6. The stem and branches are covered with small, simple, sessile and spirally arranged leaves with 3/8 phyllotaxy.
7. The leaves at the apex of the gametophore are crowded to form a bud-like head.
8. Each leaf is nearly ovate in shape and bears a clear midrib except when young.
9. Sex organs are borne at the apices of the axis.

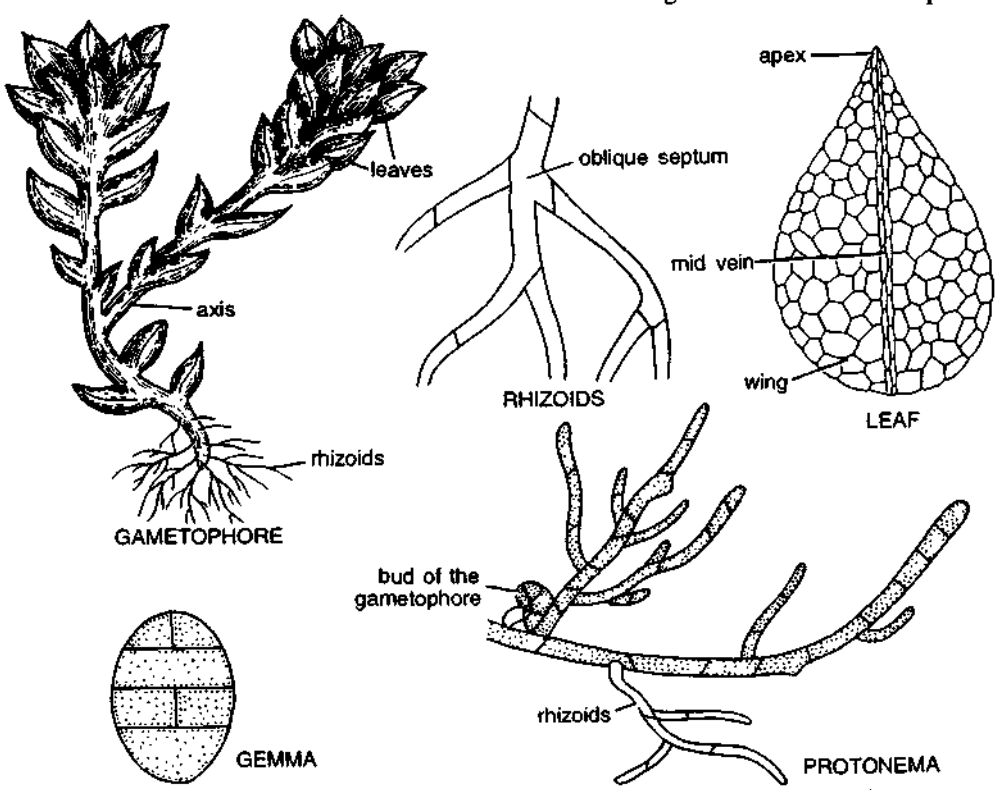


Fig. 1. *Funaria*. External features of the gametophyte : gametophore, rhiozoids, leaf, gemma and protonema.

Exercise 2

***Object* : Study of anatomy of the axis.**

Work procedure

Place gametophore in the pith and cut T.s. with a sharp razor or blade. Stain in safranin or fast green, mount in glycerine and study.

Comments

1. The transverse section shows an almost circular outline.
2. It is differentiated into (i) an epidermis, (ii) cortex and (iii) the central cylinder.
3. The single-layered epidermis, with tangentially elongated cells has chloroplasts and bounds the underlying cortex.
4. The multilayered cortex surrounds central cylinder. Peripheral cells of the mature cortex are slightly thick walled than the rest.
5. Near the periphery of the cortex, small leaf traces with blind ends are present.
6. The outer cells of the cortex sometimes contain the chloroplasts.
7. The central cylinder is present in the centre. The cells are vertically elongated, smaller and the walls are slightly thickened. The cells are dead due to lack of protoplasm. The cylinder takes part in the conduction of water and food materials.

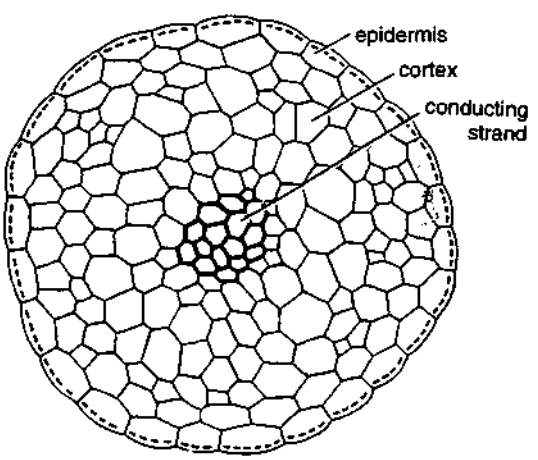


Fig. 2. *Funaria.* T.s. axis (cellular).

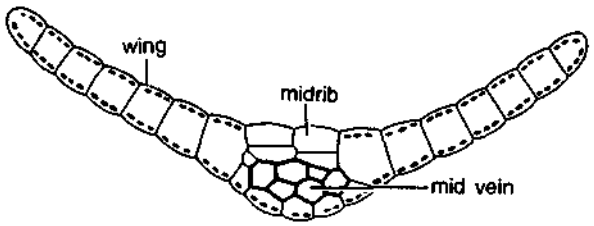


Fig. 3. *Funaria.* T.s. leaf (cellular).

Exercise 3

***Object* : Study of anatomy of leaf.**

Work procedure

Cut a T.s. of leaf, stain in safranin or fast green, mount in glycerine and note down the observations.

Comments

1. The leaf consists of a single layer of cells containing chloroplasts except in the middle where it forms a distinct midrib.
2. The centre of the midrib is occupied by a small strand of narrow and slightly thick-walled cells.

Exercise 4

***Object* : Study of gemmae.**

Work procedure

Shake leaves or brush off basal part of axis on the slide for collecting gemmae. Mount in glycerine and study.

Comments

1. These are vegetative reproductive structures.
2. Multicellular and green gemmae are produced on stem and leaves. On detachment, these germinate to give rise to new plants.
3. Gemmae, when grow on rhizoids, become brown in colour and are then known as bulbils.
4. Each gemma is composed of 8-12 cells. It is transversely and vertically septate.

Exercise 5

***Object* : Study of antheridial branch and antheridium.**

Work procedure

Tease a few tips of branches. Remove the cluster of leaves to bring out antheridia. Stain in safranin, mount in glycerine and study.

Comments

1. The sex organs are present at the apices of branches. These are enclosed by a group of leaves at the apex.
2. At the tip of the stem, is an antheridial branch or 'male flower'—a cluster of antheridia.
3. Intermingled with antheridia are multicellular capitate hairs, known as paraphyses.
4. Both antheridia and paraphyses are surrounded by large leaves, known as perichaetial leaves.
5. In the antheridial branch antheridia in various stages of development occur together.
6. The mature antheridium consists of massive stalk and a club-shaped body.
7. The body has a single layered outer jacket, the cells of which contain chloroplasts.
8. At the apex of the jacket is an operculum, which helps in liberation of antherozoids.
9. A dense central mass of androcytes lies within the jacket.

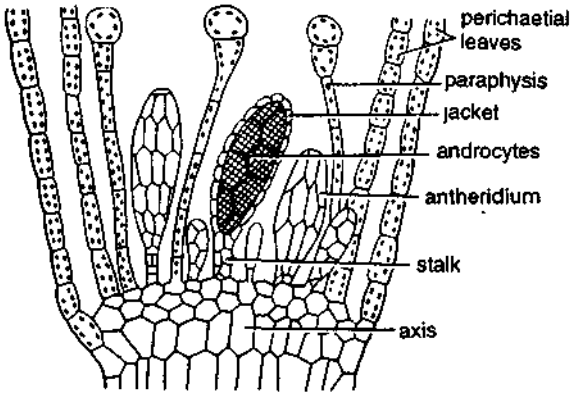


Fig. 4. ***Funaria.*** L.s. apex of the male branch showing antheridia.

Exercise 6

***Object* : Study of archegonial branch and archegonium.**

Work procedure

Tease the apex of the female branch to remove the leaves. Stain in safranin, mount in glycerine and study.

Comments

1. The sex organs are situated at the apices of branches inside the cluster of leaves.
2. The archegonia also arise in clusters at the apex of the archegonial branch.
3. Intermingled with archegonia are paraphyses.
4. The archegonia and paraphyses are surrounded by closely folding, unmodified leaves.
5. All the archegonia of this cluster are almost of the same age and developmental stage.
6. The nearly mature archegonium is a multicellular, stalked structure, with a broad venter and narrow twisted neck.
7. The wall of the venter is double layered. The neck consists of six longitudinal rows of cells surrounding a central canal.
8. In the neck there are six or more neck canal cells and the venter has one venter canal cell and one egg cell.

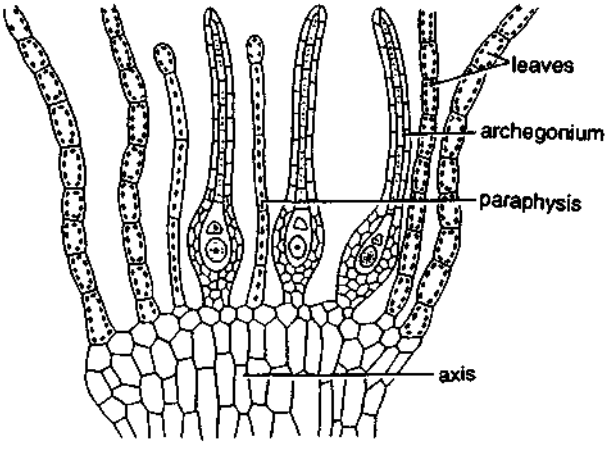


Fig. 5. ***Funaria.*** L.s. apex of the female branch showing archegonia.

Exercise 7

***Object* : Study of external features of sporophyte.**

Work procedure

Select out a plant that has a sporophyte. Place it on the stage of a dissecting microscope and study.

Comments

1. A gametophyte shows a sporophyte attached to it.
2. The sporophyte is developed at the apex of the archegonial branch.
3. A mature sporophyte shows three parts (i) foot, (ii) seta and (iii) capsule.
4. Foot is poorly developed and is embedded in the apex of the archegonial branch.
5. Seta is long, slender and twisted. It bears a capsule at the top.
6. The capsule is slightly oblique and pear-shaped. Calyptra covers the apex of capsule.

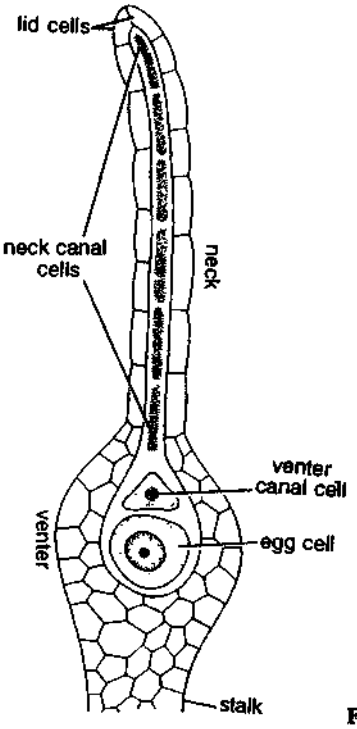


Fig. 6. ***Funaria.*** An archegonium.

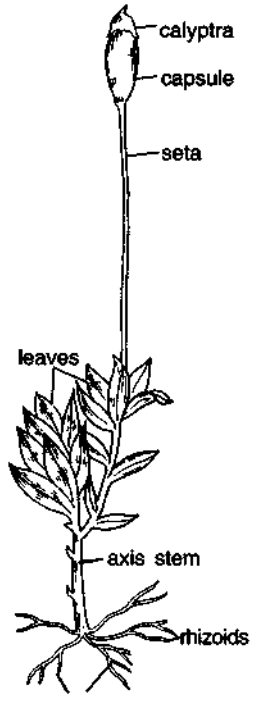


Fig. 7. ***Funaria.*** A gametophyte with sporophyte.

Exercise 8

***Object* : Study of internal structure of sporophyte.**

Work procedure

Cut a T.s. of the capsule and stain in safranin and fast green; mount in glycerine and study.

Comments

1. L.s. of the capsule can be divided into three regions—(i) apophysis, (ii) theca proper and (iii) upper region.
2. Apophysis is the basal region. In its centre is a conducting stand in continuation with that of seta.
3. Around the conducting strand are few layers of cells with intercellular spaces and chloroplast. The epidermis in this region is ventilated (stomata present).
4. The theca proper is the fertile region. It has a central columella, the upper part of which is cone-shaped, projecting into the concavity of the operculum. On the basal end, it is

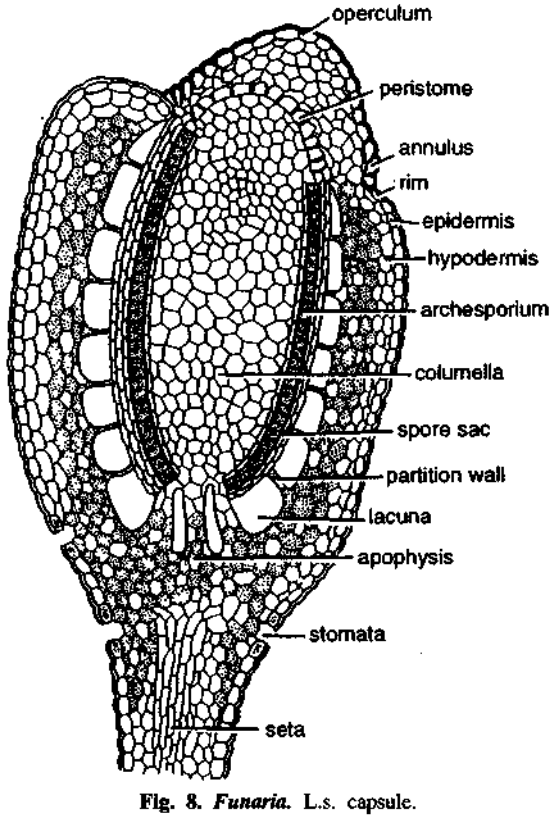


Fig. 8. ***Funaria.*** L.s. capsule.

connected with the central tissue of the apophysis.

5. Around the columella is a U-shaped spore sac, broken at the base, thus separating the two arms of U.
6. Spore sac has an outer wall of 3-4 layers of cells and an inner of one layer. Between these, only spores are present, elaters being absent.
7. Each spore has an inner hyaline endosporium and a coloured, almost smooth exosporium.
8. Inside the endosporium is the cytoplasm, with a nucleus, oil globules and chloroplasts.
9. Outside the spore sac, is an air space that is divided into many air cavities by green filaments which run from the external tissue of the wall to the outer wall of the spore sac.
10. The wall of the capsule is many layered. Two to three inner wall layers of the capsule in theca region are green and show intercellular spaces while outermost 2-3 layers just beneath the epidermis are compact parenchymatous and colourless.
11. The upper region consists of operculum and peristome. It is marked off by a conspicuous constriction, immediately below which is a rim and above the annulus.
12. Calyptra covers the capsule. The peristome teeth encircle the operculum.

Exercise 9

***Object* : Study of peristome.**

Work procedure

Keep a mature capsule on the stage of a dissecting microscope, remove the operculum by needles while viewing through the lens, yellow-black or yellow-brown coloured ring of peristomial teeth would be seen; mount in glycerine and study.

Comments

1. The peristome consists of 2 rows of curved triangular plate-like teeth. Each row has 16 teeth.
2. Outer peristomial teeth are ornamented with thick transverse bands and are spirally twisted to the left.

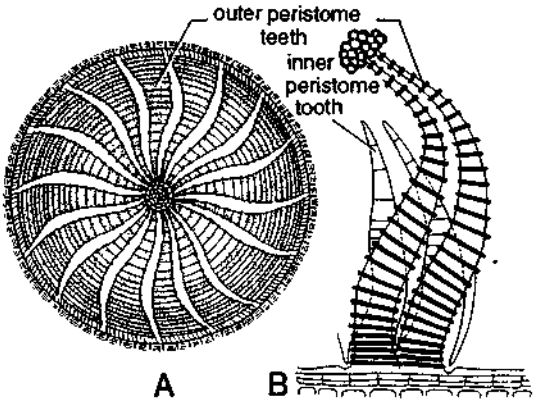


Fig. 9. ***Funaria.*** Outer and inner peristome.

3. Inner peristomial teeth are colourless, shorter and comparatively more delicate.
4. The bases of inner peristome teeth are directly covered by the teeth of the outer peristome, but as they move away from the base, they curve, thus narrowing the slits between outer peristome teeth.
5. Hygroscopic movements in the outer peristome teeth assist in liberation of spores from capsule.

Identification

Division—**Bryophyta.** (1) True roots absent, instead are present the rhizoids, (2) No vascular strand.

Class—**Bryopsida.** (1) Gametophore erect and leafy, (2) Rhizoids multicellular with oblique septa.

Sub-class—**Bryidae.** (1) Leaves with distinct midrib, (2) Seta long, (3) Spore sac usually separated from the capsule wall by air space.

Order—**Funariales.** (1) Leaves ovate or spathulate, (2) Peristome usually double, (3) Calyptra usually distended.

Family—**Funariaceae.** (1) Calyptra has a long beak, (2) Capsule pyriform and somewhat dropping.

Genus—***Funaria.*** (1) Leaves arranged spirally and 3/8 phyllotaxy, (2) Stem internally distinguished into an epidermis, cortex and conducting strand, (3) Leaves crowded at the apex to form a bud-like head.

Hints for Collection

Funaria is very common in hills as well as in plains. It is generally found growing on moist walls and tree trunks, during rainy season.

Polytrichum
(Pigeon Wheat Moss)

Classification

Division	—	**Bryophyta**
Class	—	**Bryopsida**
Sub-class	—	**Bryidae**
Order	—	**Polytrichales**
Family	—	**Polytrichaceae**
Genus	—	***Polytrichum***

Exercise 1

***Object* : Study of external features of gametophyte.**

Work procedure

Take a gametophore, observe the branching, arrangement of leaves and the rhizoids. Pick up a few rhizoids, stain in safranin and observe oblique septa.

Comments

1. The gametophyte is differentiated into an underground rhizome and aerial, erect, leafy stems 20 cms or more tall. In *P. commune*, transitional zone between rhizome and upper leafy shoot is present.
2. Rhizoids are produced by the rhizome. These are long and thick walled with oblique septa. The rhizoids coil round one another to form a rope like structure. These rhizoidal strands provide mechanical support also.
3. The leaves on the rhizome and middle transitional region occur in 3 vertical rows. These are either brown in colour or colurless. The leaves on aerial leafy shoot are green, large and spirally arranged.
4. Each leaf possesses a broad, colourless, membranous, one celled sheathing leaf base that narrows above into a lanceolate limb. The margins of the wings are coarsely toothed. The leaf has a dark green midrib.

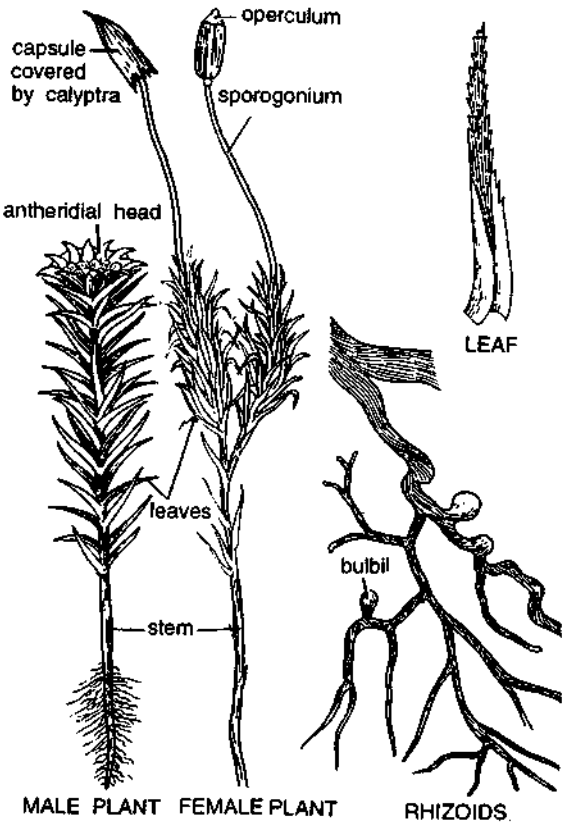


Fig. 1. *Polytrichum*. External features of gametophore : male and female plant, leaf and rhizoids.

Exercise 2

***Object* : Study of anatomy of rhizome.**

Work procedure

Place rhizome in the pith and cut T.s. with a sharp razor or blade. Stain in safranin or fast green, mount in glycerine and study.

Comments

1. The transverse section shows an almost circular outline.
2. It is differentiated into piliferous layer, cortex, endodermis and the central cylinder.

3. A piliferous layer is the outermost. It bears rhizoids.
4. This is followed by two or three layers of cortical parenchyma. It is interrupted by three hypodermal strands, the cells of which are distinctly prosenchymatous with pointed ends.
5. Passing radially inwards from the hypodermal strands are cells of greater diameter, which do not show a clear demarcation with the cells of hypodermal strands. These are called the radial strands.
6. The cortex is delimited from the conducting strand by large, radially elongated endodermal cells. The endodermis is discontinuous and consists of three arcs separated by radial strands.
7. The central cylinder is trilobed. The central mass consists mainly of very thick-walled, elongated living cells (with oblique end walls), known as stereids. The stereids are collectively called as stereom.
8. Scattered among the stereids are the hydroids which serve for the conduction. The hydroids are of about the same diameter as the stereids, or slightly bigger and as a whole being called as hydrome.
9. Surrounding the trilobed central strand is an interrupted pericycle composed of 2 or 3 layers.
10. The furrows between the lobes are occupied by 6-8 polygonal cells known as leptoids, collectively called as leptom. These cells appear similar to sieve tubes.
11. In between the leptom and hydrome is a layer of starchy parenchyma called as amylom.

Exercise 3

***Object* : Study of anatomy of axis.**

Work procedure

Place a piece of axis in the pith and cut T.s. with a sharp razor or blade. Stain in safranin or fast green mount in glycerine and study.

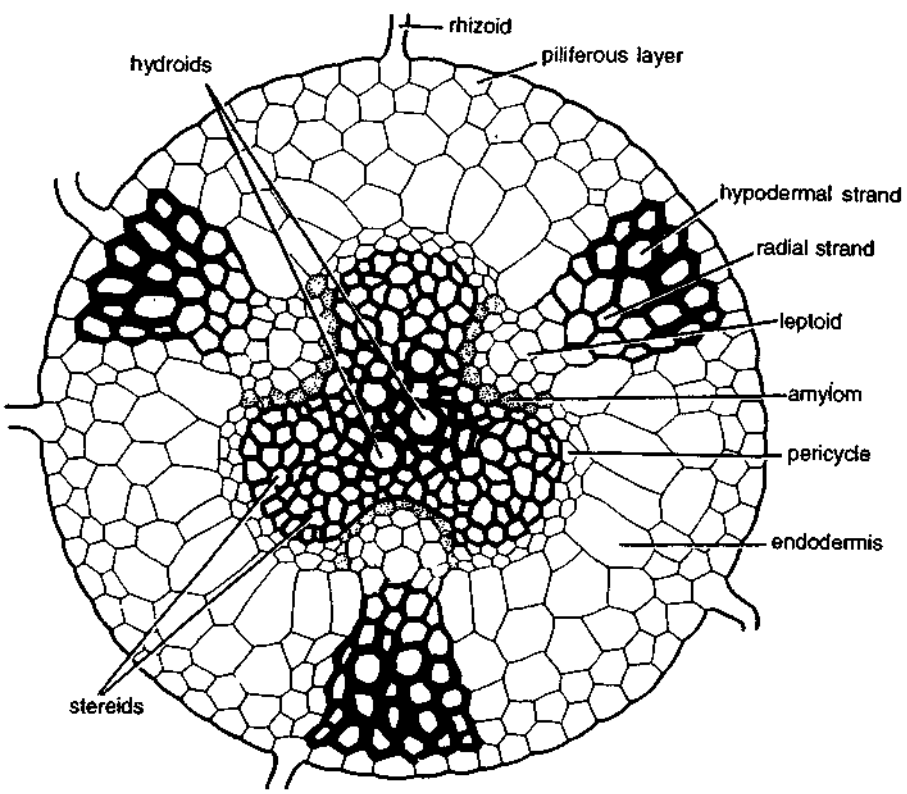


Fig. 2. ***Polytrichum.*** T.s. rhizome (cellular).

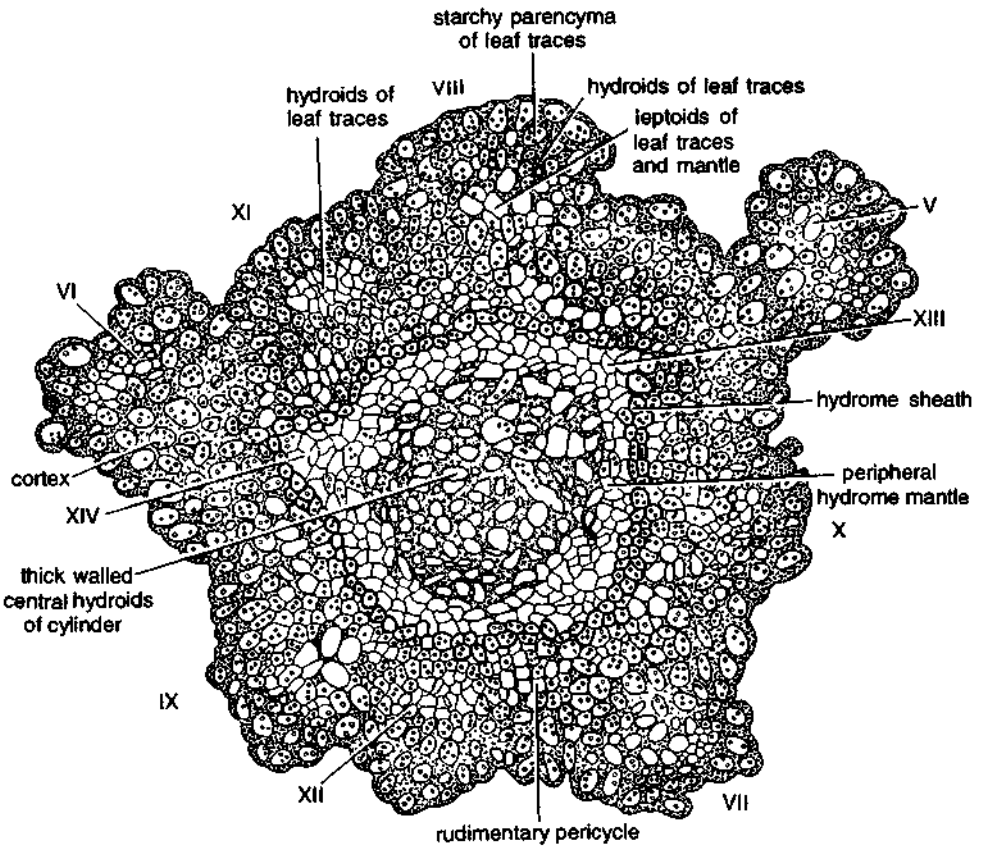


Fig. 3. ***Polytrichum.*** T.s. axis (cellular)

Comments

1. The outline of the section is irregular due to attachment of leaves.
2. The tissues show outermost superficial layer followed by cortex, pericycle, leptom mantle, hydrom sheath, hydrom mantle and the hydrom cylinder.
3. The superficial layer does not form clearly defined epidermis.
4. The cortex is divisible into outer and inner cortex. The outer cortex is made of compact, elongated prosenchymatous cells gradually merging into the inner cortex made of parenchymatous cells. Leaf traces are quite common in cortex.
5. Following the cortex is present the rudimentary pericycle which is not clearly differentiated.
6. Inner to pericycle is the leptom mantle, the cells of which are typical sieve tube-like. The leptom mantle is regarded as equivalent to the phloem of vascular plants.
7. Internal to the leptom mantle is the hydrom sheath (amylom layer) composed of one or two layers of cells with prominent starch.
8. Immediately following the hydrom sheath is the hydrom mantle which is composed of thin-walled cells without contents.
9. The centre of axis is occupied by the hydrom cylinder, made of thick walled cells.

Exercise 4

***Object* : Study of anatomy of leaf.**

Work procedure

Place the leaf in pith, cut T.s. with a sharp blade or razor. Stain in safranin or fast green, mount in glycerine and study.

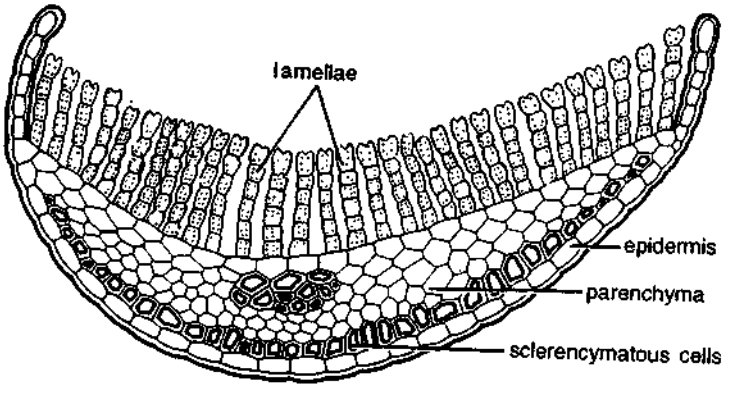


Fig. 4. ***Polytrichum.*** T.s. leaf (cellular).

Comments

1. The section shows several celled thick midrib that gradually merges into rudimentary wings which are made of hyaline cells.
2. On the lower side is the cuticularized epidermis. Just inside the epidermis are one or two layers of small, sclerenchymatous elongated cells.
3. The central tissue of the leaf is made up of large parenchymatous cells with some groups of sclerenchymatous cells scattered between them.
4. On the upper surface there is a layer of large cells from which arise many parallel plates known as lamellae.
5. Each lamella is uniseriate and is composed of 5-8 cells. Each cell contains chlorophyll. The terminal cell of each lamella is wider or papillose. Terminal cells of the adjacent lamellae almost touch each other.
6. These lamellae are the chief photosynthetic tissue of the leaf and compensate for the reduced wing.

Exercise 5

Object **: Study of antheridial head and antheridium.**

Work procedure

Select a male plant, select antheridial head that is situated at the tip, tease out antheridia or cut L.s. of head, stain in safranin, mount in glycerine and study.

Comments

1. Plants are usually dioecious and the antheridia and archegonia are present at the apices of the gametophores.
2. The antheridia are surrounded by specialized leaves known as perichaetial leaves which are usually short and may be pale pink or rose.

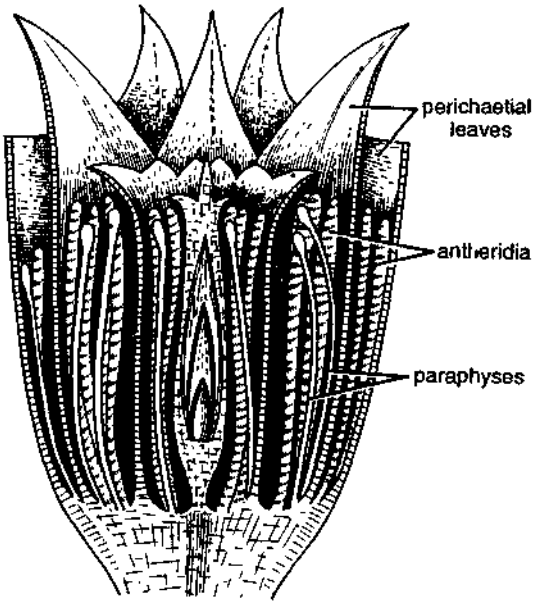


Fig. 5. ***Polytrichum.*** L.s. through antheridial head.

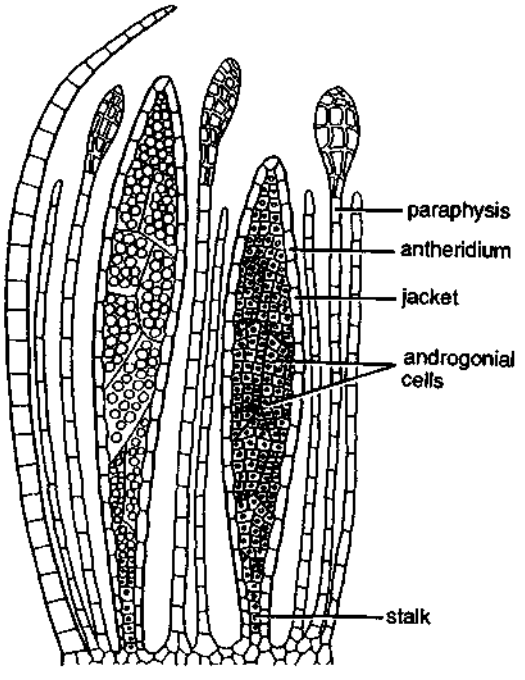


Fig. 6. ***Polytrichum.*** Antheridia and paraphyses.

They form a cluster or rosette, superficially resembling a small flower.

3. The antheridia are present in groups at the base of each perichaetial leaf in the position of lateral buds.
4. Intermingled with the antheridia are the paraphyses. Some of the paraphyses are filamentous, whereas the others are broadened at their tips.
5. A mature antheridium is usually stalked and somewhat club-shaped structure.
6. It consists of a jacket of cells surrounding a mass of androgonial cells.

(Since the apical cell is not consumed in the formation of the antheridia, the growth of the male shoot is not arrested by the development of antheridia. So after the antheridia have been matured, the vegetative axis may grow out in the following year through the antheridial cup and produce a new shoot. This new shoot may also behave likewise).

Exercise 6

Object **: Study of archegonial branch and archegonium.**

Work procedure

Select a female plant, select archegonial head present at the tip, tease out the perichaetial leaves to expose the archegonia or cut L.s. of head, stain in safranin or fast green, mount in glycerine and study.

Comments

1. The archegonia are surrounded by coloured perichaetial leaves. This gives the appearance of a small flower.
2. The archegonia are found in terminal groups at the apex of the gametophore, thus arresting the further growth of the axis.
3. In each group there are usually three archegonia.

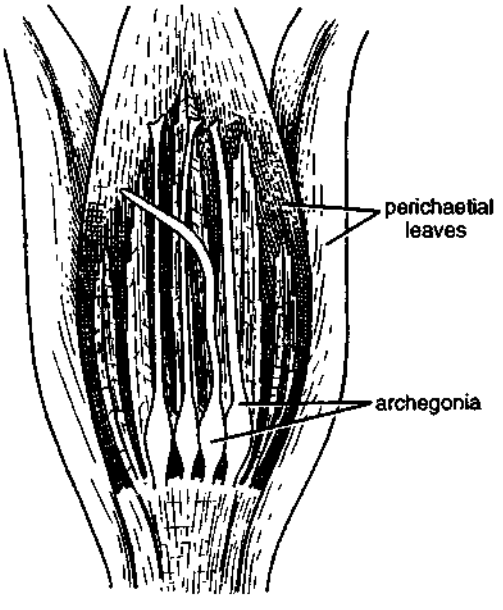


Fig. 7. ***Polytrichum.*** L.s. through archegonial head.

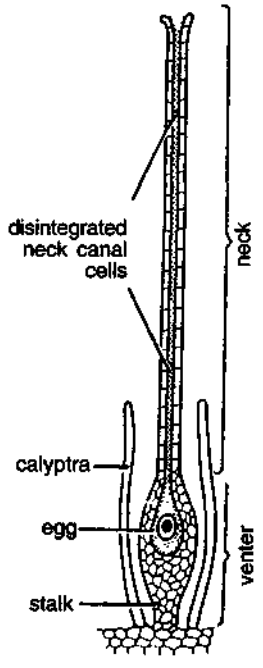


Fig. 8. ***Polytrichum.*** An archegonium.

4. Scattered among the archegonia are modified hair-like structures, the paraphyses.
5. The archegonia are also stalked and greatly elongated and consist of venter and a neck.
6. The venter is several cells thick and contains a venter canal cell and an egg.
7. The neck consists of six vertical rows of cells and contains a large number of neck canal cells which disintegrate as the archegonium matures.

Exercise 7

***Object* : Study of the external features of sporophyte.**

Work procedure

Study the specimen of gametophore that bears sporophyte.

Comments

1. The sporophyte is formed after fertilization and consists of foot, seta and capsule.
2. The foot is buried in the tissues of the leafy gametophore.

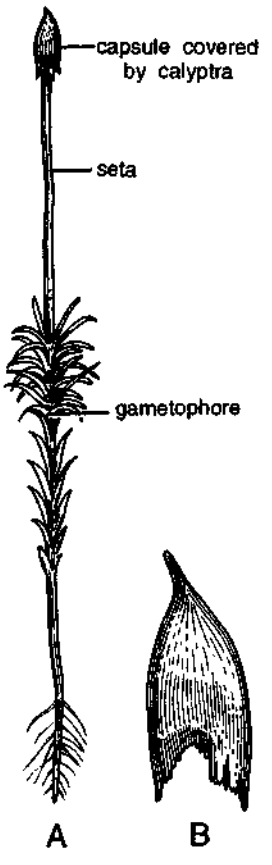


Fig. 9. ***Polytrichum.*** **A.** Sporophyte attached to the gametophore. **B.** Calyptra

3. Just above and in continuation of the foot is the long and slender seta which support the capsule at its apex.
4. With the growth of the sporophyte, the lower part of the archegonium enlarges following elongation, and is converted into a calyptra, covering the capsule.
5. The wall of the capsule is several layered and the outermost layer is differentiated into an epidermis with thick outer walls. All the cells of the wall layers contain chloroplast.
6. Inner to the wall there is an outer lacuna (air space), traversed radially by the chlorophyllous filaments. The filaments are connected internally with the outer wall of the spore sac.
7. The spore sac is internally bound by an inner lacuna made of filaments that connect the spore sac with the central columella.

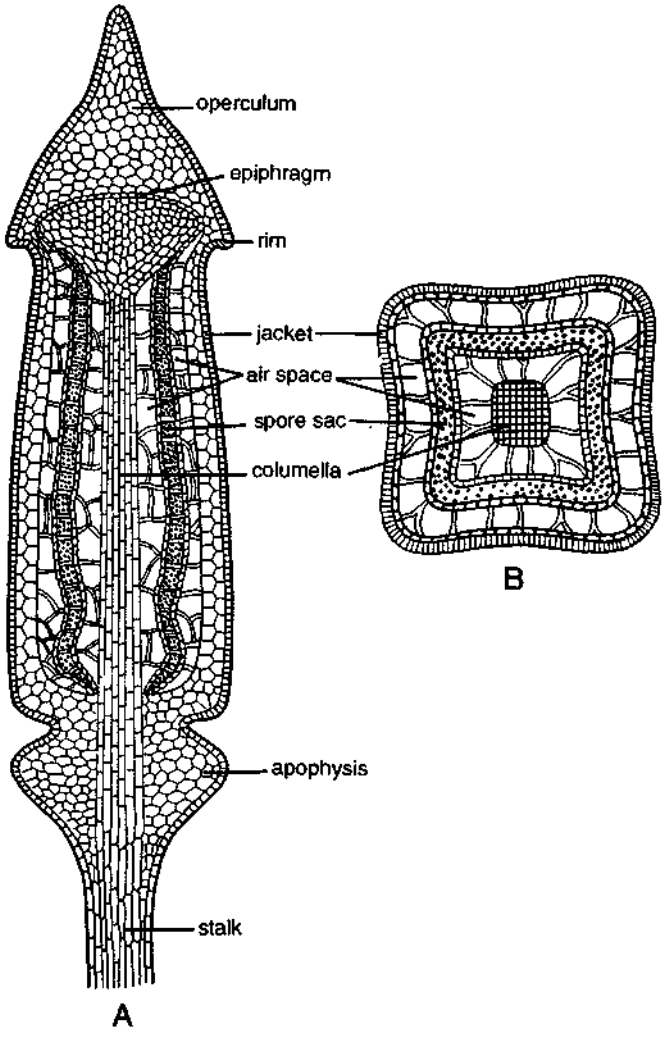


Fig. 10. ***Polytrichum.*** **A.** L.s. capsule. **B.** T.s. capsule.

8. The spore sac extends the entire length of the capsule. The archesporium (spore producing tissue) is 1 to 16 layered and all its cells develop into spore mother cells which after meiosis, give rise to spores.
9. At the top of the capsule is present a lid, the operculum.
10. Just below the operculum is present the epiphragm which stretches like a drum head over the opening of the capsule.
11. Just within the mouth of the capsule and under the epiphragm is a ring of peristome teeth.

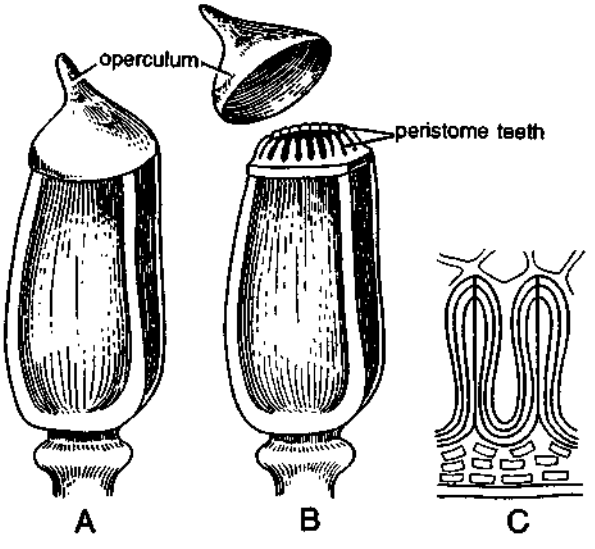


Fig. 11. ***Polytrichum.*** **A.** Ripe capsule after removing calyptra. **B.** Capsule after removing operculum. **C.** Two peristome teeth.

12. At maturity peristomial ring is composed of 32 or 64 short pyramidal teeth. These teeth are not hygroscopic but control the dispersal of spores.

Identification

Division—**Bryophyta.** (1) True roots absent and instead are present the rhizoids, (2) No vascular strand.

Class— **Bryopsida.** (1) Gametophore erect and leafy, (2) Rhizoids multicellular with oblique septa.

Sub-class—**Bryidae.** (1) Leaves with distinct midrib, (2) Seta long, (3) Spore sac usually separated from the capsule wall by air spaces.

Order—**Polytrichales.** (1) Gametophores tall and perennial, (2) Leaves narrow with lamellae on the upper surface of the midrib, (3) Peristome teeth 32 or 64 (4) Calyptra, cucullate, either smooth spinulose or hairy.

Family—**Polytrichaceae.** Characters same as those of Polytrichales.

Genus—***Polytrichum.*** (1) Rhizoids rope-like, (2) Capsule angular.

Hints for Collection

Only three species of *Polytrichum* viz. *P. densifolium, P. xanthopiium* and *P. juniperinum* are found in India, mostly in hills. The species are found in a variety of habitats. Such as sandy ground, dry and stony places, peat, bog, marshy moores and damp soil, etc.

Pogonatum

Classification

Division	—	**Bryophyta**
Class	—	**Bryopsida**
Sub-class	—	**Bryidae**
Order	—	**Polytrichales**
Family	—	**Polytrichaceae**
Genus	—	***Pogonatum***

Exercise 1

***Object* : Study of external morphology of the gametophyte.**

Work procedure

Observe the external features of the plant, the rhizome, rhizoids, axis and the leaves.

Comments

1. The gametophyte is differentiated into rhizoids, stem or axis and leaves.
2. The basal rhizomatous part of the erect stem is slightly stouter and stiffer. It bears rhizoids.
3. The rhizoids are thick walled and multicellular. The septa are oblique. Many rhizoids twist together in a rope-like manner forming strong cable-like strings.
4. The aerial part of the stem bears leaves. The leaves on the lower part are very small, scale-like and much paler in colour.
5. The upper leaves are crowded together spirally, spreading out from the stem and are rather stiff.
6. The leaves are sessile, pale in colour with sheathing broad base. The upper part of the leaf is deep green to brown or reddish brown in colour. The leaves gradually taper towards the apex and the margins are serrated.
7. A leaf has a distinct thick midrib in the centre with narrow wing-like lamina on either sides.
8. The upper surface of the midrib is completely covered by parallel longitudinal vertical plate-like structures called lamellae.

Exercise 2

***Object* : To study anatomy of axis.**

Work procedure

Cut a thin transverse section of the axis. Stain in safranin, mount in glycerine and study.

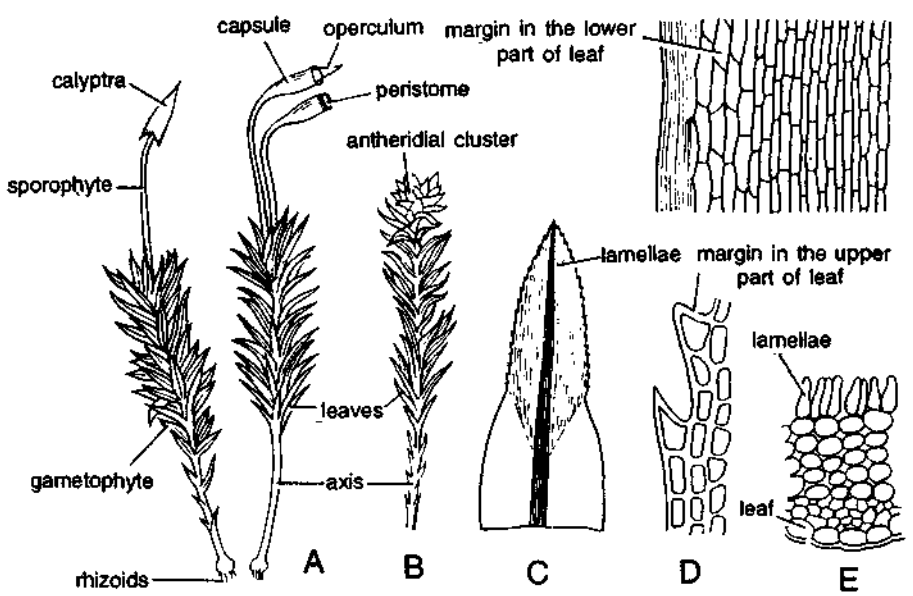


Fig. 1. ***Pogonatum.*** External features. **A.** Female plants. **B.** Male plant. **C.** Leaf showing lamina. **D.** Leaf cells at margin and base **E.** A part of T.s. of leaf showing lamellae.

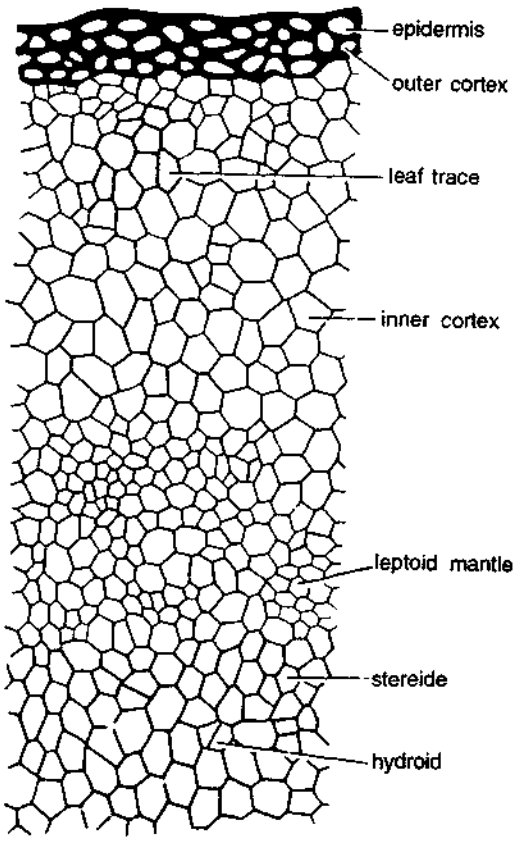


Fig. 2. *Pogonatum.* Anatomy of axis (a part cellular).

Comments

1. The transverse section shows epidermis, cortex, leptoid mantle, stereids and hydroids.
2. The outermost single layer of slightly thick walled cells is the epidermis. It is broken in the upper part of the stem due to presence of leaves.
3. A wide zone of cortex follows.
4. It shows outer and inner regions. The cells of the outer cortex are thick walled, elongated and deeply coloured.
5. The inner cortex is wider than the outer. The cells are thin walled, parenchymatous, lighter and compact.
6. A few thick walled leaf traces are also found in the cortex.
7. Inside the cortex is a zone of elongated cells with protoplasm but no starch. The cells are considered to be similar to sieve tubes and show oblique intervening cells like sieve plates. The cells are leptoids. This zone is called as leptoid mantle.
8. The centre of the stem shows hydrom cylinder which is made of two types of cells—the elongated, thick walled cells with living contents called stereids and similar cells devoid of contents called hydroids.
9. Hydroids are dispersed amongst stereids. They are considered to be helpful in water conduction.

Exercise 3

***Object* : Study of the male plant and the antheridium.**

Work procedure

Study the position of antheridia on the male plant, tease or dissect the antheridial head, and study an antheridium.

Comments

1. Antheridia are borne at the apex of the branches of male plants.
2. Antheridia are surrounded by specialized leaves, the perichaetial leaves, at the apex. These are coloured red or orange and form a flower-like head.

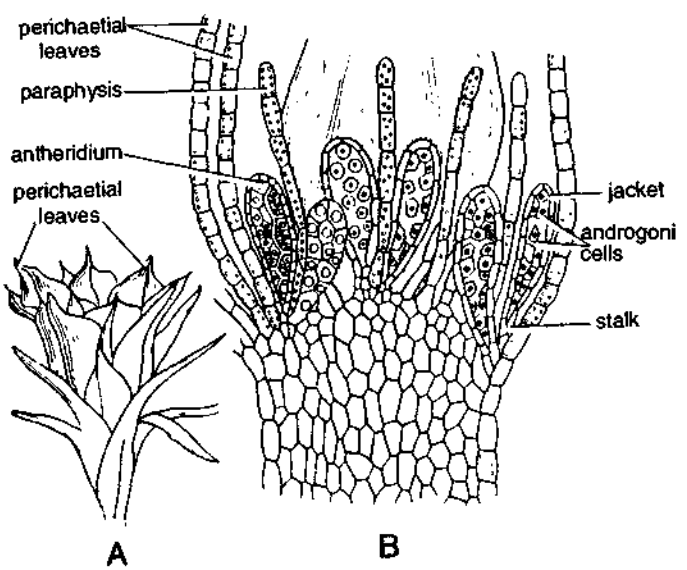


Fig. 3. *Pogonatum.* A. Male flower. B. L.s. of male head.

3. The group of these leaves enclose a cluster of antheridia and paraphyses.
4. The antheridia are borne in such a way that the center of the axis remains free for further growth.
5. Each antheridium is a club-shaped structure with a short stalk.
6. The stalk is multicellular and holds the body of the antheridium.
7. The body of antheridium is made of a single layered jacket that surrounds many androcytes.
8. Many paraphyses occur scattered amongst the anteridia. Paraphyses are long, multicellular, hair-like structures with rounded apical cell. Each cell has many chloroplasts.

Exercise 4

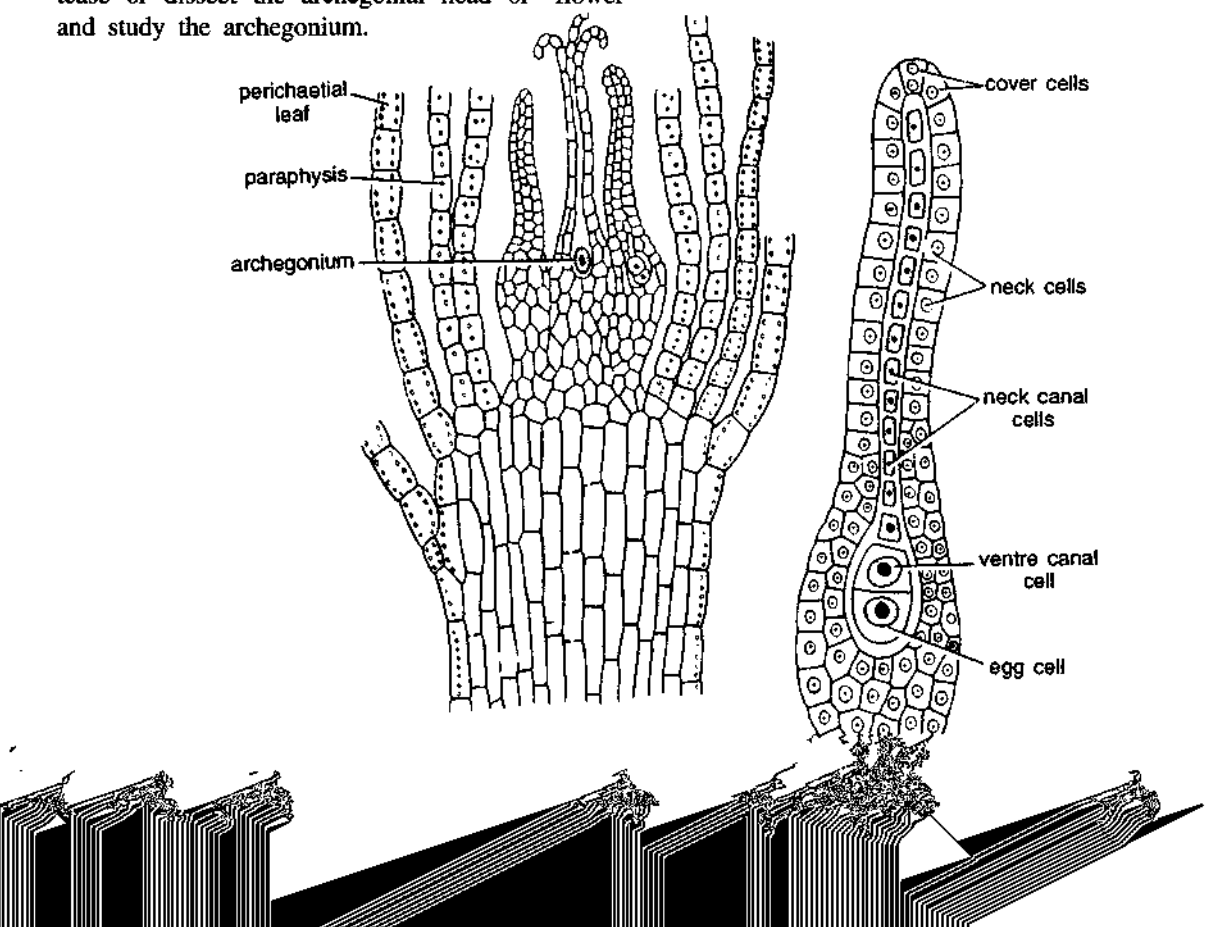
***Object* : To study the female plant and the archegonia.**

Work procedure

Study the position of archegonia on the female plant, tease or dissect the archegonial head or 'flower' and study the archegonium.

Comments

1. An archegonial cluster develops at the tip of the plant.
2. Each cluster consists of archegonia and paraphyses, surrounded by perichaetial leaves.
3. Perichaetial leaves are specially modified leaves located at the apex.
4. During the formation of archegonia, apical cell is used up and hence the axis stops any further growth.
5. The archegonium is attached to the stem apex by a short multicellular stalk.
6. The archegonium consists of a neck and a ventre. The neck consists of six vertical rows of cells, two cover cells and 8-12 (or more) neck canal cells. The ventre is made of venter canal cell and an egg cell. The wall of the ventre is made of 2 layers of cells.
7. The paraphyses occurring among the archegonia are multicellular, long, hair-like structures made of single row of cells. The cells are rich in chloroplasts.



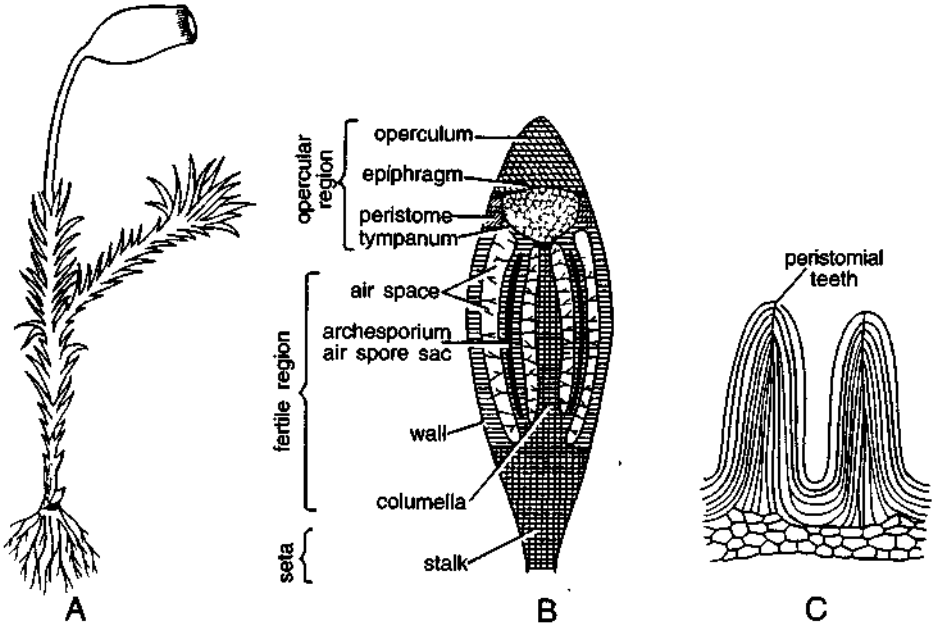


Fig. 5. ***Pogonatum.*** **A.** Sporophyte. **B.** L.s. sporophyte. **C.** Two peristome teeth.

Exercise 5

Object **: To study the sporophyte.**

Work procedure

Study the external features of the sporophyte and the internal structure by studying the slide of L.s. of the sporophyte.

Comments

1. The mature sporophyte consists of a foot, seta and a capsule covered by a calyptra.
2. L.s. of the capsule shows a lower stalk, middle fertile region and the upper operculum.
3. The stalk consists of a parenchymatous tissue that merges with columella. It is surrounded by chlorophyllous cells.
4. The capsule lacks a basal apophysis with stomata.
5. The fertile region of the capsule shows the following structure.
6. One layered epidermis with thick outer walls.
7. Several layered wall of chlorophyllous cells.
8. Large cylindrical air space or outer lacuna connected by string-like filaments of green cells with outer wall of the inner spore sac cylinder.
9. The spore sac has an outer one layered wall and inner two layered wall consisting of thin walled cells.
10. The spore sac is usually two layered thick. It shows archesporial tissue when young and spores when mature.
11. Inner spore wall is followed by another air space (inner lacuna).
12. The green filaments of inner air space are connected with centrally located parenchymatous columella. It is not cylindrical but produces four wing-like extensions.
13. Columella passes into opercular region and swells up to form drum-like roof of the capsule called epiphragm (tympanum).
14. Above the epiphragm is a conical and beaked operculum which is connected to the capsule by a ring-like diaphragm. Organised annulus is absent.
15. Above the diaphragm is a ring of 32 short peristomial teeth. These are formed of the

bundles of fibrous cells. The teeth are hygroscopic and control the dispersal of spores.

Identification

Division—**Bryophyta**. (1) True roots absent, (2) Presence of antheridia and archegonia, (3) True vascular tissues absent.

Class—**Bryopsida**. (1) Gametophore erect and leafy, (2) Rhizoids multicellular with oblique septa.

Sub-class—**Bryidae**. (1) Leaves with distinct midrib, (2) Seta long, (3) Spore sac usually separated from the capsule wall by air space.

Order—**Polytrichales**. (1) Gametophores tall and perennial, (2) Leaves narrow with lamellae on the upper surface of the midrib, (3) Peristome 32 or 64, (4) Calyptra cucullate, either smooth, spinulose or hairy.

Family—**Polytrichaceae**. (1) Single family, characters same as those of the order.

Genus—***Pogonatum***. (1) The leptoid and hydroid cells poorly demarcated, (2) Neck or apophysis absent from the capsule, (3) Peristomial teeth solid, 32 in number.

Hints for Collection

Pogonatum is the largest genus with about 199 species distributed all over the world. Of these, 34 are found in the temperate hills of India and Sri Lanka. It is commonly found in the hills of India, growing on the rock soil. The most common Indian species are *P. aloides*, *P. microstomum*, *P. junghunianum*, etc.

8 Chapter

Pteridophyta

Preamble

The pteridophyta include those plants which are sometimes called **"Vascular cryptogams"**, because of the presence of true xylem and hidden type of sexual reproduction. This group includes not only a large number of present day genera, but also a great many fossil types. Many of the genera which at the present day are quite small plants, have descended from ancient groups which in their days, formed large trees. Unlike bryophytes, the pteridophytes are found in great majority of habitats, ranging from aquatic to xerophytic. Generally they are land inhabiting but *Salvinia* and *Azolla* grow in aquatic habitat.

The members of the group vary greatly in form. These show two main evolutionary tendencies. One resulted in the production of large leaves and relatively small stems, and is known as the *megaphyllous* types. It is represented by ferns. The second tendency in which the leaves are small in relation to the stem and moreover the leaf trace leaves no gap in the stele, are known as the *microphyllous* types. This tendency is represented by club mosses and horse tails. The anatomy of these plants is to some extent dependent upon the type of the leaf they bear, but basically in all of them, the stem is divided into an outer cortex, and a central conducting system, the stele. A similar, though generallysimpler structure is found in roots. The leaves in megaphyllous types consist of a petiole and a leaf blade or lamina with many veins. Microphyllous leaves are much simpler, with no petiole and usually only one vein.

The reproductive organs are generally borne either on the leaves or in the axils between the leaves and the stem. They are made up of little capsules called sporangia, in which are developed the spores. All the spores may be of the same size, when the plant is said to be the homosporous, or they may be of the two different sizes and the plant is called as heterosporous. In heterosporous types, the smaller spores are termed as microspores, and are developed in microsporangia, while in larger spores, which are generally produced in smaller numbers, are termed as megaspores, and are found in megasporangia.

Since the plant body of the members belonging to this group, produces spores, they represent the sporophytes, being comparable to the sporogonium of bryophyta. The gametophytes are, however, small and insignificant and bear sex organs. The fern plant and the moss plant, thus cannot be compared, as they belong to different generations of life cycle.

Distinguishing Characters of Taxa

Various classifications of Pteridophytes have been proposed, time and again. Of these, a few classifications have been adopted by different workers. The classification followed in this book is a modified version of Riemers (1954). Below are given the characters of certain texa, described in the book.

DIVISION **PTERIDOPHYTA**

(1) True roots generally present
(2) Plant body differentiated into stem, roots and leaves
(3) True vascular strand present

SUB-DIVISION **1. PSILOPHYTOPSIDA**

(1) True roots absent
(2) Sporangia borne at the tips of erect branches either singly or in pairs
(3) Plants homosporous
(4) Plants found only as fossils

Order **Psilophytales**

(1) Sporophyte dichotomously branched
(2) Sporangia generally borne singly

Family **Rhyniaceae**

(1) Rhizoids unicellular, on rhizomes
(2) Aerial portion leafless

Classification of Pteridophyta

Division—PTERIDOPHYTA

Sub-division	Class	Order	Family	Examples
1. Psilophytopsida		Psilophytales	Rhyniaceae	*Rhynia**
				*Horneophyton**
2. Psilotopsida		Psilotales	Psilotaceae	*Psilotum*
3. Lycopsida		1. Lycopodiales	Lycopodiaceae	*Lycopodium*
		2. Lepidodendrales	Lepidodendraceae	*Lepidodendron**
				*Lepidocarpon**
		3. Selaginellales	Selaginellaceae	*Selaginella*
		4. Isoetales	Isoetaceae	*Isoetes*
4. Sphenopsida		1. Equisetales	Equisetaceae	*Equisetum*
		2. Calamitales	Calamitaceae	*Calamites**
5. Pteropsida	1. Eusporangiatae	1. Ophiglossales	Ophioglossaceae	*Ophioglossum*
		2. Marattiales	Angiopteridaceae	*Angiopteris*
	2. Leptosporangiatae	1. Filicales	1. Adiantaceae	*Adiantum*
			2. Polypodiaceae	*Dryopteris*
				Lastraea
				Nephrolepis
				Polypodium
				Pteridium
		2. Marsileales	Marsileaceae	*Marsilea*
		3. Salviniales	1. Salviniaceae	*Salvinia*
			2. Azollaceae	*Azolla*

* Fossils members

Examples ***Rhynia**, **Horneophyton****

SUB-DIVISION **2. PSILOTOPSIDA**

(1) Sporangia are borne in the axils of scaly appendages or foliage leaves
(2) Plants living, true roots absent and homosporous

Order **Psilotales**

(1) Sporophyte dichotomously branched
(2) Sporangia generally borne singly
(3) Stele protostele to actinostele
(4) Eusporangiate and homosporous

Family **Psilotaceae**

(1) Axis branched
(2) Scale leaves small and minute

Example ***Psilotum***

SUB-DIVISION **3. LYCOPSIDA**

(1) Leaves microphyllous
(2) Sporangia borne singly on adaxial face of the sporophyll or in its axil
(3) Sporophytes homosporous

Family **Lycopodiaceae**

(1) Leaves without ligules
(2) Sporophylls and foliage leaves may be similar or dissimilar in shape

Example ***Lycopodium***

Order **2. Lepidodendrales**

(1) Plants tree-like
(2) Secondary tissues formed due to cambium
(3) Leaves microphyllous and ligulate
(4) Strobili heterosporous.

Family **Lepidodendraceae**

(1) Aerial portion freely branched
(2) Strobili at the tips of branches
(3) Trunk and branches with spirally arranged leaf scars

Examples ***Lepidodendron**, **Lepidocarpon****

Order **3. Selaginellales**

(1) Each foliage leaf with a ligule at the base on adaxial side
(2) Sporophytes heterosporous

Family **Selaginellaceae**

(1) Stem herbaceous and dorsiventral or erect
(2) Gametophytes extremely reduced

Example ***Selaginella***

Order **4. Isoetales**
(1) Herbaceous sporophytes with a massive rhizomorph at the base of the stem
(2) Leaves microphyllous and ligulate
(3) Sporophytes heterosporous
(4) Sporophylls may or may not be grouped in strobili
(5) Antherozoids multiflagellate

Family **Isoetaceae**
(1) Stem corm-like
(2) Sporophylls bearing sporangia on adaxial face, not grouped in strobili

Example ***Isoetes***

SUB-DIVISION **4. SPHENOPSIDA**
(1) Stem branched, articulated, ridged and furrowed with distinct nodes and internodes
(2) Leaves microphyllous, small, scaly and arranged in whorls at the nodes

Order **1. Equisetales**
(1) Stem branched, branches in transverse whorls
(2) Intenodes alternate with one another
(3) Vascular cylinder siphonostele, endarch

Family **Equisetaceae**
(1) No secondary growth
(2) Monosporous
(3) Sporagnia borne on sporangiophores which form a compact cone

Example ***Equisetum***

Order **2. Calamitales**
(1) Tree-like sporophytes with considerable secondary thickening of stem and branches

Family **Calamitaceae**
(1) Stem branched, branches in whorls at nodes
(2) Stem shows endarch siphonostele

Example ***Calamites****

SUB-DIVISION **5. PTEROPSIDA**
(1) Vascular cylinder siphonostelic, with leaf gaps
(2) Leaves megaphyllous, compound with rachis
(3) Leaves bear sporangia in sori
(4) Gametophytes small, green and free-living

CLASS **1. EUSPORANGIATAE**
(1) Sporangium develops from a group of initials (eusporangiate development)
(2) Sporangial jacket more than one cell in thickness
(3) Large number of spores within sporangium
(4) Sporangia borne in spike or sori situated on the abaxial surface of the leaf.

Order **1. Ophioglossales**
(1) Sporangia borne on a special structure called spike. It projects adaxially from a leaf and near the junction of blade and petiole.

Family **Ophioglossaceae**
(1) Single family, characters same as the order

Example ***Ophioglossum***

Order **2. Marattiales**
(1) Young leaves with circinate vernation
(2) Leaves with fleshy stipules

Family **Angiopteridaceae**
(1) Sporangia almost free
(2) Sporangia linear in two rows on both the sides of the veins

Example ***Angiopteris***

CLASS **2. LEPTOSPORANGIATAE**
(1) Sporangium develops from a single initial cell (leptosporangiatae development)
(2) Sporangial jacket one cell in thickness
(3) Definite number of spores

Order **1. Filicales**
(1) Homosporous

Family **1. Adiantaceae**
(1) Sori apparently marginal but superficial in origin
(2.) Indusia oblong or linear, usually many and distinct
(3) Leaflet margins bearing sori sharply reflexed

Example ***Adiantum***

Family **2. Polypodiaceae**
(1) Annulus vertical
(2) Each sporangium with 32 to 64 spores

Examples ***Dryopteris, Lastraea, Nephrolepis, Polypodium, Pteridium***

Order **2. Marsileales**
(1) Members heterosporous
(2) sporangia formed within sporocarps

Family **Marsileaceae**
(1) Members aquatic
(2) Sorus of gradate type, each producing both the types of sporangia
(3) Leaf circinately coiled in bud condition

Example ***Marsilea***

Order **3. Salviniales**
(1) Members heterosporous

(2) Sporangia produced within sporocarps
(3) Sporocarp contains either a single megasporangium or numerous microsporangia
(4) The wall of the sporocarp is a modification of an idusium

Family **1. Salviniaceae**

(1) Sporocarps globose or ovoid, all of them of the same size

Example ***Salvinia***

Family **2. Azollaceae**

(1) Sporocarps of two types, one is larger and male-microsporocarp and the other smaller and female-megasporocarp.

Example ***Azolla***

Psilotum

Classification

Division	—	**Pteridophyta**
Sub-division	—	**Psilotopsida**
Order	—	**Psilotales**
Family	—	**Psilotaceae**
Genus	—	***Psilotum***

Exercise 1

***Object* : Study of external features of the plant.**

Work procedure

Study the plant specimen.

Comments

1. The plant body may be pendent or erect and dwarfed (about 8 cm high) or may reach a height of 75-100 cm.
2. It is differentiated into (i) a basal rhizomatous system and (ii) aerial branches.
3. Basal rhizomatous system is subterranean, brown and rootless. The rhizome is repeatedly dichotomously branched and remains covered by small scales. The rhizome bears aerial branches.
4. Aerial shoots may be pendent (epiphytic species) or erect (terrestrial species). The slender and green aerial system is freely and dichotomously branched. The basal part of the shoot is cylindrical with longitudinal ribs. The distal green portion is radially cylindrical with three longitudinal ribs.
5. Aerial shoots bear many, small and scale-like, irregularly distributed scale leaves.
6. Sporangia are borne in triads (synangium) on very short stalks in axil of leaves (bifid), mostly towards the tip of the aerial branches.

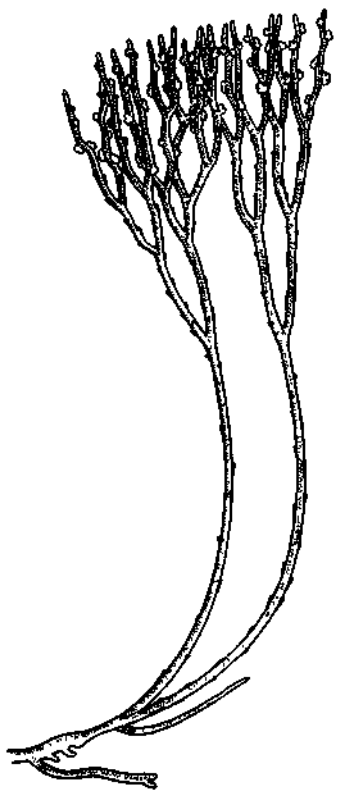


Fig. 1. ***Psilotum.*** External features.

Exercise 2

***Object* : Study of anatomy of the rhizome.**

Work procedure

Cut a T.s. of the rhizome, stain in safranin and fast green combination, mount in glycerine and study.

Comments

1. The transverse section is almost circular in outline.

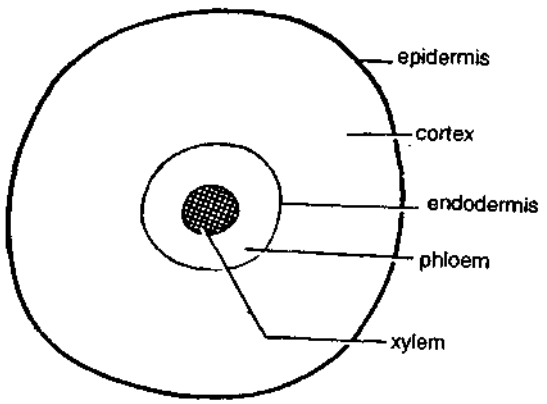


Fig. 2. *Psilotum*. T. s. rhizome (outlines)

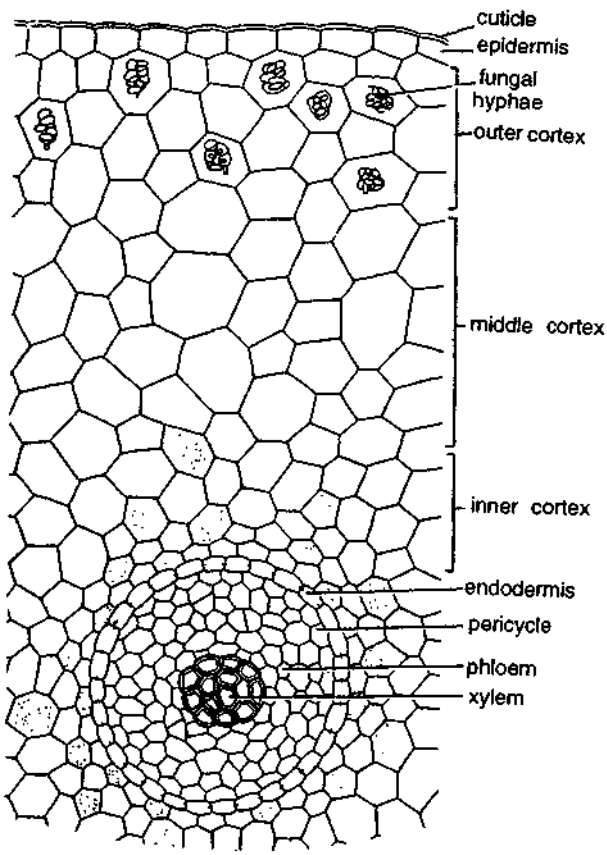


Fig. 3. *Psilotum*. T.s. rhizome (cellular).

2. It shows three distinct regions—epidermis, cortex and stele.
3. The cuticularised epidermis consists of rectangular or square cells, not much different from the underlying cells. The cells are slightly thick on their outer tangential faces.
4. The cortex is divisible into three regions—
   (i) Outer: The cells are thin walled and parenchymatous containing the hyphae of endophytic mycorrhiza.
   (ii) Middle : The cells are thin walled and parenchymatous with abundant starch grains.
   (iii) Inner : The cells are small, thin walled and parenchymatous. These are coloured brown due to the presence of tannins.
5. Endodermis separates cortex from the stele. The cells are radially elongated and bear distinct casparian strips.
6. The centrally located stele is a protostele. It remains enclosed by a pericycle situated next to the endodermis. Pericycle is single layered and parenchymatous.
7. In the centre of the stele is a solid xylem strand, consisting of a few tracheids (the number and lobes of xylem vary with the age of rhizome. In young condition only 2-3 tracheids and a solid strand is present while in mature rhizome, number of tracheids increases and core becomes progressively lobed). The distinction between metaxylem and protoxylem elements is not clear.
8. The phloem extends from the xylem strand upto the pericycle thus completely surrounding the xylem strand.

Exercise 3

***Object* : To study the anatomy of aerial shoot.**

Work procedure

Cut a T.s. of the aerial shoot, stain in safranin-fast green combination, mount in glycerine and study.

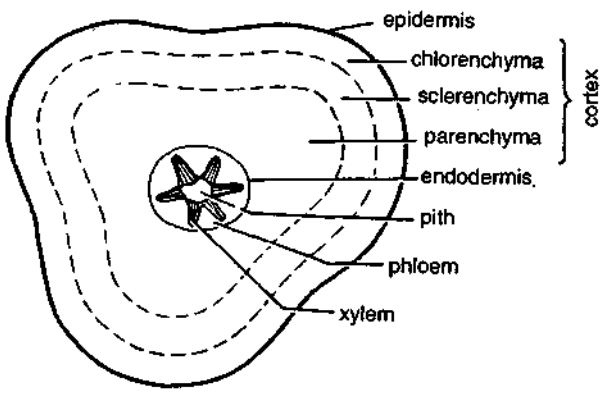


Fig. 4. *Psilotum*. T.s. aerial branch (outlines).

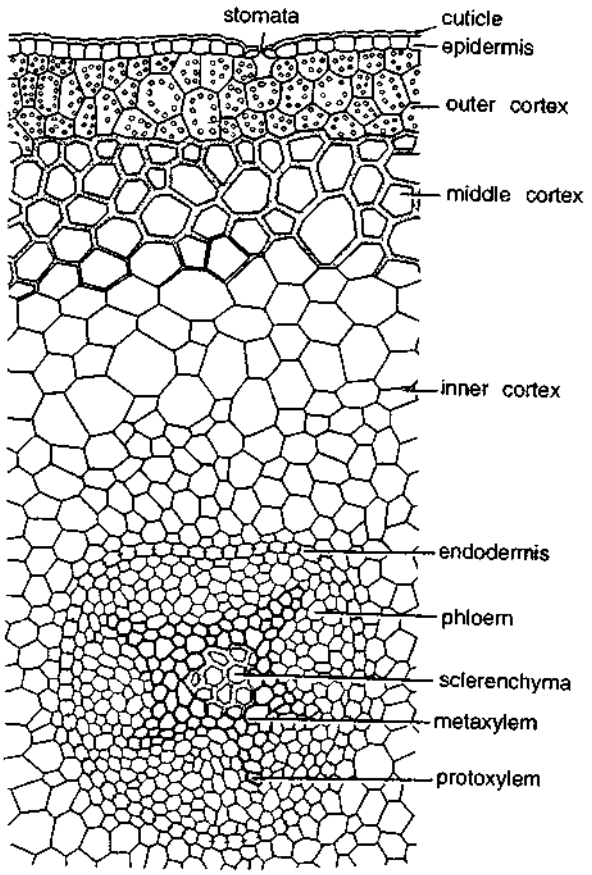


Fig. 5. ***Psilotum.*** T.s. aerial branch (a part cellular).

Comments

1. The transverse section appears slightly triangular in outline.
2. It is shows three distinct regions—epidermis, cortex and stele.
3. **The epidermis** consists of single layered, rectangular cells. The outer tangential walls are heavily cutinised and covered by a definite cuticle. Stomata are slightly sunken and are situated mainly in areas between the longitudinal ribs.
4. Internal to the epidermis is a broad cortex distinguishable into three zones—outer, middle and inner.
5. **Outer cortex**—the photosynthetic region, about 2-5 cells broad, is composed of vertically elongated cells and with small intercellular spaces. These cells contain numerous small chloroplasts.
6. **Middle cortex.** This zone is made of thick walled cells. The cells are sclerenchymatous and become progressively thinner towards inner zone.
7. **Inner cortex** is many celled broad, parenchymatous and contain numerous starch grains progressively towards centre.
8. **Endodermis** separates stele and cortex. The cells of the endodermis are tangentially elongated and exhibit distinct casparian strips on the radial end walls.
9. **The stele** is actinostelic, generally with six lobes. Each lobe has a few protoxylem elements at the tip while metaxylem is situated at its base.
10. The lobes of xylem are surrounded by phloem which extends upto the endodermis. (Typical sieve tubes are said to be absent).
11. Centre of the xylem is occupied by thick walled sclerenchymatous fibres with simple pits on their walls.

Exercise 4

***Object* : To study the anatomy of leaf.**

Work procedure

Study a slide of T.s. of leaf.

Comments

1. The leaf is divisible into (i) epidermis, (ii) cortical tissue and (iii) a small leaf trace if present.
2. **The epidermis** consists of thin walled cells while the rest of the foliar appendage is filled by photosynthetic tissue.
3. **A leaf trace** ends into the base of foliar appendage (e.g. *P. flaccidium*), however, in *P. nudum* there is no vascular bundle.

Exercise 5

***Object* : To study the spore producing organ–the synangium.**

Work procedure

Study the external features of synangium, slide of T.s. and also a single spore.

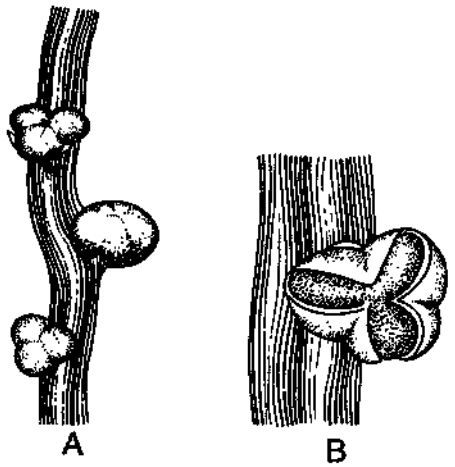


Fig. 6. *Psilotum*. A. Aerial branch with synangia, **B.** A single synangium.

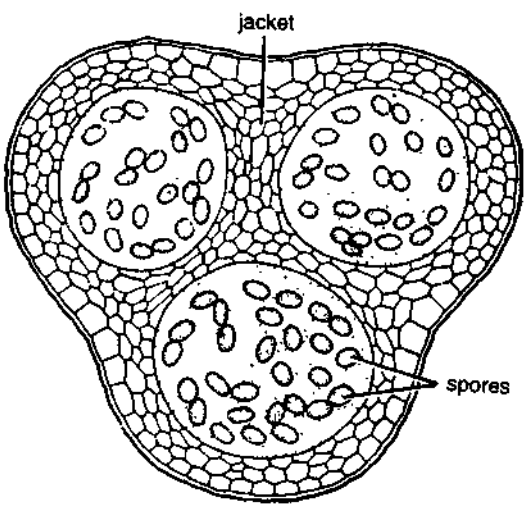


Fig. 7. *Psilotum*. T. s. synangium.

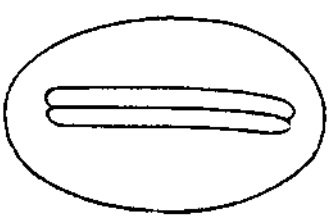


Fig. 8. *Psilotum*. A single spore.

Comments

1. Sporangia, the spore producing organs, are produced on the aerial branches.
2. These are borne in triads on minute appendages subtended by a bract. (Since the sporangia are fused with one another, the structure is called as synangium).
3. In a transverse section, synangium reveals 4-5 layered jacket, outer of which is made of thick walled cells. The loculi are filled with numerous spores. Interspersed among the spores are

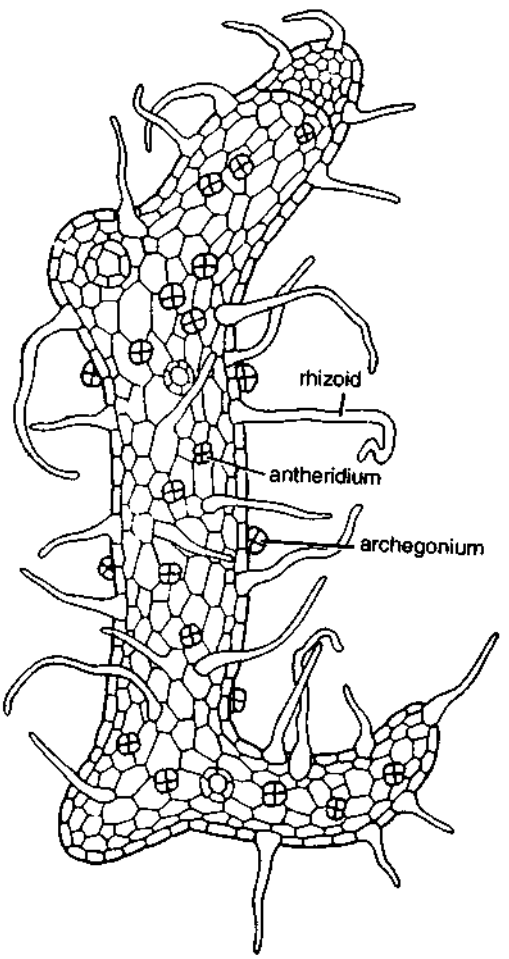


Fig. 9. *Psilotum*. A gametophyte.

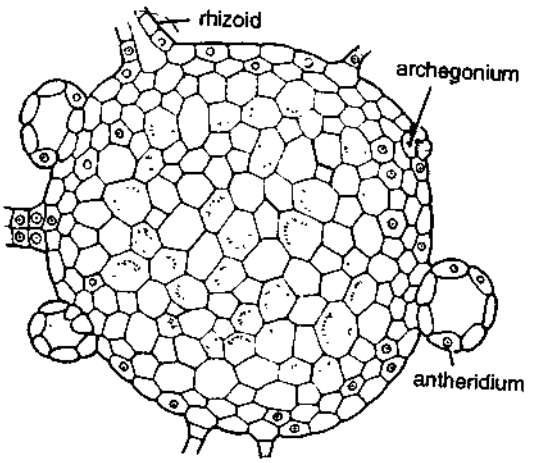


Fig. 10. ***Psilotum.*** T.s. gametophyte.

disintegrated sporocytes which serve as nutritional fluid.

4. Individual spores are bean-shaped or bilaterally symmetrical. The wall pattern is reticulate. There is a narrow slit with a median ridge.

Exercise 6

***Object* : Study of gametophyte.**

Work procedure

Study the slide of prothallus.

Comments

1. Gametophyte is subterranean and colourless. It is saprophytic and lives through the medium of symbiotic phycomycetous fungi.
2. Gametophytes are irregularly cylindrical and once or twice dichotomously forked. Rhizoids are also given out.
3. Gametophytes are homothallic. Sex organs are scattered over the entire surface. Archegonia are more in number than antheridia (or otherwise).

Identification

Division—**Pteridophyta**. (1) True roots generally present (except in Psilopsida), (2) True vascular strand present.

Sub-division—**Psilotopsida**. (1) True roots absent, (2) Shoot differentiated into subterranean rhizome and aerial portion, (3) Sporangia borne terminally.

Order—**Psilotales**. (1) Sporophyte dichotomously branched, (2) Sporangia generally borne singly, (3) Stele protostele, generally actinostele, (4) Eusporangiate and homosporous.

Family—**Psilotaceae**. (1) Axis branched, (2) Scale leaves small and minute

Genus—***Psilotum***. Sporangia borne in triads (synangium).

Hints for Collection

Only two species of *Psilotum* viz. *P. nudum* (=*P. triquetrum*) and *P. flaccidum* (=*P. complanatum*) are known. These are widespread in tropical and subtropical regions of both the hemispheres. *P. nudum* is of widespread occurrence and is known to occur at Pachmarhi in M. P. and Darjelling, West Bengal. It is primarily terrestrial and is collected from crevices of rocks and occasionally as epiphyte on tree ferns and palms.

Lycopodium (Club Moss)

Classification

Division	—	**Pteridophyta**
Sub-division	—	**Lycopsida**
Order	—	**Lycopodiales**
Family	—	**Lycopodiaceae**
Genus	—	***Lycopodium***

The genus *Lycopodium* is divided in to 2 sub-genera—Urostachya and the Rhopalostachya. The following are the differences between the two.

Urostachya	Rhopalostachya
1. Plant body erect or pendent.	1. Plant generally trailing or creeping.
2. Branching rare; if present always dichotomous.	2. Branching is dichotomous at the base but in the upper region only one of the branches grows more prominently.
3. The roots take their origin only from the basal part of the stem.	3. Adventitious roots may arise from any part of the stem.
4. Organized strobili are rarely found.	4. Strobili are always well organized and borne on long stalks.
5. Sporophylls are almost similar to the foliage leaves, the only difference is in their size.	5. Sporophylls are different from foliage leaves. They are pale yellowish and chaffy.
6. The margins of sporophylls are entire.	6. Margins of sporophylls are toothed.
7. The spores possess a pitted surface without any external outgrowth.	7. Spores possess reticulate surface

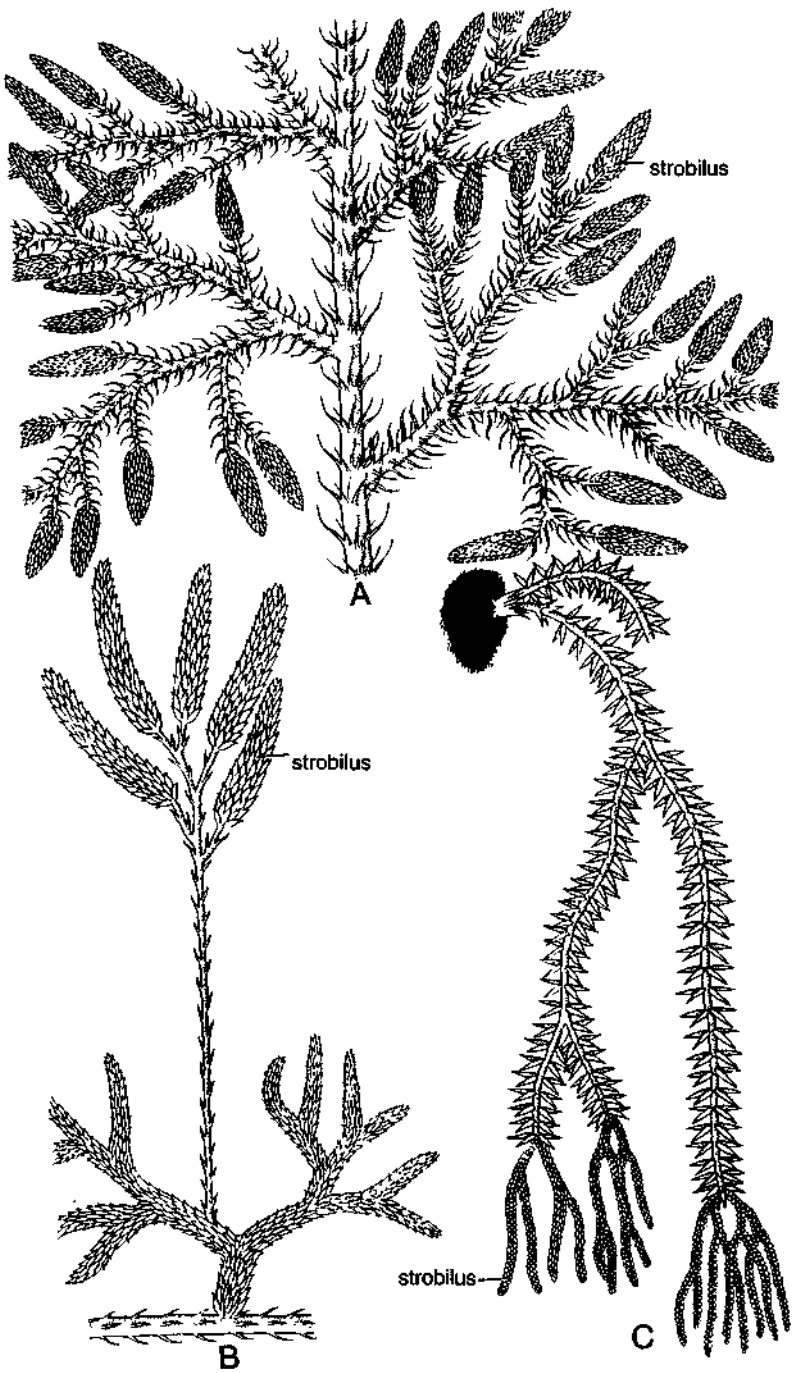


Fig. 1. ***Lycopodium.*** Sporophytes with strobili. **A.** *L. cernum* (terrestrial), **B.** *L. clavatum* (terrestrial), **C.** *L. phlegmaria* (epiphytic).

Exercise 1

***Object* : Study the external morphology.**

Work procedure

Study the specimen. Observe the differentiation of plant body into root, stem and leaves. Study the leaves and the stomata.

Comments

1. **The plant body** consists of creeping rhizome which gives off slender, elongated aerial branches from the upper side and adventitious roots from the lower. The aerial branches vary from 3-8 inches in length. *L. cernum* is exceptional in attaining a height of 2 feet or more.
2. **Habitat.** Most of the species are terrestrial and the sporophyte may either have an upright stem or a horizontally creeping stem. Some species grow as epiphytes on higher plants which show pendent habit e.g. *L. phlegmaria, L. squarrosum.*
3. **The branching** is mostly dichotomous but in some species it may be monopodial also.
4. **The stem** and its branches are densely covered with small leaves present in close spirals or whorls.
5. **The leaves** are entire, small and membranous, rarely, exceeding 1 cm in length. Each leaf is supplied by a single mid-vein which runs almost unbranched right upto the apex.
6. **Epidermis.** The walls of the epidermal cells of the leaf are sinuous.
7. **Stomata.** Stomata are more or less parallel to the midrib. These are equally distributed on both of the leaf surfaces.

Exercise 2

***Object* : Study of anatomy of root.**

Work procedure

Cut a T.s. of the root, stain in safranin and fast green combination, mount in glycerine and study.

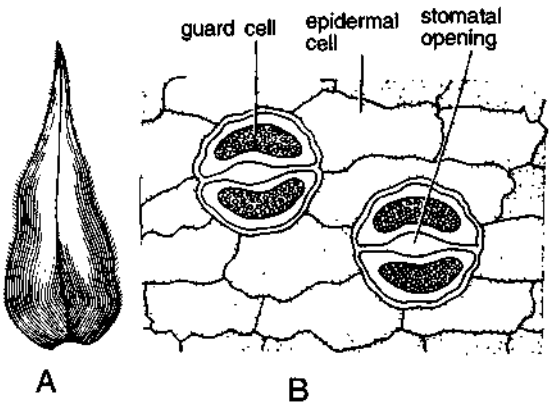


Fig. 2. ***Lycopodium.*** **A.** Entire leaf, **B.** A part of leaf epidermis showing stomata.

Comments

1. The root is differentiated into an epidermis, cortex and the stele.
2. **The epidermis** is single layered and gives rise to root hairs, the latter occur in pairs.
3. **The cortex** is several layered and in older roots a few of the outer layers become sclerified. The inner cells are thin walled and parenchymatous without any intercellular spaces.
4. **The stele** ranges from monarch to tetrarch but generally it is diarch with two protoxylem masses.

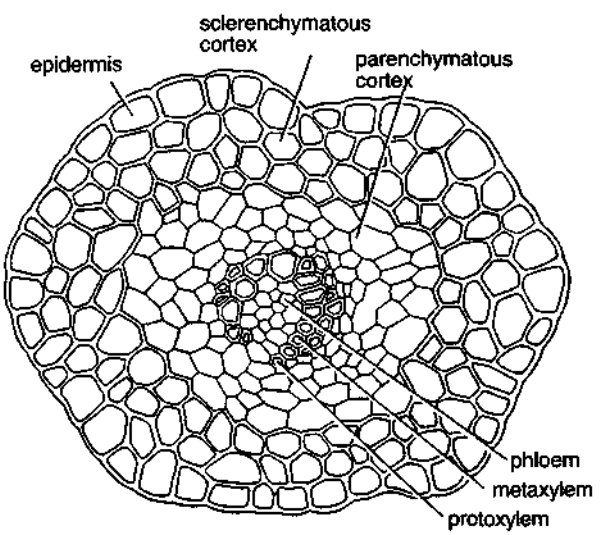


Fig. 3. ***Lycopodium.*** T.s. root.

5. The xylem is C or U shaped and is so oriented that the opening of C or U faces away from the stem.
6. The protoxylem is present at the tips of C or U and the intervening portion consists of metaxylem.
7. The phloem is present in between the arms of C or U.

Exercise 3

***Object* : Study of anatomy of stem.**

Work procedure

Cut T.s. of the stem, stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. A transverse section of the stem shows an epidermis, a wide cortex and a stele.
2. **Epidermis** is single layered and is provided with stomata.
3. **The stem** has certain ridges and grooves. Chloroenchyma is present in the ridges.
4. **Cortex.** The structure varies from species to species. In some species, it is parenchymatous throughout, in others the inner and other portions are thick walled, and in still others the entire cortex is thick walled.
5. **Endodermis.** It is single layered and lies inner to cortex. In older stems, however, the endodermis may not be well defined.
6. **Pericycle.** The endodermis is follows this layer which is composed of 3 to 6 cells.
7. **Stele.** The centre is occupied by a protostele. Three different types of styles are found in species of *Lycopodium*.
   (i) In some species viz. *L. clavatum* and *L. complanatum*, it is definitely organised into a plectostele i.e. xylem and phloem occur in alternating bands that are more or less parallel.
   (ii) In other species viz. *L. seratum* and *L. phlegmaria*, it is star-shaped with 4 arms in which grooves are occupied by phloem. This is known as actinostele.
   (iii) In still other species, as exemplified by *L. cernum*, it is a haplostele in which the xylem strands lie scattered in phloem.

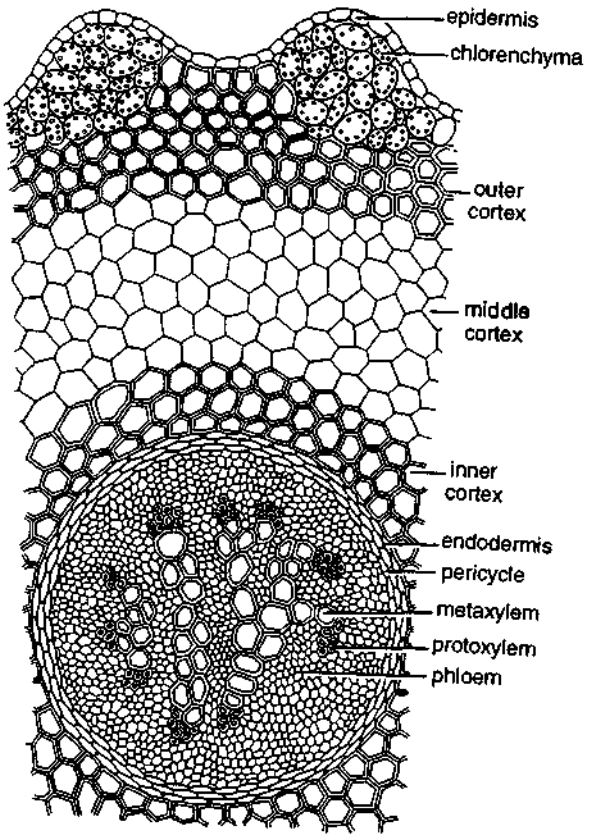


Fig. 4. *Lycopodium*. T.s. stem (a part cellular).

8. **The xylem** is exarch with protoxylem facing towards the periphery and metaxylem towards the centre.
9. **The tracheids** in metaxylem are scalariform while in protoxylem they are spiral or annular.
10. **The phloem** consists of unicellular sieve tubes, with numerous sieve plates, and phloem parenchyma. The companion cells are absent.
11. **Leaf traces** are seen to traverse the cortex.

Exercise 4

***Object* : Study the anatomy of leaf.**

Work procedure

Place the leaf in pith, cut T.s., stain in safranin-fast green combination, mount in glycerine and study.

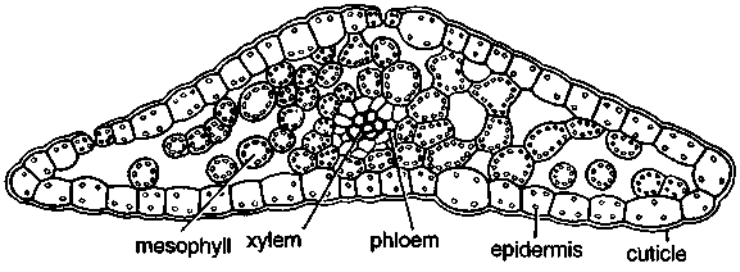


Fig. 5. ***Lycopodium.*** T.s. leaf.

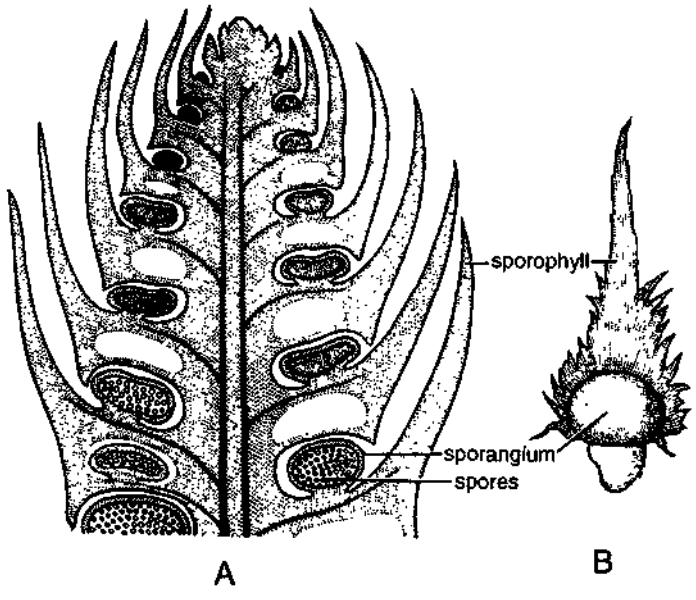


Fig. 6. ***Lycopodium.*** **A.** L.s. apical portion of strobilus. **B.** Dorsal view of sporophyll and a sporangium.

Comments

1. The epidermis is single layered. The stomata are equally distributed on both the sides.
2. The leaf has a single vascular strand which is concentric with xylem in the centre.
3. The cells between the epidermis and the vascular strand form spongy parenchyma.

Exercise 5

***Object* : Study of spore producing organ.**

Work procedure

Study the strobili, L.s. of strobilus and the spores; by observing a prepared slide.

Comments

1. **External features of strobilus.** Sporangia are the spore producing organs. These are grouped to form strobili which are situated at the apices of branches. (In *L. selago* distinct strobilus is lacking and the vegetative and reproductive regions alternate each other.).
2. **L.s. of the strobilus** shows a central strobilar axis with spirally arranged sporophylls.
3. Each sporophyll bears a sporangium near its base on the adaxial side.
4. A sporangium is a black, kidney shaped structure, with a long or short massive stalk.
5. Sporangium consists of a wall and the cavity with spore.

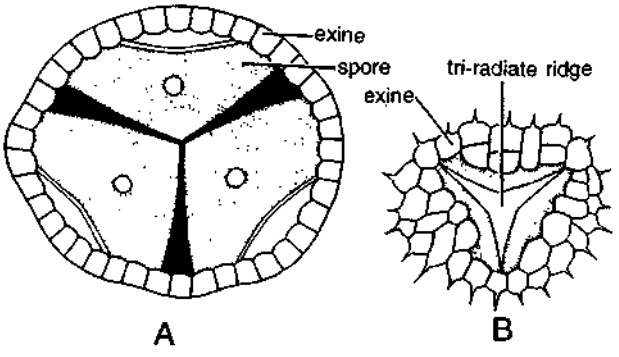


Fig. 7. ***Lycopodium.*** **A.** Spore tetrad, **B.** A spore.

6. The wall of sporangium is several layered thick. Tapetum forms the innermost layer.
7. The cavity has many spores, arranged in tetrahedral tetrads. Since all the spores are of one type, the plant is called homosporous.
8. Each spore is a minute structure with a triradiate ridge. It has a thick and spiny exine and a thin and membranous intine.
9. The spores germinate to form the prothallus.

Exercise 6

Object **: To study the gametophyte.**

Work procedure

Study the slide showing gametophyte. Observe the structure of sex organs.

Comments

1. The gametophytes may be subterranean or sub-aerial.
2. The sub-aerial type is green, about 2 or 3 mm in length and bears the sex organs.
3. The subterranean type is non-green and is bigger as compared to the sub-aerial type. It generally consists of a tuberous body with a lobed crown that bears the sex organs.
4. The prothallus is monoecious and the sex organs lie almost wholly embedded in the tissue of the prothallus except the uppermost portion.
5. The antheridium is spherical with a single layer of jacket, containing within, a number of antherozoids or antherozoid mother cells. The antherozoids are fusiform and biciliate.

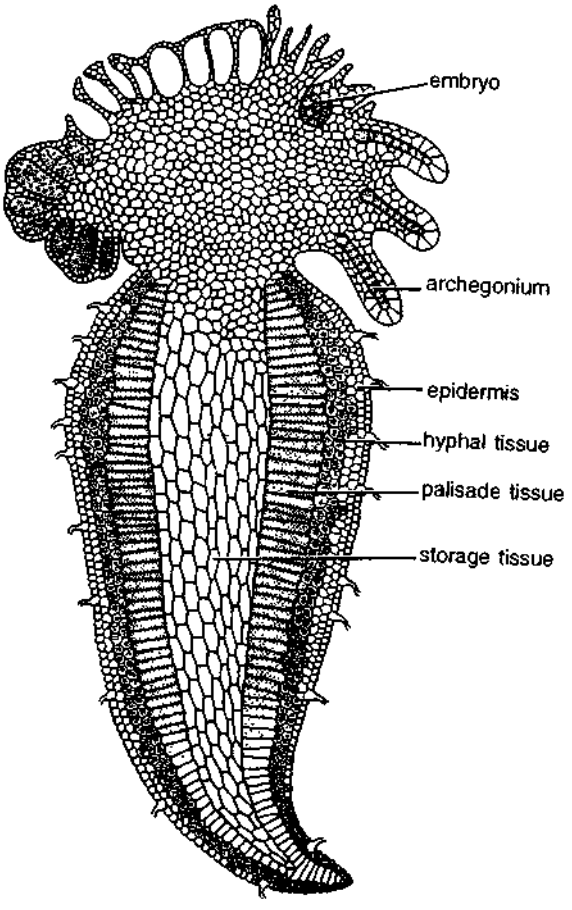


Fig. 8. ***Lycopodium.*** V.s. of mature gametophyte.

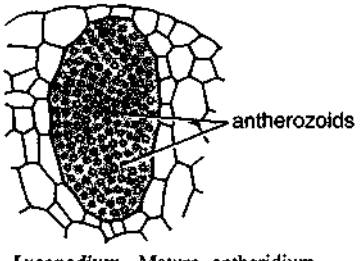


Fig. 9. ***Lycopodium.*** Mature antheridium.

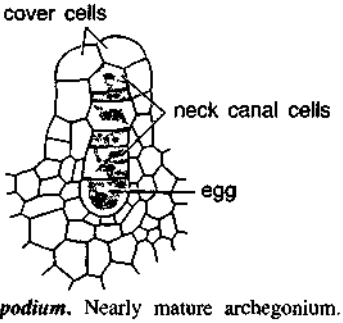


Fig. 10. ***Lycopodium.*** Nearly mature archegonium.

6. The archegonium is a narrow elongated structure. It has a narrow venter with an egg and venter canal cell and a long neck generally containing 4-6 neck canal cells.

Identification

Division—**Pteridophyta.** (1) Plant body differentiated into stem, roots and leaves, (2) A definite vascular strand present.

Sub-division—**Lycopsida.** (1) Laves microphyllous, (2) Sporangia borne singly on adaxial face of the sporophyll or in its axil, (3) Sporophylls borne in strobili.

Order—**Lycopodiales.** (1) Stem has protostele, (2) Sporophytes homosporous.

Family—**Lycopodiaceae.** (1) Leaves without ligules, (2) Sporophylls and foliage leaves may be similar or dissimilar in shape.

Genus—***Lycopodium.*** (1) The sporophyte is long and always more than 2 inches, (2) Sporangia kidney-shaped, (3) Stele either a plectostele or actinostele or haplostele.

Hints for Collection

Out of the 100 species of *Lycopodium* about 18 occur in India. These are found in Himalayan and sub-Himalayan tracts, Garhwal, Assam, Bengal and also in Nilgiris.

Selaginella (Small Club Moss)

Classification

Division	—	**Pteridophyta**
Sub-division	—	**Lycopsida**
Order	—	**Selaginellales**
Family	—	**Selaginellaceae**
Genus	—	***Selaginella***

Exercise 1

***Object* : Study the external features of the plant.**

Work procedure

Study the plant, specimen observe the differentiation of plant body into root, stem and leaves. Study the two types of leaves, their arrangement and structure. Also observe the structure of a ligule. Note the presence of rhizophore.

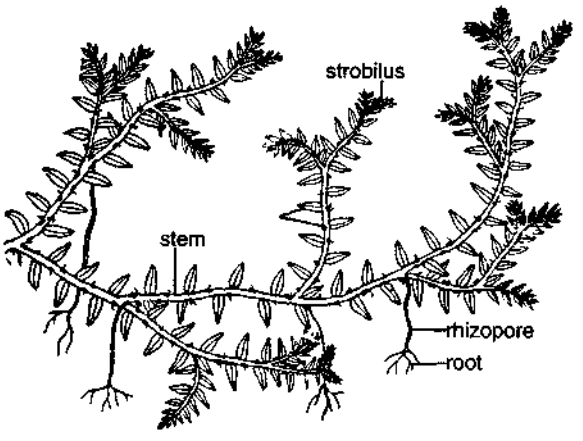


Fig. 1. ***Selaginella.*** External features.

Comments

1. Many species are prostrate, creeping on the ground e.g. *S. kraussiana*, others are sub-erect e.g. *S. trachyphylla* or erect e.g. *S. erythropus*. A few species climb with the help of rhizophores e.g. *S. alligans*.
2. The plant body is divided into root, stem and leaves.
3. The primary root is short lived and all other roots are adventitious.
4. On the basis of nature of stem and form of the leaves, the genus is sub-divided into two

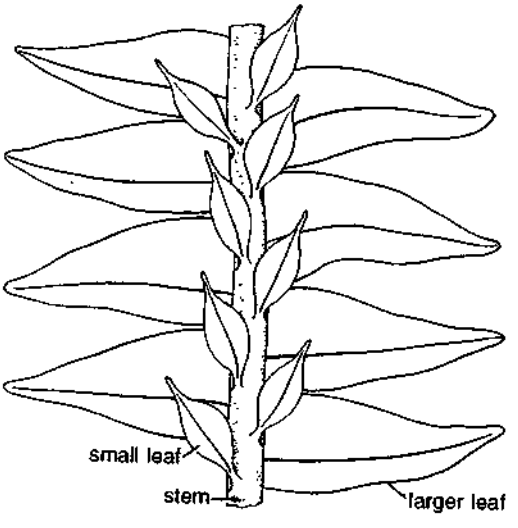


Fig. 2. ***Selaginella.*** A part of stem showing arrangement of leaves.

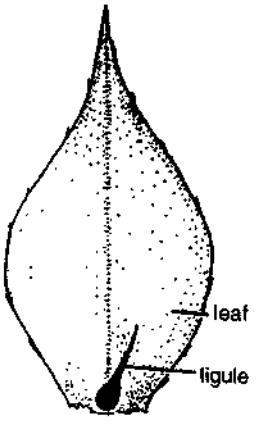


Fig. 3. ***Selaginella.*** Leaf (adaxial face showing ligule).

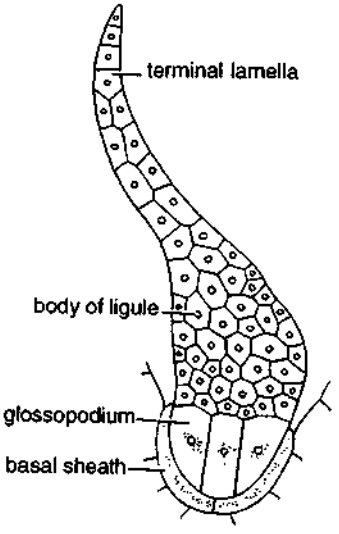


Fig. 4. ***Selaginella.*** A ligule.

sub-genera—the homoeophyllum and the heterophyllum.

5. In homoeophyllum species (*S. selaginoides*, *S. rupestris*, etc.) the stem is upright and all leaves are alike, while in heterophyllum species (majority of the species), the stem is prostrate and dorsiventral; and leaves are dimorphic (small and large).
6. In homoeophyllum, all the leaves are alike, spirally arranged, small and simple.
7. In heterophyllous species, they are dimorphic and are borne in pairs on dorsiventral stem. The two leaves are markedly different in size (one is larger and other smaller).
8. The smaller leaf of each pair is inserted on the dorsal side of the stem while the larger leaf is inserted on the ventral side.
9. The successive pairs of leaves are so arranged, that large leaf always alternates with the large leaf, and small leaf with the small leaf.
10. Each leaf is sessile, generally obovate with acute apex, and has a distinct midrib.
11. At the base of each young leaf, on the adaxial face, their is small tongue-like out growth, the ligule.
12. It is differentiated into basal sheath, glossopodium and the body of the ligule.
13. Whereas the cells of the sheath are tubular in shape and are dead, those of the glossopodium are vertically elongated.
14. The body of the ligule has parenchymatous cells with dense protoplasm.
15. From the point where stem branches, a cylindrical leafless organ is seen growing downward. This is known as rhizophore.
16. On reaching the ground, rhizophore terminates into roots (The morphological nature of the rhizophore is still open to question).
17. Certain vertical branches from the stem are reproductive in nature and bear strobili.

Features of special interest

1. Presence of rhizophore.
2. Dimorphic leaves (in heterophyllous species).
3. Presence of ligule.

Exercise 2

***Object* : To study anatomy of the root.**

Work procedure

Cut a T.s. of the root, stain in safranin-fast green combination, mount in glycerine and study.

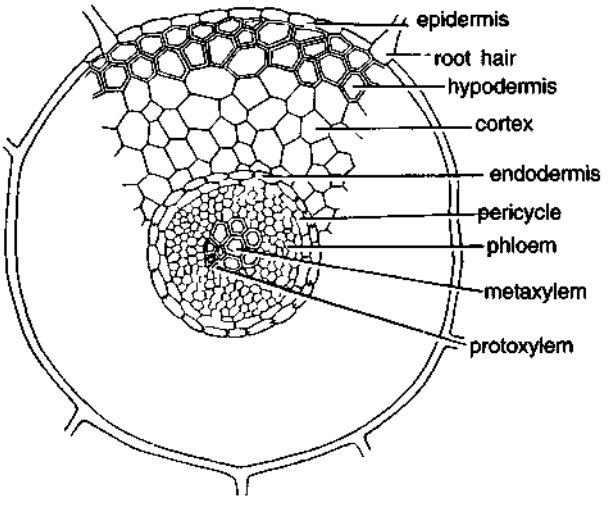


Fig. 5. ***Selaginella.*** T.s. root (a part cellular).

Comments

1. The section is almost circular in outline.
2. The tissues are differentiated into epidermis, cortex and stele.
3. **The epidermis** is single layered and its cells are tangentially elongated. Few of these cells give rise to the root hairs.
4. **Cortex** may either be made of parenchymatous (thin walled) cells or the outer layer of cells may form a sclerenchymatous (thick walled) hypodermis.
5. **The stele** lies in the centre. It is protostelic, monarch and exarch.
6. **Endodermis** is one layered and generally indistinct.
7. **Pericycle** is one to three layered.
8. **Xylem** forms only one group. Protoxylem is situated towards the periphery.
9. **Phloem** surrounds the centrally located xylem.

Exercise 3

***Object* : Study of anatomy of rhizophore.**

Work procedure

Cut a T.s. of the rhizophore, stain in safranin-fast green combination, mount in glycerine and study. Anatomically, the structure of the rhizophore is similar to that of root, with some minor differences, which occur on account of its environment.

Comments

1. The outline of the section is almost circular.
2. The section shows epidermis, hypodermis, cortex, endodermis and stele.
3. **The epidermis** is cuticularised.
4. **Hypodermis** that follows is 2-3 celled thick.
5. **Cortex** is few celled and parenchymatous. It occupies most of the part of section.
6. **Endodermis** is present between the stele and the cortex. It is followed by a single layered parenchymatous pericycle.
7. **The stele** is a protostele. It shows monarch and exarch condition. In some species (e.g. *S. atroviridis)* the metaxylem is lunar shaped and many protoxylem groups are situated on the concave adaxial side.

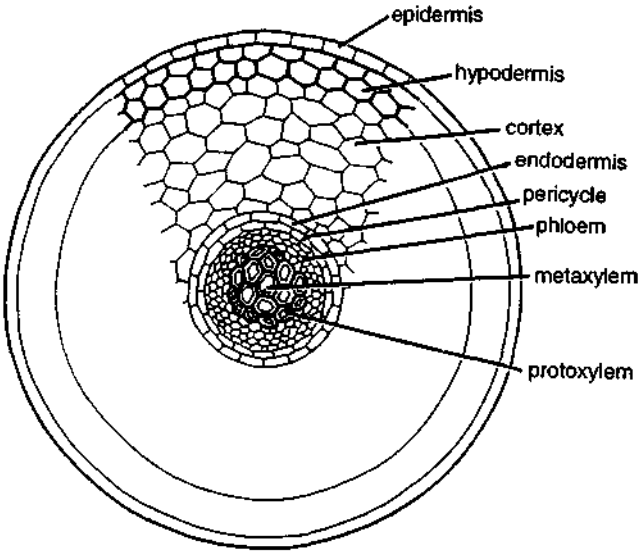


Fig. 6. ***Selaginella.*** T.s. rhizophore (a part cellular).

Exercise 4

***Object* : Study of anatomy of the stem.**

Work procedure

Cut a T.s. of the stem, stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. **The outline** of the section appears slightly wavy.
2. **The section** shows epidermis, cortex and the stele.
3. **Epidermis** is the outermost layer. It is cuticularised and lack stomata.
4. **The cortex** consists of parenchymatous cells, without any intercellular spaces. All the cells of the cortex are thin walled.
5. **Hypodermis** occurs close to epidermis. It develops from cells of outer cortex which become thick walled. In xerophytic, species (e.g. *S. rupestris*, *S. lepidophylla*) hypodermis is more thickened.
6. **The stele** is generally a protostele.
7. **Endodermis** separates vascular tissue from the cortical region, by radially elongated endodermal cells, called as trabeculae, with

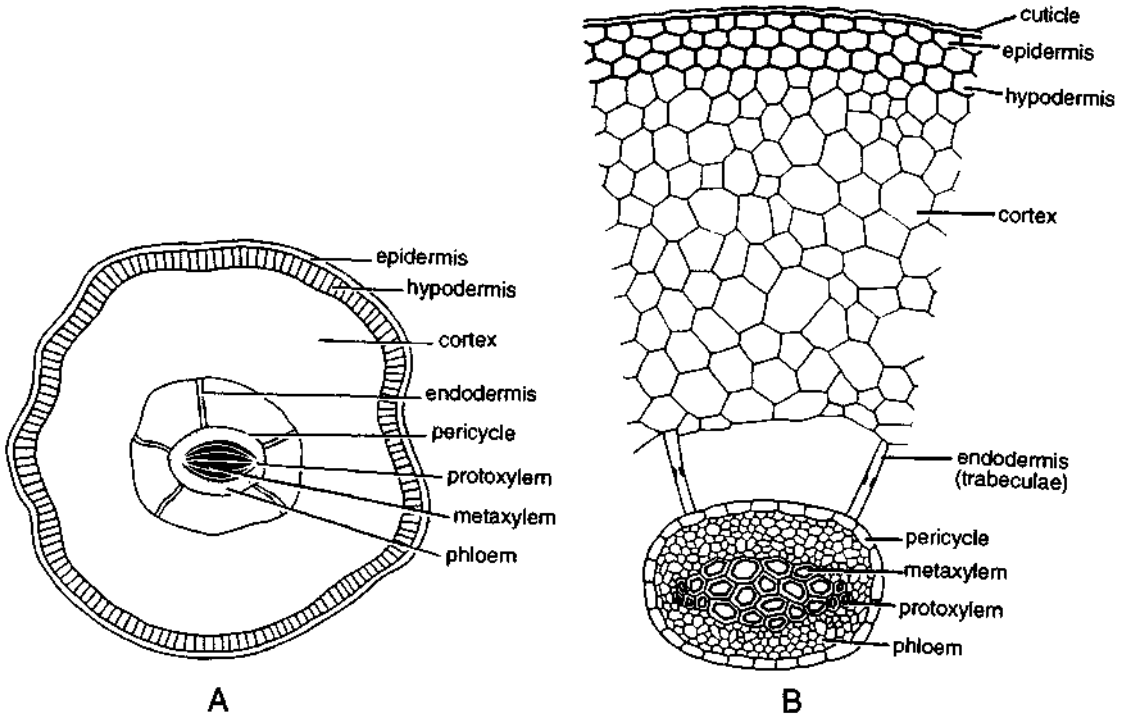


Fig. 7. ***Selaginella.*** T.s. stem **A.** Outline **B.** A part cellular.

conspicuous intercellular spaces between two trabeculae.

In spite of their great elongation, trabeculae still retain the transverse thickenings, the casparian strips, on their radial walls, characteristic of endodermal cells. Xerophytic species lack trabeculae (e.g. *S. lepidophylla* and *S. rupestris*).

8. **Pericycle** is a single layer surrounding the xylem and phloem and follows endodermis.
9. **Stele.** The number of steles in a stem varies from 1-16 thus exhibiting a polystelic condition.
10. Single stele, when present is generally diarch and exarch.
11. In *S. kraussiana,* the commonest species, there are two steles, each with a single exarch mass of protoxylem.
12. **The protoxylem** masses of the two steles point in opposite directions.
13. **The phloem** consists of smaller cells with dense protoplasm and completely surrounds the central core of xylem, in each stele.

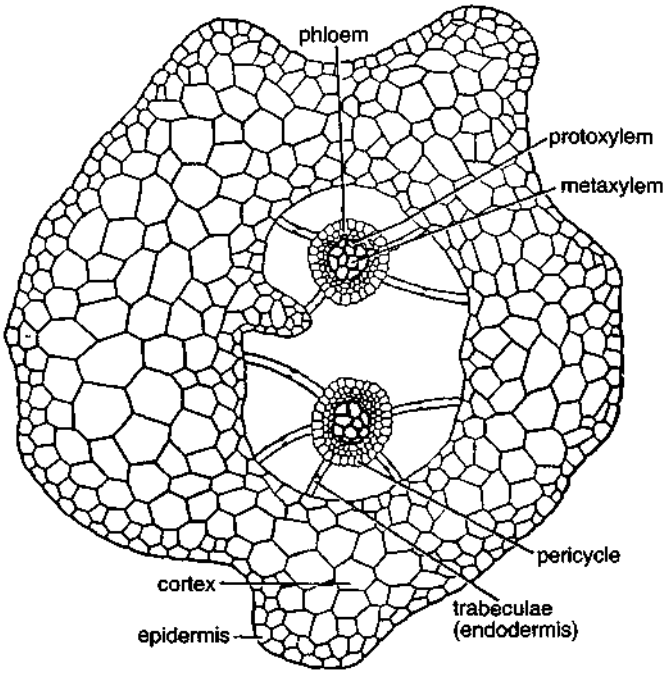


Fig. 8. ***Selaginella.*** T.s. stem—*S. kraussiana* (cellular).

Features of special interest

1. Presence of modified endodermis in the form of trabeculae.
2. Presence of more than one stele i.e. polystelic condition.

Exercise 5

***Object* : Study of anatomy of leaf.**

Work procedure

Cut a T.s. of leaf, stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. The section shows a slightly bulged midrib in the centre and the wings.
2. It shows definite upper and lower epidermis, usually undifferentiated mesophyll and a central vascular bundle.
3. **The epidermis** is one layered. The stomata are generally present on the abaxial surface (lower) but may also be present on the adaxial surface (upper), or on both the surfaces.
4. **The mesophyll** is usually not differentiated into palisade and spongy parenchyma. It shows many conspicuous intercellular spaces.
5. The cells of mesophyll contain chloroplasts, each of which has several pyrenoid-like bodies.
6. **The vascular bundle** is concentric with xylem surrounded by phloem and is bounded by a bundle sheath.

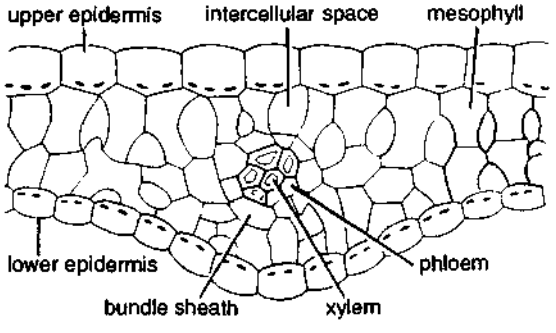


Fig. 9. ***Selaginella.*** **T.s. leaf (a part cellular).**

Exercise 6

***Object* : Study of spore producing organs.**

Work procedure

Study the external features of the strobilus. Cut L.s. of the strobilus, stain in safranin-fast green combination, mount in glycerine and study. (Alternatively study the slide of L.s. of the strobilus).

Comments

1. The spore producing organs are sporangia, aggregated in strobili which are generally present at the apices.
2. In some cases (as exemplified by *S. patula*) the axis may grow beyond the strobilus, terminating into a vegetative shoot or even in a second strobilus.
3. L.s. of the strobilus shows a strobilar axis, around which sporophylls are spirally arranged. Each sporophyll is ligulate and similar to a foliage leaf.
4. The sporangia are of two types, borne in the axils of the sporophylls, attached either strictly to the axils or to the axis just above.
5. *Selaginella* is heterosporous, with megaspores (large) and microspores (small), borne in their respective sporangia, known as megasporangia and microsporangia.

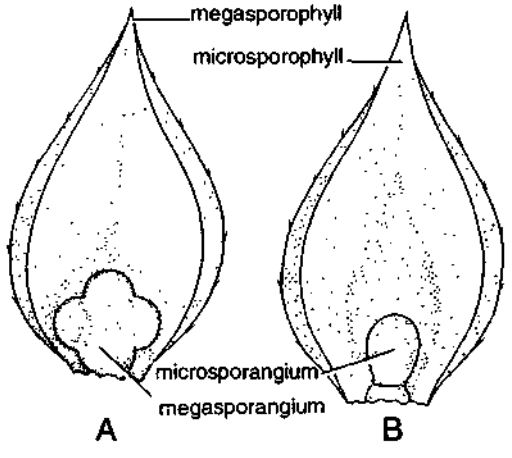


Fig. 10. ***Selaginella.*** **Adaxial views of sporophylls showing sporangia; A. Megasporophyll, B. Microsporophyll.**

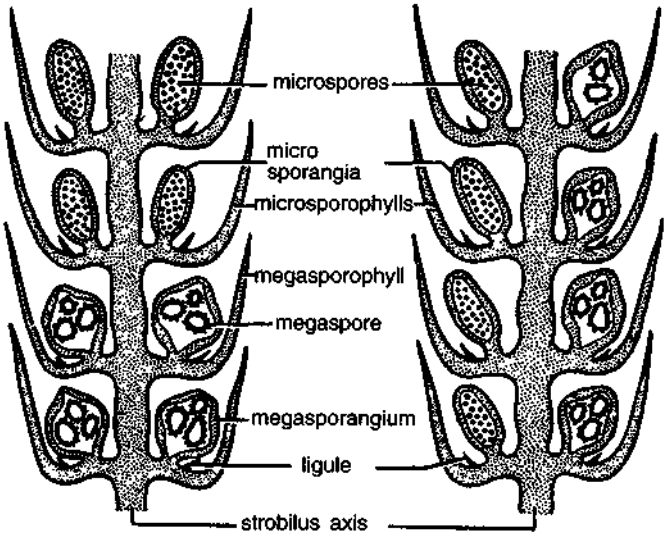


Fig. 11. ***Selaginella.*** L.s. strobilus showing different positions in which megasporangia and microsporangia occur.

6. If a microsporangium is borne in the axil of the sporophyll, it is known as a microsporophyll but if it is a megasporangium, the sporophyll is termed as a megasporophyll.
7. Generally strobilus bears both types of sporangia but in *S. gracilis*, there are only one type of sporangia (either mega-or micro sporangia).

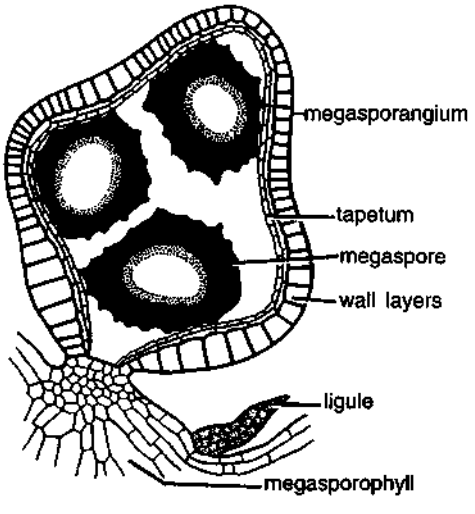


Fig. 12. ***Selaginella.*** L.s. megasporangium.

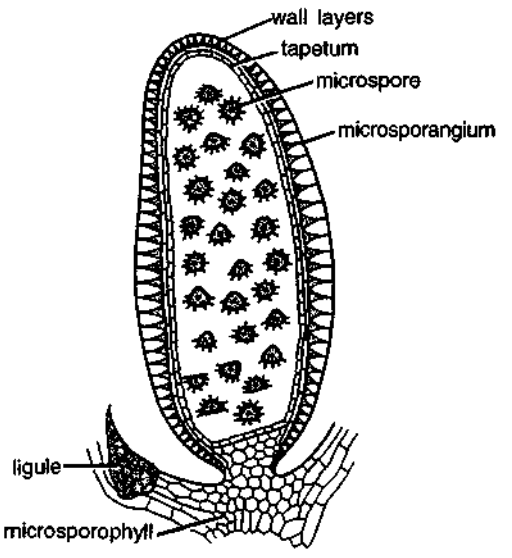


Fig. 13. ***Selaginella.*** L.s. microsporangium.

8. When both kinds of sporangia occur in one and the same strobilus, their arrangement differs from species to species:
   (i) In some species (e.g. *S. oregana*) there are only megasporangia on one side and only microsporangia on the other.

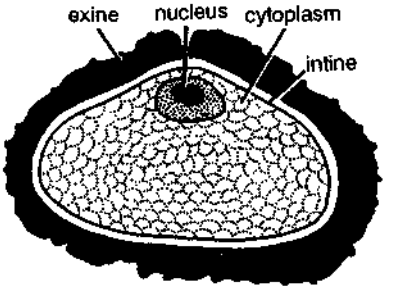


Fig. 14. ***Selaginella.*** A megaspore

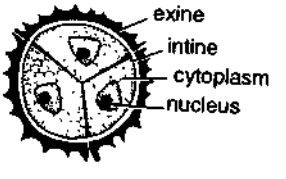


Fig. 15. ***Selaginella.*** Microspore tetrad.

(ii) In most of the species (e.g. *S. kraussiana*) there are only one or two megasporangia at the base and the rest are microsporangia.

9. Both types of sporangia are stalked and have two layered jackets. The outer layer of the jacket is chlorophyllous and has columnar cells, whereas the inner layer has tangentially elongated cells. It may form tapetum.
10. The cells of the outer jacket are thickened, except at the apex.
11. The two types of sporangia when ripe, differ in their size, form, structure and colour.
12. The megasporangium is much larger, four lobed, pale green or orange in colour and has only four megaspores.
13. The microsporangium is smaller with uniform outline. It is dark brown or red in colour and has many spores.
14. The megaspores are large in size and posses a triadiate ridge at its apex. It has thick sculptured exine and thin uniform intine.
15. The microspores are pyramidal in shape, and have thick, ornamented exine and a thin, uniform intine.
16. Both types of spores have a nucleus suspended in a rich cytoplasm.

Identification

Division—**Pteridophyta**. (1) Plant body differentiated into stem, roots and leaves, (2) A definite vascular strand present.

Sub-division—**Lycopsida**. (1) Leaves microphyllous, (2) Sporangia borne singly on the adaxial face of the sporophyll or in its axil, (3) Sporophylls borne in strobili.

Order—**Selaginellales**. (1) Each foliage leaf with a ligule at the base on adaxial side, (2) Sporophytes heterosporous.

Family—**Selaginellaceae**. (1) Stem herbaceous and dorsiventral or erect, (2) Gametophytes extremely reduced.

Genus—***Selaginella***. (1) Roots arise from rhizophore, (2) Trabeculae present, (3) Stele generally a protostele, sometimes siphonostele.

Hints for Collection

About 58 species of *Selaginella* have so far been reported from India. Many Indian species are found growing in western and eastern Himalayas and the hills of South India on damp shady sides. A few species are xerophytic. *S. oregana* is epiphyte on trunks and branches of moss covered trees in the forests.

Equisetum (Horse Tails)

Classification

Division	—	**Pteridophyta**
Sub-division	—	**Sphenopsida**
Order	—	**Equisetales**
Family	—	**Equisetaceae**
Genus	—	***Equisetum***

Exercise 1

***Object* : Study of external morphology.**

Work procedure

Study the external features of the plant. Observe the differentiation of plant body into roots, rhizome, aerial branches and leaves. Note the ribbed nature of the stem, its branching and the scaly leaves. Also see the difference between sterile and fertile branches.

Comments

1. The plants are erect and bushy.
2. The plant is differentiated into roots, rhizome, aerial branches and leaves.
3. **The underground rhizome** has distinct nodes and internodes. The nodes bear aerial branches and roots.
4. **The roots** are produced on the lower side of the node. These are slender and fibrous.
5. **The aerial stems** are less than a metre in height with characteristic joints. Stem is rough due to the deposition of silica.
6. **The aerial branches** fall into two general categories—(i) typical sterile branches which are green and branched, and (ii) typical fertile branches which are non-green, unbranched and terminate in a cone. Such branches die after the spores are shed.
7. Some species have green, branched fertile shoots, with a cone at the apex of each lateral branch. Such branches do not die after the spores are shed.
8. Organization of the rhizome and aerial branch is the same, but is best seen in aerial branches.

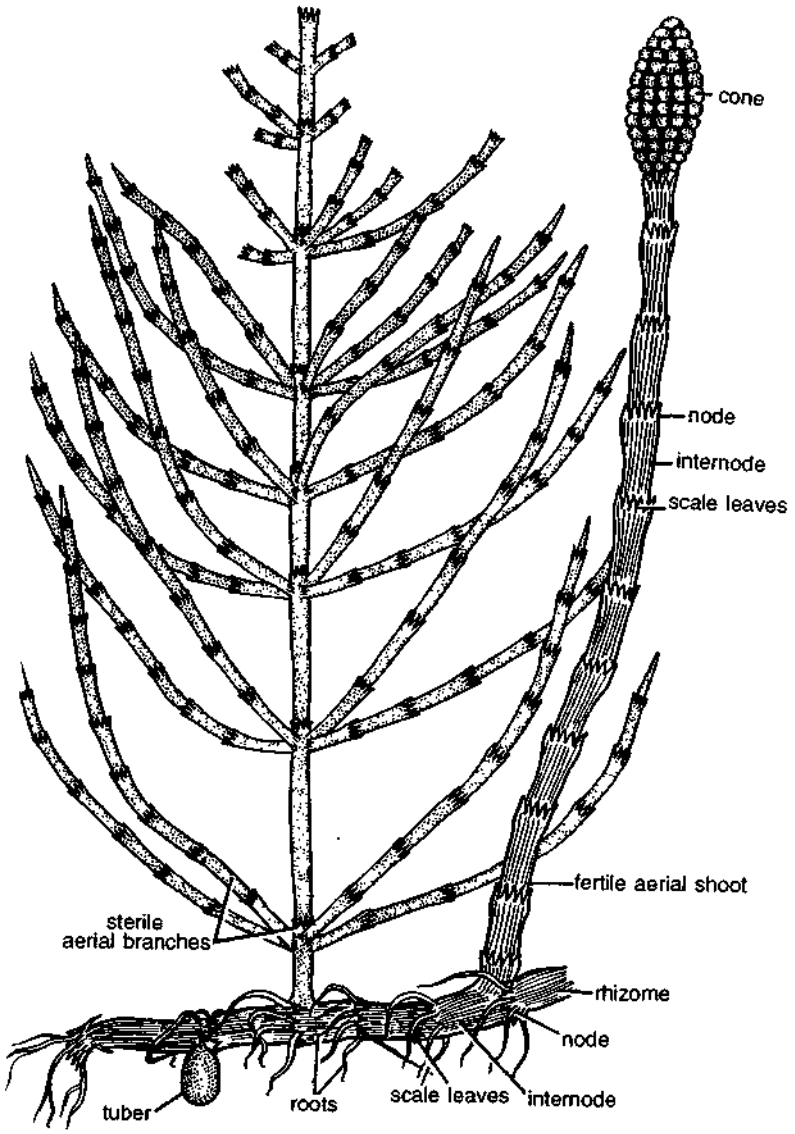


Fig. 1. ***Equisetum.*** External features.

9. **Each internode** of an aerial branch is longitudinally ribbed. The number of ridges is same as the number of leaves, and each leaf stands directly above a ridge present in the internodes below.
10. The ridges on the stem of successive internodes alternate, as also the leaves of the successive nodes.
11. **Leaves** are simple, small, scaly, whorled and fused laterally and possess longer or shorter free tips.
12. Leaves are present at nodes in whorls. Each whorl forms a sheath closely appressed to the node. The number of leaves in a whorl varies with the species and the size of the stem.
13. The leaves are non-chlorophyllous and scaly. These alternate at the successive nodes.
14. **The branches** develop at the node in between each two leaves. Therefore, the branches are equal in number to the leaves and appear to arise in a whorl.

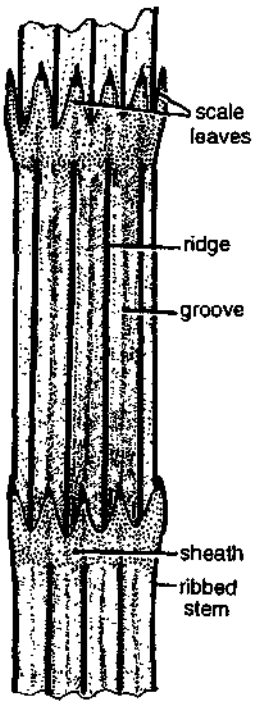


Fig. 2. ***Equisetum.*** A part of stem showing alternation of ridges and grooves and scale leaves.

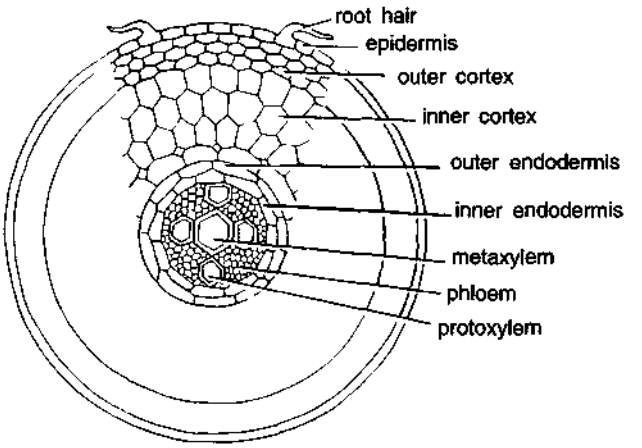


Fig. 3. ***Equisetum.*** T.s. root (a part cellular).

7. **The vascular bundle** shows a single, large metaxylem element in the centre with 3 to 4 protoxylem, triarch to tetrarch elements surrounding it. The number of protoxylem groups increases with increase in the diameter of the root.
8. The angles between the protoxylem are occupied by phloem.

Exercise 2

Object **: Study of anatomy of root.**

Work procedure

Cut a T.s. of the root, stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. The section appears almost circular in outline.
2. **Epidermis** is single layered and possesses a few root hairs.
3. **The cortex** is often divided into an outer cortex and an inner cortex.
4. **The outer cortex** is a few layered deep. It is made of thick walled cells.
5. **The inner cortex** is also a few layered deep. The cells are large sized and parenchymatous with intercellular spaces.
6. **Endodermis** separates from the vascular tissues. It is two layered—outer and inner endodermis. The pericycle is absent.

Exercise 3

Object **: Study of anatomy of internode of aerial shoot.**

Work procedure

Cut a T.s. of the aerial shoot passing through the internode, stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. The outline is wavy with ridges and grooves.
2. The tissues are organised into epidermis, cortex, stele and a pith cavity.
3. **The epidermis** is cuticularized with tangentially elongated and silicified cells.
4. **The stomata** are mostly found in the grooves. The guard cells are surrounded by two subsidiary cells, one on either side.
5. **Cortex** follows the epidermis and is highly differentiated. It is divided into outer and inner cortex.

6. **Outer cortex**, below the ridges has a group of sclerenchyma. Small patches of sclerenchyma may also occur, below the grooves.
7. Beneath the ridges radially elongated chlorenchymatous cells (palisade tissue) are present. The amount of palisade beneath the grooves is lesser.
8. **The inner cortex** is composed of large and thin-walled, parenchymatous cells.
9. **Vallecular canals** are present in the cortex. These are situated below the grooves.
10. **The stele** is an ectophloic siphonostele that consists of ring of vascular bundles.
11. **Endodermis** occurs at different positions in different species.
    (i) Most commonly, the endodermis forms a simple sheath, outside the ring of bundles.
    (ii) In some cases, in addition, there is also an internal endodermis and outer endodermis dips in between the bundles.
    (iii) In third condition, each bundle is surrounded by an individual endodermis.
12. **Pericycle** lies below the endodermis.
13. **The vascular bundles** are collateral and endarch, arranged in a ring and each bundle lies below each ridge.
14. Each bundle has one inner strand of protoxylem and two outer of metaxylem.

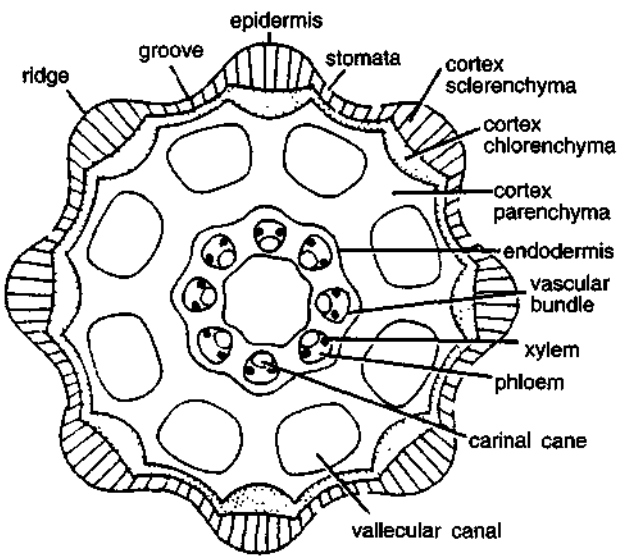


Fig. 4. ***Equisetum.*** T.s. aerial shoot : internode (diagrammatic).

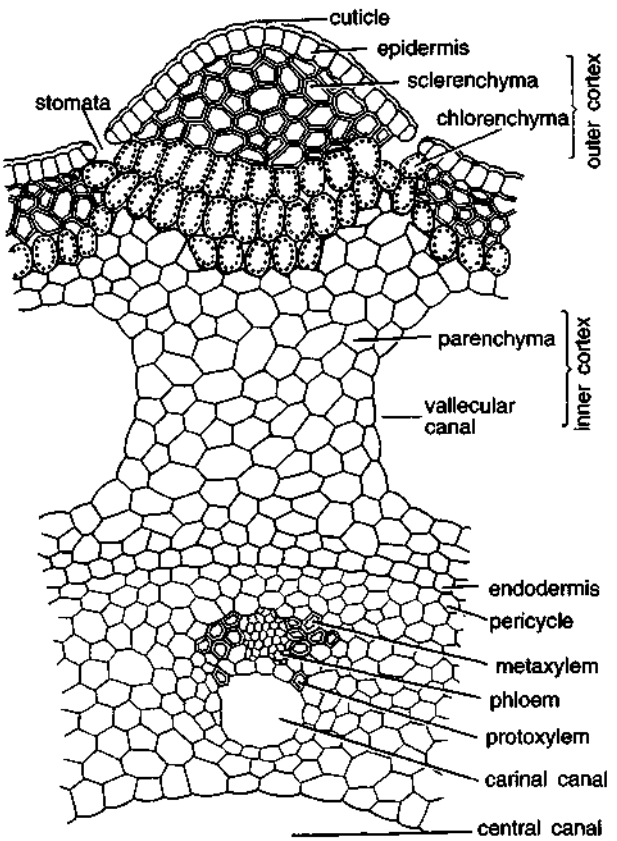


Fig. 5. ***Equisetum.*** T.s. aerial shoot : internode (a part cellular).

15. **The protoxylem** elements lie on the sides of a protoxylem lacuna, the carinal canal, formed by the disintegration of protoxylem elements.
16. **The two metaxylem** groups lie on two lateral sides of carinal canal (i.e. on the shoulders of the bundle).
17. The rest of the tissue of the vascular strands is parenchymatous.
18. Pith cavity known as central canal lies in centre.

Features of special interest

Anatomy shows both xerophytic as well as hydrophytic characters.

Xerophytic characters

(1) Presence of ridges and grooves.
(2) Position of stomata in grooves.
(3) Thick cuticle over epidermis.
(4) Well developed sclerenchyma below the ridges.
(5) Presence of palisade.

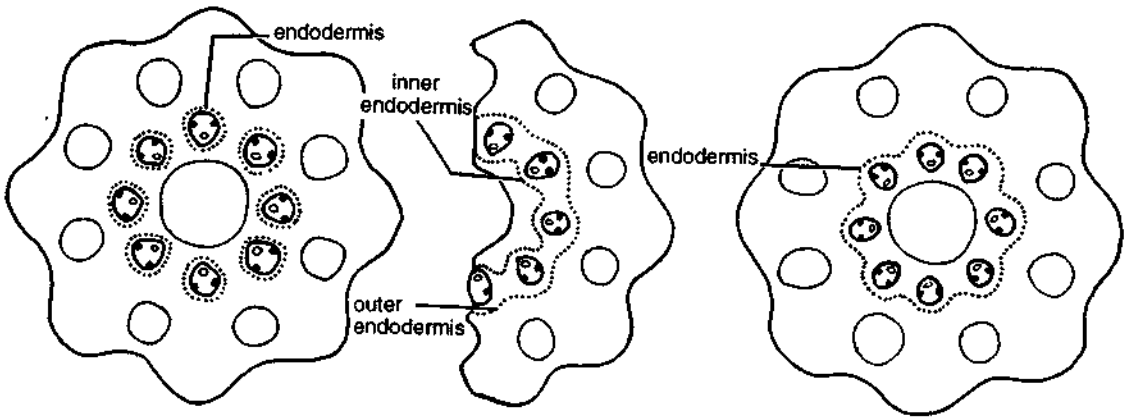


Fig. 6. ***Equisetum.*** T.s. aerial shoot : internode showing different conditions of endodermis.

Hydrophytic characters

(1) Presence of vallecular, carinal and central canals.

Exercise 4

***Object* : Study the anatomy of node of aerial shoot.**

Work procedure

Cut a T.s. of the aerial shoot passing through the node, stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. The section shows distinct ridges and grooves.
2. The anatomy is almost similar to that of internode except for a few differences.
3. The section shows epidermis, cortex, stele and nodal diaphragm instead of pith cavity in internode.
4. **The epidermis** is the outermost thickly cuticularised layer.
5. **The cortex** is divisible into outer, middle and inner cortex.
6. **The outer cortex** is sclerenchymatous. It is followed by middle cortex made of palisade (chlorenchyma) tissues.
7. **The inner cortex** is parenchymatous and occupies most part of the section.
8. **Vallecular canals** are absent. Many leaf traces and branch traces are found scattered all over the inner cortex.
9. **Vascular bundles.** Instead of ring there is a complete vascular cylinder with outer ring of phloem enclosing a ring of xylem.
10. **Leaf and branch traces** are given off from the vascular cylinder. Leaf traces arise beneath the ridges and do not produce leaf gaps in the vascular cylinder. Branch traces arise beneath the grooves.
11. **Nodal diaphragm**. In the centre there is parenchymatous or sclerenchymatous tissue. It is known as nodal diaphragm. In L.s. it appears like an arc. The internodes easily break and separate at these places.

Exercise 5

***Object* : Study of anatomy of rhizome.**

Work procedure

Cut a T.s. of rhizome, stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. The outline is wavy with ridges and grooves.
2. **Epidermis.** This is the outermost thickly cuticularised layer. Stomata are absent.
3. **The cortex** consists of a few layers of sclerenchyma just below the epidermis and a large zone of parenchyma spread upto the ring of vascular bundles.
4. **Large vallecular canals** are present in the parenchymatous cortex below the grooves.

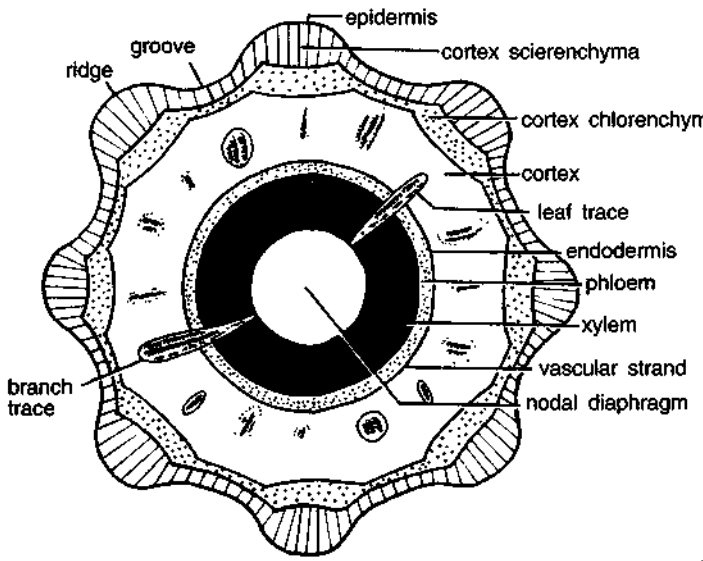


Fig. 7. ***Equisetum.*** T.s. aerial shoot : node (diagrammatic).

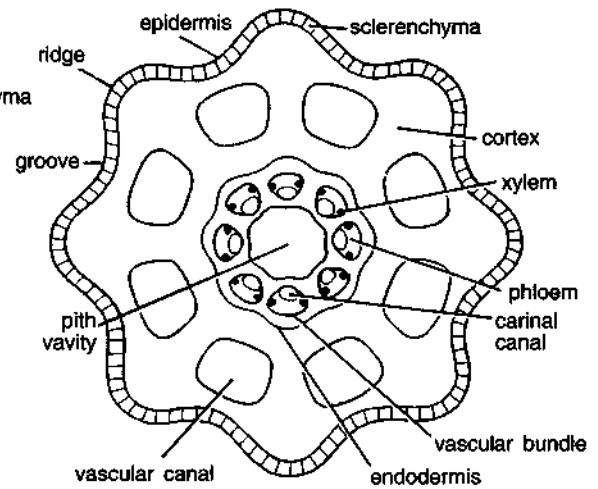


Fig. 8. ***Equisetum.*** T.s. rhizome : internode (diagrammatic).

5. **Endodermis** is single layered and encloses a ring of vascular bundles.
6. **Each bundle** is located below the ridge.
7. The bundle is conjoint, collateral and endarch.
8. The bundle has a large protoxylem lacuna, carinal canal.
9. **Pith cavity**. The centre has a large cavity, called pith cavity.

Exercise 6

Object **: Study of spore producing organs : L.s. cone.**

Work procedure

The spore producing organs are sporangia borne in cones, generally terminating the main axis and sometimes the lateral branches. The structure is best studied by observing L.s. of cone, single sporangiophore and spores. Study the features shown by respective slides.

Comments

1. L.s. of the cone shows cone axis and attached sporangiophores.
2. Cone axis is centrally located.
3. It bears sporangiophores in whorls which are mostly alternate though not regularly.

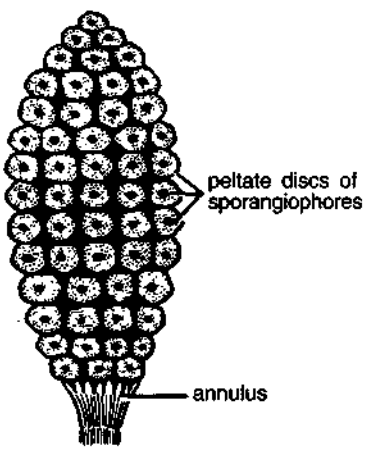


Fig. 9. ***Equisetum.*** A cone.

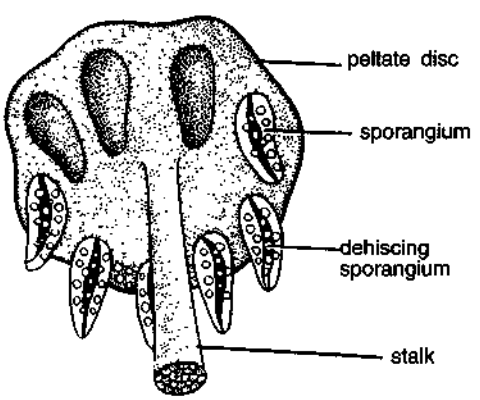


Fig. 10. ***Equisetum.*** Sporangiophore from ventral side.

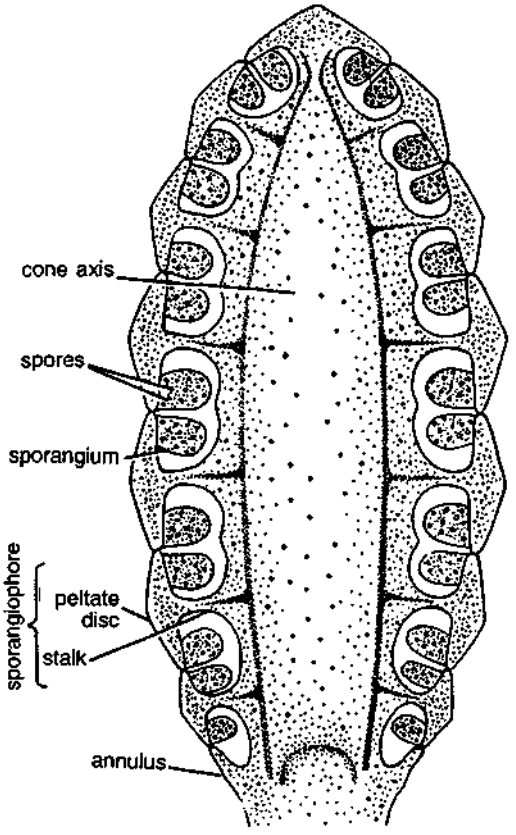


Fig. 11. ***Equisetum.*** L.s. cone

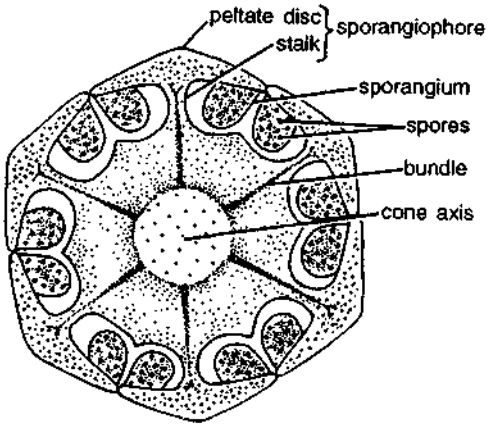


Fig. 12. ***Equisetum.*** T.s. cone.

4. At the base of the cone is a calyx-like whorl, the annulus (which most probably represents a modified leaf whorl).
5. The sporangiophores are attached to the cone axis at right angles with its stalk.
6. The stalk holds a polypogonal peltate disc at right angles to it. The peltate discs of sporangiophores fit closely to form a protective cover for the sporangia below.
7. Sporangia appear attached on the lower side of the disc.
8. Each sporangium is elongated and sac-like. It has one-layered jacket that encloses numerous spores.

Exercise 7

Object **: Study of spore producing organs : T.s. cone.**

Work procedure

Study the characters of the cone by observing various features as shown by the slide of T.s. cone.

Comments

1. T.s. of cone shows a cone axis and sporangiophores attached to it.
2. Centrally located part is called cone axis.
3. Sporangiophores are attached in a whorl.
4. Each sporangiophore consists of a stalk and a disc.
5. Stalk keeps the disc attached to cone axis.
6. The peltate disc bears sporangia on the underside, with one layered jacket which enclose the spores.
7. Each sporangium appears elongated and cylindrical.
8. Sporangiophore is one of the units, of which cone is made of.
9. These are attached to the central cone axis in successive whorls.
10. Each sporangiophore consists of a stalk and a polygonal peltate disc.
11. The stalk is attached to the cone axis on one side and to the peltate disc on the other.
12. About 5-10 cylindrical sporangia are arranged in a ring near the margins on the lower side of the disc.
13. Sporangium has a one layered jacket with helical thickenings.
14. Numerous spores, all similar (homosporous condition) are present in the sporangial cavity.
15. A longitudinal line of dehiscence is also clearly seen.

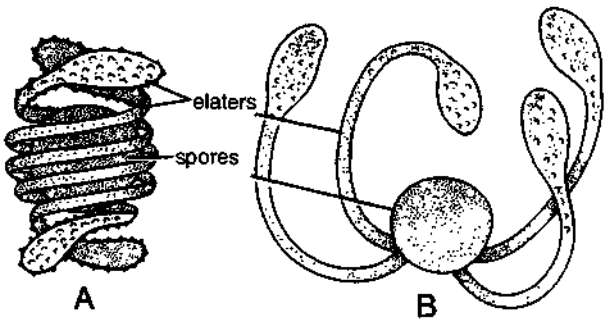


Fig. 13. ***Equisetum.*** Spores. **A.** Spore with elaters coiled, **B.** Spore with elaters uncoiled.

Exercise 8

Object **: Study of spores.**

Work procedure

Tease a sporangium with needle. Mount spores in water. These can also be stained with safranin and then studied.

Comments

1. The spores consist of a four layered wall.
2. Surrounding the two usual wall layers, there is a third cuticular layer known as the middle layer and a fourth, thick, outermost layer known as perispore.
3. The perispore of each spore is differentiated into four narrow spirally wound bands, with flat-spoon tips, all attached at the common point.
4. These projecting bands are called as "elaters", but are very different from the elaters of bryophyta.
5. The elaters are hygroscopic and with the changes in the atmospheric humidity, they coil and uncoil. (this can be observed under the microscope by allowing the wet spores to dry on a slide).
6. Each spore in a section shows a single nucleus with rich cytoplasm and all the four wall layers.

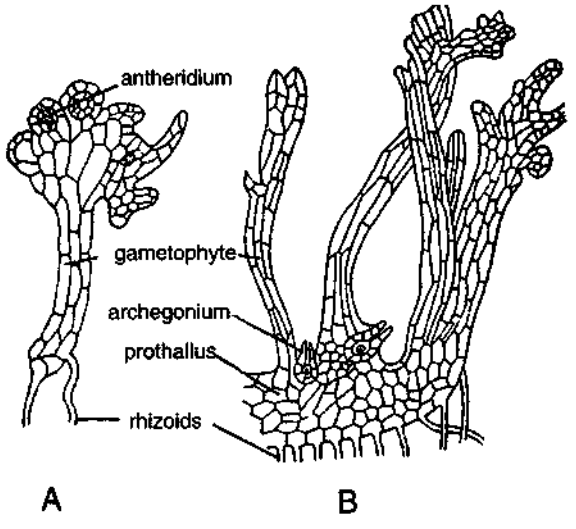


Fig. 14. ***Equisetum.*** Prothalli. **A.** Prothallus with antheridia, **B.** Prothallus with archegonia.

Exercise 9

Object **: Study of prothallus.**

Work procedure

Study a prepared slide of prothallus.

Comments

1. Both male (antheridia) and female (archegonia) sex organs are borne on the same prothallus. Thus it is monoecious.
2. In younger stages only antheridia are developed. Therefore, small and younger prothalli show antheridia only. In older prothalli, however, archegonia are found. Hence it is protandrous.
3. The multicellular central part gives out many flat branches. These branches further get irregularly dissected in uniseriate filaments.
4. From the central region, long, brown and unbranched rhizoids are also given off.
5. Archegonia remain embedded in the tissue of the prothallus, at the place where branches are given out.

6. Prothallus that bears antheridia, is less branched and smaller. Antheridia may arise at the base of the branch or on the branch itself.

Identification

Division—**Pteridophyta**. (1) Plant body differentiated into stem, roots and leaves, (2) A definite vascular strand present.
Sub-division—**Sphenopsida**. (1) Stem branched, articulated, ridged and furrowed with distinct nodes and internodes, (2) Leaves microphyllous, small, scaly and in whorls at nodes.
Order—**Equisetales**. (1) Stem branched. Branches borne in transverse whorls, (2) Internodes alternate with one another, (3) Vascular cylinder endarch, siphonostele.
Family—**Equisetaceae**. (1) Homosporous. (2) Sporangia borne on sporangiophores which form a compact cone, (3) No secondary growth.
Genus—***Equisetum***. (1) Leaves scaly and colourless, (2) Sunken stomata in grooves, (3) Presence of palisade in the stem, (4) Presence of valecular, carinal and central canals.

Hints for Collection

Equisetum debile which is common in India grows abundantly along the banks of rivers, in sandy soil and on the woods along the river. Another common species, *E. arvense,* grows in grasslands.

Adiantum (Maiden Hair Fern)

Classification

Division	—	**Pteridophyta**
Sub-division	—	**Pteropsida**
Class	—	**Leptosporangiatae**
Order	—	**Filicales**
Family	—	**Adiantaceae**
Genus	—	***Adiantum***

Exercise 1

***Object* : Study of external features of the plant.**

Work procedure

Study a fresh plant or a preserved specimen for external morphology. Observe the differentiation of plant body into roots, rhizome and leaves. Note the circinate vernation of young leaf, compound nature of mature leaf and reflexed margins of the leaflets.

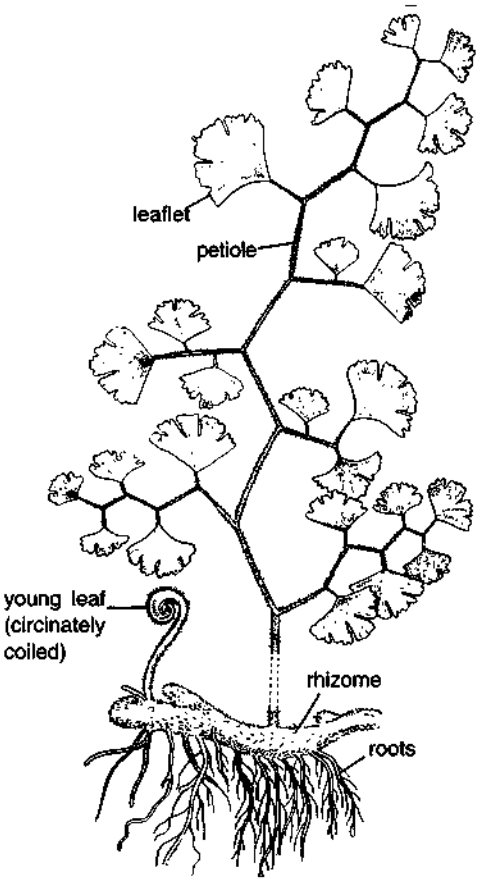


Fig. 1. ***Adiantum.*** External features.

Comments

1. **Plant body** is a sporophyte. It is differentiated into roots, rhizome and leaves.
2. **Roots** are produced on the lower side of the rhizome. Primary root is short-lived. Secondary roots are adventitious and branched.
3. **Rhizome** may either be creeping or erect. It is scaly, covered with hairs and bears adventitious roots and leaves.
4. **Leaves** with a long petiole, are spirally or alternately arranged on the rhizome. Young leaves are circinately coiled. Young rhizome, petiole, rachis and circinately coiled leaves are covered with hairs known as ramenta.
5. The leaves are compound and are borne on shining black and brittle petiole.

6. Leaves are often dichotomously branched into many leaflets.
7. The blade of the leaflets may be entire, and either simply or repeatedly branched. The leaflets are deltoid in shape. When fertile, the leaflet margin remains folded toward the lower side forming a false indusium which encloses many sori.
8. **Leaflet** is traversed by dichotomously branched veins which generally do not unite to form a reticulum. The venation is, therefore, of open dichotomous type.

Exercise 2

***Object* : Study of anatomy of root.**

Work procedure

Cut a T.s. of the root, stain with safranin-fast green combination, mount in glycerine and study.

Comments

1. The root is almost circular in outline.
2. It is differentiated into epidermis, cortex and stele.
3. **The epidermis** is single layered, cells are thin walled and tangentially elongated. It bears a few unicellular root hairs.
4. **Cortex** is inner to the epidermis. It is multilayered and parenchymatous.

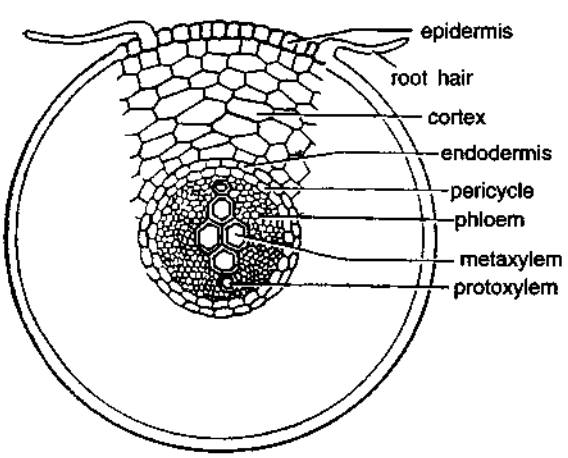


Fig. 2. ***Adiantum.*** T.s. root (a part cellular).

5. **Endodermis** is single layered and is followed by a single layered pericycle.
6. **A protostele** is present in the centre. It is diarch and exarch.
7. **Xylem** elements occur in the centre. Of these, metaxylem elements are present in the centre. Protoxylem groups are situated on the two opposite sides of the metaxylem (Thus xylem groups are exarch and diarch).
8. **Phloem** surrounds the xylem on all the sides.

Exercise 3

***Object* : Study of anatomy of rhizome.**

Work procedure

Cut a T.s. of rhizome, stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. Rhizome appears almost circular or gutter-shaped in a transection.
2. It shows differentiation into epidermis, hypodermis, ground tissue and stele.
3. **Epidermis** is single layered and bears numerous multicellular hairs.
4. **Hypodermis** that follows epidermis is a 2-3 layered deep and sclerenchymatous.
5. **Ground tissue** occupies major part of rhizome. It is parenchymatous and many layered deep.

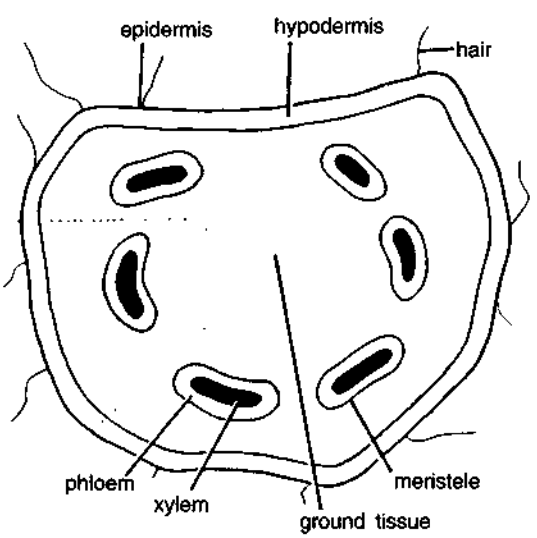


Fig. 3. ***Adiantum.*** T.s. rhizome (outlines : diagrammatic).

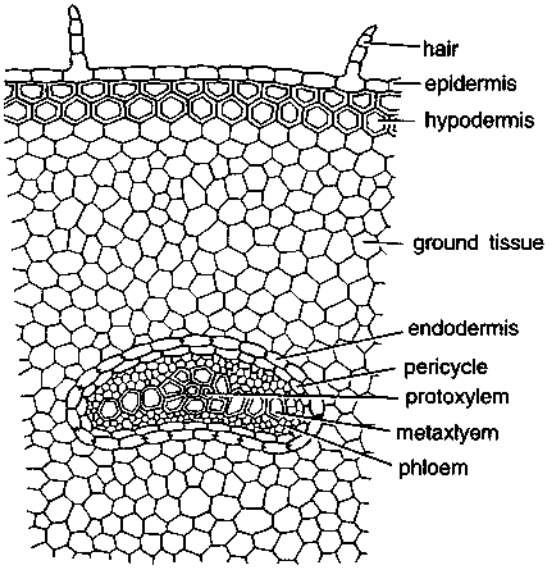


Fig. 4. ***Adiantum.*** T.s. rhizome (part shown by dotted lines in Fig. 3 : cellular).

6. **Stele** is variable in nature, differing from one region to another. Species with elongated rhizome (*A. pedatum and A. hispidulum*) show actual solenostele (amphiphloic siphonostele). But commonly the stele is gutter shaped and appears as several meristeles arranged in a ring, due to numerous leaf gaps (dictyostele).
7. **Meristeles** varying in number, but more often 5-7, lie arranged in ground tissue in a gutter-shaped ring, thus exhibiting dictyostelic condition. The spaces between neighbouring meristeles are leaf gaps.
8. Each of the meristeles is surrounded by a distinct, single-layered endodermis subsequently followed by a single layered pericycle.
9. **Xylem** elements occupy the central part. Metaxylem and protoxylem are arranged in a way to form mostly mesarch condition.
10. **Phloem** surrounds xylem.

Exercise 4

***Object* : Study of anatomy of rachis.**

Work procedure

Cut a T.s. of rachis, stain with safranin-fast green combination, mount in glycerine and study.

Comments

1. Tissues of the rachis are differentiated into epidermis, hypodermis, cortex and stele.
2. **Epidermis** is a single layer of cells, covered by a cuticle.
3. **Hypodermis** follows the epidermis. It is few layered deep. The cells are sclerenchymatous.
4. **Cortex** forms larger part of the rachis. It is made of many layers of parenchyma.

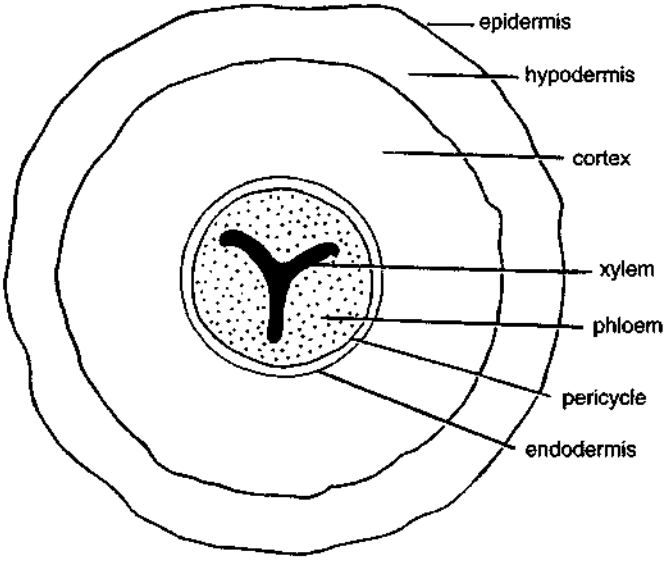


Fig. 5. ***Adiantum.*** T.s. rachis (outlines : diagrammatic).

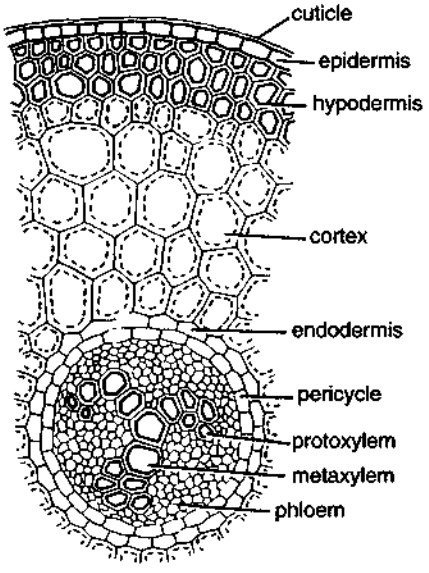


Fig. 6. ***Adiantum.*** T.s. rachis (a part cellular).

5. **Stele** is a protostele.
6. **Endodermis** is single layered and is followed by a pericycle.
7. **The xylem** group is almost Y-shaped. Protoxylem elements are situated at the tips of three free ends; while the rest of the part is occupied by metaxylem.
8. **Phloem** surrounds the xylem on all the sides.

Exercise 5

***Object* : Study of anatomy of leaflet.**

Work procedure

Cut a T.s. of leaflet by keeping a leaf in pith. Stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. Leaflet is differentiated into upper and lower epidermis, mesophyll, sclerenchyma and vascular bundle.
2. **Epidermis.** The cells of the upper and lower epidermis possess chloroplast. The lower epidermis is frequently interrupted by stomata.
3. **Chloroenchyma.** Just above the lower epidermis lies a single layer of compactly arranged cells containing numerous chloroplasts.
4. **Mesophyll.** Following this compact layer, mesophyll tissue extends up to the upper epidermis. It is undifferentiated into palisade and spongy parenchyma but is composed of loosely arranged spongy parenchyma only.
5. **Vascular bundle.** Each vascular bundle is surrounded by a thick sclerenchymatous sheath.
6. **Endodermis.** Surrounding the vascular bundle is endodermis followed by a pericycle.
7. **Xylem.** Centrally located xylem has protoxylem groups, facing towards the adaxial surface of the leaf.
8. **Phloem** surrounds xylem.

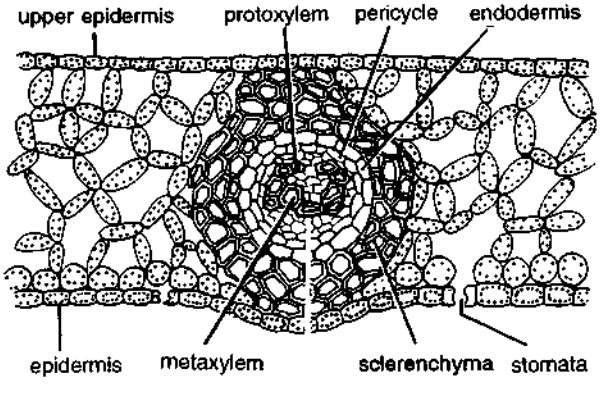


Fig. 7. ***Adiantum.*** T.s. leaflet (part cellular).

Exercise 6

***Object* : Study of structure of sorus.**

Work procedure

Since the sori are present on the lower reflexed side of the leaflet, sections of this part are cut to study the arrangement and structure of sorus. The sections are stained in safranin-fast green combination, mounted in glycerine and studied.

Comments

1. The spore producing organs are the sporangia grouped in sori. Each sorus is mixed in nature and shows sporangia of different ages.
2. Sori are present, along both the sides of the veins, on the dorsal side of the marginal reflexed lobe. This part remains folded towards the lower side and acts as a false indusium which is membranous and brown coloured.
3. Lower part of each leaflet shows many such reflexed lobes along its margins. The reflexed part is traversed by veins in continuation with those in the unfolded part.

To study the relation of the folded part with the unfolded, cut a L.s. of leaflet in folded condition.

1. It shows the upper part of the leaflet possessing vascular bundles cut longitudinally and the reflexed or folded margin on its lower side.
2. This reflexed part is a portion of the leaflet and bears sporangia in sori, thus forming a false indusium.
3. Many sporangia are seen arranged in groups.
4. Sporangia are attached to the indusium by their long slender stalks.

To study the relation between veins, sori and sporangia with indusium, unfold the reflexed lobe and cut its T.s.

1. Reflexed lobe of leaflet covers sori and is called false indusium.

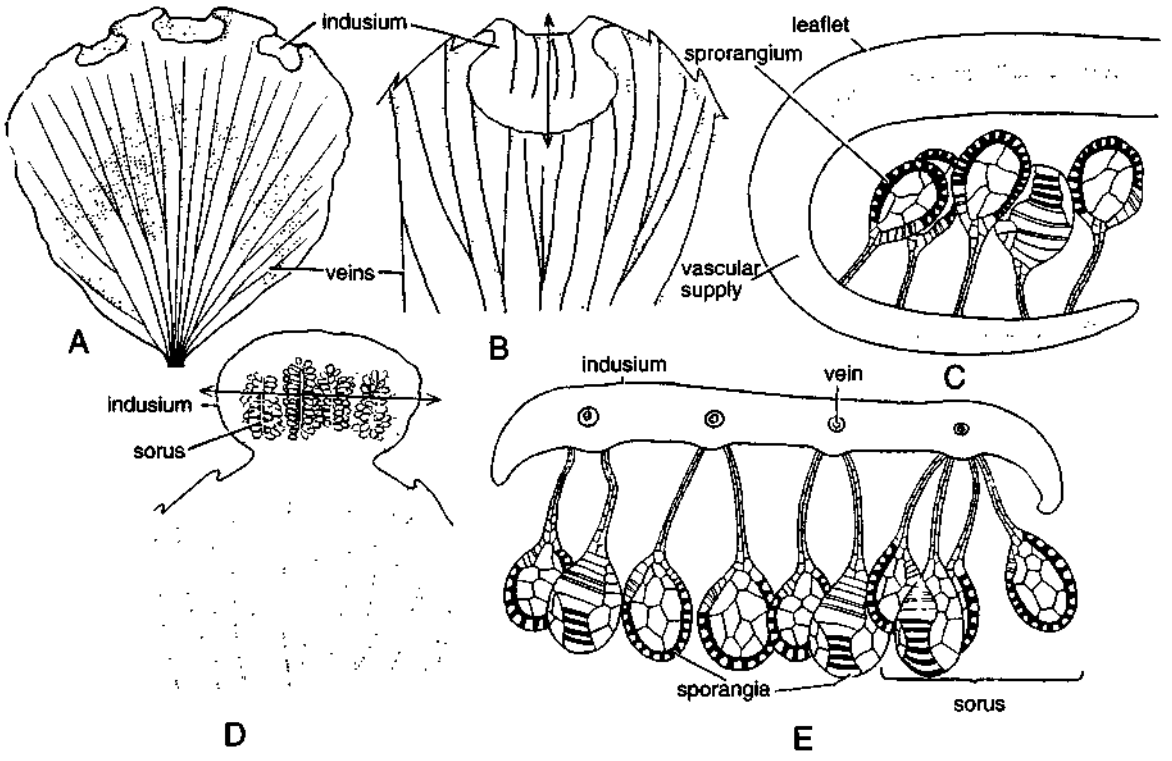


Fig. 8. ***Adiantum.*** **A.** Surface view of leaflet showing reflexed margin (indusium) and venation. **B.** Magnified portion of leaflet showing single reflexed lobe (indusium). **C.** L.s. leaflet through indusium (plane shown by arrow in Fig. B) **D.** Unfolded reflexed lobe (indusium) showing sori on both the sides of vein. **E.** T.s. through indusium (plane shown by arrow in Fig. D).

2. Veins traverse the indusium but do not form reticulum (open dichotomous venation).
3. Along both the sides of each vein are many sporangia, attached by their long and slender stalks. This group of sporangia is called a sorus and many such sori are situated along each of the veins.

Exercise 7

Object **: Study of structure of a sporangium and a spore.**

Work procedure

Study the preparation of section of leaflet showing sori or unfold the reflexed lobe of a leaflet, tease out a few sporangia, also crush open a few of these sporangia to release spores. Stain with safranin, mount in glycerine and study.

Comments

1. Each sporangium is attached to the indusium by a slender, long and multicellular stalk.
2. The sporangium (capsule) is oblong in shape and borne at the tip of the stalk.
3. The wall of the sporangium is made of thin-walled cells.
4. Some cells of this wall lying in a vertical row are characteristically thickened on their radial and inner tangential walls. These together are called as annulus.
5. On one side of the annulus are a few (2-3) thin walled cells forming a stomium wherefrom dehiscence of the sporangium takes place.
6. The wall encloses many spores inside.
7. Each spore is a double walled structure. The outer layer is exine which is thick and ornamented. The inner layer, called intine, is thin and smooth.

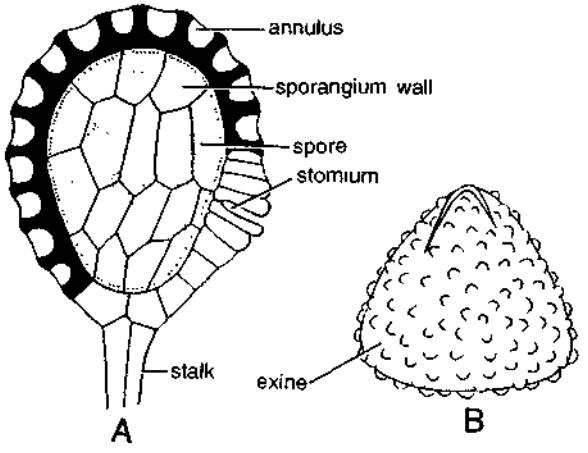


Fig. 9. ***Adiantum.*** **A.** A sporangium. **B.** A single spore.

8. It has a single big nucleus, surrounded by cytoplasm.

Exercise 8

Object **: Study of structure of prothallus.**

Work procedure

Mount young prothallus, stain in fast green, mount in glycerine and study.

Comments

1. It is formed after the germination of a spore and is thus a gametophytic structure.
2. It is leafy and heart-shaped.
3. It consists of a single layer of cells, one cell in thickness, except in the central region where apical notch is situated.
4. Many unicellular rhizoids are given out from the ventral surface.
5. Antheridia are located in the posterior part of prothallus away from the apical notch.
6. Archegonia lie near the apical notch, on the thickened, central apical cushion.
7. Parts of antheridia and necks of archegonia protrude outside the general surface of the prothallus.
8. All the cells of the prothallus are thin walled and bear many discoid chloroplasts.

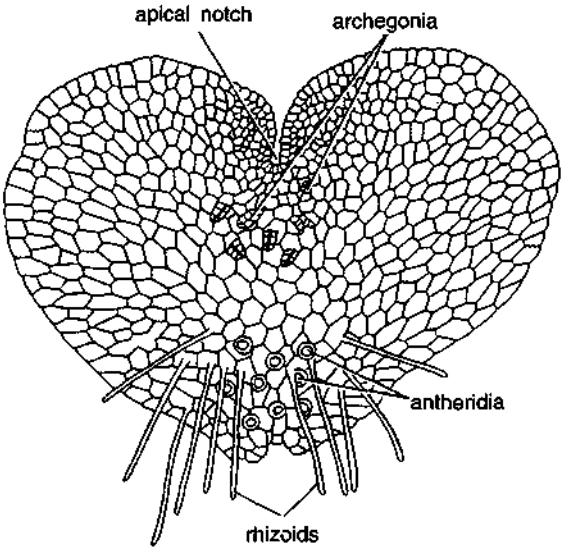


Fig. 10. ***Adiantum.*** Prothallus bearing young leafy sporophyte.

Exercise 9

Object **: Study of old prothallus with sporophyte.**

Work procedure

Mount an old prothallus that bears a sporophyte stain in fast green and mount in glycerine.

Comments

1. Sporophyte is formed as result of fertilization.
2. Gametophyte (prothallus) still persists.
3. Young sporophyte is differentiated into young leaves, primary root and secondary roots.
4. Leaves stand erect and appear near the apical notch. They are simpler than the mature leaves. They may also be circinately coiled.
5. Primary root grows on the lower side and gives out secondary roots.

Identification

Division—**Pteridophyta**. (1) Plant body differentiated into stem, roots and leaves, (2) A definite vascular strand present.

Sub-division—**Pteropsida**. (1) Vascular cylinder siphonostelic, with leaf gaps, (2) Plants macrophyllous, leaves compound, with rachis, (3) Leaves bear sporangia in sori, (4) Gametophytes small, green and free living.

Class—**Leptosporangiatae**. (1) Sporangium with a jacket layer one cell in thickness, (2) Definite number of spores.
Order—**Filicales**. (1) Sori are mixed, (2) Homosporous.
Family—**Adiantaceae**. (1) Sori marginal, (2) Indusium oblong or linear, formed of the more of less changed and reflexed margin of the frond. opening inwardly.
Genus—***Adiantum***. (1) Sori apparently marginal, but superficial in origin, (2) Indusia globose to linear, usually many and distinct, (3) Leaflet margins bearing sori are sharply reflexed, (4) Open dichotomous venation of the leaflet.

Hints for Collection

Adiantum is very common in hills, lower slopes of the hills and in the plains. In hills it is commonly seen in dense evergreen forests and also on limestone rocks. In plains, it can easily be collected from moist places such as banks of rivers, etc. It is also seen growing on the inner walls of the wells.

Nephrolepis (Sword Fern)

Classification

Division	—	**Pteridophyta**
Sub-division	—	**Pteropsida**
Class	—	**Leptosporangiatae**
Order	—	**Filicales**
Family	—	**Polypodiaceae**
Genus	—	***Nephrolepis***

Exercise 1

Object : **Study of external morphology.**

Work procedure

Study the characters of roots, rhizome and leaves of a potted plant or a museum specimen.

Comments

1. The plant body is a sporophyte. It is differentiated into roots, rhizome and leaves.
2. The rhizome gives out adventitious roots from its underside. These adventitious roots are small and branched.
3. The stem is modified to rhizome. It is subterranean, short and erect. The rhizome produces elongated slender stolons. Peltate scales cover the rhizome.
4. In *N. tuberosa*, rhizome bears tubers. These are reservoirs of carbohydrates and water.
5. The leaves are long, narrow, sub-coriaceous and unipinnate.
6. The pinnae are sessile or shortly petioled. They have a usually rounded or cordate base. Each pinna has articulation with a pouch-like structure at the base.
7. The veins are prominent and the veinlets are branched with open ends. The tips of veinlets are gland dotted and they extend up to the margins.

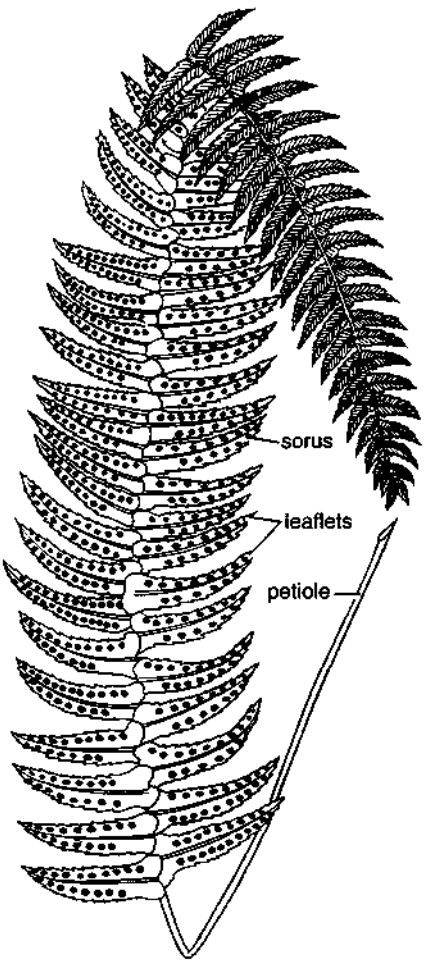


Fig. 1. ***Nephrolepis***. External morphology.

Exercise 2

***Object* : Study of anatomy of the root.**

Work procedure

Cut a thin transverse section of the root. Stain with safranin-fast green combination. Mount in glycerine and study.

Comments

1. **The outline** of the section is almost circular.
2. The tissues are differentiated into—epiblema, cortex and the vascular cylinder.
3. **Epiblema** is the outermost single layer of cells. The cells are unicellular and thin walled. A few root hairs are produced by this layer.
4. **Cortex** forms the major part of the section. It shows outer parenchymatous region and the inner small sclerenchymatous region.
5. **Endodermis** follows the cortex and separates it from the vascular tissues. The cells of endodermis show casparian strips.
6. **Pericycle.** Endodermis is followed by 1 or 2 layered parenchymatous pericycle.
7. **Vascular cylinder** is represented by a radial, diarch and exarch vascular bundle.

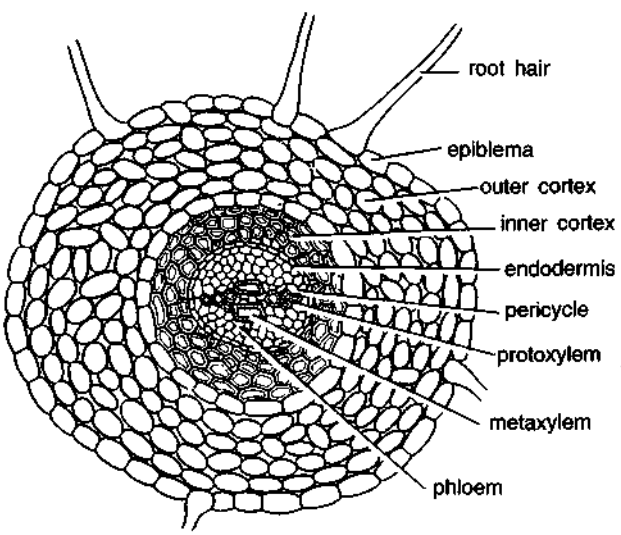


Fig. 2. ***Nephrolepis.*** T.s. root (diagrammatic).

Exercise 3

***Object* : Study of anatomy of rhizome.**

Work procedure

Cut a thin transverse section of rhizome, stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. **The outline** of the section is almost biconvex.
2. The section can be divided into epidermis, hypodermis, ground tissue and the stele.
3. **Epidermis** is the outermost single layer of thickly cuticularised cells.
4. **Hypodermis** that follows epidermis is made of a few sclerenchymatous layers.
5. **Ground tissue.** Rest of the tissue is called ground tissue. It is parenchymatous with numerous starch grains in the cells.
6. **Stele.** The structure of the stele varies with the age of the rhizome.
   (i) In youngest part of rhizome, it is protostele.
   (ii) In a few weeks old plant with a few leaves, the rhizome shows ectophloic siphonostele.
   (iii) The old part of rhizome shows a dictyostele.
7. **Dictyostele** is made of two rings of meristeles, separated by two sclerenchymatous bands.
8. **Meristele** has its own endodermis and pericycle. The centre is occupied with xylem which is completely surrounded by phloem on all its sides.

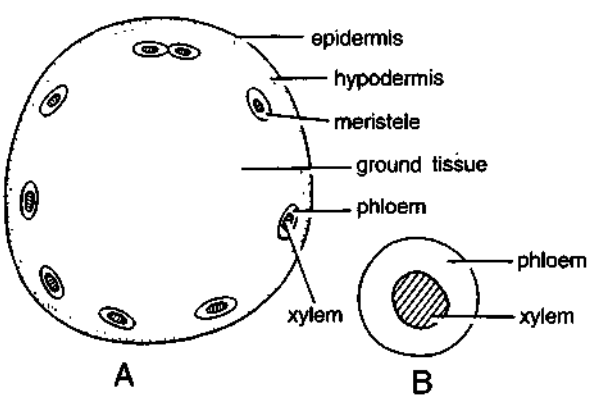


Fig. 3. ***Nephrolepis.*** T.s. rhizome (diagrammatic).

Exercise 4

***Object* : Study of anatomy of rachis.**

Work procedure

Cut a thin and uniform transverse section of the rachis, stain with safranin-fast green combination, mount in glycerine and study.

Comments

1. The section appears horse-shoe shaped.
2. It shows epidermis, hypodermis, ground tissue and the stele.
3. **Epidermis** is made of single layer of thickly cuticularised cells.
4. **Hypodermis** lies below the epidermis. The cells are sclerenchymatous.
5. **Ground tissue.** The rest of the parenchymatous region extending throughout the section is called ground tissue.
6. **Stele.** In the ground tissue is situated U-shaped or horse-shoe shaped stele.
7. **Endodermis.** The stele is surrounded by a single layered endodermis followed by a few layered pericycle.
8. **Xylem and phloem.** Centrally located xylem is surrounded by phloem on all sides.
9. **The structure of the stele** differs at various levels of rachis—
   (i) In younger parts, there is a single U-shaped stele.
   (ii) Little above the base, the U-breaks at the bottom, thereby producing two steles.
   (iii) In mature parts, dissection of the stele results in many meristeles.

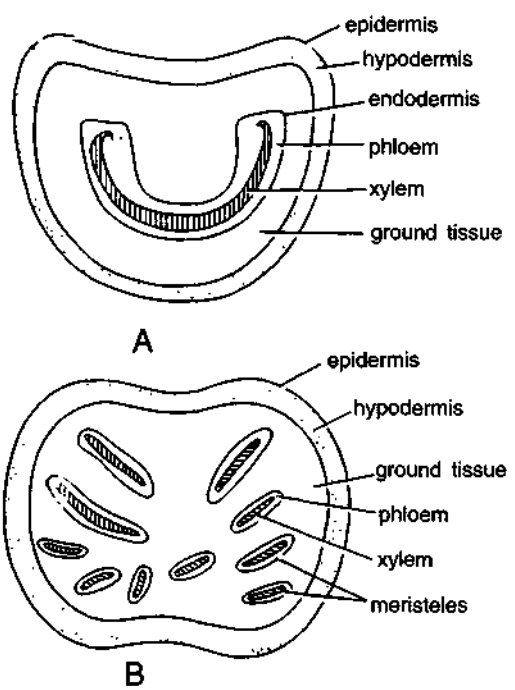


Fig. 4. ***Nephrolepis.*** T.s. rachis (diagrammatic).

Exercise 5

***Object* : Study of structure of the sporophyll.**

Work procedure

Observe the underside of the sporophyll, cut a transverse section of pinnae passing through a sorus. Stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. The leaf bearing sori is called sporophyll.
2. The sporangia are present on the lower side of

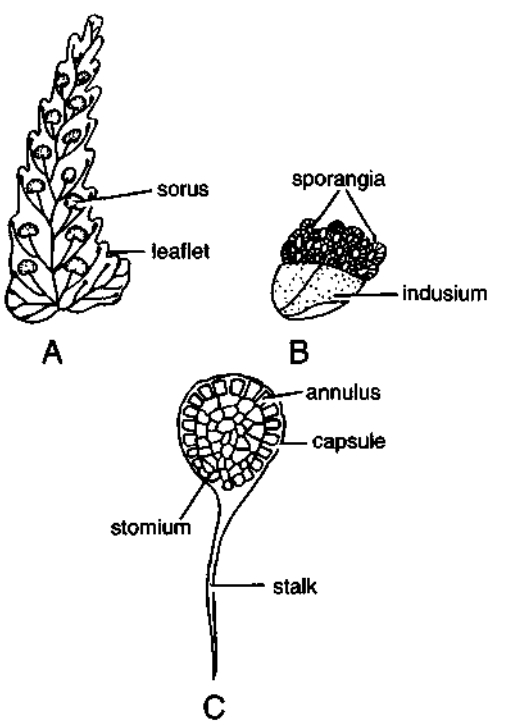


Fig. 5. ***Nephrolepis.*** **A.** Sporophyll. **B.** Sorus. **C.** A sporangium.

mature pinnae. These occur in groups called sori.

3. Sori are superficial and form definite rows, one on either side of the vein.
4. The sorus appears semi-rounded, and arises at the tip of the veinlet.
5. The sori are indusiate. The indusium is reniform (kidney-shaped), roundish or sub-orbicular.
6. Each sporangium has a stalk and a capsule.
7. The stalk is long, slender and multicellular.
8. The wall of sporangial capsule is one celled thick. A ring of thick walled cells called annulus is present. A few thin walled cells forming stomium are situated in the ring.
9. The capsule wall encloses 32 or 64 spores. All the spores are similar, the fern being homosporous.

Identification

Division—**Pteridophyta**. (1) Plant body differentiated into stem, root and leaves. (2) A definite vascular strand present.

Sub-division—**Pteropsida**. (1) Vascular cylinder siphonostele/ dictyostele, (2) Plants macrophyllous with large leaf gaps, (3) Leaves bear sporangia in sori, (4) Gametophytes small, green and free-living.

Class—**Leptosporangiatae**. (1) Sporangial wall one-celled thick, (2) Number of spores per sporangium definite.

Order—**Filicales**. Mixed sori.

Family—**Polypodiaceae**. (1) Annulus of sporangium vertical, (2) Each sporangium with 32-64 spores.

Genus—***Nephrolepis***. (1) Leaves unipinnate with articulate or pouch like base, (2) Sori distinct and enclosed by individual indusium, (3) Indusium true.

Hints for Collection

It is commonly found in tropics, but a few species like *Nephrolepis acuta, N. tuberosa,* etc. are also grown as ornamentals.

Pteridium (Bracken Fern)

Classification

Division	—	**Pteridophyta**
Sub-division	—	**Pteropsida**
Class	—	**Leptosporangiatae**
Order	—	**Filicales**
Family	—	**Polypodiaceae**
Genus	—	***Pteridium***

Exercise 1

***Object* : Study of external morphology of the plant.**

Work procedure

Study a fresh plant or a preserved specimen, observe the differentiation of plant body into roots, rhizome and leaves.

Comments

1. **The plant body** is a sporophyte. It is differentiated into roots, rhizome and leaves.
2. **Stem** is modified to rhizome. It is subterranean. The rhizome is long, slender and dichotomously

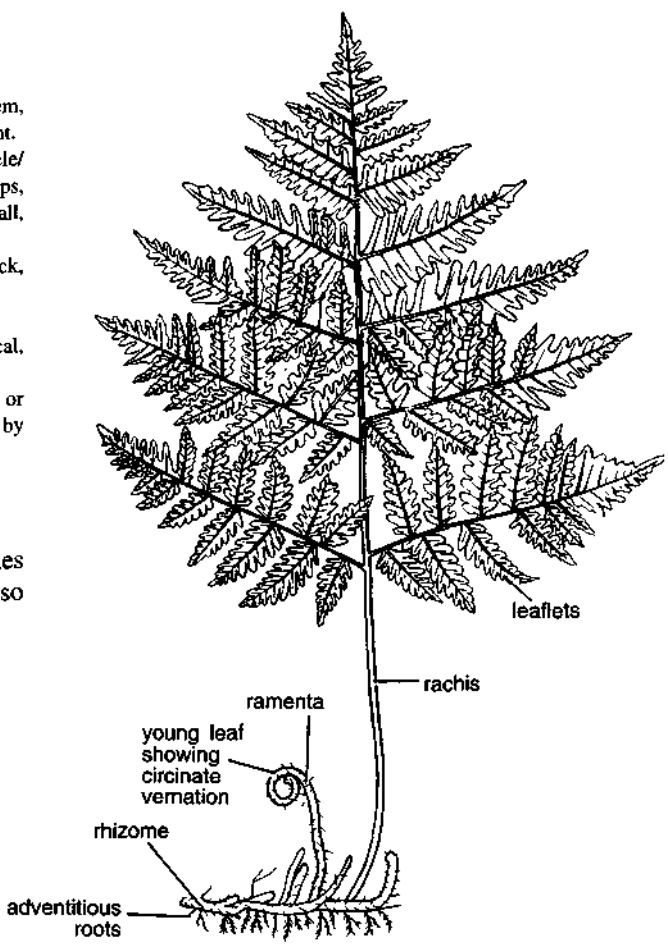


Fig. 1. ***Pteridium.*** External morphology : Plant showing young and mature leaves, rhizome and roots.

branched. It is covered with brown and multicellular hairs called ramenta.

3. **Roots**. The rhizome gives out adventitious roots on its underside. These are small and branched.
4. **The leaves** are borne alternately on the upper side of the rhizome at the nodes.
5. **The young leaves** are circinately coiled. The rachis is covered with ramenta.
6. Each leaf is tripinnately compound. Each pinna is sessile. It has a distinct midrib that gives out lateral branches.

Exercise 2

***Object* : Study of anatomy of the root.**

Work procedure

Cut a thin transverse section of the root. Stain with safranin-fast green combination. Mount in glycerine and study.

Comments

1. **The outline** of the section is almost circular.
2. It shows three regions—epiblema, cortex and the vascular cylinder.
3. **Epiblema** is the outermost single layer of cells. The cells are thin walled and produce unicellular root hairs.

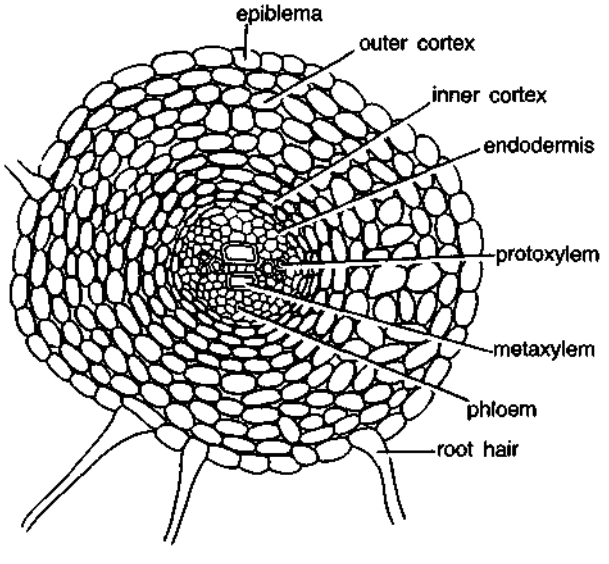


Fig. 2. ***Pteridium.*** T.s. of root (cellular).

4. **Cortex** occupies most part of the section It is differentiated into outer and inner regions.
5. The outer region is parenchymatous while the inner few layers are sclerenchymatous.
6. **Endodermis** follows the cortex. The radial walls of endodermal cells are characterised by casparian thickenings.
7. **Pericycle** is situated inner endodermis. It is 1 or 2 layered and parenchymatous.
8. **Vascular cylinder** shows radial, diarch and exarch conditions.
9. **The xylem** consists of two central metaxylem tracheids with groups of small protoxylem elements on their both sides.
10. **Phloem** is present on both the sides of xylem plate.

Exercise 3

***Object* : Study of anatomy of rhizome.**

Work procedure

Cut a transverse section of rhizome, stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. **The outline** of the section appears almost like a biconvex lens.
2. The tissues are differentiated into epidermis, hypodermis, ground tissue and the stele.
3. **Epidermis** is the outermost single layer of cells. The cells are thickly cuticularised.
4. **Hypodermis** lies below the epidermis. The cells are sclerenchymatous which often show pitted walls. It is generally interrupted on the lateral sides by parenchyma.
5. **Ground tissue** follows the hypodermis. It is parenchymatous and is spread up to the centre of the section. The cells are filled with starch grains.
6. **Stele**. The structure of the stele varies with the age of the rhizome.
   (i) In just formed rhizome, condition is protostelic.
   (ii) In a few weeks old plant with 2-3 leaves, the rhizome shows ectophloic siphonostele.

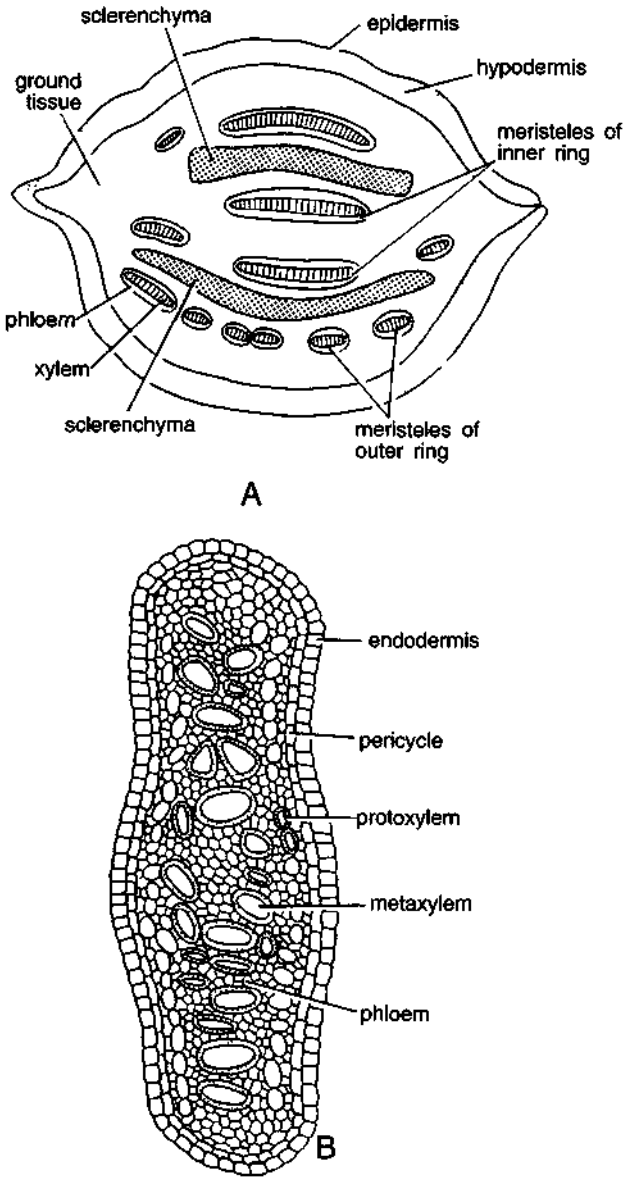


Fig. 3. ***Pteridium.*** T.s. rhizome; **A.** Diagrammatic, **B.** A meristele enlarged.

(iii) In mature plant, the old part of rhizome shows a dictyostele.

7. **Dictyostele** is made of meristeles arranged in two rings, separated by two sclerenchymatous bands.
8. **Meristele** is surrounded by its own endodermis, which is followed by one or two layers of parenchymatous pericycle.
9. The centre of the meristele is occupied by xylem which is completely surrounded by phloem on all sides.

Exercise 4

***Object* : To study the anatomy of rachis.**

Work procedure

Rachis is thin and wiry, hence a sharp blade or razor would be required to cut a section. Cut transverse section, stain in safranin-fast green combination , mount in glycerine and study.

Comments

1. **The outline** of the section appears horse-shoe shaped or hemispherical.
2. The tissues of the section are differentiated into epidermis, hypodermis, ground tissue and the stele.
3. **Epidermis** which is the outermost single layer of cells is thickly cuticularised.
4. **Hypodermis** is present below the epidermis. It is 2 to 3 layered thick. The cells are sclerenchymatous.
5. **Ground tissue**. Following the hypodermis is a large region of parenchyma called ground tissue.
6. **Stele**. In the ground tissue is situated U-shaped or horse-shoe shaped stele.
7. **Endodermis and pericycle**. Stele is surrounded by a single layered endodermis followed by a few layered parenchymatous pericycle.
8. **Xylem**. The centre of the stele is occupied by massive xylem. Metaxylem is present in the centre with protoxylem located at two of its ends.
9. **Phloem**. The region between xylem and the pericycle is filled by phloem.
10. The nature of the stele varies with the maturity of the rachis.
    (i) In younger parts stele is U-shaped.
    (ii) Little above the base, it gets dissected into two large meristeles.
    (iii) In mature parts, many meristeles are present as a result of further dissection of the original stele.

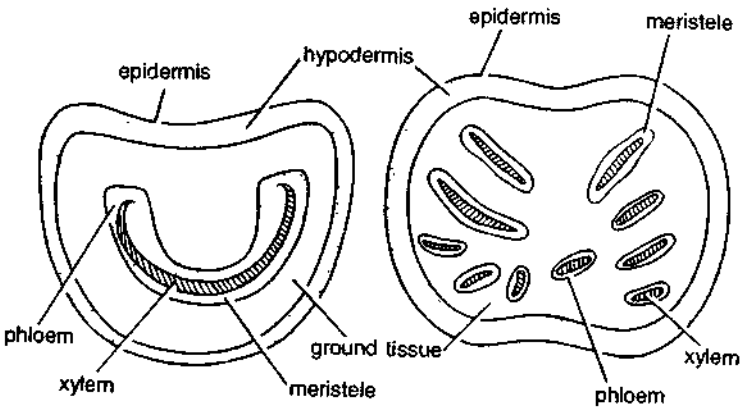


Fig. 4. ***Pteridium.*** Anatomy of rachis; **A.** T.s. of young rachis, **B.** T.s. of old rachis (both diagrammatic).

Exercise 5

***Object* : Study of anatomy of pinnule.**

Work procedure

Cut vertical transverse section of the pinnule. Stain with safranin-fast green combination, mount in glycerine and study.

Comments

1. The section shows the 'midrib' region and the wings.
2. **The midrib region** consists of compact parenchyma in which a single concentric vascular bundle is situated. It shows centrally located xylem surrounded by phloem. A distinct parenchymatous bundle sheath surrounds the bundle.
3. **The upper and the lower epidermis** are single layered. The stomata are present only on the lower surface.
4. **Mesophyll** that lies between the two epidermal layers is differentiated into palisade and spongy parenchyma.
5. **The spongy tissue** is situated close to the lower epidermis. The cells are loosely arranged and contain many chloroplasts. The intercellular spaces open into stomata.

Exercise 6

***Object* : Study of structure of the sporophyll.**

Work procedure

Cut a vertical transverse section of the pinnule that has sori on the lower side. Stain in safranin and mount in glycerine. Study the characters of sorus and the sporangium.

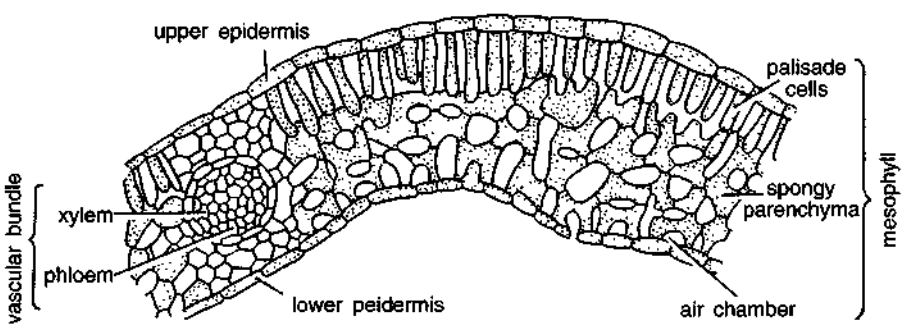


Fig. 5. ***Pteridium.*** T.s. pinnule.

Comments

1. The leaf bearing sori is called sporophyll.
2. The sporangia occur in groups called sori on the lower or abaxial side of pinnules. The sporangia form a continuous linear sorus along the margins. Such a confluent sorus is called coenosorus. The identity of sorus is thus lost and only one long sorus appears along the two lateral margins of the fertile pinnules.
3. The sorus is protected by indusium. It is made of upper indusial flap formed by the incurved margins of the pinnule and the lower true indusial flap that is poorly developed.
4. The sporangia in the sorus occur mixed. The development is leptosporangiate.
5. Each mature sporangium is differentiated into a stalk and a capsule.
6. The stalk of the capsule is made of three rows of cells. It is long and slender.
7. The capsule is ovate or biconvex. The sporangial jacket is single layered thick. A ring of thick walled cells forms the annulus. A few thin walled cells of the ring form the stomium. The capsule wall encloses 32 or 64 spores.
8. All the spores being similar, the fern is homosporous. Spores are haploid and uninucleate. The wall is two layered. The outer thick layer is called exine and the inner thin layer is called intine.

Exercise 7

***Object* : Study of structure of prothallus.**

Work procedure

Study a slide of prothallus showing sex organs. Note the positions of sex organs and also the young sporophyte.

Comments

1. The prothallus is a gametophyte formed as a result of spore germination.
2. It is dark green, heart-shaped and single layered sheet of cells. The midrib region becomes a

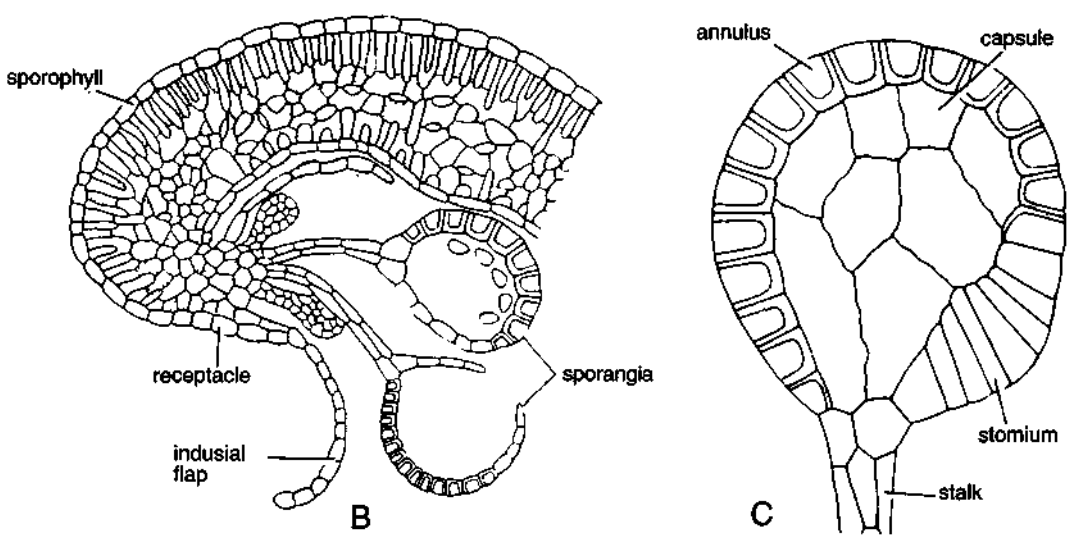


Fig. 5. ***Pteridium.*** **A.** sporophyll, **B.** Vertical section of a leaflet, **C.** A sporangium.

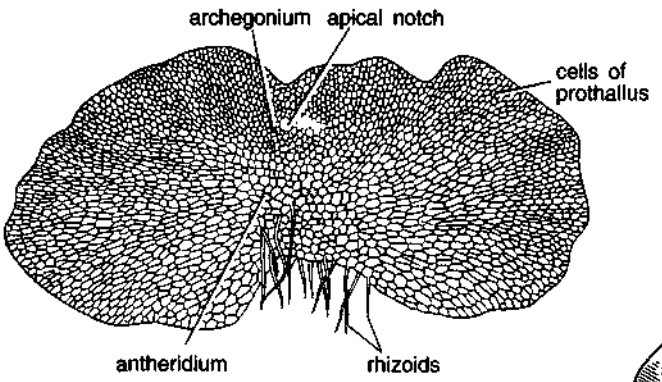


Fig. 7. ***Pteridium.*** Young prothallus with sex organs.

cushion of several cells. It remains attached to the substratum by rhizoids produced on the lower side in the central region.

3. The antheridium is surrounded by the cells of the prothallus. Each antheridium consists of wall of three rings of cells. It encloses 30-40 multiflagellate antherozoids at maturity.
4. Archegonia develop near the apical notch. Each is made of neck and ventre. The neck is 5-7 celled high with a single binucleate neck canal cell. The ventre has a small ventre canal cell and a large egg.

Exercise 8

Object **: Study of prothallus with young a sporophyte.**

Work procedure

Study a slide of old prothallus. If prothallus is collected from the pot or natural habitat, stain in fast green, mount in glycerine and study.

Comments

1. Sporophyte is formed as a result of fertilization. The zygote grows into a sporophyte that still remains attached to the prothallus.
2. Young sporophyte is differentiated into young leaves, primary and secondary roots.
3. The leaves are petiolate and erect. These emerge through the apical notch. The leaves are simpler than the mature leaves. Sometimes these even show circinate vernation.

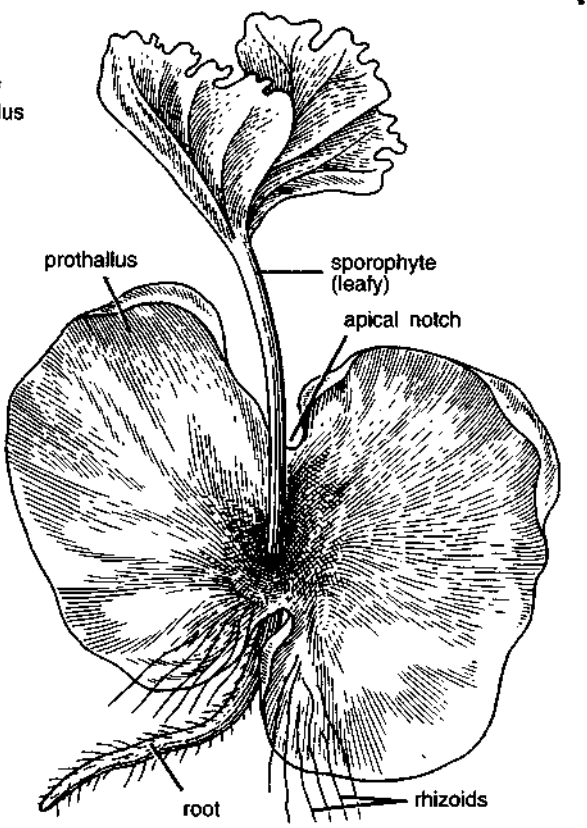


Fig. 8. ***Pteridium.*** Prothallus with a young sporophyte.

4. Primary root grows on the lower side and gives out secondary roots.
5. The sporophyte is dependent on the gametophyte till first leaf is formed. It absorbs its food through the foot of the young embryo.

Identification

Division—**Pteridophyta.** (1) Plant body differentiated into stem, root and leaves, (2) A definite vascular strand present.

Sub-division—**Pteropsida.** (1) Vascular cylinder siphonostele/ dictyostele, (2) Plants macrophyllous with large leaf gaps, (3) Leaves bear sporangia in sori, (4) Gametophytes small, green and free-living.

Class—**Leptosporangiatae.** (1) Sporangial wall one-celled thick, (2) Number of spores per sporangium is definite.

Order—**Filicales.** Mixed sori.

Family—**Polypodiaceae.** (1) Annulus of sporangium vertical, (2) Each sporangium with 32-64 spores.

Genus—***Pteridium.*** (1) Leaves tripinnately divided, (2) Presence of coenosorus, (3) Sorus enclosed between indusial flaps.

Hints for Collection

Pteridium is cosmopolitan. It is widely distributed along the entire Himalayan tract. It grows particularly well at altitudes between 1,000 to 3,000 meters. *P. aquilinum* is found on forest floors, mountain slopes, open grasslands, etc.

Marsilea

Classification

Division	—	**Pteridophyta**
Sub-division	—	**Pteropsida**
Class	—	**Leptosporangiatae**
Order	—	**Marsileales**
Family	—	**Marsileaceae**
Genus	—	***Marsilea***

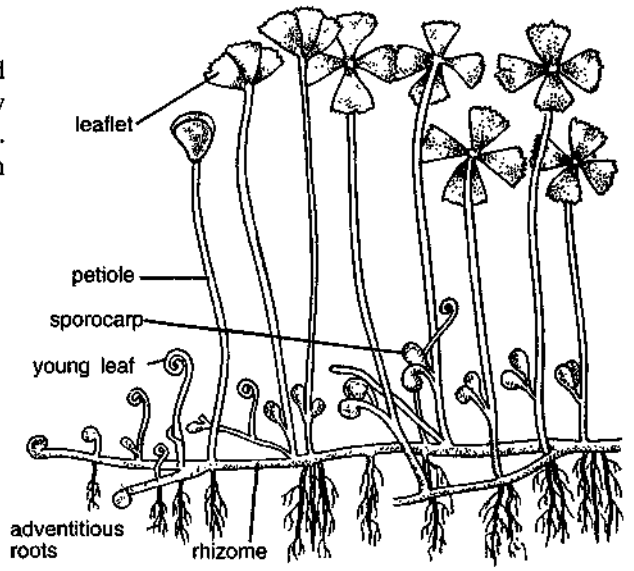


Fig. 1. ***Marsilea.*** External features.

Exercise 1

***Object* : Study of external morphology.**

Work procedure

Study external characters of the plant. Observe various features of root, rhizome and leaves. Note the circinate vernation of young leaves and the characteristic leaf venation.

Comments

1. **The plant body** is differentiated into a rhizome, roots and leaves.
2. **The rhizome** is slender, creeping branched. It may either grow in water or attached by roots in the damp soil.
3. It bears nodes and internodes. The leaves and roots occur in acropetal succession (youngest towards the apex of rhizome) on the nodes. The adventitious roots grow downwards and the leaves grow upwards. Young leaves are circinately coiled, a characteristic of most ferns.
4. **The leaves** present at the nodes occur in two rows, (two ranked) one on either side of the mid-line of the rhizome.
5. Each leaf consists of a long petiole, bearing at its top generally four leaflets or pinnae, apparently arising from one common point. In M. *quadrifolia*, a common Indian species, six leaflets are found. (Puri and Garg, 1953, call the leaflets as pinnules).
6. The division of lamina into four pinnae is the result of three dichotomies, close to each other. Therefore, out of the four leaflets, two form a distal pair while the lower two are alternate. The leaflets, thus give a false impression of arising from one common point.
7. **Each leaflet** is obovate. The venation is dichotomous with several cross connections. The free veinlets at the apex of the leaflet are tied up with marginal loops.
8. Leaflets fold up in the night or early morning, thus showing sleeping movements.
9. The plant when grows in water, has long, flexible petioles and the leaflets float on the surface of the water but when it grows on

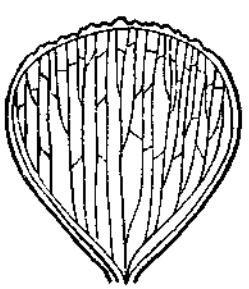


Fig. 2. ***Marsilea.*** Leaflet showing dichotomous venation.

mud or damp soil, the petioles become short and rigid.

(It is interesting to note that, when in a pond in which *Marsilea* is growing, water level rises, the petioles are also seen to increase in length. Contrary to it when level goes down, the petioles are found to coil, as such in both the conditions, the leaflets float on water surface).

10. The spore bearing structures known as sporocarps are commonly borne laterally near the base, on the petiole, but sometimes higher up. The two common Indian species, *M. minuta* and *M. quadrifolia* show variation in the number of sporocarps from one to four.

Exercise 2

***Object* : Study of anatomy of the root.**

Work procedure

Cut a T.s. of the root, stain in safranin-fast green combination, mount in glycerine and study.

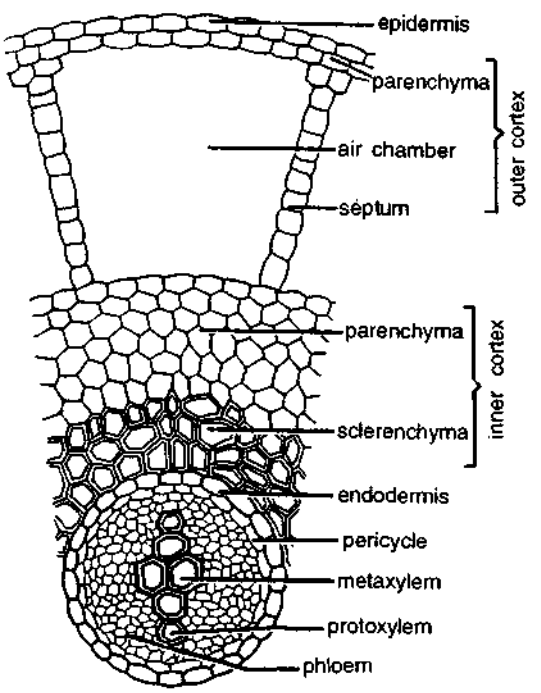


Fig. 3. ***Marsilea.*** T.s. root (a part cellular).

Comments

1. **The outline** of the section appears almost circular.
2. **The epidermis** is single layered with tangentially elongated cells.
3. **The cortex** is differentiated into an outer and an inner cortex.
4. **The outer cortex** has many air chambers separated by radial septa.
5. **The inner cortex** has either all the parenchymatous cells or some of the cells towards the inner side may become thick walled and sclerenchymatous.
6. **Endodermis** is single layered. It is followed by one layered pericycle. These surround vascular bundle.
7. **Xylem** is diarch and exarch xylem. It is situated in the centre. The protoxylem elements are situated opposite one another.
8. **The phloem** has smaller cells and forms two bands, one on either side of the xylem mass.

Features of special interest

The root shows aerenchyma in the outer cortex (hydrophytic character).

Exercise 3

***Object* : Study of anatomy of rhizome.**

Work procedure

Cut a T.s. of rhizome, stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. **The outline** of the section appears almost circular.
2. **The section** shows three regions—epidermis, cortex and stele.
3. **The epidermis** is single layered without stomata. The epidermis of aquatic plants lacks cuticle but that of terrestrial individuals has a distinct cuticle.
4. **The cortex** is differentiated into three regions—the outer, the middle and the inner.
5. **The outer cortex** has well-developed air

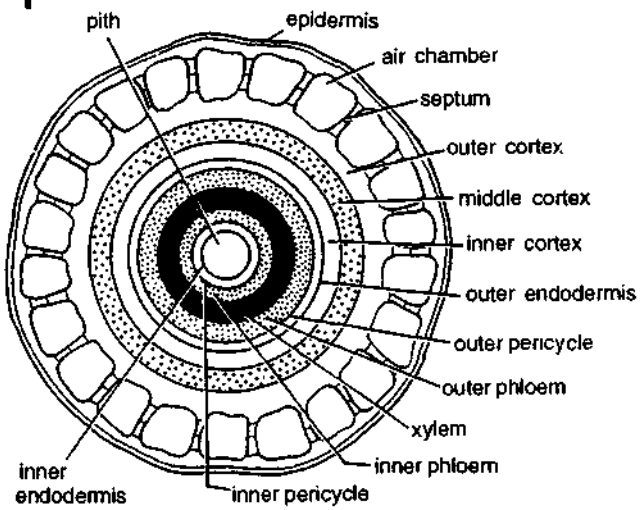


Fig. 4. ***Marsilea.*** T.s. rhizome (diagrammatic).

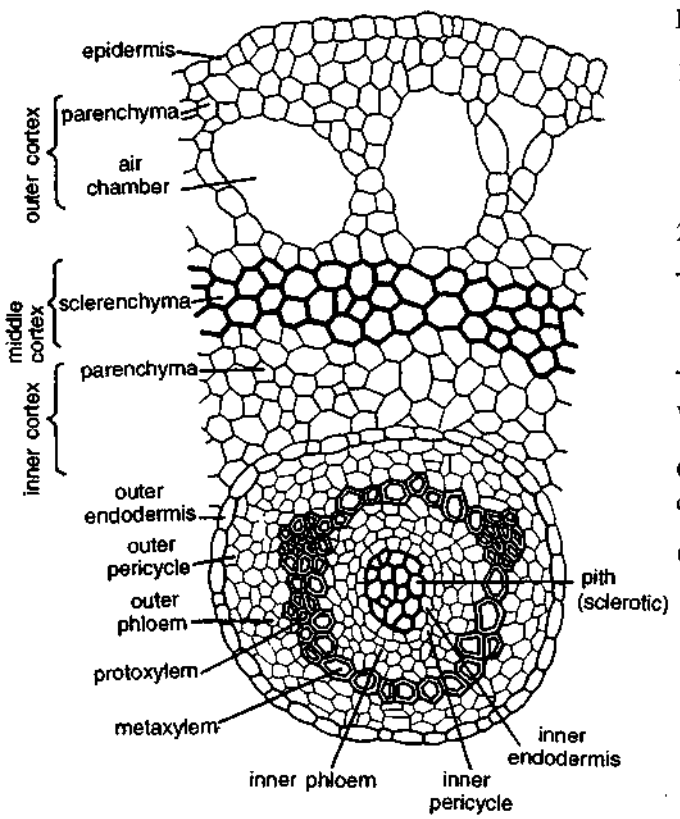


Fig. 5. ***Marsilea.*** T.s. rhizome (a part cellular).

spaces, separated by radially arranged parenchymatous cells (aerenchyma). The outermost cells of the cortex contain chloroplasts.

6. **The middle cortex** is thick walled, made up of sclerenchymatous cells and is only a few celled thick.
7. **The inner cortex** is composed of thin-walled parenchymatous cells containing starch.
8. **The stele** is an amphiphloic solenostele.
9. **Stele** shows a central xylem ring. On its outer side is outer phloem ring, outer pericycle and outer endodermis. On the inner side i.e. towards the pith are present inner phloem ring, inner pericycle and inner endodermis.
10. **Protoxylem** groups may or may not be distinct. They are generally exarch, but in some cases mesarch too.
11. **Pith** lies in the center. In aquatic plants it is parenchymatous and in terrestrial plants it is sclerotic.

Features of special interest

1. It shows hydrophytic character viz. presence of aerenchyma in the cortex, as well as some xerophytic characters viz.
   (i) thick walled middle cortex and
   (ii) sclerotic pith
2. Presence of amphiphloic solenostele.

Exercise 4

Object **: Study of anatomy of petiole.**

Work procedure

Cut a T.s. of petiole, stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. **The outline** of the section is circular.
2. **Epidermis** is the outermost layer with rectangular cells.
3. **Hypodermis** is sometimes present below the epidermis. It is one or two layered.
4. **The cortex** is differentiated into an outer and an inner zone.
5. **The outer cortex** has many air chambers, separated by narrow radially arranged parenchymatous cells (aerenchyma).
6. **The inner cortex** has parenchymatous cells containing starch. A few cells contain tannins also.

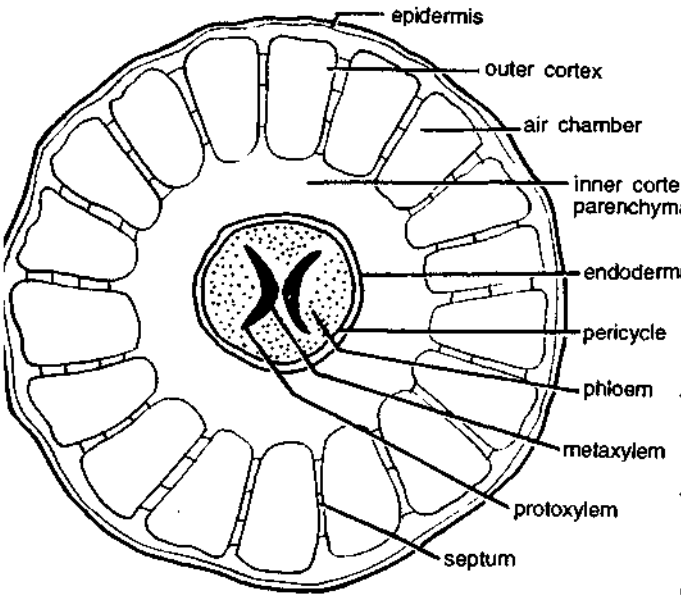


Fig. 6. ***Marsilea.*** T.s. petiole (outlines).

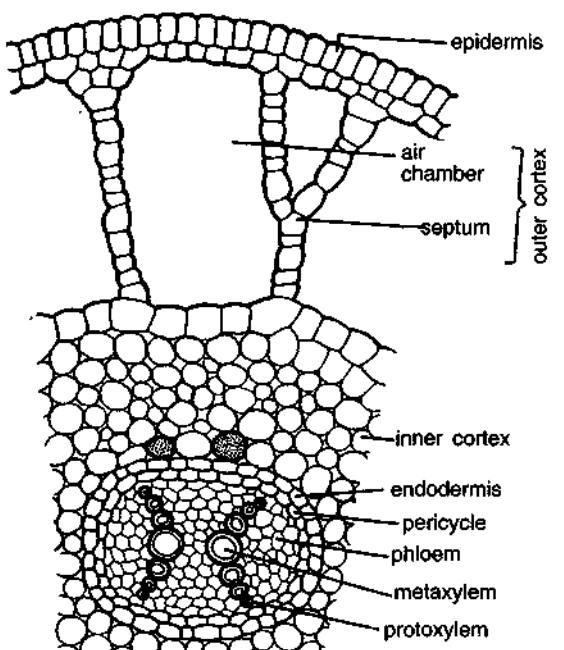


Fig. 7. ***Marsilea.*** T.s. petiole (a part cellular).

7. **The stele** is a protostele.
8. **Endodermis** is single layered. It is followed by a single layer of pericycle.
9. **The xylem** is 'V shaped' with exarch protoxylem. The two arms of 'V' are slightly curved and separate. Each arm has generally one or two large tracheids in the middle and smaller tracheids towards both the ends. The open end of 'V' always points towards the adaxial side of the petiole (towards the axis).
10. **Phloem** surrounds the xylem.

Features of special interest

1. Shows hydrophytic character viz. presence of aerenchyma in the outer cortex.
2. Presence of V-shaped xylem.

Exercise 5

***Object* : Study of anatomy of leaflet.**

Work procedure

Cut a T.s. of the leaflet, stain with safranin-fast green combination, mount in glycerine and study.

Comments

1. The section shows an upper and lower epidermis, mesophyll and a vascular bundle.
2. **The stomata** are found on both upper and lower epidermis if the plant is terrestrial but they are found only on upper epidermis if leaves float on water surface.
3. **Mesophyll** is differentiated into palisade and spongy parenchyma.
4. **Palisade** is arranged in one layer near the upper epidermis. Spongy parenchyma is located near

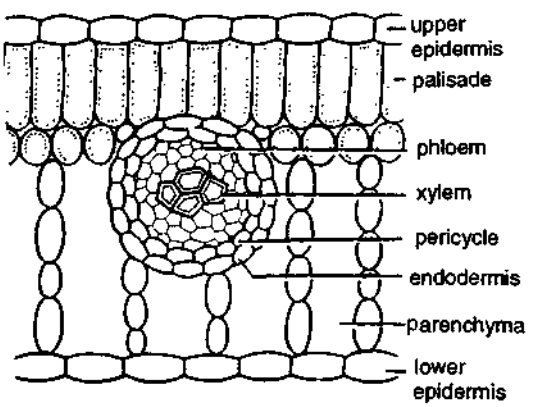


Fig. 8. ***Marsilea.*** T.s. leaflet (a part cellular).

the lower epidermis. It is loosely arranged to form large air spaces and is called aerenchyma.

5. There are many vascular bundles. Each bundle is concentric with centrally located xylem surrounded by phloem.
6. The distinct endodermis is present just outside the vascular bundle.

Exercise 6

***Object* : Study of external features of sporocarp.**

Work procedure

Study the external characters of a sporocarp.

Comments

1. The spore-bearing organs are the sporocarps which are borne laterally on the adaxial side of the petiole. Their number and positions vary from species to species.
2. Sporocarp is stalked, bean-shaped or ovoid structure.
3. The place of attachment of the body of the sporocarp to the peduncle (stalk) is known as raphe.
4. Beyond the raphe, there are two projections known as teeth or tuberceles, one tooth being lower than the other.
5. The lower tooth is usually stouter and more prominent while the upper tooth, which lies a short distance above is usually more slender and delicate.
6. The side on which the raphe is present is the basal side and the side opposite to it is the apical side. The side on which the tubercles are present is the dorsal side and the side opposite to it is ventral side.

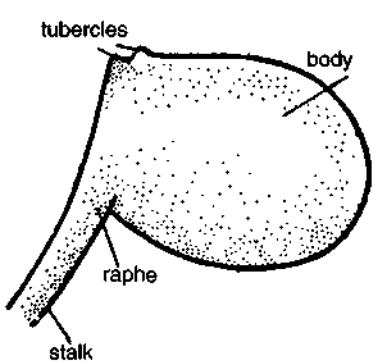


Fig. 9. ***Marsilea.*** A single sporocarp.

Exercise 7

***Object* : Study of V.T.s. of sporocarp.**

Work procedure

Cut a section of the sporocarp in a plane almost parallel to the stalk as shown in reference diagram. Stain the section in safranin, mount in glycerine and study.

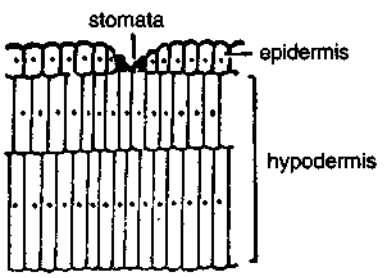


Fig. 10. ***Marsilea.*** A part of the sporocarp wall (cellular).

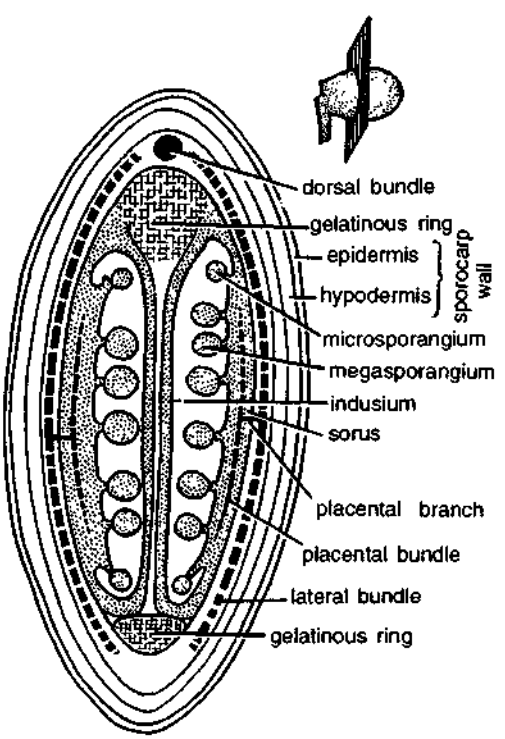


Fig. 11. ***Marsilea.*** V.T.s. sporocarp.

Comments

1. **The section** shows wall of the sporocarp which encloses sori.
2. **The wall** is made of outer epidermis followed by hypodermis.
3. **Epidermis** consists of thick walled cells. Numerous stomata are present in the epidermis.
4. **Hypodermis** consists of two layers of radially elongated cells. The cells of the inner layer are double in length as compared to the cells of the outer layer.
5. All the cells of both the layers have their nuclei arranged in one row.
6. **Receptacles** are cut longitudinally. Only two sori are seen, each of which is covered by its own 2 layered indusium. The receptacle of the sorus bears microsporangia at the corners and megasporangia all along the receptacular ridge.
7. On the upper and lower sides of the receptacles, two masses of gelatinous ring, cut transversely, are present. The upper one is bigger in size than the lower.
8. The dorsal bundle, lateral bundles, placental branches and placental bundles are seen.

Exercise 8

***Object* : Study of V.L.s. of the sporocarp.**

Work procedure

Hold the sporocarp with tubercles pointing upwards. Split the sporocarp by a sharp blade in two halves. Study the section under dissecting microscope, section being thick.

Comments

1. The section shows wall of the sporocarp enclosing sori embedded in a gelatinous wall.
2. The outermost is the sporocarp wall. It is made of an epidermis with stomata and two layered hypodermis.
3. Below the sporocarp wall is a gelatinous ring which surrounds sori. It is relatively more prominent on the dorsal side than on the ventral.
4. The sori are cut longitudinally and appear in a row.

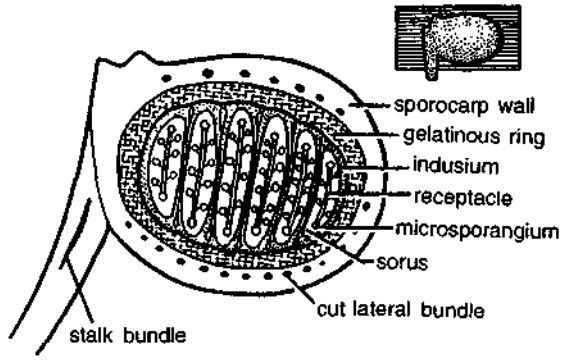


Fig. 12. ***Marsilea.*** V.L.s. sporocarp showing microsporangia.

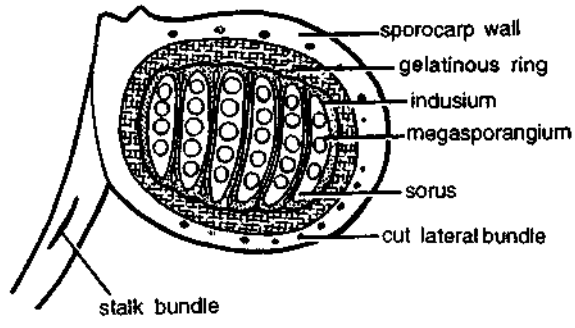


Fig. 13. ***Marsilea.*** V.L.s. sporocarp showing megasporangia.

5. Each sorus is surrounded by its own indusium.
6. If the section passes through the centre, then megasporangia are seen in all the sori. Since the megasporangia are present at the apex of the receptacle, no receptacle is seen.
7. If the section is not perfectly median, then microsporangia are seen attached on either sides of the receptacle in each sorus.
8. In this section the stalk bundle and cut lateral bundles are seen.

Exercise 9

***Object* : Study of H.L.s. of the sporocarp.**

Work procedure

Hold the stalk between the thumb and the index finger. Cut a section by passing a blade at right angles to the stalk axis (see reference diagram). Stain in safranin, mount in glycerine and study.

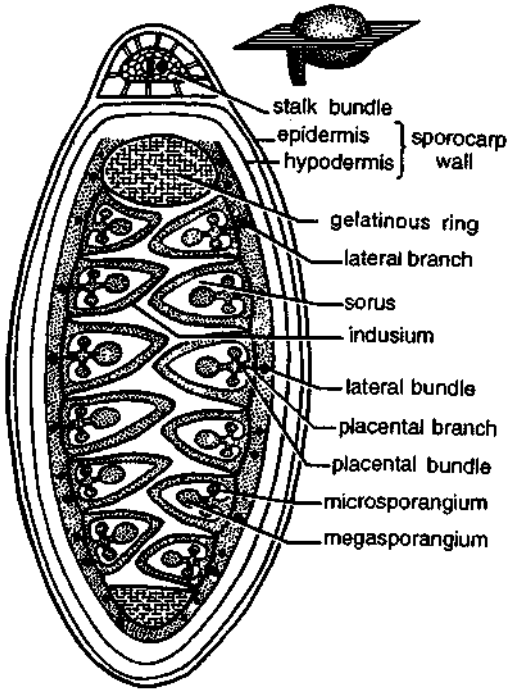


Fig. 14. ***Marsilea.*** H.L.s. sporocarp.

Comments

1. The section shows transversely cut stalk, wall of the sporocarp and two rows of sori.
2. Transversely cut stalk appears on one side. It shows the stalk bundle.
3. The wall of the sporocarp is made of epidermis with stomata and two layered hypodermis.
4. Gelatinous ring shows two patches, heavier on the dorsal side than on the ventral.
5. There are two rows of sori, one row alternating with the other.
6. Each sorus is covered by its indusium.
7. A sorus consists of a receptacle. Megasporangium is present at the apex of receptace while microsporangia are present on the sides.
8. The lateral bundles are cut transversely and each is seen to supply its own receptacle by a receptacular or placental branch.
9. Thus, in this section dorsal bundle, many lateral bundles and receptacular branches (placental branches) are seen.

Exercise 10

***Object* : Study of dispersal of spores.**

Work procedure

Cut open the body of the sporocarp on ventral side by a sharp blade or scalpel. Place in water for some time. Gelatinous ring with sporangia attached to it comes out.

Comments

1. The sporocarp is hard and resistant to unfavourable conditions.
2. It opens through its ventral margins.
3. It imbibes water and the gelatinous ring inside swells up.
4. This ring ultimately comes out of the sporocarp wall.
5. Gelatinuous ring bears two rows of sporangia, one on each side, alternating with one another.

Identification

Division—**Pteridophyta.** (1) Plant body differentiated into stem, roots and leaves, (2) A definite vascular strand present.
Sub-division—**Pteropsida.** (1) Plants are always megaphyllous

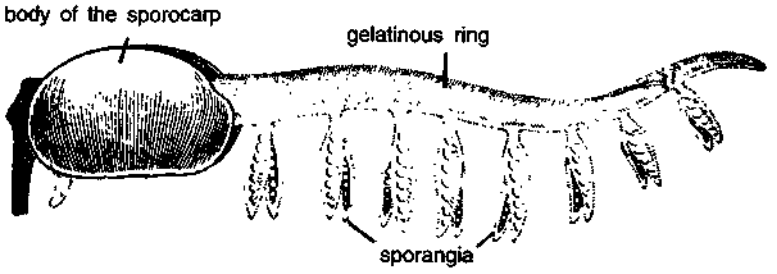


Fig. 15. ***Marsilea.*** Sporocarp showing extension of gelatinous ring during germination.

excluding a few exceptions, (2) Leaves differentiated into a petiole and dissected blade, (3) The sporangia are borne on abaxial surface of leaves.

Class—**Leptosporangiatae.** (1) Development of sporangium is of leptosporangiate type, (2) Jacket one cells in thickness, (3) Spores definite within a sporangium.

Order—**Marsileales.** (1) Members heterosporous, (2) Sporangia formed within sporocarps.

Family—**Marsileaceae.** (1) Members aquatic, (2) Sorus gradate type and each produces both types of sporangia, (3) Leaf circinately coiled in bud condition.

Genus—***Marsilea.*** (1) Leaflet with dichotomous venation and cross connections, (2) Presence of aerenchyma in vegetative organs of the sporophyte, (3) Presence of amphiphloic solenostele in the rhizome, (4) Presence of V-shaped xylem in petiole.

Hints for Collection

The two Indian species, *Marsilea minuta* and *M. quadrifolia*, are commonly found growing either in shallow water or on moist banks of ponds and ditches. They grow either completely submerged or partially or entirely out of water in damp and wet places.

Azolla

Classification

Division	—	**Pteridophyta**
Sub-division	—	**Pteropsida**
Class	—	**Leptosporangiatae**
Order	—	**Salviniales**
Family	—	**Salviniaceae**
Genus	—	***Azolla***

Exercise 1

***Object* : Study of external morphology of the sporophyte.**

Work procedure

Collect a fresh specimen or study a preserved plant.

Comments

1. The plant is a sporophyte. It grows free floating in ditches and ponds.

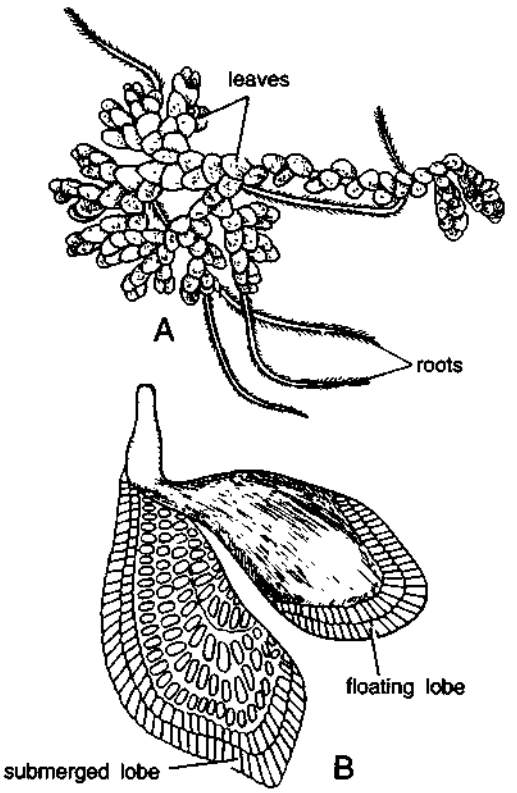


Fig. 1. *Azolla.* External features of *A. filiculoides*; **A.** Plant showing roots and leaves, **B.** A single leaf.

2. **The plant body** is differentiated into stem, roots and leaves.
3. **The stem** is pinnately branched. It is horizontally floating. The branches are extra-axillary.
4. **Roots** are produced from the lower side of the stem. These remain submerged in water.
5. **Leaves** cover stem and its branches. These are present in two alternate and overlapping rows.
6. **Each leaf** is divided into two lobes of approximately equal size.
7. The upper or aerial lobe is thick and green. It is somewhat obliquely placed and only one of the edges touches the water.
8. The thin lower or submerged lobe is nearly colourless. The absorption of water is believed to take place through this lobe.

Exercise 2

***Object* : Study of anatomy of root**

Work procedure

Cut a T.s. of the root, stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. **The outline** of the section is almost circular.
2. It shows epidermis, cortex and the stele.
3. **Epidermis** is the outermost single layer of cells.
4. **Cortex** consists of 2-8 layers of parenchymatous cells.
5. **Endodermis** lies inner to cortex. It is made of a single layer consisting of 6 cells.
6. **Pericycle** that follows is also made of a single layer consisting of 6 cells.
7. **Xylem** lies in the centre. It is represented by two centrally placed metaxylem tracheids. These are surrounded by four small outer groups of protoxylem elements.
8. **Phloem** consists of only a few elements. These are placed on either sides of the metaxylem elements.

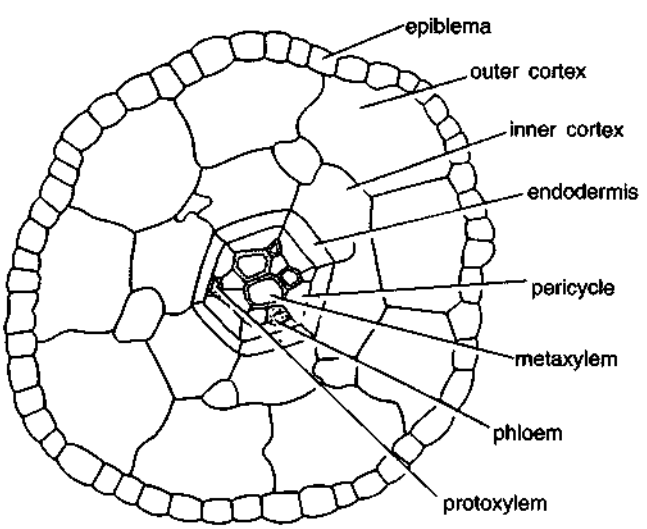


Fig. 2. *Azolla.* T.s. root (cellular).

Exercise 3

***Object* : Study of anatomy of stem.**

Work procedure

Cut a transverse section of the stem, stain with safranin-fast green combination, mount in glycerine and study.

Comments

1. **Outline.** Transverse section of the stem is almost circular in outline.
2. It shows epidermis, cortex and stele.
3. **Epidermis** is the outermost single layer of cells.
4. **Cortex** is five to eight cells in thickness. The cells are thin walled and parenchymatous without intercellular spaces.
5. **Stele** is centrally located. It is surrounded by single layer of endodermis followed by a single layer of parenchymatous pericycle.
6. The central cylinder is protostelic. The vasculature of the stem is greatly reduced in response to aquatic habitat.
7. **Vascular tissues** are represented by about six xylem elements and twice as many phloem elements, in a stele.

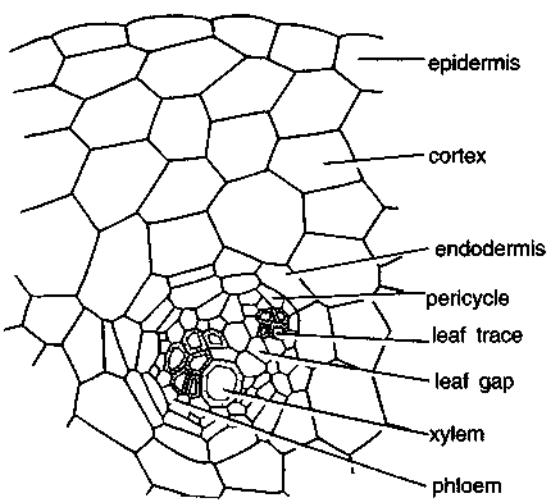


Fig. 3. *Azolla.* T.s. stem (cellular).

Exercise 4

***Object* : Study of anatomy of leaf.**

Work procedure

Cut a vertical transverse section of the upper lobe by keeping it in suitable sized pith. Stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. The upper lobe of leaf is bound on both the sides by upper and lower epidermal cells.
2. Both the layers possess stomata.
3. The upper epidermis has many unicellular or bicelled hairs.
4. Major portion of the leaf between both epidermal layers is made of palisade-like photosynthetic cells. Large intercellular spaces are present between them.
5. The upper lobe has a large cavity at its base. It opens to the outside through a circular pore.
6. The cavity is filled with the filaments of blue green alga—*Anabaena azollae*. The alga has a symbiotic relationship with the fern. It fixes atmospheric nitrogen.
7. The pore is later closed by ougrowths of the tissue of the margin. It becomes filled with mucilage.

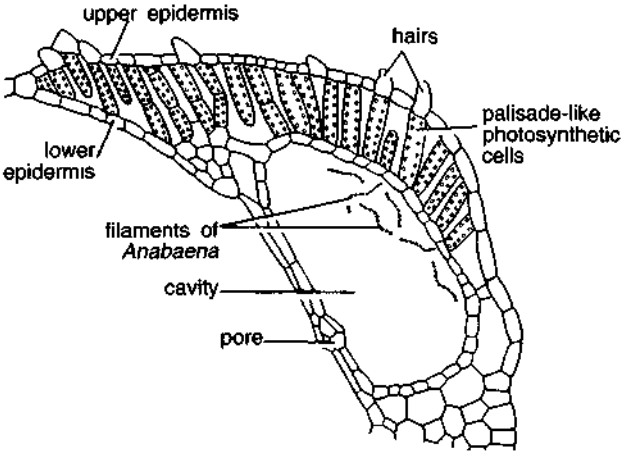


Fig. 4. *Azolla*. T.s. through dorsal (floating) lobe of leaf.

Exercise 5

***Object* : Study of structure of sporocarp.**

Work procedure

Look for the sporocarp on the lower side of the plant. Identify microsporocarp and megasporocarp. Tease them. Stain with safranin, and study the internal structure.

Comments

1. Sporocarps are borne only on the lowermost leaf of a lateral branch at the end of annual season.
2. Submerged lobe of the leaf bears 2-4 sporocarps.
3. The upper lobe of the fertile leaf forms a hood-like covering around the sporocarp.
4. The sporocarps are dimorphic i.e. these are of two types: microsporocarps and megasporocarps.
5. Larger sized is a microsporocarp and the smaller sized is a megasporocarps.
6. Each sporocarp is a sorus covered by indusium.
7. Microsporocarp shows a central raised cushion on which sporangia develop basipetally. Each microsporangium has one layered jacket. It is followed by tapetum. The cavity encloses 64 microspores.
8. Microsporangium has a multinucleate periplasmodium formed as a result of breakdown of tapetum. Periplasmodium forms four or more quadrately arranged massulae in which spores remain embedded at periphery.
9. The surface of massulae has many anchor-shaped barbed hairs called glochidia which help the attachment of massulae to the microspore.
10. Megasporocarp shows a single large megasporangium. It is surrounded by a flask-shaped indusium. It envelops the sporangium completely except for a narrow slit at the apex.
11. Megasporangium is covered by a single layered wall. It encloses a single megaspore.
12. Megaspore is surrounded by a hardened vacuolate layer—the perispore. The megaspore wall is hard and ornamented. It is called epispore.

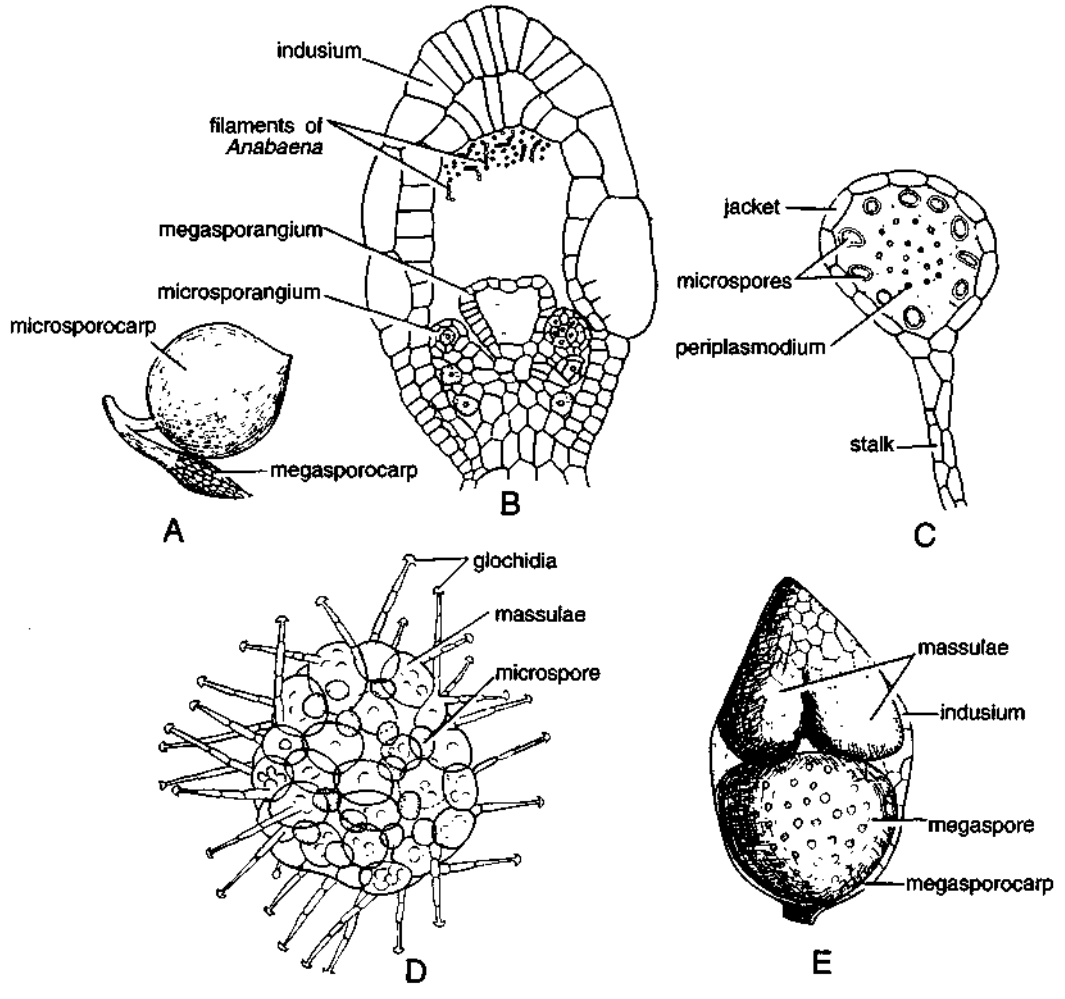


Fig. 5. ***Azolla.*** **A.** The fertile submerged lobe with one large microsporocarp and one small megasporocarp. **B.** L.s. of nearly mature microsporocarp. **C.** Nearly mature microsporangium. **D.** Massulae inside microsporangium. **E.** Massulae inside megasporangium.

13. At the distal end of the megaspore, four quadrately arranged massulae are present. These are formed by the remaining aborted spores and the tapetal cells.

Identification

Division—**Pteridophyta**. (1) Plant body differentiated into stem, root and leaves, (2) A definite vascular strand present.

Sub-division—**Pteropsida**. (1) Vascular cylinder siphonostele/ dictyostele, (2) Plants macrophyllous with large leaf gaps, (3) Leaves bear sporangia in sori, (4) Gametophytes small, green and free living.

Class—**Leptosporangiatae**. (1) Sporangial wall one celled thick, (2) Number of spores per sporangium is definite.

Order—**Salviniales**. (1) Sporocarp is a single sorus enclosing either megasporangia or microsporangia, (2) Sporocarp walls formed by the indusia.

Family—**Salviniaceae**. Single family.

Genus—***Azolla***. (1) Presence of endophytic blue green algae *Anabaena* in the leaf, (2) Each leaf divided into two lobes, (2) Megasporocarp with only one megasporangium.

Hints for Collection

Azolla forms red coloured bloom in ditches and ponds. It is found floating freely on the surface of water. Common Indian species is *A. pinnata*. Another species *A. filiculoides* is also known to occur frequently while the third species *A. imbricata* is found mostly in Eastern Himalayas.

Gymnosperms

9 *Chapter*

Preamble

Gymnosperms form a large group of evergreen, slow growing plants. Though true seeds are formed, the group differs from other group of seed-bearing plants the angiosperms, firstly in possessing naked ovules; secondly, in the lodging of pollen grains directly on the micropyle and thirdly, in the absence of true vessels and companion cells. This group is more ancient than angiosperms, claiming fossils as well as living members and form a bridge between the pteridophyta on one hand and the angiosperms on the other.

The gymnosperms vary in size from small plants to very large gigantic plants. *Sequoia sempervirens* grows up to a height of about 150 meters (California) and *Taxodium maxicanum* has a trunk with the enormous diameter of about 17 meters. (Contrary to this, *Zamia pygmia* is the smallest gymnosperm with and underground tuberous stem. In gymnosperms, there are two main structural types, the leaves. Most of the members of this group grow in relatively dry and poor soils, the plants thus exhibit thermographic features.

The fructifications (cones) are made up of an aggregation of sporophylls bearing sporangia, in which the spores are produced. The cones are generally unisexual. The male and female cones differ in shape and size. Whereas the male cones are usually smaller and short lived, the female cones are quite larger and long lived. Considerably the gametophytic generation is even more reduced than it is in any of the pteridophyta.

The gymnosperms are also important from economic point of view. Some conifers as *Cedrus deodara* (vern.deodar) form valuable timber. Canada balsam, a chief familiar mounting medium used in biological laboratories, is the resin of *Abies balsamea*. Turpentine oil which is chiefly used as medicine is also extracted from a conifer tree. Last, but not the least gymnosperms have also proved themselves for their food value viz. sago palm (*Cycas revoluta*) yield sago or sabudana (of course the chief commercial supply now comes from *Metroxylon rumphii*- an angiosperm) and the very familiar fruit of chilgoza is the seed of *Pinus gerardiana*.

Classification of Gymnosperms

Division. GYMNOSPERMS

Class	Order	Family	Examples
Cycadopsida	Pteridospemales	Lyginopteridaceae	*Heterangium*, Lyginopteris**
		Glossopteridaceae	*Glossopteris**
	Bennettitales	Williamsoniaceae	*Williamsonia**
		Cycadeoidaceae	*Cycadeoidea**
	Cycadales	Cycadaceae	*Cycas*
Coniferopsida	Coniferales	Pinaceae	*Pinus*
	Taxales	Taxaceae	*Taxus*
Gnetopsida	Gnetales	Gnetaeceae	*Gnetum*
		Ephedraceae	*Ephedra*

*Fossil members

Distinguishing Characters of Taxa

DIVISION. **GYMNOSPERMS**
(1) Ovules naked
(2) Seeds attached to a scale
(3) Scales forming a strobilus

CLASS **1. CYCADOPSIDA**
(1) Wood manoxlic
(2) Large frond-like leaves
(3) Seeds with radial symmetry

Order **1. Pteridospermales**
(1) Leaves large, frond-like, pinnately compound
(2) Large leaf traces with one or more strands
(3) Spores formed in sporangia, aggregated in synangia

Family **1. Lyginopteridaceae**
(1) Stem monostelic
(2) Petioles with a strong midrib
(3) Seeds small

Examples. ***Heterangium***, **Lyginopteris****

Family **2. Glossopteridaceae**
(1) Leaves with a strong midrib
(2) Stelar structure unusual, showing several plates of vascular tissues
(3) Reproductive structure cupulate and bisexual

Example. ***Glossopteris****

Order **2. Bennettitales**
(1) Tree trunk covered by a mantle of persistent leaf-bases
(2) Microsporophylls in groups at the tip of frond-like leaves
(3) Megasporophylls in cone-like organization

Family **1. Williamsoniaceae**
(1) Stem delicate, branched
(2) Inflorescence stalked or sessile, not sunk in the scales of persistent leaf bases

Example. ***Williamsonia****

Family **2. Cycadeoidaceae**
(1) Trunk columnar
(2) Trunk covered by a mantle of leaf bases
(3) Flowers' sunk in the distal part of the trunk

Example. ***Cycadeoidea****

Order **3. Cycadales**
(1) Plants woody, stem unbranched
(2) Wood manoxylic
(3) Presence of mucilage canals
(4) Leaf trace diploxylic
(5) Dioecious plants
(6) Ovules orthotropous
(7) Sperm with spiral band of flagella

Example. ***Cycas***

CLASS **2. CONIFEROPSIDA**
(1) Wood pycnoxylic
(2) Leaves needle-shaped, or fan-shaped
(3) Seeds with bilateral symmetry

Order **1. Coniferales**
(1) Plants branched, leaves needle shaped
(2) Resin canals present
(3) Male and female cones compact
(4) Male gametes non-flagelate

Family 1. **Pinaceae**
(1) Wood resinous
(2) Plants monoecious
(3) Sporophylls spirally arranged
(4) Microsporophylls with two microsporangia
(5) Pollen grains winged
(6) Female cone woody
(7) Polyembryony present
(8) Seeds dry and winged

Example. ***Pinus***

Order **2. Taxales**
(1) Profusely branched trees or shrubs
(2) Leaves simple, solitary, flat and spirally arranged
(3) Wood pycnoxlic wihtou parenchyma
(4) Plants mostly dioecious
(5) Female strobilus represented by a single terminal ovule, enclosed in aril

Family. **Taxaceae**
(1) Typical of order

Example. ***Taxus***

CLASS **3. GNETOPSIDA**
(1) Wood with vessels,
(2) Flowers in compound strobili or inflorescence, unisexual, usually dioecious,
(3) Ovule surrounded by several envelopes.

Order **1. Gentales**
(1) Plants woody trees, shrubs or lianas
(2) Leaves simple, arrangement opposite or whorled
(3) Male flowers with perianth

Family **1. Gnetaceae**
(1) Ovules cauline
(2) Leaves - scaly and foliage; foliage leaves oblong-lanceolate

* Fossil members

(3) Plants dioecious
(4) Male and female cones in panicles
(5) Cones with 'cupules' or collars'
(6) Seeds with protective inner envelope

Example. ***Gnetum***

Family **2. Ephedraceae**

(1) Plants shrubs or woody climbers
(2) Leaves- scaly and foliage
(3) Presence of nodal diaphragm
(4) Stamens enclosed by bract
(5) Seeds covered with fleshy bracts

Example. ***Ephedra***

Cycas

Classification

Division	–	**Gymnosperm**
Class	–	**Cycadopsida**
Order	–	**Cycadales**
Family	–	**Cycadaceae**
Genus	–	***Cycas***

Exercise 1

***Object* : Study of external features of the plant.**

Work procedure

Study the external features of the plant. Observe the armour of leaf bases on the stem, absence of branching, crown of leaves, two types of roots, etc.

Comments

1. **Plant body** is differentiated into an underground root system, that is distinguished into an erect stem and a crown of leaves.
2. **Roots** are of two types : (i) primary or normal root and (ii) secondary of coralloid root.
3. **Normal root** is a tap root, growing deep into the soil (positively geotropic). It is sparsely branched and sometimes grows as thick as aerial stem.
4. **Secondary roots** are negatively geotropic projecting above the soil surface, repeatedly dichotomously branched and appear as coralloid clusters.

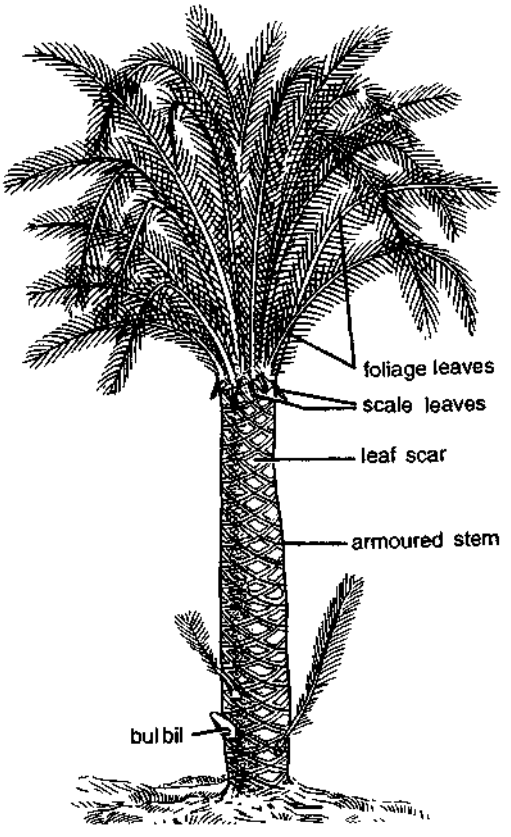


Fig. 1. *Cycas*. External features.

5. **The young stem** is almost tuberous but when grows old, it becomes thick, columnar and unbranched (Branching is rare and is caused due to injury, etc.). The trunk is covered by persistent leaf bases.
6. **Leaves.** The stem bears a terminal group of leaves which are dimorphic (i.e. of two types) (i) foliage leaves (green assimilatory fronds) and (ii) scale leaves (brown and hairy). These leaves alternate with one another.
7. Young foliage leaves are circinately coiled and are covered with ramenta (hairs).
8. **Mature leaves** are spirally arranged and pinnately compound. Each leaf has about 80-100 pairs of pinnae that are closely arranged, opposite one another on the rachis with a decurreht base. Each pinna is tough, leathery and entire with a definite midrib but no lateral veins.

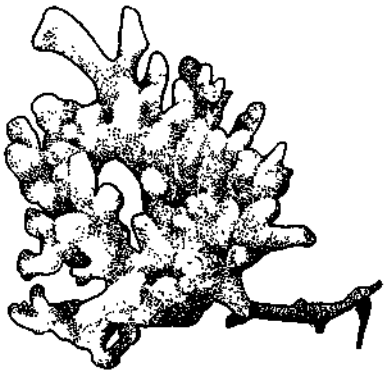


Fig. 2. *Cycas*. Coralliod root-external features.

9. **Scale leaves** are small, simple , brown with aborted lamina and covered with hairs. These leaves cover the apex and young developing foliage leaves. Scales are also persistent, like leaf bases.
10. **Reproductive organs.** *Cycas* is dioecious and, as such, bears terminally, either male cone or female reproductive structures.
11. **The male cone is** borne terminally at the apex of the stem and the further growth of the stem continues by axillary bud (developed at the base of the cone) which pushes the male cone on one side. The branching in *Cycas* stem is thus referred to as sympodial.
12. **The female reproductive structures** are the sporophylls developing in place of foliage leaves. The vegetative apex continues to grow as usual.
13. **The sporophylls** are smaller than the foliage leaves. They are brown or light brown in colour and are densely covered with wooly hairs.

Exercise 2

***Object* : Study of anatomy of normal young root.**

Work procedure

Cut a T.s. of the young part of primary root, stain in safranin-fast green combination, mount in glycerine and study.

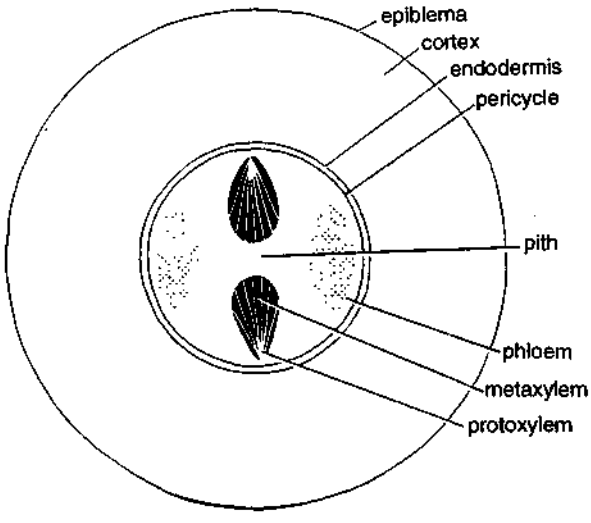


Fig. 3. *Cycas*. T. s. of normal young root (diagrammatic).

Comments

1. **The section** is circular in outline. It shows an outer layer or epiblema, cortex and centrally located stele.
2. **Epiblema** is made of single layer of thin walled cells. Some of these cells bear unicellular root hairs.
3. **Cortex** is multilayered with starch filled parenchymatous cells. A few tannin filed cells are also scattered in this region.
4. **Endodermis** is single layered and indistinguishable. Many-layered pericycle separates the cortex from vascular tissues.
5. **The central stele** is made of radial and exarch vascular bundles. There are two protoxylem groups and thus condition is diarch.

Exercise 3

***Object* : Study of anatomy of older part of normal root.**

Work procedure

Cut a T.s. of the older part of normal or primary root, stain in safranin-fast green combination, mount in glycerine and study.

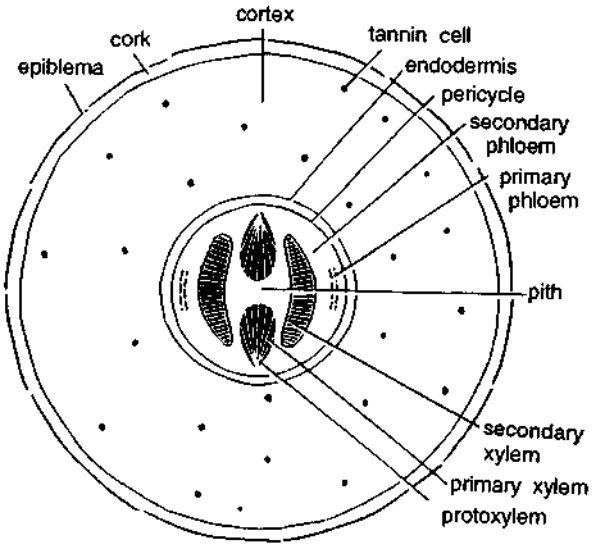


Fig. 4. *Cycas.* T. s. of normal old root (diagrammatic).

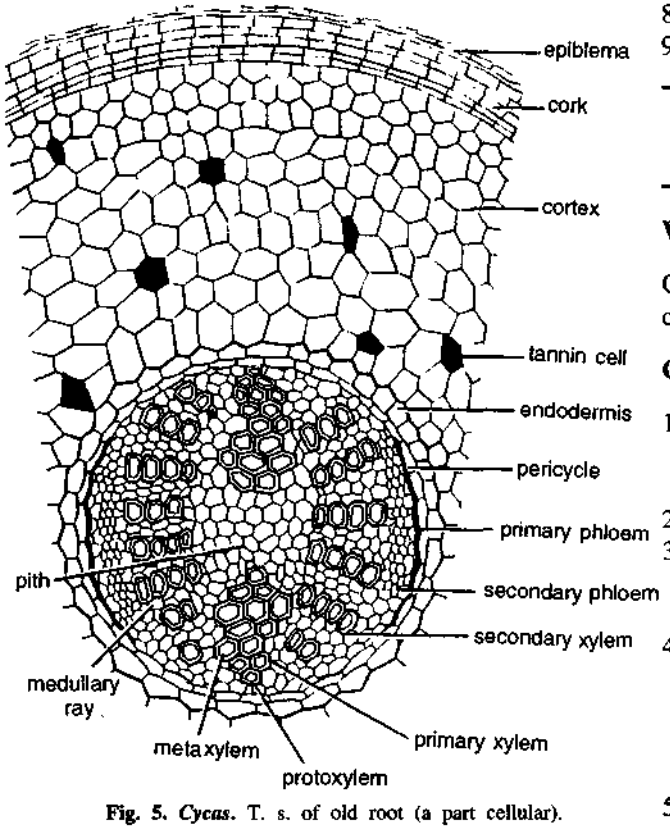


Fig. 5. *Cycas.* T. s. of old root (a part cellular).

Comments

1. It shows secondary growth, rest of the structures being similar to that of a young root.
2. **The epiblema** is ruptured due to the thick walled cork cells formed below it. Cork cells are a few layered deep and are arranged in brick-like fashion.
3. **Cortex** is large, parenchymatous and multilayered. It is present below the cork. A few tannin filled cells occur scattered in the cortex.
4. **Endodermis** is single layered. It is followed by many layered pericycle.
5. **Primary** phloem is the outermost (near the pericycle) and is crushed during secondary growth. Secondary phloem follows this layer, the cells of which are intact.
6. **Cambium** arcs are formed along the inner edges of phloem in the vascular region.
7. **Secondary xylem** is situated towards pith. The primary xylem is situated in the same region as it was before the secondary growth.
8. **Medullary rays** are formed.
9. **In the centre** is a small parenchymatous pith.

Exercise 4

***Object* : Study of anatomy of coralloid root.**

Work procedure

Cut a T.s. of the root, stain in safranin- fast green combination mount in glycerine and study.

Comments

1. The structure is almost similar to that of a normal root. It consists of epiblema, differentiated cortex and vascular tissues.
2. **Epiblema is** outermost and single layered.
3. **The cortex** is divisible into three regions -outer, middle and inner. These are similar in size. Cortex parenchymatous.
4. **The middle** cortex is also called algal zone. The cells are radially elongated. A blue-green alga *Anabaena cycadae* occurs endophytically in these cells. It is believed to be symbiotic and helps in nitrogen fixation.
5. **Endodermis** separates cortex and vascular tissues . It is single layered and followed by many layered pericycle.
6. **Vascular bundles** are radial and xylem is triarch and exarch.

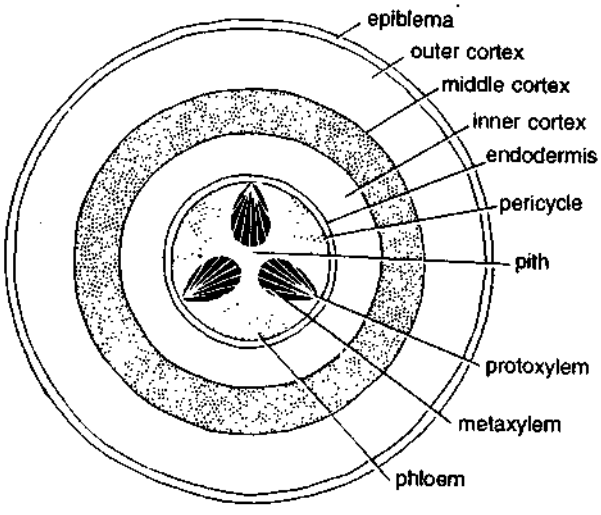


Fig. 6. *Cycas.* T.s. of coralloid root (diagrammatic).

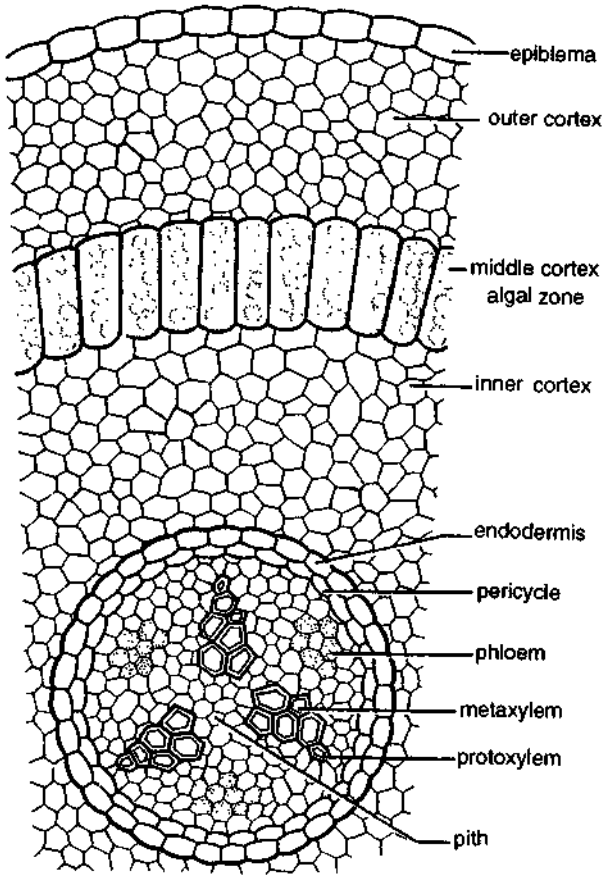


Fig. 7. *Cycas.* T.s. of coralloid root (a part cellular).

7. **Secondary** growth is generally absent; if present, it is verry less.

Exercise 5

***Object* : Study the anatomy of young part of stem.**

Work procedure

Since the stem is very thick, unbranched and very slow growing, sections are not cut, instead a slice of stem cut transversely can be preserved as specimen. It shows some important anatomical characters.

Comments

1. **Outline** of the section is irregular due to the presence of numerous persistent leaf bases.
2. **The structure** is divisible into cortex, vascular tissue and pith.
3. **Cortex.** Greater part of the stem is made of starch filled parenchymatous cortex. It is traversed by many cut, girdle-shaped leaf traces, supplying the leaves. Many mucilage ducts are irregularly scattered in this region. (In *Cycas*, a leaf is supplied by two large girdle traces, two direct traces and numerous smaller radial traces. The two girdle traces arise from the side of the stele, opposite the leaf. These unite, bifurcate and take a circular route through the cortex before entering the leaf. The radial traces arise from other points of vascular ring but contrary to girdle traces, they adopt a straight radial course in the cortex. They bifurcate producing anastomosing branches which get attached to the girdle traces. In a trancverse section large number of girding leaf traces are cut. This is one of the most conspicuous features of the stem anatomy).
4. **Stele** is an ectophloic siphonostele.
5. **Endoermis** surrounds the stele. It is single layered while underlying pericycle is few celled thick
6. **Vascular cylinder** is composed of many vascular bundles arranged in a ring. Ring of vascular bundles lies near the centre and is very small in comparison to the massive cortex.
7. **The vascular bundles** are conjoint, collateral, endarch and open.

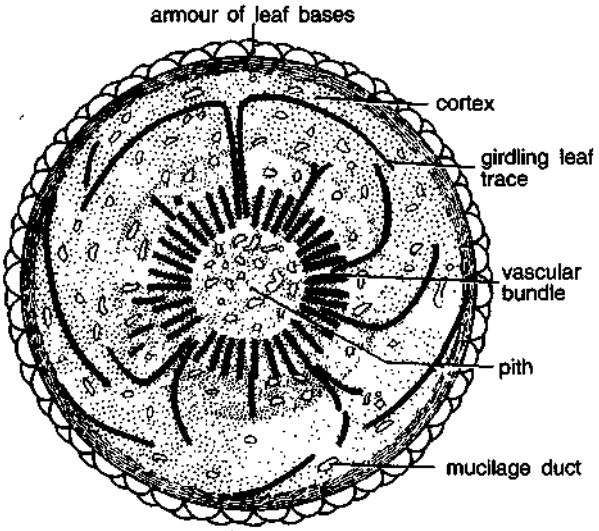


Fig. 8. *Cycas.* T.s. of young stem (diagrammatic).

8. **Xylem** is made of tracheids only and xylem parenchyma. Vessels are absent.
9. **Phloem** consists of sieve tubes, phloem parenchyma and phloem fibres.
10. The young stem is **monoxylic** (i.e. with one ring of vascular bundles only).
11. **Pith.** There is parenchymatous pith in the centre, with scattered mucilage canals.

Exercise 6

***Object* : Study of anatomy of the old stem.**

Work procedure

A thck slice of an old stem is generally preserved as specimen. Only prominent features could be observed.

Comments

1. It shows almost the same structures as those in young stem, except those formed after secondary growth.
2. **A periderm** is present on the outer side. It is composed of thick walled cells.
3. **Cortex** is large and parenchymatous. It forms most part of the section. A few mucilage canals are also present.

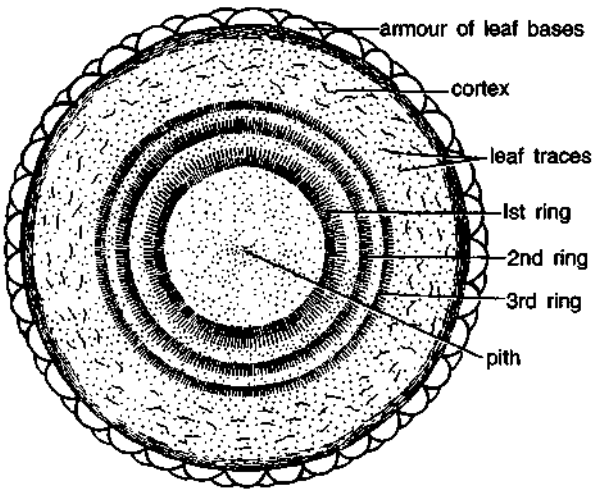


Fig. 9. *Cycas.* T.s. of old stem (diagrammatic).

4. **Vascular bundles** are formed, due to successive development of cambium rings. Thus, the old stem is **polyxylic** (with more than one ring of vascular bundles). The number of vascular bundles as well as the thickness of the successive vascular rings, thus formed, is lesser than the first formed ring.
5. **Secondary vascular tissues.** The successive rings of secondary vascular tissue are separated by parenchymatous zone. This loose, soft and scanty wood is called **manoxylic.**
6. **Medulllary rays** are present.
7. **Pith.** A large pith lies in the centre. Cells are parenchymatous and starch filled. Many mucilage canals are also present.

Exercise 7

***Object* : Study of anatomy of rachis.**

Work procedure

Cut a T.s. of rachis from its middle region, stain in sarfanin-fast green combination, mount in glycerine and study.

Comments

1. **Outline.** It is cylindrical. It shows insertion of pinnae on the adaxial side (upper side).

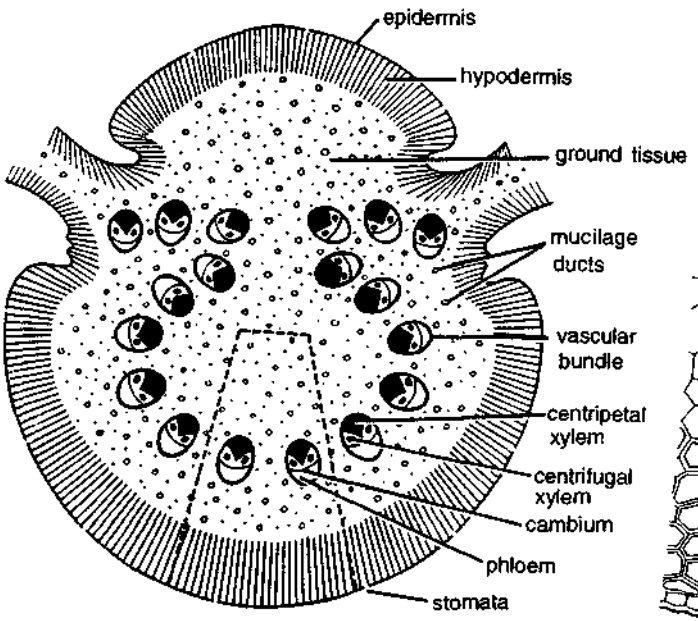


Fig. 10. *Cycas*. T.s. of rachis (diagrammatic).

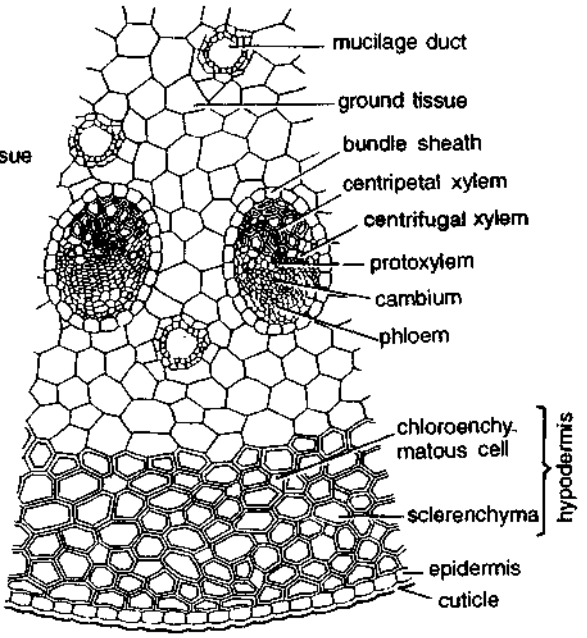


Fig. 11. *Cycas*. T.s. of rachis (a part shown by dotted lines in Fig. 11 in details).

2. **The rachis** is differentiated into epidermis, hypodermis, ground tissue and a ring of vascular bundles.
3. **Epidermis** is single layered, thickly cuticularized and is interrupted by stomata throughout its surface. The condition is known as amphistomatic.
4. **Hypodermis** is mainly composed of thick-walled cells (sclerenchyma). Intermixed with these cells are a few cells having chloroplasts-chlorenchyma.
5. This sclerenchymatous hypodermis is 2-3 layered toward adaxial side and many layered toward abaxial side.
6. **Ground tissue.** The rest of the tissue that forms most part of the section is called ground tissue. It is parenchymatous.
7. **Mucilage ducts** are scattered throughout the ground tissue. Mucilage ducts are double layered, the inner layer being composed of epithelial cells and the outer of tangentially elongated sclerenchymatous cells.
8. **The vascular bundles** are arranged in an inverted omega (Ω) shaped arc. Each vascular bundle is surrounded by a thick walled, single-layered bundle sheath. It is conjoint, collateral and open.
9. **The arrangement of xylem and phloem** differs in vascular bundles at the base, middle and upper region of the rachis.
   (i) Higher up and for most part of the rachis, bundles are **diploxylic** i.e. two types of xylem elements are present - centripetal and centrifugal xylem. The centrifugal xylem occurs in two small groups, present on both the sides of large triangular and centrally located centripetal xylem. The phloem is situated on the abaxial side of the rachis.
   (ii) At the very base of the rachis, vascular bundles show only centrifugal xylem which is endarch. Phloem occupies the abaxial side of the rachis.
   (iii) Little higher up the base of rachis, vascular bundles show centrifugal xylem on abaxial side and centripetal xylem on adaxial side. In the centre of these two xylem groups, lies the protoxylem. This conditionis is said to be mesarch.

Features of special interest

1. Presence of chlorenchyma, dispersed among the thick walled sclerenchymatous hypodermis.

2. Presence of sunken stomata all over the surface. (xerophytic characters).
3. Vascular bundles arranged in inverted omega (Ω) shaped arc.
4. Diploxylic nature of the vascular bundles.
5. Mucilage ducts scattered throughout.

Exercise 8

***Object* : Study of anatomy of leaflet (pinna).**

Work procedure

Cut a T.s. of leatlet, stain in safaranin-fast green combination, mount in glycerine and study.

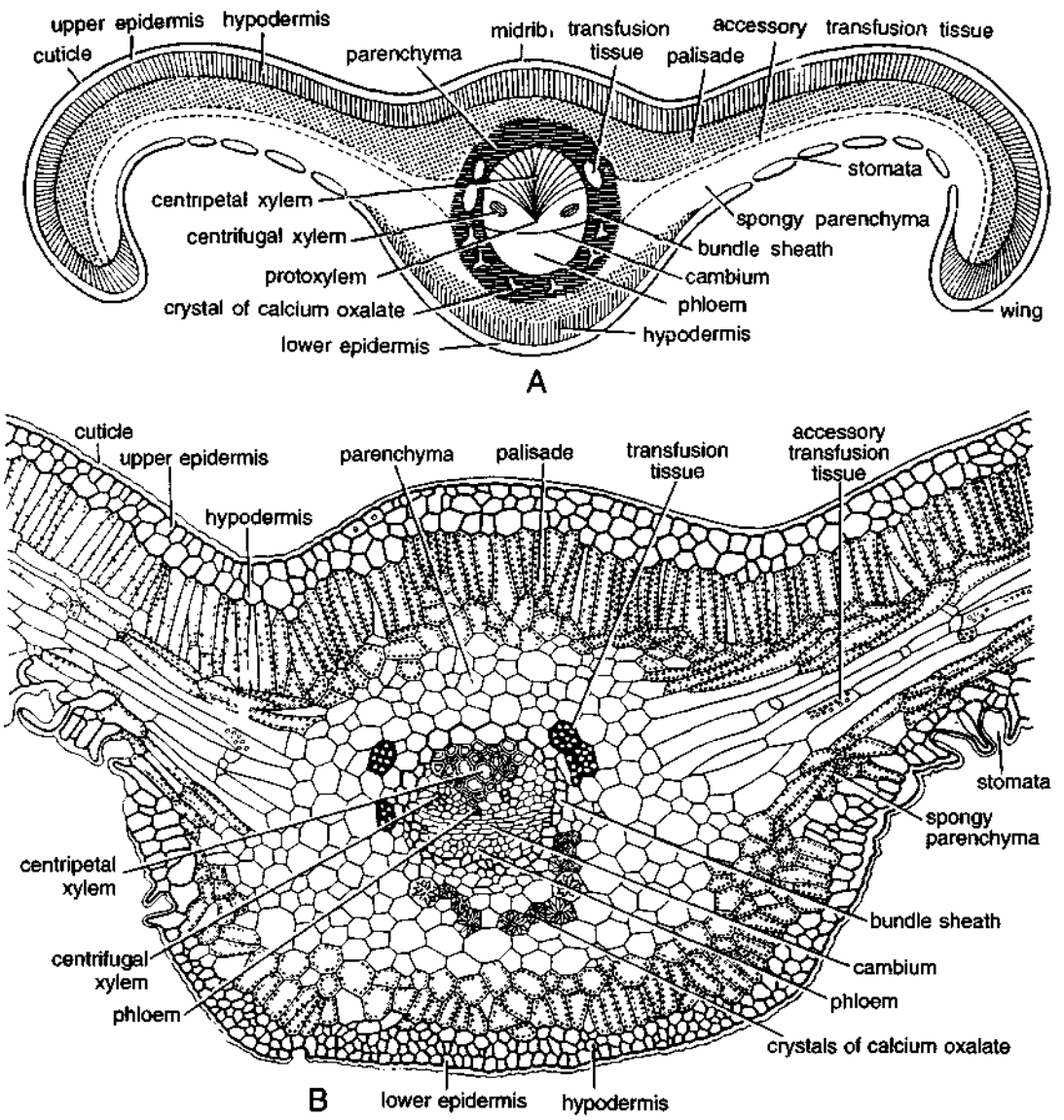


Fig. 12. *Cycas.* **A.** and **B.** T.s. of leaflet.

Comments

1. **The leaflet shows** a distinct midrib and the wings.
2. **The midrib** is swollen, while wings on the lateral sides are narrower and flattened.
   (i) In *C. revoluta* midrib is less projected than in *C. circinalis,* where it is much projected on the upper side.
   (ii) Margins of wings are revolute in *C. revoluta,* and *C. beddomei* while they are straight in *C. circinalis, C. rumphii, C. pectinata* and *C. siamensis.*
3. **Upper epidermis** is present on the upper side. It is thickly cuticularized and single-layered.
4. **Hypodermis** is present below the epidermis. It is sclerenchymatous.
   (i) In *C. revoluta,* hypodermis is present in the midrib (near both upper and lower epidermis) and wings (below the upper epidermis).
   (ii) In *C. circinalis,* hypodermis in the midrib region is present on both the sides (upper and lower) while in the wings, it occupies only the corners, being absent from rest of wings.
5. **Mesophyll** lies below the hypodermis and is well developed. It is differentiated into upper palisade layers and lower of spongy parenchyma.
   (i) In *C. revoluta,* palisade is present beneath the hypodermis, both in the midrib and the wings.
   (ii) In *C. circinalis* palisade is absent from the midrib region
6. **Spongy parenchyma** with many intercellular spaces lies immediately above the lower epidermis.
7. **Transfusion tissue.** On either side of the centripetal metaxylem of mid rib bundle and somewhat connected with it, are present two tracheid-like cells-transfusion tissue.
8. **Accessory transfusion tissue.** Between the palisade and spongy parenchyma cells, there are 3 or 4 layers of tracheid-like, long colourless cells which run transversely from the midrib to near the margin of the lamina. This is known as accessory transfusion tissue. It is connected with the xylem of the vascular bundle of midrib through the transfusion tissue.
9. **Lower epidermis** bounds the leaflet from lower side. It is thickly cuticularized and single layered. Sunken stomata are found in the lower epidermis in the midrib region.
10. **Stomata** are very much sunken in the lower epidermis in *C. revoluta,* while they are not so much sunken in *C. circinalis.*
11. **Midrib bundle.** In middle of the swollen portion representing the midrib lies a single vascular bundle surrounded by parenchymatous tissue (with calcium oxalate crystals). Vascular bundle has a definite and thickened, parenchymatous bundle sheath.
12. **The vascular bundle** is similar in all respects to that found in the upper region of the rachis. It is conjoint, collateral, open and diploxylic.
13. **Phloem** lies towards the abaxial (lower) side. In between xylem and phloem, cambium is present.
14. **Xylem.** It shows a large, triangular patch of centripetal xylem and two small groups of centripetal protoxylem.

Features of special interest

1. Lateral veins are absent.
2. Thickly cuticularized upper and lower epidermis.
3. Sunken stomata in the lower epidermis.
4. Presence of transfusion tissue.
5. Diploxylic nature of vascular bundle.

Exercise 9

***Object* : Study of bulbil.**

Work procedure

Study the position on the lower part of the stem and observe external characters.

Comments

1. Bulbils are produced adventitiously, on basal part of the plant, in the crevices between the persistent leaf bases.
2. The decurrent base of the bulbil remains covered with scale leaves.
3. A few foliage leaves are given out from the central part.

4. It germinates under favourable conditions and produces new plant or else develops into a branch (rarely), giving an appearance of dichotomous branching.
5. This is the commonest method of reproduction in *C. revoluta* in north india, male plants being rare in this region.

Exercise 10

***Object* : Study of external features of male cone.**

Work procedure

Study the male cone attached to the plant if possible.

Comments

1. The male cone is terminal, shortly stalked, compact, large and oval or conical in shape and consists of a central cone axis around which numerous microsporophylls are spirally arranged. (Since the male cone terminates the growth of the apex of male plant, a lateral bud later grows and takes over the continuation of growth of apex. The male plant thus shows sympodial growth).
2. The outer covering of the male cone is formed by closely set sterile ends of the microsporophylls usually possessing upcurved apices, apophysis.

Exercise 11

***Object* : Study of L.s. of the male cone.**

Work procedure

Since the male cone is about 60-80 cms in height, it can be split into two and specimen is studied.

Comments

1. The L.s. shows stalk and the cone.
2. Male cone is attached at the apex of the plant by a stout and broad stalk.
3. The cone itself consists of a central cone axis with many microsporophylls.
4. Each microsporophyll is attached to the cone axis. The part of microsporophylls away from the axis is upcurved and is called apophysis.

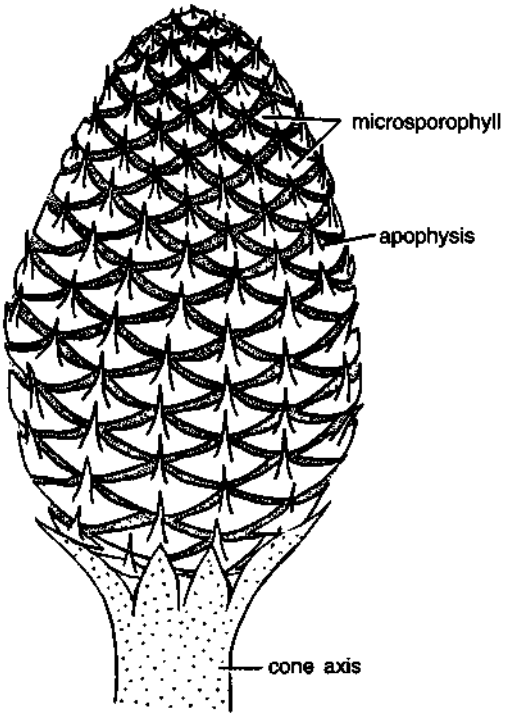


Fig. 13. *Cycas*. A male cone (external features).

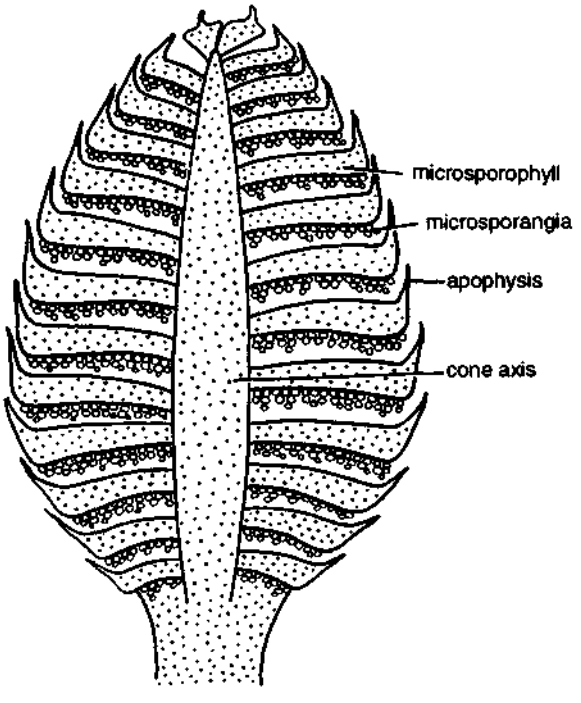


Fig. 14. *Cycas*. L.s. of male cone.

5. The upper surface of the microsporophyll is sterile.
6. The lower surface of the microsporophyll is fertile and bears many microsporangia in groups (sori).
7. Microsporophylls in the middle part of the cone are largest and get gradually smaller towards the base and the apex.

Exercise 12

***Object* : Study of microsporophyll and microsporangia.**

Work procedure

Take out a microsporophyll from the male cone. Study both- upper and lower surfaces. Observe the sporangia on the lower surface with a magnifying lens.

Comments

1. A single microsporophyll is woody, more or less horizontally flattened and triangular structure.
2. It is differentiated into a fertile and sterile parts. Fertile part is wedge-shaped and is expanded distally from a narrow point of attachment. Sterile part is the distal part of the microsporophyll which tapers into an upcurved apophysis.
3. Lower (abaxial) surface of the fertile part of the microsporophyll bears microsporangia in groups of 3-4, forming definite sori.
4. Microsporangia are arranged in sori around central papilla. Sporangia show radial lines of dehiscence. Many hairs are distributed on this surface mixed with sporangia.

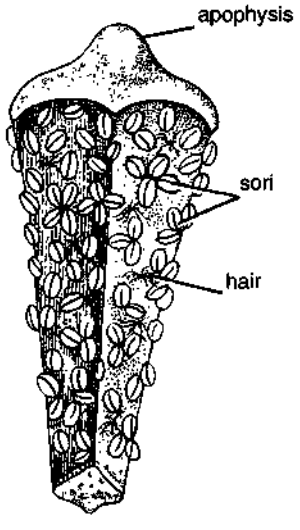


Fig. 15. *Cycas*. A microsporophyll from lower side.

Exercise 13

***Object* : Study of T.s. of microsporophyll.**

Work procedure

Study the characters observed in sliok of T.s. of microporophyll.

Comments

1. The section shows microsporangia attached to the abaxial (lower) surface by their short stalks.
2. A mature microsporangium has three layered wall. The outermost layer is thick and cutinized, termed as exothecium. The remaining inner layers are thin and are collectively known as endothecium and enclose a tapetum.
3. Numerous microspores remain enclosed inside the wall of the microsporangium.
4. In the microsporophyll are present many mucilage ducts, regularly scattered, among the rounded mesophyll-like cells forming the tissue of the sporophyll.

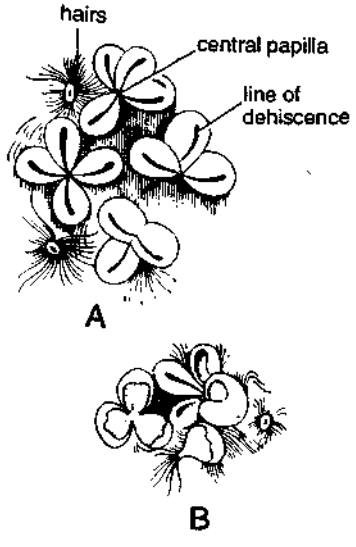


Fig. 16. *Cycas*. Microsporangia in sori. **A.** Before dehiscence, **B.** After dehiscence.

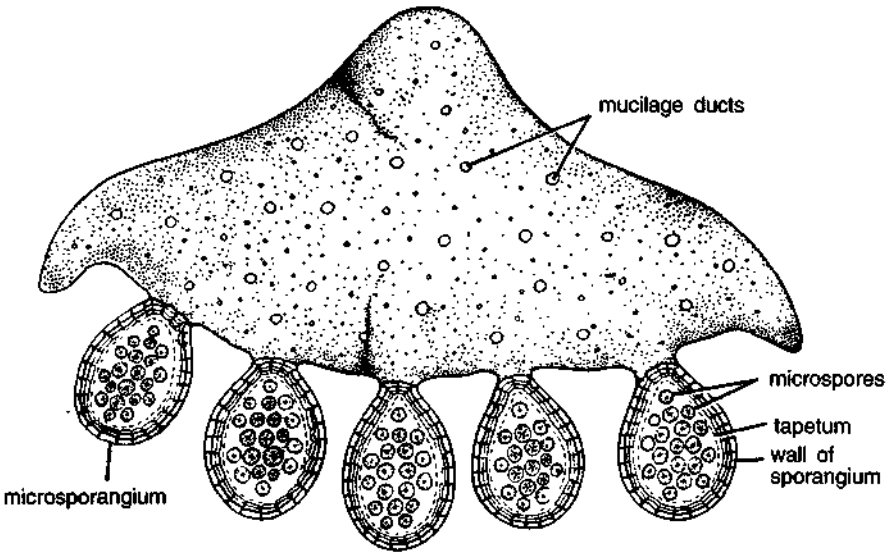


Fig. 17. *Cycas*. T.s. of microsporophyll.

Exercise 14

***Object* : Study of megasporophyll.**

Work procedure

Since there is no female cone, megasporophylls form a crown at the apex like foliage leaves. Only a megasporophyll can be studied as a specimen.

Comments

1. Female reproductive body consists of megasporphylls arranged spirally and arising in acropetal succession on the stem.
2. Megasporophylls appear as a rosette or a crown, leaving the apical meristem unaffected to grow further. A crown of megasporophyll is formed each year. Numerically they are more than the leaves.

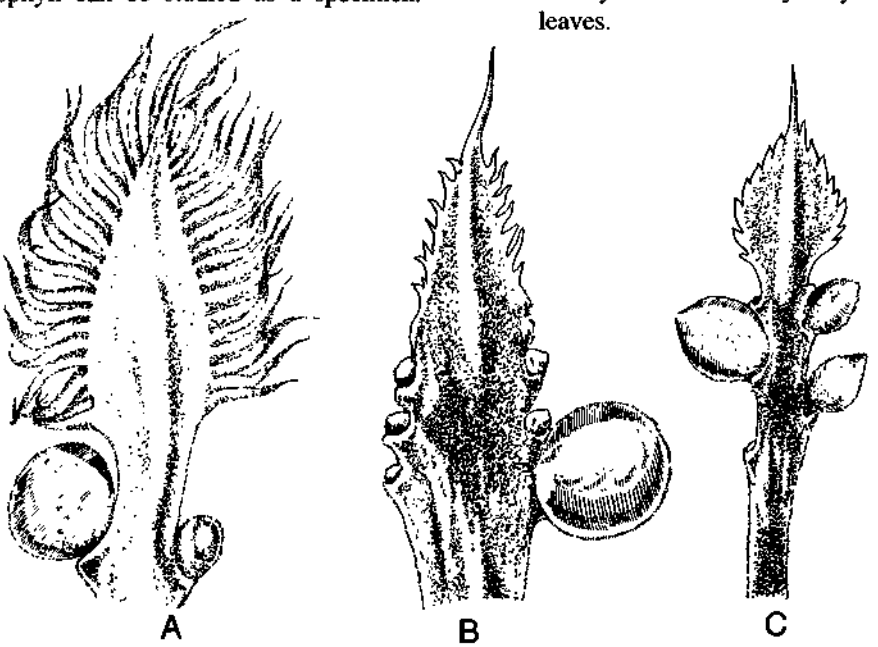


Fig. 18. *Cycas*. Megasporophylls of different species with ovules. **A.** *C. revoluta*, **B.** *C. circinalis*, **C.** *C. rumphii*.

3. They leave their persistent bases on the stem.
4. Each megasporophyll is leaf-like and densely covered with brown hairs. It varies in size from 6 to 12 inches.
5. Each megasporophyll is distinguished into a proximal (lower) petiole, a middle ovule bearing portion and a distal (upper) pinnately dissected sterile part.
6. The nature of upper sterile part varies with species.
   (i) In *C. revoluta*, the upper part is very much dissected, forming many pinnae.
   (ii) In *C. rumphii*, the upper part bears only short spines which represent reduced pinnae.
   (iii) In *C. circinalis*, the pinnate character is altogether absent and upper part shows only dentate or serrate margins.
7. The middle portion of sporophyll bears ovules which are borne in two rows, one on either side. The ovules of the two rows may be opposite or alternate.
8. Ovules are generally yellow or orange or dark green coloured, shortly stalked, oval and smooth. Number and size of the ovules differ from species to species.
   (i) In *C. revoluta*, ovules are many and orange coloured,
   (ii) In *C. circinalis* also, they are numerous, but these are dark green and attain a large size,
   (iii) In *C. siamensis*, the number of ovules is reduced to only two and
   (iv) In *C. thouarsii*, the ovules become still larger and may be that they are the largest ovules in the plant kingdom.
9. All the ovules do not develop fully. Some of those which remain unpollinated and small, finally abort.

Exercise 15

***Object* : Study of L.s. of mature ovule.**

Work procedure

Study the slide showing L. s. of mature ovule.

Comments

1. The section shows that the ovule is orthotropous.
2. It is unitegmic (possesses a single integument). The integument is very thick. It remains fused with the nucellus except for the nucellar beak leaving a small and narrow micropyle.

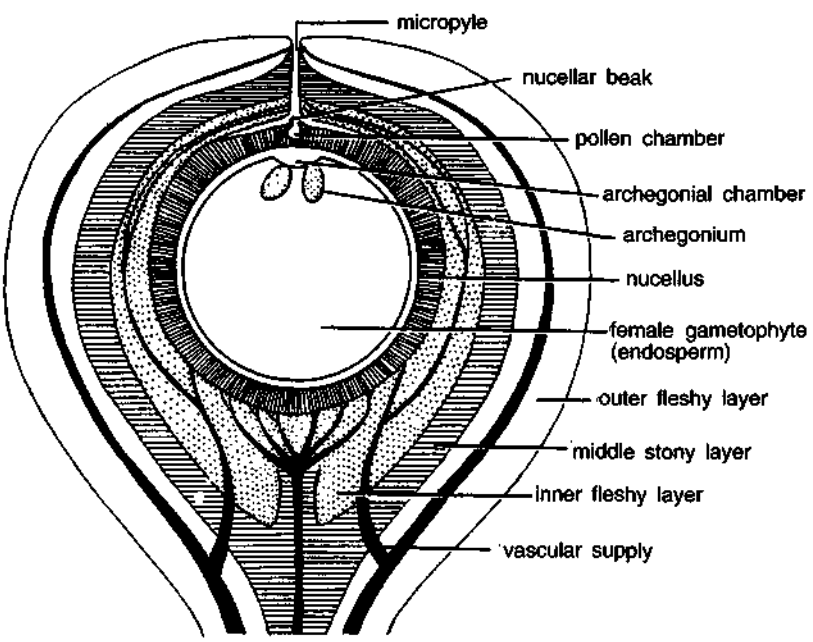


Fig. 19. *Cycas*. L.s. of ovule.

3. **The integument** consists of three distinct layers- an outer fleshy layer, middle stony layer and an inner fleshy layer. The outer and inner flshy layers are supplied with vascular strands but the middle stony layer receives no vascular supply.
4. **The nucellus** lies just below the integument and forms a nucellar beak in the region of the micropyle.
5. A few cells of this nucellar beak dissolve themselves and form a pollen chamber that lies in the tissue in the central region of the beak.
6. **Female gametophyte.** The innermost region of the ovule is filled with the tissue of female gametophyte, wherein lie two archegonia, situated opposite the pollen chamber.
7. **Archegonial chamber.** Just above the archegonia is the archegonial chamber.
8. **Micropyle.** The orange coloured, fleshy ovules are oval in shape and each shows a small point at the distal end which represents the remnant of the micropyle.

Exercise 16

***Object* : Study of L.s. of seed.**

Work procedure

Study a double-stained preparation of the L.s. of seed.

Comments

1. It shows seed coat, nucellus, embryo and the female gametophyte.
2. **Seed coat** consists of sarcotesta (from outer fleshy layer of integument), and middle sclerotesta (from middle stony layer). The inner fleshy layer of the integument appears as thin and papery structure in the seed.
3. **Nucellus** is papery and is situated inside the seed coat.
4. **Endosperm** and female gametophyte form the inner part of seed.
5. **A straight embryo** remains embedded in the endosperm. It has two unequl cotyledons.

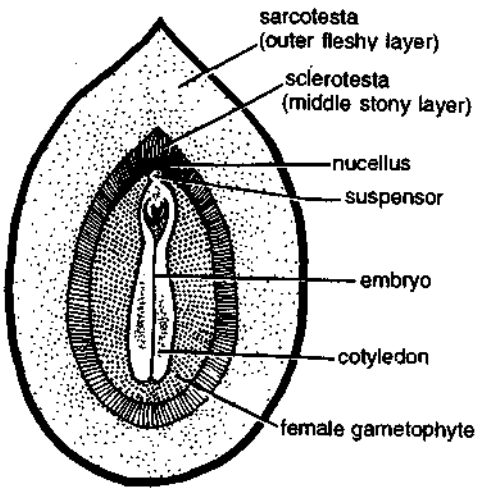


Fig. 20. *Cycas.* L.s. of seed.

Identification

Division—**Gymnosperms**. (1) Absence of vessels, (2) Ovules naked, (3) Seeds attached with woody acales, (4) Scales generally form a cone.

Class—**Cycadopsida**. (1) Wood manoxylic, (2) Large frond-like leaves (3) Seeds with radial symmetry.

Order—**Cycadales**. (1) Plants woody, stem unbranched, (2) Wood manoxylic, (3) Pressence of mucilage canals, (4) Leaf trace diploxylic, (5) Dioecious, (6) Ovules orthotropous, (7) Sperm with band of flagella.

Family—**Cycadaceae**. (1) Leaves with circinate vernation, (2) Presence of coralloid roots and endophytic blue green algae, (3) Megasporophylls foliar.

Genus—***Cycas***. (1) Two types of leaves, (2) Foliage leaves pinnately compound, circinately coiled when young, (3) Presence of trasfusion-tissue and diploxylic pascular bundle in leaf, (4) Secondary xylem in stem manoxlic, (5) Two types of roots, (6) Vascular bundles arranged in an inverted omega-shaped manner in the rachis, (7) Male cone large and single.

Hints for Collection

In India the genus grows naturally only in the north-east (East Nepal, Champaran-Bihar, Sikkim, Assam and East Bengal) and South (Orissa, Andhra Pradesh and Tamil Nadu). Six species are found in India of which *C. circinalis, C. pectinata. C. rumphii,* and *C. beddomei* grow wild but *C. revoluta,* a native of Japan and *C. siamensis* is found in Burma and Siam are cultivated.

Pinus (Pine)

Classification

Division	–	**Gymnosperms**
Class	–	**Coniferopsida**
Order	–	**Coniferales**
Family	–	**Pinaceace**
Genus	–	***Pinus***

Exercise 1

***Object* : Study of external morpohology.**

Work procedure

Note the pattern of branching, the two types of branches, two types of leaves, and male and female cones.

Comments

1. It is a tall conical tree and, therefore, commonly grouped under conifers.
2. **The plant body** is differentiated into root, stem and leaves.
3. **Underground root system** is formed by tap roots which disappear early and only lateral roots persist later on.
4. **The younger roots** are generally surrounded by fungal hyphae- the ectotrophic mycorrhizae.
5. **Aerial branch system** consists of cylindrical, rough (being covered with scaly bark) and branched stem.
6. **The branching** is monopodial and the branches are arranged in whorls.
7. **The branches** are dimorphic (of two types)- branches of unlimited growth or long shoots and branches of limited growth or dwarf shoots.
8. **Branches of unlimited growth** or long shoots are present on the main trunk. These are produced at regular intervals.
9. **Branches of limited growth** or dwarf shoots are borne on the main stem and on long shoots in the axils of scale leaves. Dwarf shoots also possess many scale leaves and bear group of foliage leaves at the apex.

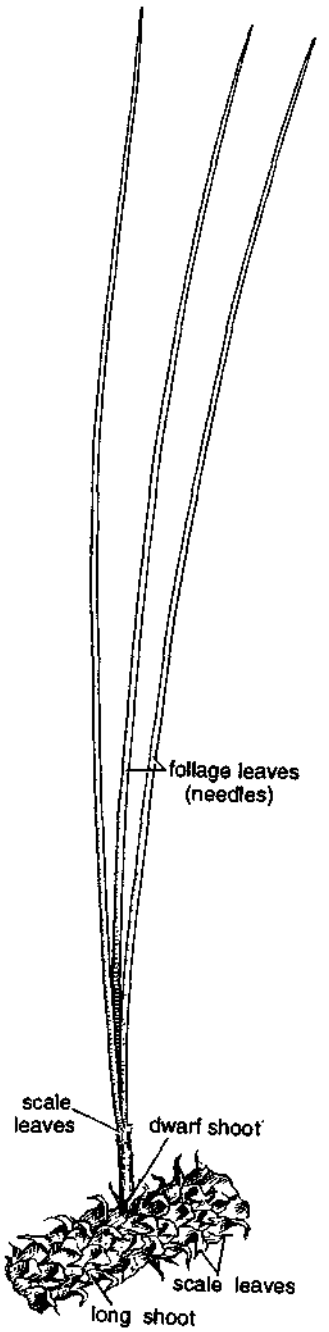


Fig. 1. ***Pinus***. A part of stem showing two types of branches.

10. **The leaves** are also dimorphic (of two types)- scale leaves and foliage leaves.
11. **Scale leaves** are brown, membranous and small. They are present on both the types of branches (i.e. long and dwarf shoots).

12. **Foliage leaves** are green, acicular and needle-like. They are borne only by the dwarf shoots.
13. **A dwarf shoot** with a group of needle-like foliage leaves is known as a foliar spur. The number of needles in a group varies from species to species. *P. monophylla* has a single leaf and spur is known as monofoilar, while in *P. sylvestris*, two leaves are present and spur is called as bifoiiar. In *P. longifolia* and *P. gerardiana*, they are three in number, the spur being called as trifoliar. Quadrifoilar spur occurs in *P. quadrifolia* and pentafoliar in *P. excelsa.*
14. **The shape of the needle** varies, according to their number in a spur. In *P. sylvestris* (with bifoliar spur), single needle is semi-circular in T.s. while in *P. longifolia* (with trifoliar spur), single needle is almost triangular in shape.
15. ***Pinus* is monoecious.** Plant bears male and female reproductive parts in cones on the same plant .
16. **The male cones** are borne on lateral branches of unlimited growth. They are produced in clusters and replace the dwarf shoots. Also, they are formed earlier in the season than the female cones.
17. **The female cones** are borne terminally on branches of unlimited growth. They are produced singly and replace the long shoot. The female cone appears after every three years.
18. Generally male and female cones are not formed on one and same branch.

Exercise 2

***Object* : Study of anatomy of young root.**

Work procedure

Study a double stained prepared slide of T.s. of young part of root.

Comments

1. **The section** is almost circular in outline.
2. The tissues are differentiated into epiblema cortex and vascular tissues.
3. **Epiblema** is outermost single layer. It gives out many thin and unicellular root hairs.

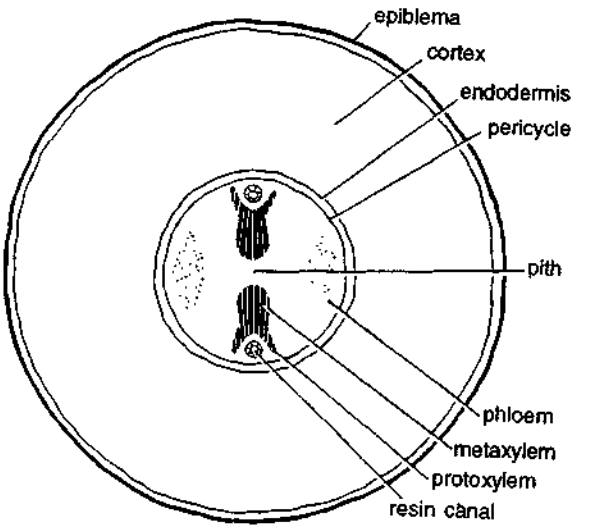


Fig. 2. ***Pinus.*** T.s. of young root (diagrammatic).

4. **Cortex** is multilayered and parenchymatous.
5. **Endodermis** separates outer cortex and central vascular cylinder. It is single layered and cells are radially thickened.
6. **Pericycle** follows endodermis. It is multilauered.
7. **Vascular bundles** are radial, exarch and diarch to hexarch.
8. **Protoxylem** is generally Y-shaped and a resin canal is present in between the arms of Y.
9. **Pith** is very small and lies between the groups of xylem.

Exercise 3

***Object* : Study of anatomy of the old root.**

Work procedure

Study a double stained prepared slide of T.s. of old part of root.

Comments

1. **The section** shows cork, cortex, primary and secondary vascular tissues and a small pith.
2. **Cork** forms the outermost several layers. (developed from pericycle and hence primary cortex is completely peeled off).
3. **Stone cells** occur in many groups scattered just below the zone of cork.

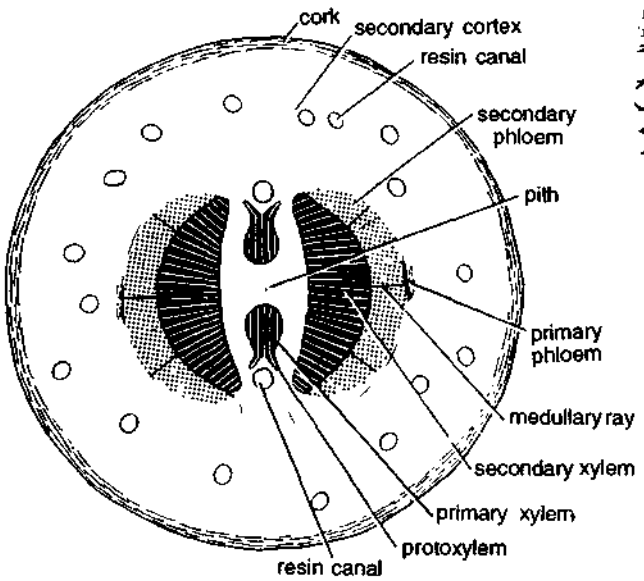


Fig. 3. ***Pinus.*** T.s. of old root (diagrammatic).

4. **Secondary cortex** follows cork. It is parenchymatous and a few layered deep.
5. **Many resin canals** are found in the secondary cortex.
6. **Primary phloem** occurs in two patches. The tissues are mostly crushed and obliterated.
7. **Secondary phloem** that follows is a few layered deep ring. It consists of sieve tubes, sieve plates, phloem parenchyma and albuminous cells.
8. Secondary phloem and secondary xylem are separated by a cambium.
9. **Secondary xylem** is composed of tracheids arranged in regular rows. It is traversed by uniseriate medullary rays.
10. **Pith** is small and parenchymatous. Two groups of primary xylem are situated on opposite radii.
11. **Each primary xylem** group is Y shaped. The divided arm faces the outer side (away from the pith).
12. **Resin canal.** The characteristic of the pine root is the presence of large resin canal between the divided arm of Y, close to each primary protoxylem group.

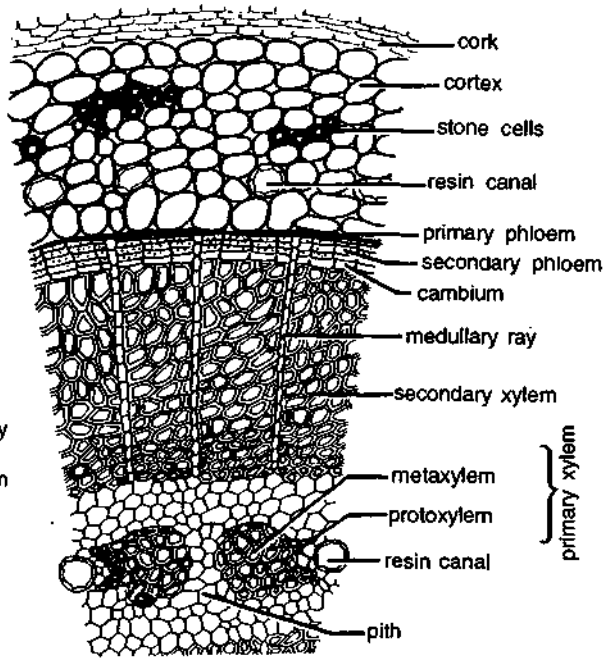


Fig. 4. ***Pinus.*** T.s. of old root (a part cellular).

Exercise 4

Object **: Study of anatomy of the young long shoot.**

Work procedure

Cut a T.s. of younger part of the long shoot towards the apex, stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. **Outline** is wavy due to the presence of scaly leaves.
2. The stem is differentiated into epidermis, cortex and stele.
3. **Epidermis** is the outermost single layer. It is thickly cuticularized.
4. **Cortex** is multilayered and lies below the epidermis. The outer few layers forming hypodermis are sclerenchymatous. Inner layers are thin walled and parenchymatous in which

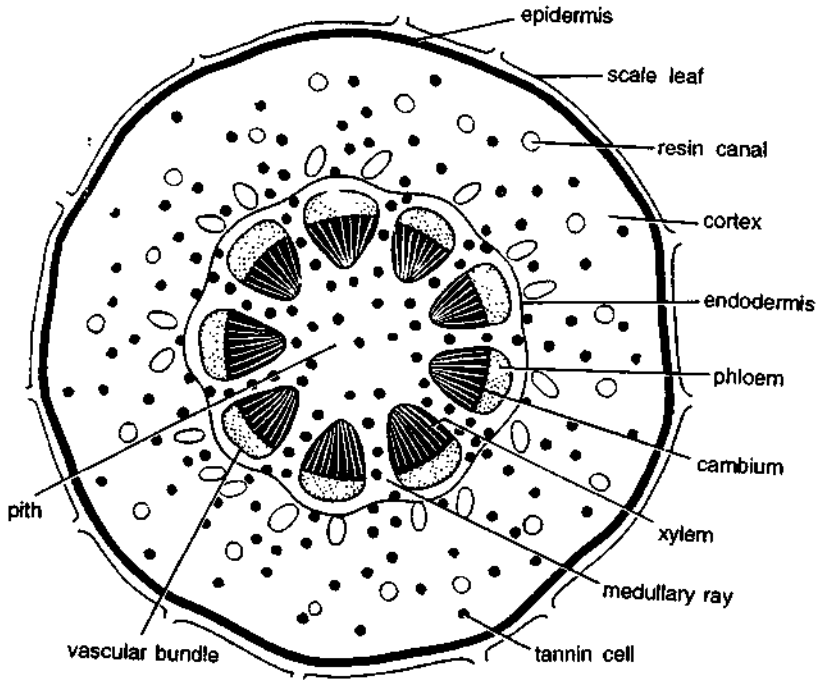


Fig. 5. ***Pinus.*** T.s. of young long shoot (diagrammatic).

large number of resin canals and leaf traces are distributed irregularly.

5. **Resin canal.** The cavity of resin canal is bounded by a glandular, resin secreting epithelial layer. Outer to this layer are one or two layers of sclerotic cells.
6. In *Pinus*, resin canals are present in the cortex and secondary wood of both stem and root and on margins of the primary xylem in the root.
7. **The stele** is ectophloic siphonostele.
8. **Endodermis** is present but is undistinguishable and so also a few layered pericycle located inner to it.
9. **Vascular cylinder** is composed of 5-8 vascular bundles, separated by medullary rays. Vascular bundles are arranged in a ring.
10. **Each vascular bundle** is conjoint, collateral endarch and open.
11. **Xylem** is composed of tracheids and xylem parenchyma only, vessels are absent.
12. **The phloem** is made up of sieve tubes, sieve plates and phloem parenchyma. Albuminous cells are also present.
13. **Pith** lies in the centre and is parenchymatous. It is connected with the cortex but narrow medullary rays separate the vascular bundles.

Exercise 5

***Object* : Study the anatomy of the old long shoot.**

Work procedure

Cut a T.s. of the old part of the stem, stain with safranin-fast green combination, mount in glycerine and study.

Comments

1. **The section** shows cork, cortex, primary and secondary vascular tissues and pith.
2. **Cork.** The outmost region is formed by the successive layers of cork. It consists of thick and suberized cells.
3. **Cork cambium** follows cork. It is made of a few layers of regularly arranged cells.
4. **Secondary cortex** present below is parenchymatous.

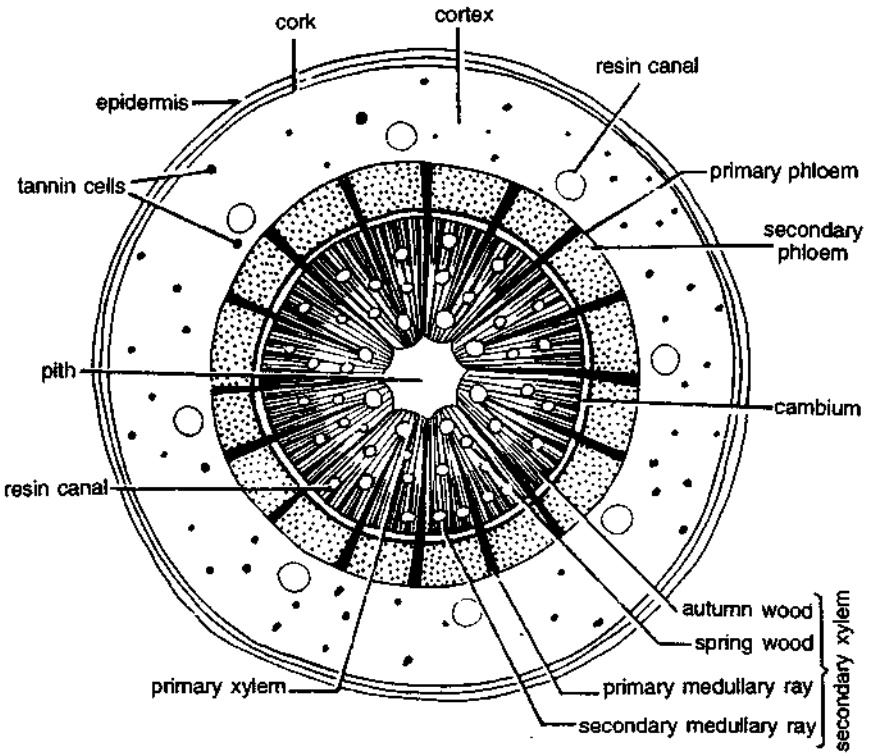


Fig. 6. ***Pinus.*** T.s. of old long shoot (diagrammatic).

5. **Primary cortex** is parenchymatous and many layered. The resin canals occur irregularly distributed in this region.
6. **Primary phloem** that lies inner to primary cortex occurs as small patches of crushed tissues.
7. **Secondary phloem** occurs as a well distinguished ring.
8. **Phloem** is composd of sieve tubes and phloem parenchyma.
9. **Cambium** separates the secondary phloem on its outer side and secondary xylem on its inner side.
10. **Secondary xylem** shows distinct and sharp annual rings. Thin walled and large xylem elements form a ring of spring wood. Thick walled and small xylem elements form a ring of autumn wood. The wood is pyconoxylic (compact).
11. **Rings of secondary xylem** — autumn and spring wood alternate one another and together form annual ring.
12. **Secondary xylem** (wood) is composed of tracheids and xylem parenchyma. Vessels are completely absent. Hence it is called non-porous wood.
13. **Medullary rays** traverse xylem and phloem. Primary medullary rays run from primary xylem to secondary phloem.
14. **Primary xylem** groups are endarch and lie just near the pith.
15. **Resin canals** are scattered in the primary and secondary xylem as in the cortex.
16. **Pith** is small, parenchymatous and many cells are filled with tannin.

Exercise 6

***Object* : Study of R.L.s. of the wood.**

Work procedure

Cut a thin section of wood along any one of the radii, stain in safranin-fast green combination, mount in glycerine and study.

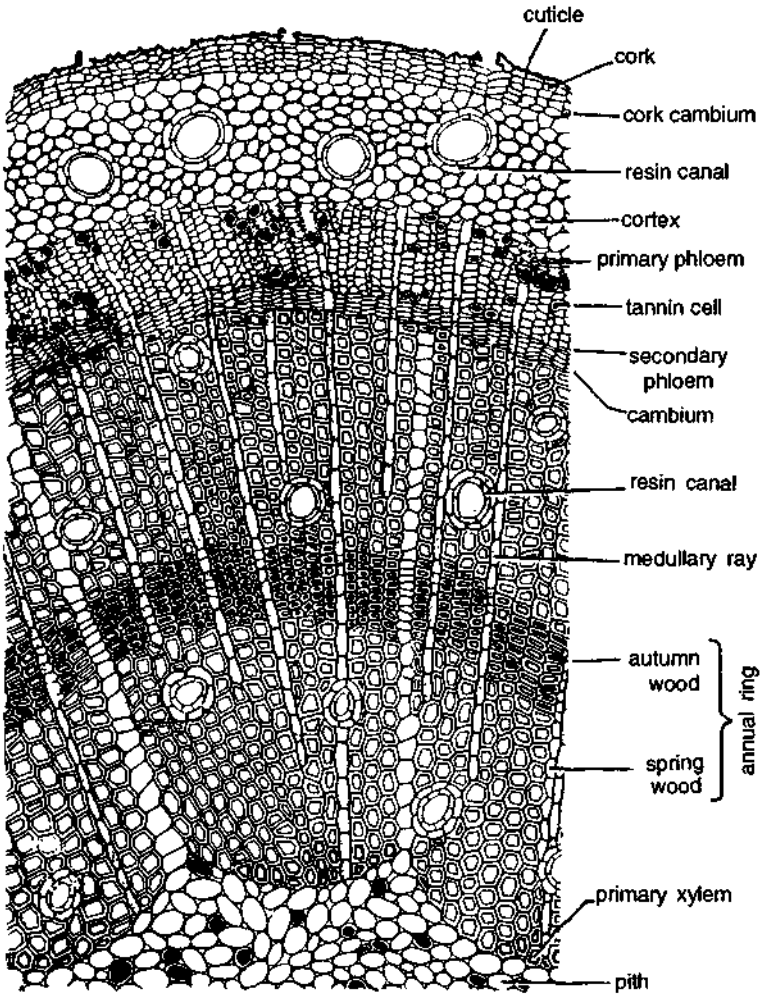


Fig. 7. ***Pinus.*** T.s. of old long shoot a part cellular.

Comments

1. It shows presence of secondary xylem, ray tracheids and medullary rays.
2. **Xylem** is composed of tracheids with bordered pits on their radial walls. The bordered pits in this section are seen in surface view.
3. **Bordered pits** are circular areas surrounded by special cellulose thickenings called crassulae or Bars of Sanio. If pits are close to one another, the bars fuse to form Rims of Sanio.
4. **Medullary rays** run horizontally. In radial longitudinal plane they are cut length-wise and their length and height can be noticed. They are uniseriate.
5. **Each medullary ray** is made up of ray cells, ray tracheids and parenchyma.
6. **Ray tracheids** are present on both the sides of the medullary ray cells, only in the region of

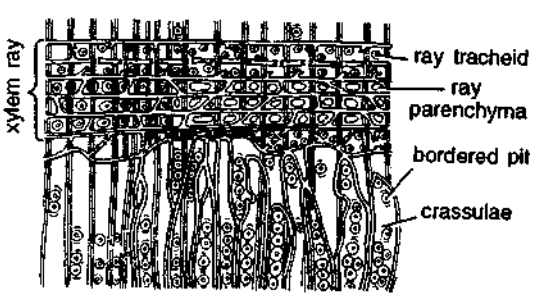


Fig. 8. ***Pinus.*** R.L..s. of wood (a part cellular).

xylem. These cells are thick, narrow and long. They show bordered pits.

7. **Ray parenchyma** occurs between the tracheids. These cells are thin, broad, small and living.
8. **Medullary ray**, in the region of phloem replaces ray tracheids with albuminous cells. They are small and contents are dense. (Ray parenchyma associated with these cells is filled with large amount of starch).

Exercise 7

***Object* : Study of T.L.s. of wood.**

Work procedure

Cut a thin section of wood along the tangent in the outer region, stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. Tracheids and medullary rays are cut transversely in this plane.
2. **The bordered pits** are cut to show overarching borders, forming a dome-like structure. It encloses in the centre a small disc, called torus.
3. **Medullary rays** are uniseriate. Since they are cut transversely, their height and breadth can thus be determined.
4. **Each medullary ray** appears to be a short row of more or less rounded cells, three or four cells high.
5. Composition of medullary ray reveals centrally placed, thin-walled and living cells-the albuminous cells (in the phloem region) and the ray cells (in the xylem region).
6. These are surrounded on the lower and upper sides by thick walled and dead cells known as ray tracheids.

Exercise 8

***Object* : Study of T.s. of dwarf shoot at the base (before secondary growth).**

Work procedure

Take out a spur, invert it with needles downwards, the base is now the uppermost, cut T.s., at the base mount in glycerine and study.

Comments

1. **The section** almost resembles with that of the main stem.

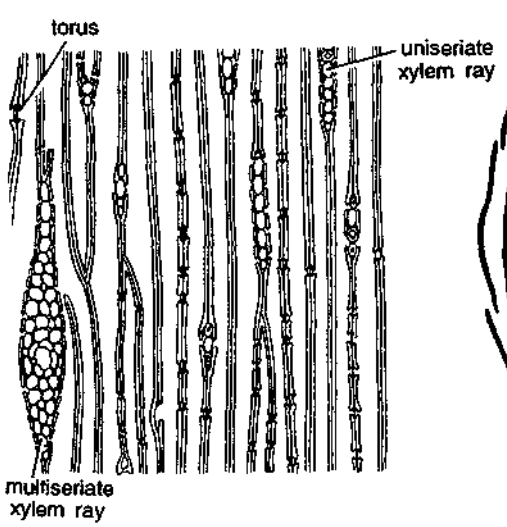


Fig. 9. *Pinus*. T.L.s. of wood (a part cellular).

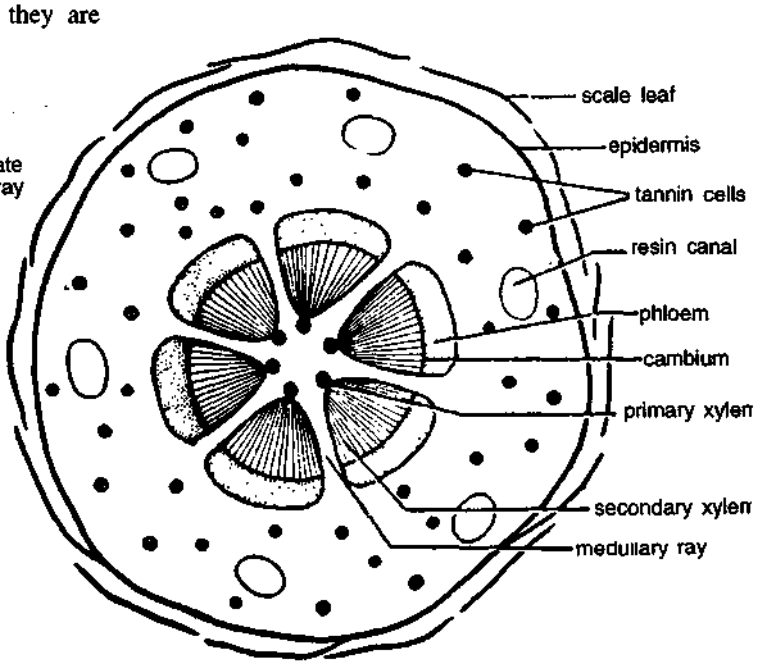


Fig. 10. *Pinus*. T.s. dwarf shoot showing secondary growth (diagrammatic).

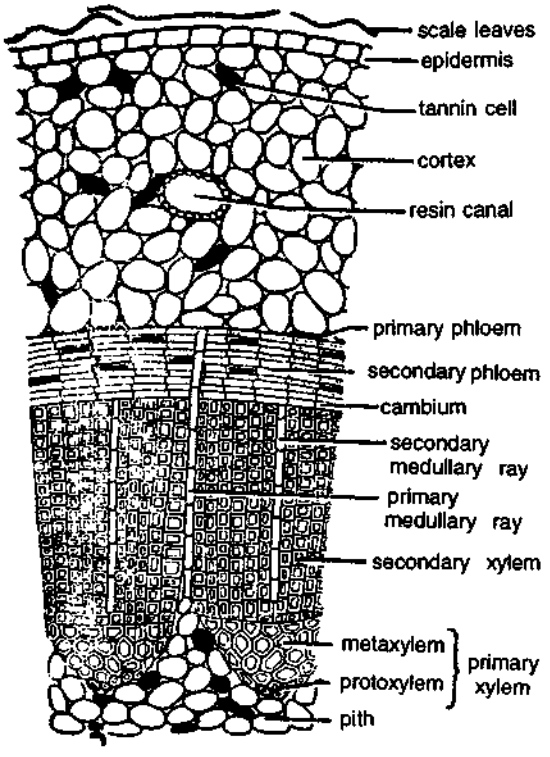


Fig. 11. *Pinus.* T.s. of dwarf shoot showing secondary growth (a part cellular).

2. **The outline** is wavy, due to ensheathing scaly leaves.
3. **The tissues** are differentiated into epidermis. cortex and stele.
4. **Epidermis** is made of single layer of thick walled cells.
5. **Cortex** follows epidermis. Outer few layers, close to epidermis are thick walled, while the inner layers are thin walled and parenchymatous.
6. **Resin canals** are present in the cortex. These are about six in number. Tannin cells are also irregularly scattered in this region.
7. **Stele** is an ectophloic siphonostele.
8. **Endodermis** is single layered and is followed by pericycle. Both the layers are indistinguishable.
9. **Vascular bundles** vary in number. They are generally six. Each vascular bundle is conjoint, collateral, endarch and open.
10. **Pith** is small. The cells are thick walled.
11. **Medullary rays** connect the pith and cortex and separate vascular bundles from one another.

Exercise 9

***Object* : Study of T.s. of dwarf shoot at base.**

Work procedure

Cut a T.s. of dwarf shoot above the base, stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. Dwarf shoot also shows a little amount of secondary growth.
2. **The section** shows scale leaves, single-layered thick walled epidermis, few layers of cork cells and tannin-filled cells.
3. **Primary phloem** is crushed and form patches. Secondary phloem underlies it and forms a complete ring.
4. **Secondary xylem** is small and is separated by a thin ring of cambium from the phloem region. Medullary rays traverse the secondary xylem.
5. **Endarch protoxylem** group lies just near the pith. It is small and consists of thick-walled cells. Few cells are tannin-filled.

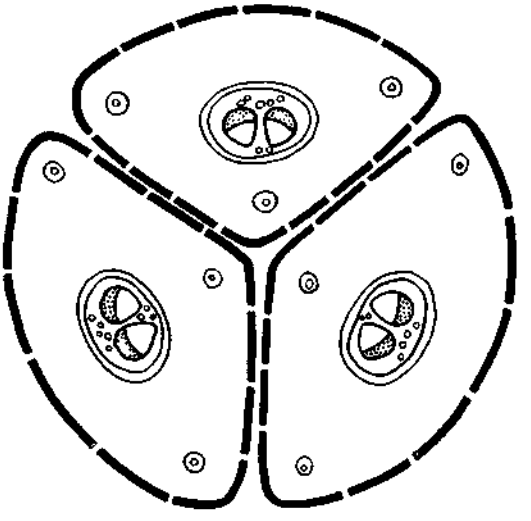


Fig. 12. *Pinus.* T.s. of dwarf shoot upper region (diagrammatic).

Exercise 10

***Object* : Study of T.s. of the dwarf shoot at upper end.**

Work procedure

Hold the dwarf shoot in upright position, cut a T.s., stain in safranin and fast green combination, mount in glycerine and study.

Comments

1. The structure is essentially similar to one found at its base.
2. The tissues of the dwarf shoot, towards the upper part, gradually become separated into equal parts, corresponding to the number of leaves in a spur (e.g. *Pinus gerardiana*, with trifoliar spur shows division of the dwarf shoot into three equal parts while in *P. quadrifolia*, with quadrifoliar spur, gets separated into four equal parts).
3. Each part shows distinct epidermis with stomata present all over.
4. Parenchymatous cortex fills most part of the section. Resin canals are located in the corners.
5. In the centre two conjoint, collateral and endarch vascular bundles are present. These are surrounded by distinct endodermis and pericycle.

Exercise 11

***Object* : Study of T.s. needle (leaf).**

Work procedure

Cut a thin T.s. of a needle, stain with safranin-fast green combination, mount in glycerine and study.

Comments

1. **The outline** of the section varies according to the species. (Triangular if spur is trifoliar, semi-circular if spur is bifoliar)
2. The needle is differentiated into epidermis, mesophyll and stele.
3. **Epidermis** is single with tangentially elongated and thickly cuticularized cells.

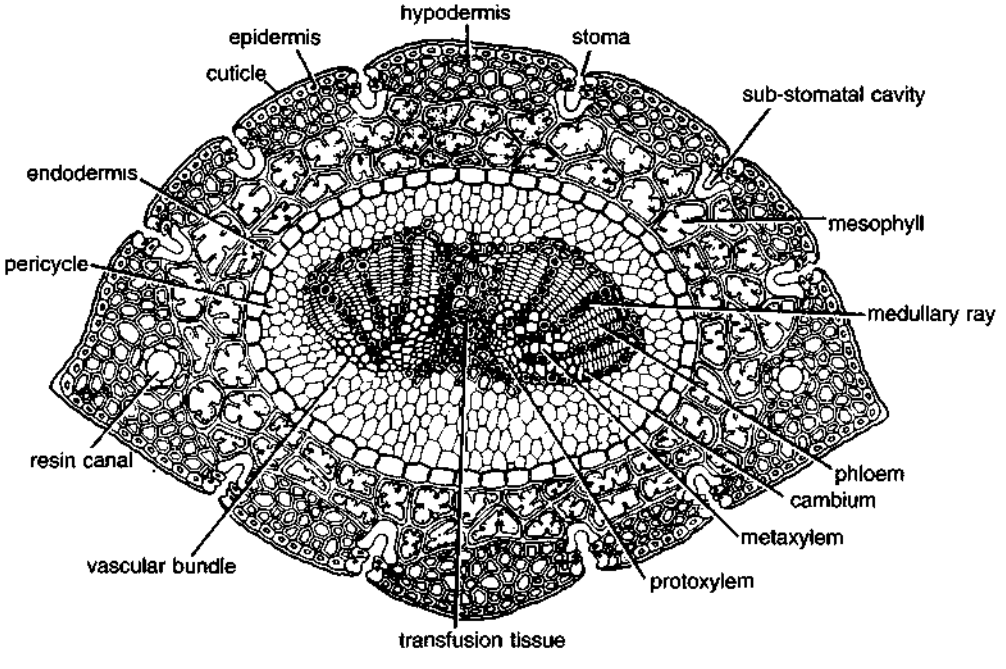


Fig. 13. ***Pinus***. T.s. of needle (foliage leaf)-cellular details.

4. **Stomata** are sunken. These are present on all the faces of epidermis. The needle is thus said to the amphistomatic.
5. **Epidermis** is followed by hypodermis. It is few layered thick at the corners and 1-2 layered in other parts. Sub-stomatal chambers occur in this region. Cells are sclerenchymatous and fibrous.
6. **Mesophyll** lies below the hypodermis. It is made up of polygonal parenchymatous cells, densely filled with the chloroplasts. Numerous plate-like or peg-like infoldings project into the cell lumen (cavity) from the wall of the mesophyll cells.
7. **Resin canals** generally occur in the sclerotic hypodermis but also occur in the mesophyll tissue.
8. **Endodermis** is conspicuous. Cells are barrel-shaped and tangentially thickened. It is followed by a many layered, parenchymatous pericycle.
9. Generally two vascular bundles remain surrounded by this tissue. (In *P. strobus* there is only one vascular bundule).
10. **The vascular bundles** are separated from one another by a T-shaped thick walled transfusion tissue.
11. **Each vascular bundle** is conjoint, collateral and open. Protoxylem faces adaxial side. Phloem is located on the abaxial side.
12. **Xylem and phloem** groups are separated from one another by cambium at the base of the needle and by parenchymatous cells in the upper region.
13. **Secondary growth** is very little during which the medullary rays run between xylem and phloem.

Features of special interest. It shows the following xerophytic characters —

1. Narrow acicular form of the leaf.
2. Presence of thick cuticle.
3. Aphistomatic nature.
4. Sunken stomata.
5. Thick and sclerenchymatous hypodermis.
6. Infolded peg-like structures in mesophyll.
7. Presence of transfusion tissue.
8. Simple vascular system.

Exercise 12

***Object* : Study of male cone, microsporophylls and microsporangia.**

Work procedure

Dissect out the male cone, separate the microsporophylls, study the shape, size and microspores.

Comments

1. Male cones replace the dwarf shoots. Each male cone arises in the axile of a scale leaf. The main shoot, on which these are produced, continues to grow further.
2. Male cones are grouped in clusters on the shoots of the same year only.
3. Each male cone has single, centrally located cone axis around which many scaly microsporophylls are spirally arranged.
4. Each microsporophyll has an expanded triangular central part and stalk-like base. Terminal part projects into a tip.
5. Few lowermost sporophylls are sterile, and do not bear any male reproductive structures.
6. On the abaxial side, each microsporophyll bears two ovoid microsporangia or pollen sacs on its lateral sides.
7. Each microsporangium has its own wall which encloses many microspores
8. The young microspore is globular or spherical in shape and is uninucleate.
9. A mature microspore or pollen grain shows two wall layers- exine and intine, 2 prothallial cells and antheridial cell.
10. Pollen grain has a thick expanded exine in the form of wings on the sides, followed by a smooth intine.

Exercise 13

***Object* : Study of L.s. of male cone.**

Work procedure

Study a slide showing L.s. of male cone.

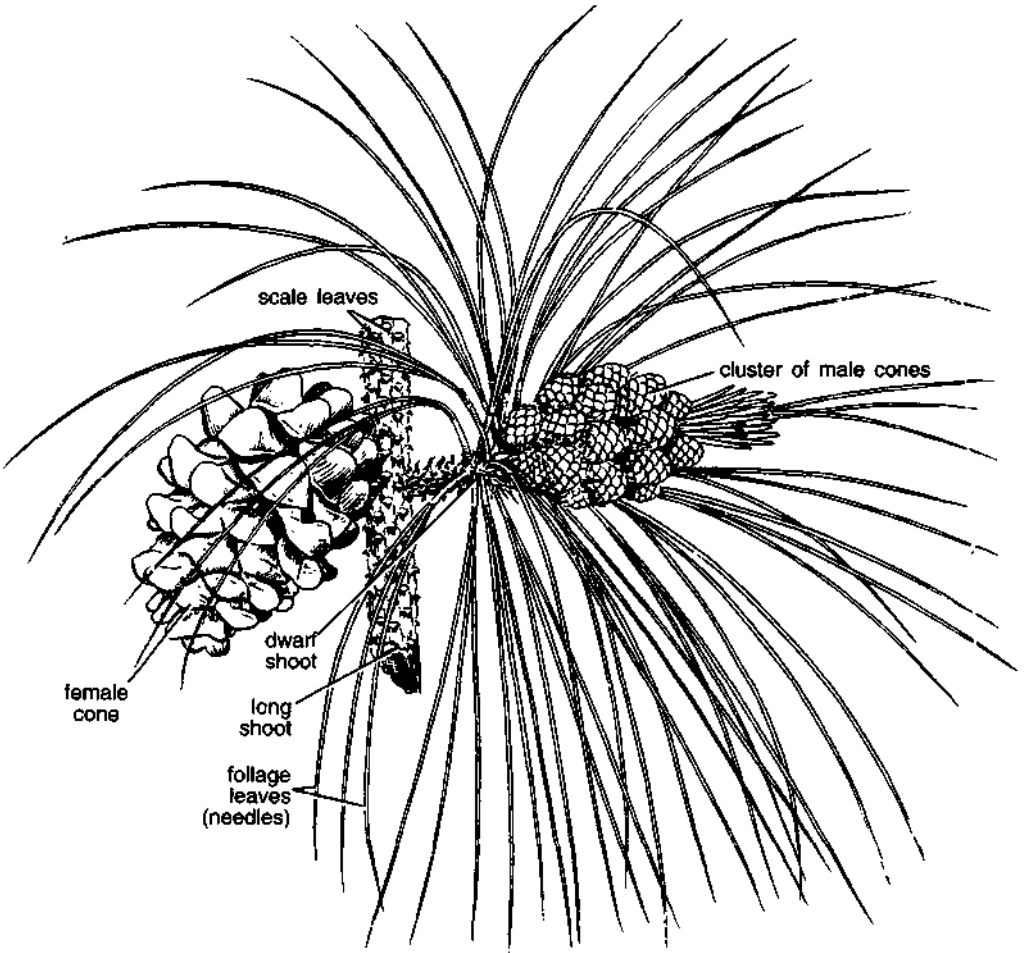


Fig. 14. *Pinus.* A twig with male and female cones.

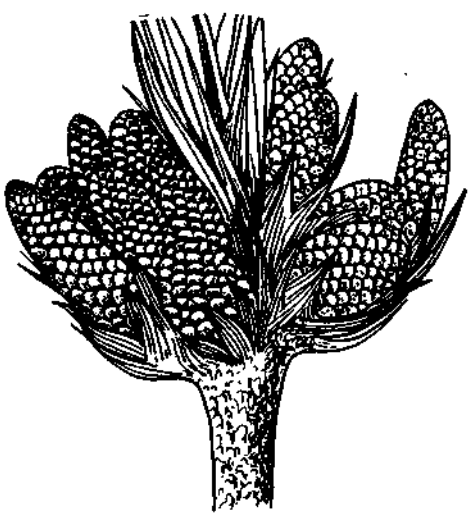


Fig. 15. *Pinus.* Male cones in cluster.

Comments

1. It shows a cone axis bearing microsporophylls.
2. The cone axis is centrally located.
3. Microsporophylls are spirally arranged. These are scaly, triangular and expanded.
4. It is attached to the cone axis by a stalk-like base.
5. The outer expanded part is sterile and is known as apophysis.
6. Microsporangia are present on the lower or abaxial surface.
7. Each microsporangium has a wall that encloses a cavity.
8. The wall consists of epidermis, wall layers and tapetum.
9. The cavity shows numerous microspores in various stages of development.

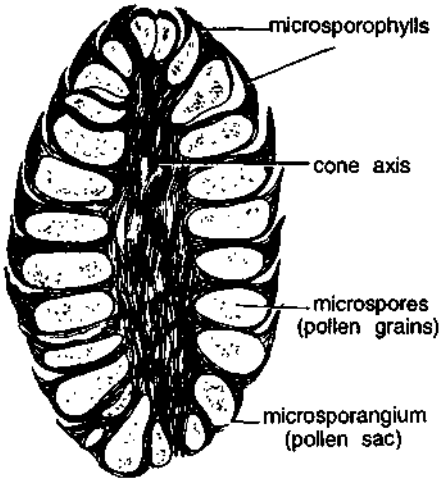


Fig. 16. ***Pinus.*** L.s. of male cone.

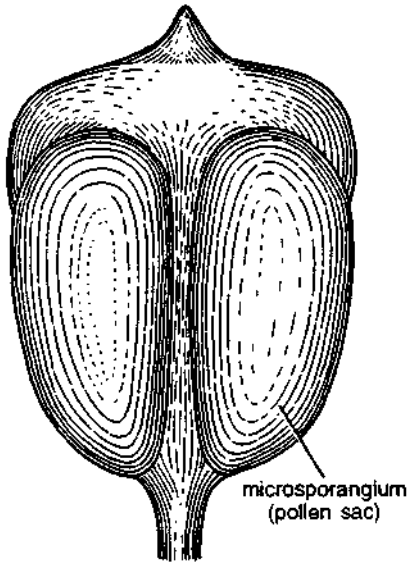


Fig. 17. ***Pinus.*** A microsporophyll with two microsporangia as seen from lower side.

Exercise 14

Object **: Study of morphology of the female cone.**

Work procedure

Study the external features of 1st, 2nd and 3rd year female cones. Note the position, arrangement and structure of sporophylls.

Comments

1. Female cones are larger than the male cones. They are borne at the apices of the young elongated shoots, replacing the shoot of unlimited growth (long shoots).
2. Single shoot may bear one to four female cones which are reddish-green in colour and mature in three years.
3. In the first year, cones are compact and sporophylls are closely arranged.
4. The second year cones are large in size and woody in nature but sporophylls are still compactly arranged.
5. In the third year, cone becomes loose. Sporophylls separate from one another due to elongation of the cone axis.
6. Each female cone consists of many sporophylls, arranged spirally around the cone axis.

Exercise 15

Object **: Study L.s. of female cone.**

Work procedure

Study a prepared slide of L.s. of female cone.

Comments

1. Female cone is made of centrally located cone axis and spirally arranged sporophylls.
2. Each sporophyll consists of two kinds of paired scales : (i) bract scale or cone scale and (ii) ovuliferous scale or seminiferous scale.
3. Many small and thin bract scales are arranged spirally around the cone axis. They are directly borne on the cone axis. Each of these is present on the abaxial (lower) side of the ovuliferous scale.
4. On the adaxial (upper) side of the bract scale, a thick, large, woody and triangular ovuliferous scale is present.
5. The ovuliferous scales in the middle part of the cone are the largest and get gradually smaller towards its base and apex.
6. Ovuliferous scale and bract scale are fused for a little distance near the cone axis while free at a distance away from it.

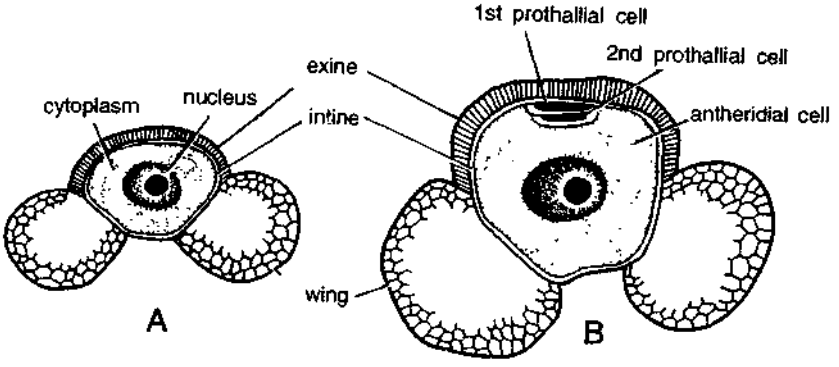


Fig. 18. ***Pinus.*** Microspores (pollen grains), **A.** Young. **B.** Old.

Fig. 19. ***Pinus.*** 1st year female cone.

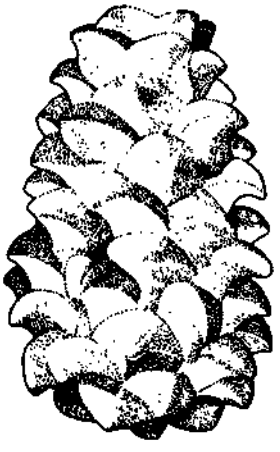


Fig. 20. ***Pinus.*** 2nd year female cone.

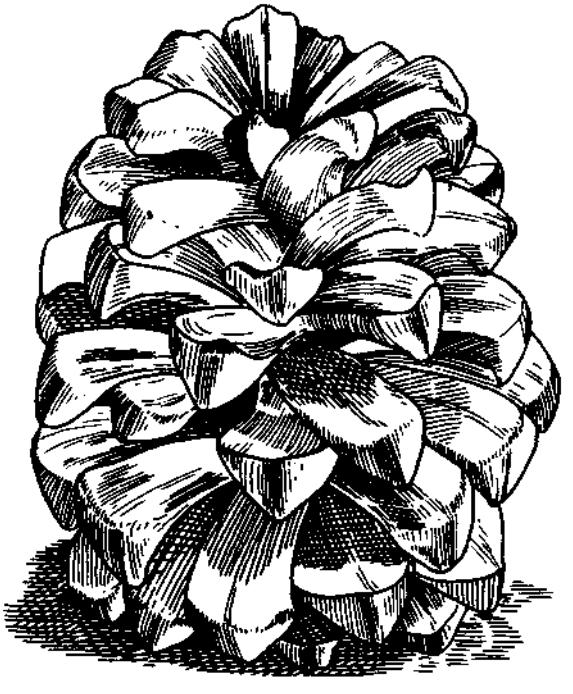


Fig. 21. ***Pinus.*** 3rd year female cone.

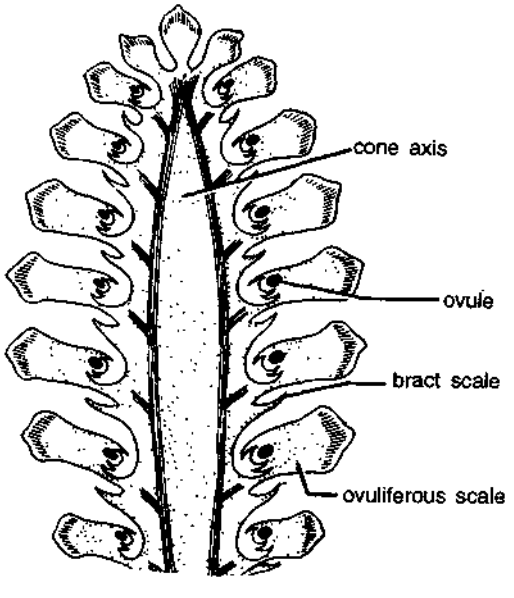


Fig. 22. ***Pinus.*** L.s. of female cone.

7. Ovuliferous scale is shortly stalked and rest of the part is expanded.
8. At the base of this expanded, triangular part, two naked and sessile ovules are present. These are situated on the adaxial, (upper) surface of the ovuliferous scale, at its base, with their micropyles directed towards cone axis.
9. The terminal part of the ovuliferous scale is broad and sterile and is known as apophysis.

Exercise 16

***Object* : Study of L.s. of ovule.**

Work procedure

Study a prepared slide of L.s. of ovule. Note integuments, nucellus, female gametophyte and archegonia.

Comments

1. Ovule is elongated in shape.
2. It is unitegmic and the integument is three layered. The outermost layer is thin. The middle layer is stony and prominent. The innermost layer is fleshy and well developed.
3. Nucellus is fused with inner layer of the integument, except at its tip where it forms an elongated and slender micropyle, directed towards the cone axis.
4. In the nucellar region lies a small cavity just opposite the micropyle. It is known as pollen chamber.
5. Female gametophyte (endosperm) is differentiated from nucellus. About 2-5 archegonia are situated in this region at the micropylar end near the base of the archegonial chamber

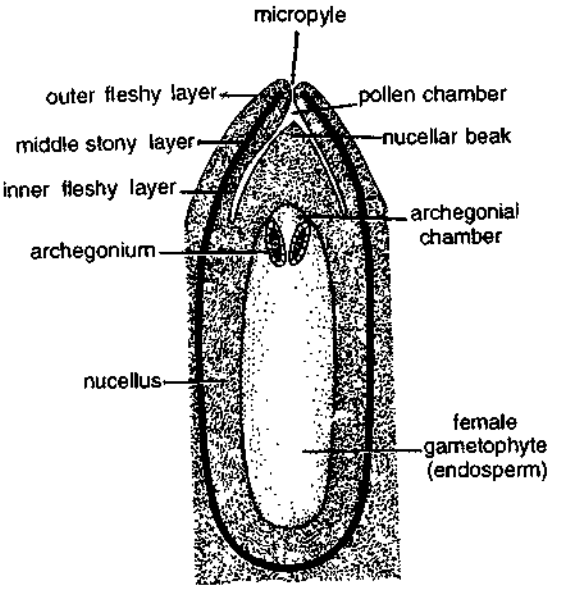


Fig. 23. *Pinus*. L.s. of ovule.

Exercise 17

***Object* : Study of seed.**

Work procedure

Study the position and arrangement of seeds on ovuliferous scale, also study a prepared slide of L.s. of seed

Comments

1. Fertilized ovules get transformed into seeds which are situated on the adaxial side of the ovuliferous scale at its base near the cone axis.
2. Seeds are small, elongated and winged. The wing is a thin layer of tissue which splits off from the adaxial face of the ovuliferous scale. (Seed can be best studied by cutting longitudinal section of the seed of *P. gerardiana*; vern. chilgoza).

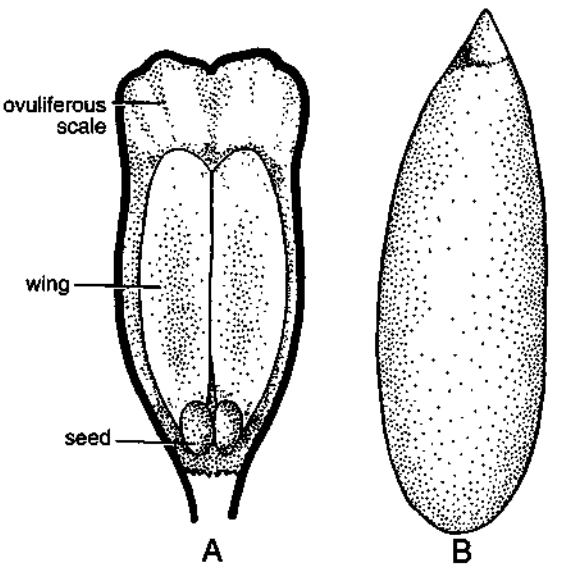


Fig. 24. *Pinus*. A. Ovuliferous scale bearing two winged seeds. **B.** seed.

3. The seed is covered with red and brown testa.
4. Inner fleshy layer of the integument still persists. It is membranous, thin and papery, termed as tegmen.
5. The nucellus is present as a thin layer and forms a nucellar cap at the micropylar end.
6. The larger part of the seed consists of oily endosperm.

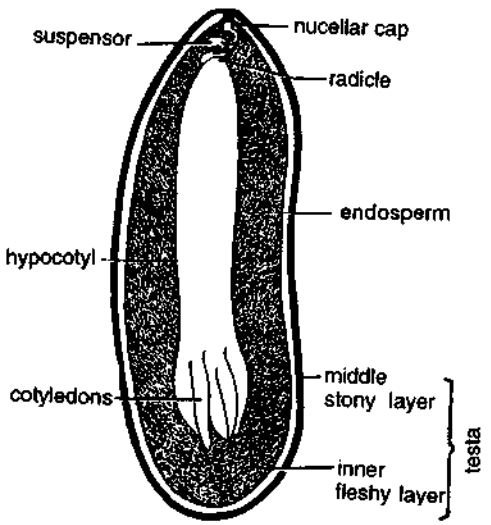


Fig. 25. ***Pinus.*** L.s. of seed.

7. The suspensor is long and becomes coiled. Embryo is differentiated into radicle, plumule and cotyledons (3-8 in number).
8. In between the radicle and plumule, is present a well developed hypocotyl.

Exercise 18

Object **: Study of seedling.**

Work procedure

Study a newly germinated seed. Observe various organs.

Comments

1. Seedling shows three parts — (i) roots (ii) hypocotyl and (iii) leaves.
2. The **roots** are well branched and arise from the radicle.
3. **Hypocotyl** gives rise to unbranched, slender and thin primary shoot.
4. **Leaves** are green and needle-like which are borne in whorls on the primary shoot. These are cotyledonary leaves.
5. **The primary leaves** or first spur shoots arise in the axils of some of these juvenile (cotyledonary) leaves and are borne in spiral series on the primary shoot.

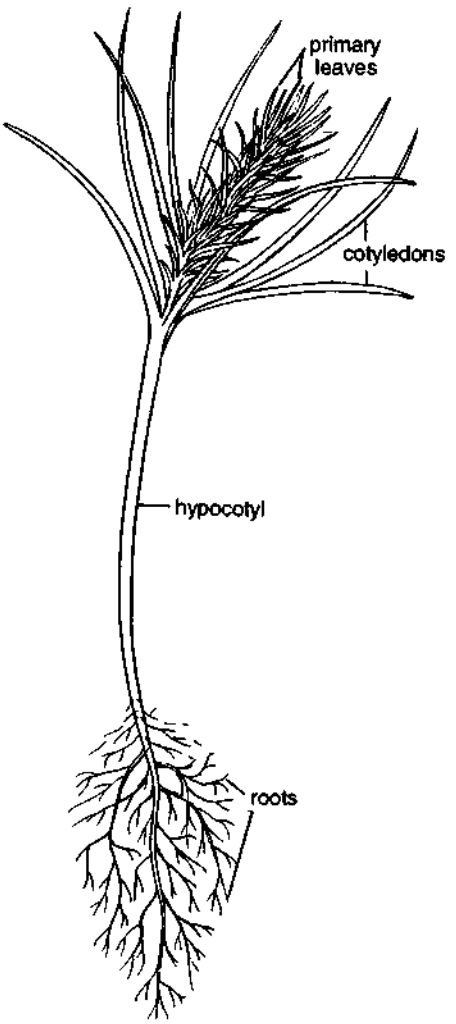


Fig. 26. ***Pinus.*** Older seedling to show cotyledons and spirally arranged primary leaves.

Identification

Division—**Gymnosperms**. (1) Absence of vessels, (2) Ovules naked, (3) Seeds attached to woody scales, (4) Scales generally form a cone.

Class—**Coniferopsida**. (1) Leaves needle shaped, (2) Wood pycnoxylic (compact), (3) Presence of resin canals, (4) Compact male and female cones, (5) Non-flagellate male gametes, (6) Seeds bilaterally symmetrical.

Order—**Coniferales**.

Family— **Pinaceae**. (1) Resinous wood, (2) Plants monoecious, (3) Sporophylls spirally arranged, (4) Microsporophylls with two microsporangia, (5) Pollen grains winged, (6) Female cone woody, (7) Polyembryony present, (8) Seed dry and winged.

Genus—***Pinus***. (1) Plants sporophytic and monoecious. Male and female reproductive organs in cones. (2) Branches dimorphic, (3) Long shoots with secondary xylem, annual rings are formed, wood pycnoxylic and resinous, (4) Dwarf shoots with a little secondary growth, (5) Leaves are of two types, (6) Scale leaves brown and membranous, (7) Foliage leaves are acicular, xerophytic, mesophyll cells with peg-like ingrowths, 2 resin canals and T-shaped transfusion tissue, (8) Male cones borne laterally, in clusters, microsporophyll bears two microsporangia on abaxial side, (9) Pollen grains winged, (10) Female cones borne single and terminal, (11) Bract scales and ovuliferous scales spirally arranged, (12) Two naked ovules on the adaxial side of the ovuliferous scale, (13) Seeds dry and winged.

Hints for Collection

In India *Pinus* is represented by five species which grow wild in north-east and north-west Himalayas. The species are *P. gerardiana* (Chilgoza in Hindi), *P. roxburghii* (=*P. longifolia*), *P. wallichiana* (*P. excelsa*), *P. insularis* (= *P. khasya*) and *P. armandi*. In plains it is cultivated for its ornamental value.

Ephedra
(Jointed Fir)

Classification

Division	–	**Gymnosperms**
Class	–	**Gnetopsida**
Order	–	**Gnetales**
Family	–	**Ephedraceae**
Genus	–	***Ephedra***

Exercise 1

***Object* : Study of external morphology.**

Work procedure

Study the external features of the plant, note the jointed nature of stem, scale leaves and underground tap root, observe the positions of male and female strobili.

Comments

1. Plants are small, bushy, trailing or climbing shrubs attaining a height of not more than 2 meters. However, *E. antisiphilitica* is a small tree, reaching a height of 3-5 meters.
2. The plant body is branched and posseses only minute leaves at the nodes. It therefore, resembles superficially with the species of *Psilotum* and *Equisetum*.
3. It is differentiated into stem, leaves and underground roots.
4. The stem remains anchored by a deep tap root and many adventitious roots.
5. The stem is delicate, slender and green when young. It is ribbed irregularly and is differentiated into short nodes and long internodes.
6. Two or three branches arranged in whorls arise from the nodes in the axils of leaves. The branches are shed off during dry season.
7. Older part of the stem may bear many branches. It becomes hard and woody due to secondary growth.
8. Leaves are borne in a whorl of 2-4 at each node.

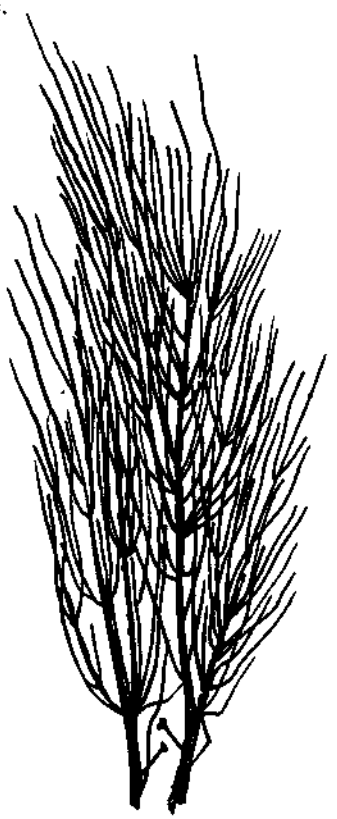


Fig. 1. ***Ephedra***. Plant showing shrubby habit.

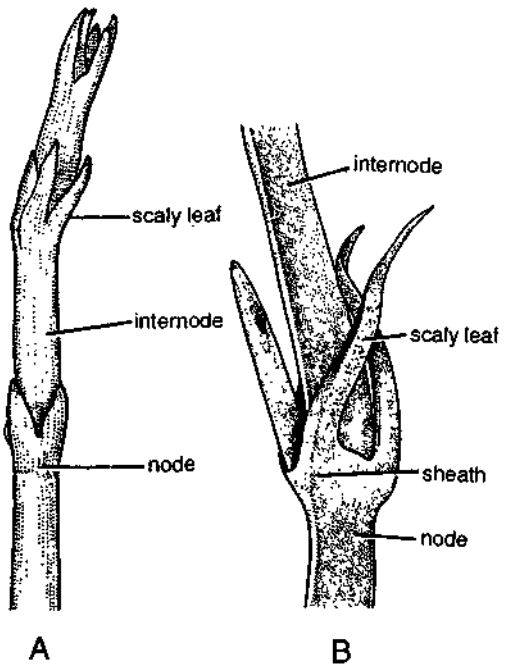


Fig. 2. ***Ephedra.*** A part of stem showing **A.** Nodes and internodes. **B.** A node with scaly leaves.

9. Leaves that are small and scale-like are connate at the base and thus form a sheath around the node.
10. Each scale leaf is traversed by two parallel and unbranched veins.
11. Foliage leaves are completely absent.
12. The male and female reproductive organs are borne in small strobill.
13. The plants are mostly dioecious and bear only one type of reproductive organs. They may also be monoecious when they bear both kinds of strobilii.

Exercise 2

Object **: Study of T.s. of young stem.**

Work procedure

Cut a T.s. of the younger part of the stem, stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. **The outline** of the section shows ribbed nature of the stem.

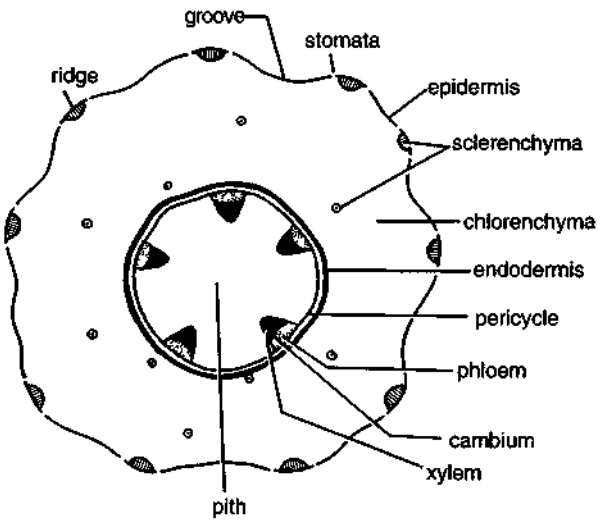


Fig. 3. ***Ephedra.*** T.s. of young stem (diagrammatic).

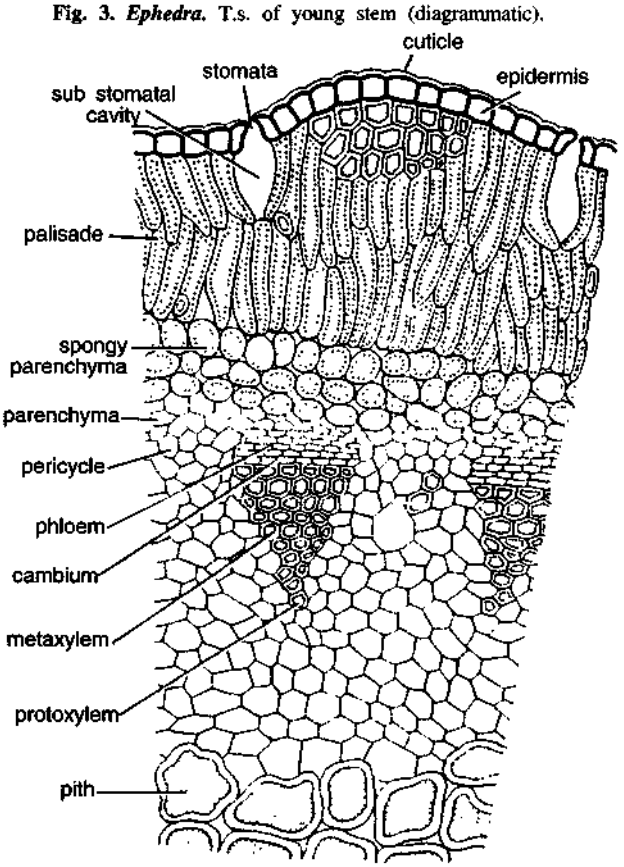


Fig. 4. ***Ephedra.*** T.s. of young stem (part cellular).

2. The tissues are differentiated into epidermis, cortex and stem.

3. **Epidermis** is the outermost layer. It is very thick and heavily cuticularized.
4. **The stomata** are sunken. These interrupt epidermis frequently and occupy a position just on the slopes of the ridges.
5. **Hypodermis** is sclerenchymatous and occur in small groups below the ridges.
6. **Cortex.** Rest of the cortical tissue is cholrenchymatous. The cells are often radially elongated and contain abundant chloroplasts. Large intercellular spaces are present between these cells.
7. A few patches of sclerenchyma occur dispersed in the cortex (specially in young axis rendering hardness and resistance).
8. **Stele** is ectophloic siphonostele. It is composed of many vascular bundles, their number being variable.
9. **Endodermis** is single layered and is followed by a pericycle.
10. **A few vascular bundles** are arranged in a ring. Each is conjoint, collateral, endarch and open.
11. **External phloem** group is separated from internal xylem group by a narrow layer of cambium.
12. **Pith** is parenchymatous and occurs in the central region.
13. **Nodal diaphragm.** The characteristic anatomical feature is the presence of diaphragm-like plate of cells at the base of each internode or at the node (nodal diaphragm). This helps the plant to shed off the branches at the nodes.

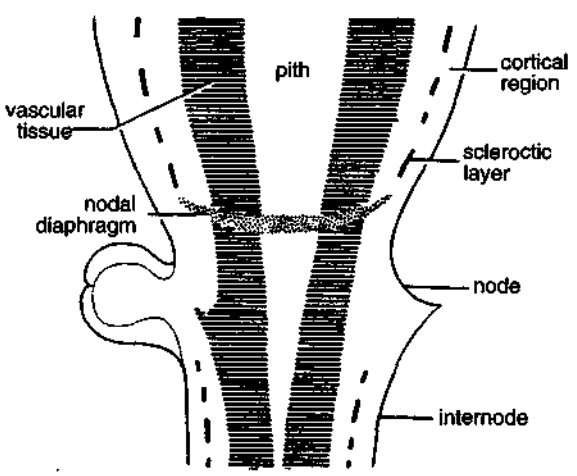


Fig. 5. ***Ephedra.*** L.s. nodal region (diagrammatic).

Exercise 3

Object **: Study of T.s. of stem showing secondary growth.**

Work procedure

Cut a T.s. of the older part of the stem, stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. **The section** shows epidermis, cortex and primary and secondary vascular tissues.
2. **The epidermis** and cortex remain unchanged. However, after (3-4 Years) of growth, cork develops just outside the phloem and outer tissues (epidermis, cortex, etc.) are, therefore, cast off.
3. **Sclerotic cells** (stone cells) develop just above the zone of secondary tissue.
4. **Primary phloem** occurs as obliterated patches.
5. **Secondary phloem** forms a zone below. Phloem is composed of sieve tubes and phloem parenchyma.
6. **Annual rings** are distinct comprising autumn and spring wood each. These are formed in the secondary xylem (wood).
7. **The secondary** xylem shows a thin walled spring wood and thick walled autumn wood, successively formed in alternating zones.
8. **Antumn** wood is made of smaller cells, while those of spring wood are bigger in size.
9. **The tracheidal cells** of the secondary wood are associated with broad vessels. Though absence of vessels is characteristics of the Gymnosperm, *Ephedra*, (i.e. order Gnetlaes) itself is an exception.
10. **Vessels** are most abundant in the spring wood and a few or none at all in the autumn wood. Spring wood is often ring porous.
11. **Tracheids and vessels** have uniseriatey or irregularly distributed bordered pits. Protoxylem elements of primary xylem show spiral, annular or reticulate tracheids.

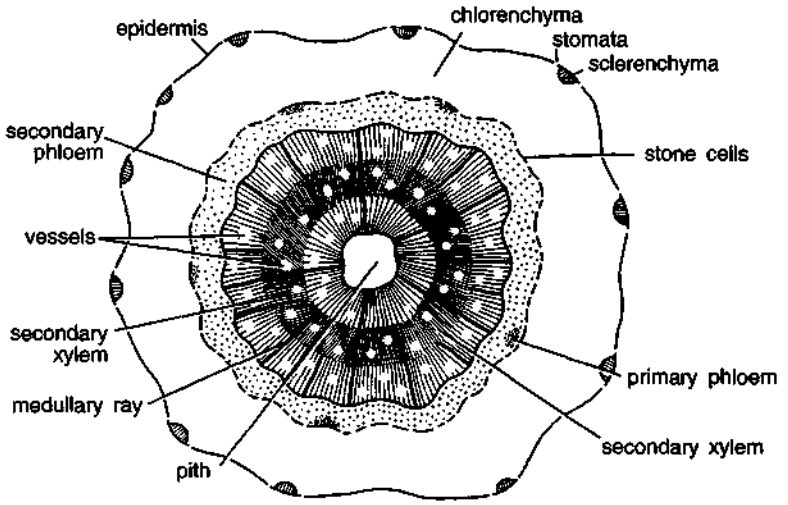


Fig. 6. ***Ephedra.*** T.s. of old stem (diagrammatic).

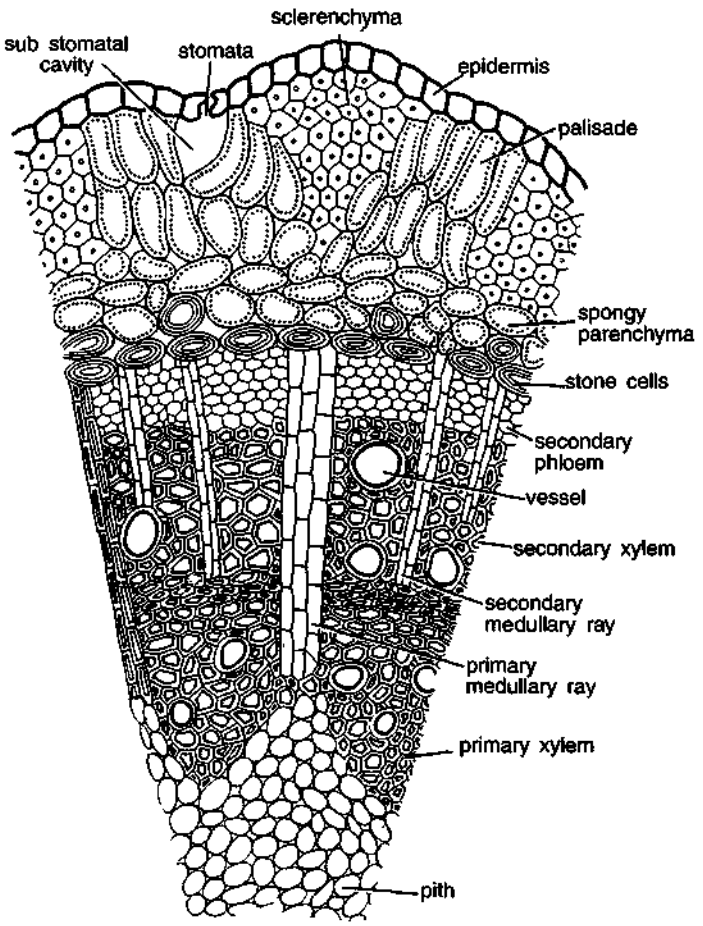


Fig. 7. ***Ephedra.*** T.s. of old stem (a part cellular).

12. **Medullary rays** traverse the wood. Primary medullary rays run from primary xylem to primary phloem while secondary medullary rays run from secondary xylem to secondary phloem.
13. **Medullary rays** are uniseriate in the young stem but are very broad and long (multiseriate) in the old stem.
14. **Primary** xylem groups are present at the end of the secondary wood near the pith. These are endarch.
15. **Pith** is large and parenchymatous. It occupies the centre.

Features of special interest. It shows the following xerophytic characters.

1. Thickly cuticularized epidermis.
2. Sunken stomata.
3. Palisade and spongy parenchyma in the cortex.
4. Patches of sclerenchyma.
5. Shedding of branches.
6. Presence of nodal diaphragm.
7. Vessel in the secondary wood.

Exercise 4

***Object* : Study of R. L.s. of wood.**

Work procedure

Cut a R.L.s. of wood along any one of the radii. Stain in safranin-fast green combination, mount in glycerine and study.

Comments

1. It shows the presence of secondary xylem and medullary rays.
2. Secondary xylem consists of tracheids with bordered pits on their radial walls.
3. The bordered pits are circular or slightly elliptical. These may form reticulations (mostly due to the dissolution of walls of cavities of the pits) and such perforations, being characteristic of *Ephedra*, are known as Ephedroid perforations. Bordered pits are either scattered or arranged in 2 or 3 tight rows. (They are never polygonal due to mutual compression).
4. Special cellulose thickening - Bars of Sanio are also present below the pits.
5. A few vessels present show bordered pits which are scattered or may remain arranged in 2 or 3 rows. The apertures of the bordered pits are commonly horizontally oriented. End walls are also perforated.
6. Medulllary rsays are uniseriate or multiseriate. These run horizontally. In this plane medullary rays are cut lengthwise and their length and height can be observed.
7. Medullary rays may range up to 40-50 cells in height.
8. Each medullary ray in the region of secondary xylem is composed of ray cells and ray tracheids dispersed regularly.

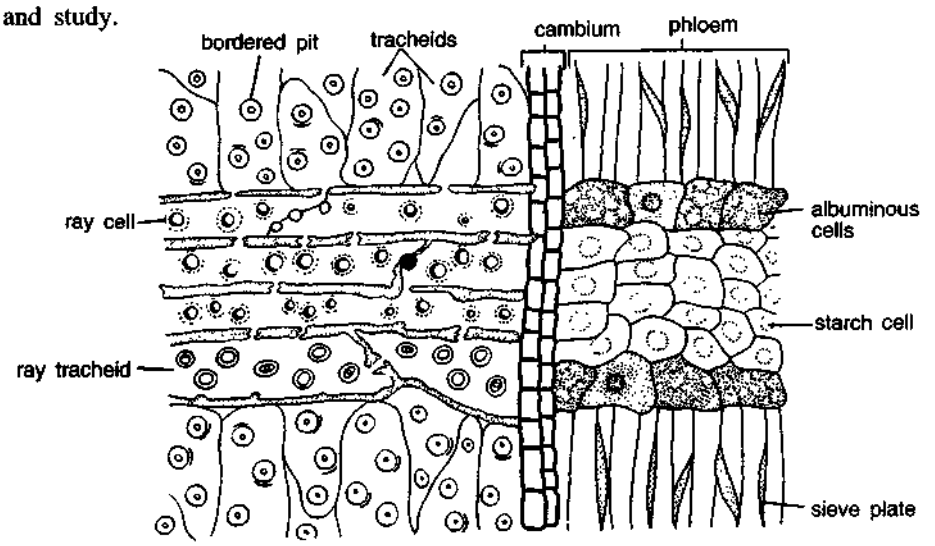


Fig. 8. ***Ephedra.*** R.L.s. of wood.

9. Ray cells are thick walled as well as thin walled. These occur in the same medullary ray. Their tangential walls possess bordered pits or slit-like openings.
10. Ray tracheids are thick walled. Their radial and tangential walls are pitted, pits being bordered.
11. In the region of phloem, medullary ray is made of starch cells surrounded by albuminous cells on both sides.

Exercise 5

***Object* : Study of T.L.s. wood.**

Work procedure

Cut a T.L.s. of wood by passing the razor along any one of the tangents, stain in safranin-fast green combination mount in glycerine and study.

Comments

1. In this plane tracheids, vessels and medullary rays are cut transversely.
2. Bordered pits are seen in surface view.
3. The bordered pits show usual over-arching dome-shaped structure and a small disc-torus.
4. Medullary rays are transversely cut and as such their height and breadth can be determined.

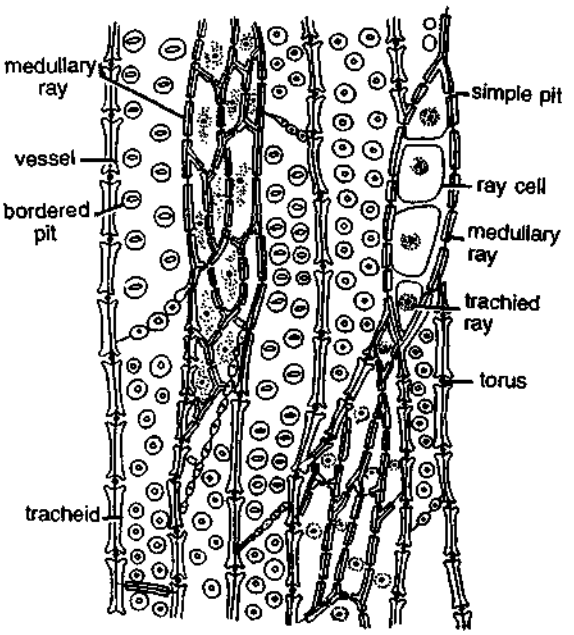


Fig. 9. ***Ephedra.*** T.L.s of wood.

5. Rays are elongate and many tangential walls show simple slit-like pits.

Exercise 6

***Object* : Study of male strobilus.**

Work procedure

Study the position, structure and organization of male strobilus. This can be done by studying external morphology of the strobilus and a slide of its longitudinal section.

Reproductive parts are borne in strobili. One of the following conditions may be found :

(i) Usually male and female strobili are different; in such a case, the strobilus may be termed as monosporangiate. These strobili may be borne on two different plants (dioecious sps.).

(ii) Sometimes one plant may bear both the strobili (monoecious sps.).

(iii) A few plants, sometimes, bear both the reproductive parts in one strobilus only (bisporarangiate strobilus), *e.g. E. foliata* and *E. intermedia*. In such cases, male flowers are situated below the female flowers which occur at the higher level in the same strobilus.

Comments

1. The strobilus resembles inflorescence, spike.
2. Each stobilus consists of an axis which bears decussately arranged sterile scales and stamens.
3. Male spike (male strobilus or staminate strobilus) arises in the axil of scale leaf.
4. Each spike is generally round in shape but may be ovoid or spherical.
5. A spike has a short axis with many scaly bracts. The bracts are arranged in decussate pairs. The number of pairs varies from 2-12.
6. In the axil of each bract arises a single male flower.

Exercise 7

***Object* : Study of male flower.**

Work procedure

Place a male strobilus under the dissecting microscope, separate the sterile scale to isolate a

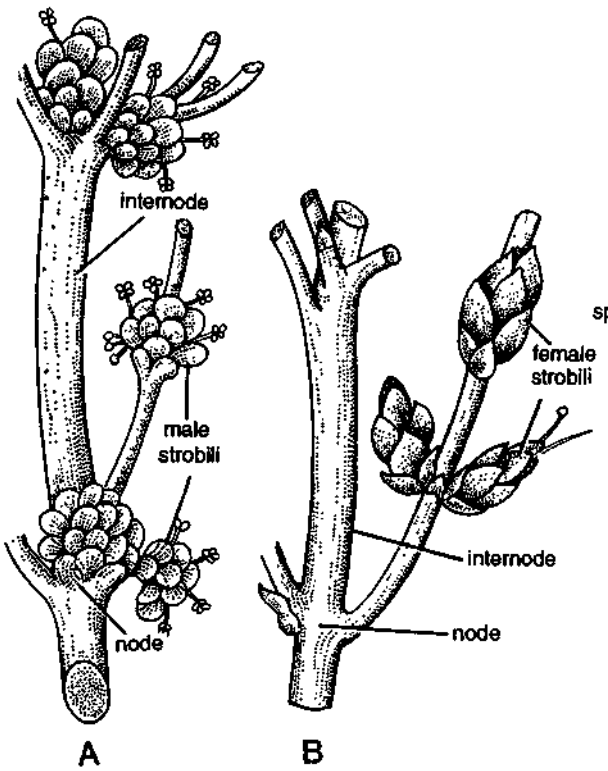


Fig. 10. ***Ephedra.*** Reproductive structures. **A.** A branch with male strobili. **B.** A branch with female strobili.

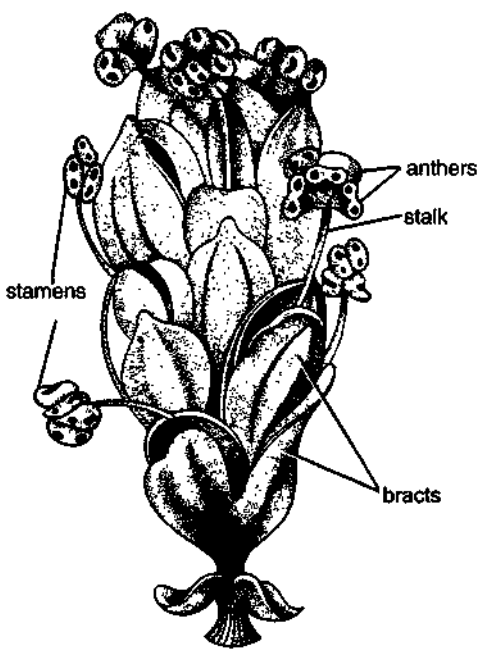


Fig. 11. ***Ephedra.*** A male strobilus.

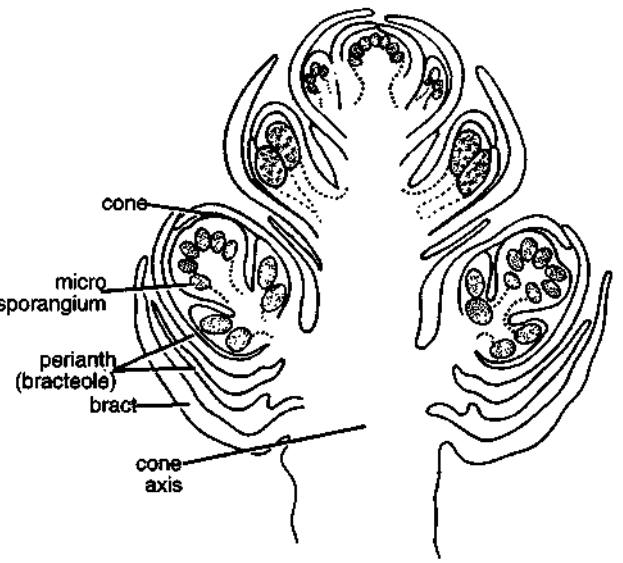


Fig. 12. ***Ephedra.*** L.s. of male strobilus.

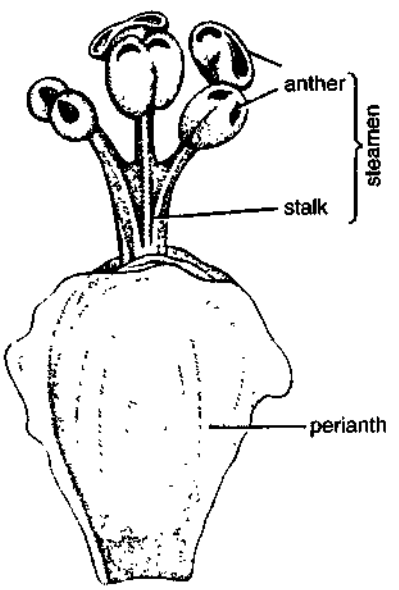


Fig. 13. ***Ephedra.*** A male flower

single male flower, stain in safranin, mount in glycerine and study. Also study slide of L.s. of a stamen.

Comments

1. **A male flower** has a perianth of bract scale which encloses a stamen.

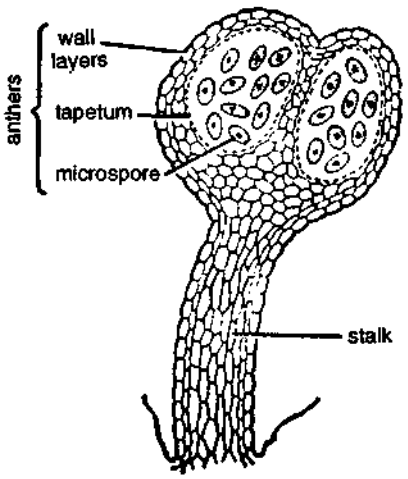


Fig. 14. *Ephedra.* L.s. of stamen.

2. **Stamen** consists of a stalk (variously termed as column or antherophore). It bears 2-5 microsporangia or anthers at its tip.
3. **Each microsporangium** is a bilocular structure. It has two wall layers and a prominent tapetal layer which encloses pollen grains or microspores.
4. **Each microspore** is elliptical and has an outer thick and ribbed exine and a thin intine.
5. A microsporangium opens by apical part (apical dehiscence).

Exercise 8

***Object* : Study of female strobilus.**

Work procedure

Study the position, structure and organization of the female strobilus. This is done by studying the external features and a slide of its longitudinal section.

Comments

1. The strobilus resembles spike inflorescence.
2. Each strobilus consists of an axis bearing decussately arranged sterile bracts (scales) and ovules.
3. The female or ovulate strobili arise in the axil of scale leaves. The female strobilus is also sessile and not so richly branched as the male.

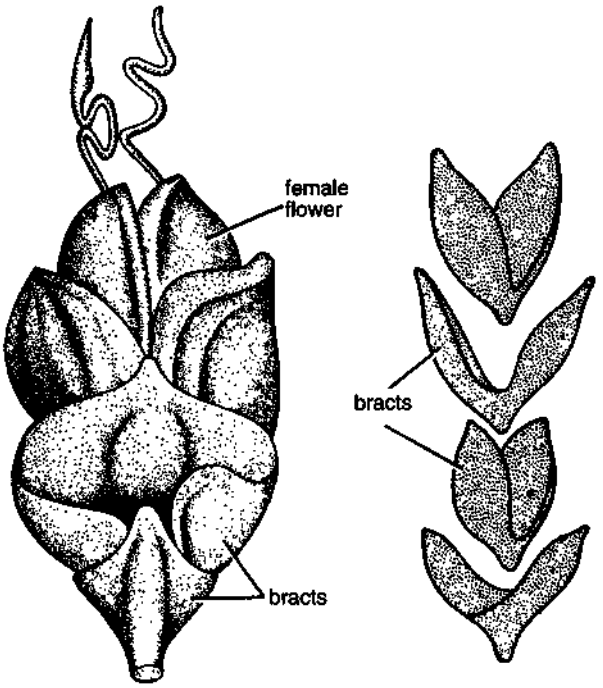


Fig. 15. *Ephedra.* Female strobilus. **A.** Female strobilus as it appears on plant. **B.** Bracts separated to show arrangement.

4. The apex of ovulate strobilus is mostly acute.
5. The spike has a short axis on which about 4-7 pairs of bracts are arranged decussately.
6. Lower most 1 or 2 pairs are sterile while terminal pairs bear short stalked ovules. The bracts are generally dry, winged and may be variously coloured.
7. Each bract mostly encloses two ovules out of which one may be abortive.

Exercise 9

***Object* : Study of L.s. ovule.**

Work procedure

Study a prepared slide of L.s. of ovule.

Comments

1. **Ovule** is covered by two integuments.
2. **Outer integument** (involucre or perianth) is a cup-like structure, attached at the base of the ovule and free above.
3. **Inner integument** is delicate, composed of two segments. It prolongs into a tubular process and

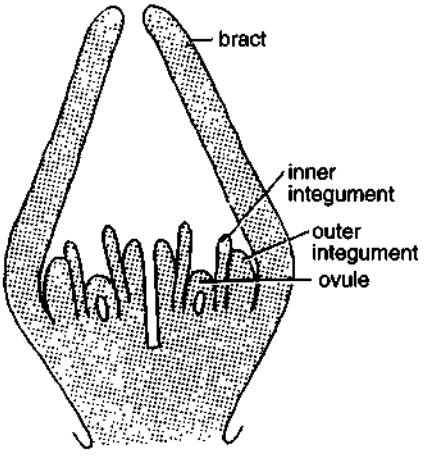


Fig. 16. ***Ephedra.*** L.s. of female flower.

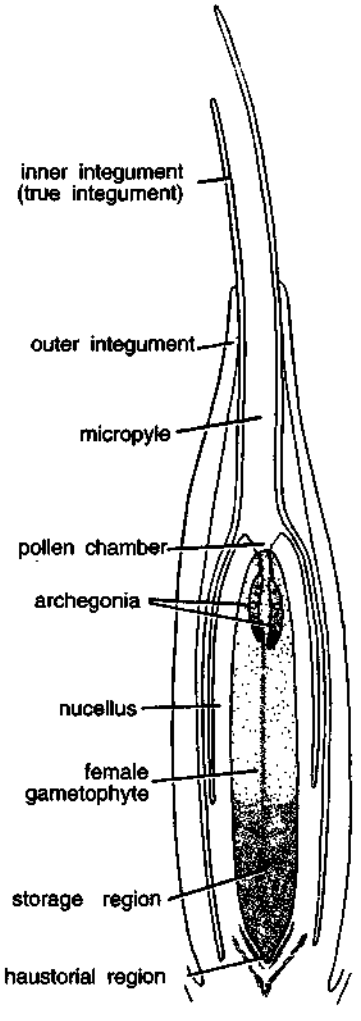


Fig. 17. ***Ephedra.*** L.s. of ovule

comes out beyond the bracts and involucre at the time of pollination.

4. **Micropyle** is an opening in between the integuments, in the upper region of the ovule.
5. **Nucellus** lies below the integuments. A small pollen chamber is present just below the micropyle in the tissue of nucellus.
6. **Female gametophyte** is a tissue situated below the pollen chamber. Two archegonia are present, just below the pollen chamber, in the female gametophyte.
7. **Haustorial region** lies opposite the micropylar end. It is occupied by tissue filled with stored food material. It also gives out haustorial processes for the absorption of food and is known as haustorial region.

Exercise 10

***Object* : Study of L.s. seed.**

Work procedure

Study a double stained prepared slide of L.s. of seed. (A seed is formed as a result of fertilization).

Comments

1. **Outer integument encloses** entire seed. It is thick walled.

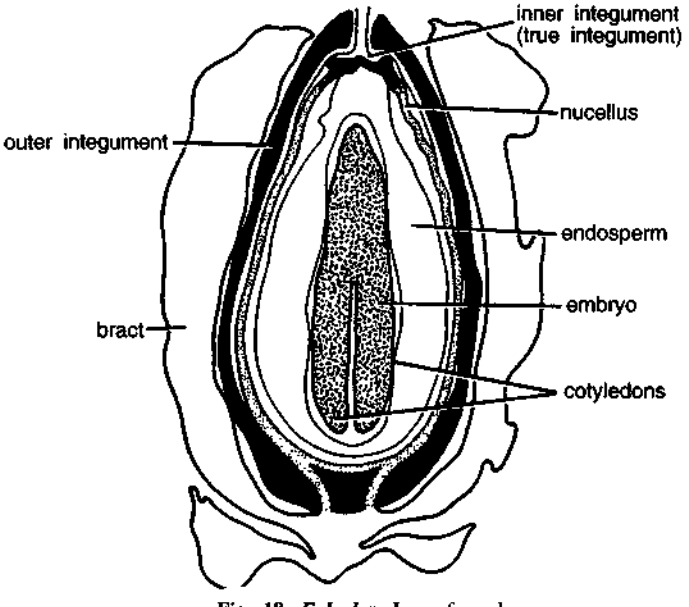


Fig. 18. ***Ephedra.*** L.s. of seed.

2. **The inner integument** ('true integument') persists at the micropylar end only.
3. **Nucellus** forms shrivelled layer in the form of a disorganized sheath of cells. It is located inside the inner integument.
4. **Female gametophyte** (endosperm) surrounds a big embryo which has two large cotyledons.
5. **Bracts** adjacent to strobilus are fleshy and thick in a completely mature seed. These form an additional envelope.

Identification

Division—**Gymnosperms**. (1) Ovules naked, (2) Seed attached to a scales, (3) Scales form a strobilus.

Class—**Gnetopsida**. (1) Wood with vessels, (2) Flowers in compound strobili or 'inflorescence', unisexual, usually dioecious, (3) Ovules surrounded by several envelops.

Order—**Gnetales**. (1) Plants woody trees, shrubs or lianes, (2) Leaves opposite or whorled, simple.

Family—**Ephedraceae**. (1) Plants either shrubs or woody climbers, (2) Leaves scaly, foliage leaves absent, (3) Nodal diaphragm present, (4) Stamens enclosed by bract, (5) Seeds covered with fleshy bracts.

Genus—***Ephedra***. Single genus.

Hints for Collection

Six species of *Ephedra* viz. *E. pachyclada, E. intermedia* var. *tibetica, E. saxatilis* var. *sikkimensis, E. gerardiana E. nebrodensis* var. *procera* and *E. regeliana* grow wild in the north west Himalayan region and are all shrubby. *E. foliata* var. *ciliata* grows widely as a scandent shrub, climbing over small trees in the southern part of the Punjab and Rajasthan. It is usually cultivated in gardens and in other places.

Palaeobotany

10 *Chapter*

Preamble

Palaeobotany is the study of plant life of geological past (i.e. the study of plant fossils). The earth has undergone large climatic changes over billion years of its geologic past. During this period of drastic weather changes, most of the plants died and their remains were decomposed. However, a few plants which escaped decay and decomposition, remained preserved. These preserved plant specimen are called plant fossils. Generally, only certain plants made of harder tissues are preserved while those made of soft tissues get decomposed. The preserved plant parts are discovered independently at different times and places, hence each part is given a status of genus, representing form genus or artificial genus. Later, all these related parts are placed together and a full plant is visualized and reconstructed.

The age of the plant can be determined by using radioactive elements like uranium-238, uranium-235, thorium-232, potassium-40 and rubidium-87. Carbon-14 has also been used for time-measuring technique.

The major stratigraphic and time divisions used are given below.

The process of fossil formation is called fossilization. This had begun ever since deposition of sedimentary rocks began. According to the nature of fossilization, following fossil types have been recognized.

1. **Petrifaction fossil.** These fossils have well preserved external form and internal structure. This is due to replacement of plant material by some 20 minerals.
2. **Cast or incrustation.** This type of fossils are formed when a plant part gets covered by sand or mud. The cast or coat is hard and, therefore, used in the study of external morphology.
3. **Impression.** These are impressions of plant or plant parts when these fall on partially hard clay. Such types of fossils show clear venation patterns.
4. **Compression.** These are formed as a result of complete burial and the constant pressure of continuing sedimentation above it. The organs generally become flat.
5. **Coal, Amber, Graphite, Diatomaceous Earth,** etc. These are also types of fossils.

The fossils are of great importance in the study of evolution. These make it possible to know the time and the type of flora and fauna that flourished. It has, therefore, been possible to trace evolutionary series and reconstruct the changes which might have occurred during the past.

In this chapter, few fossils belonging to Pteridophytes and Gymnosperms are described.

Classification

1 Division. PTERIDOPHYTA

Sub-division	Order	Family	Example
1. Psilophytopsida	Psilophytales	Rhyniaceae	*Rhynia, Horneophyton*
2. Lycopsida	Lepidodendrales	Lepidodendraceae	*Lepidodendron, Lepidocarpon*
3. Sphenopsida	Calamitales	Calamitaceae	*Calamites*

II Division. GYMNOSPERMAE

Class	Order	Family	Example
1. Cycadopsida	Pteridospermales	Lyginopteridaceae	*Lyginopteris*
	Bennettitales	Williamsoniaceae	*Williamsonia*
		Cycadeoidaceae	*Cycadeoidea*

Distinguishing Characters of Taxa

1 DIVISION. **PTERIDOPHYTA**

(1) True roots generally present
(2) Plant body differentiated into stem, roots and leaves
(3) True vascular strand present

Sub-division. **Psilophytopsida**

(1) True roots absent
(2) Sporangia borne at the tips of erect branches either singly or in pairs

Order. **Psilophytales**

(1) Sporophyte dichotomously branched
(2) Sporangia generally borne singly

Family. **Rhyniaceae**

(1) Rhizoids unicellular, present on rhizomes
(2) Aerial portion leafless

Examples. ***Rhynia, Horneophyton***

	Geological periods			Age (in million years)
	Present Day			0
CENOZOIC	**Quaternary**	Post-Glacial Glacial		
	Tertiary	Pliocene Miocene Oligocene Eocene	Angiosperms dominant	1
MESOZOIC	**Cretaceous**	Upper Lower		
	Jurassic	Upper Middle Lower	Gymnosperms and Pteridophytes dominant	58
	Triassic	Upper Middle Lower		
PALAEOZOIC	**Permian**	Upper Lower		182
	Carboniferous	Pennsylvanian Mississipian	Pteridophytes dominate Gymnospsperms	
	Devonian	Upper Middle Lower		255
	Silurian		Earliest records of land plants	313
	Ordovician		Algae	350
	Cambrian		Algae	430
	Precambrian	Upper Lower	Traces of algae	510

Sub-division. **Lycopsida**
(1) Leaves microphyllous
(2) Sporangia borne singly on adaxial face of the sporophyll or in its axil
(3) Sporophyll borne in strobili

Order. **Lepidodendrales**
(1) Plants tree-like
(2) Secondary tissues formed due to cambium
(3) Leaves microphyllous and ligulate
(4) Strobili heterosporous

Family. **Lepidodendraceae**
(1) Aerial portion freely branched
(2) Strobili at the tips of branches
(3) Trunk and branches with spirally arranged leaf scars

Examples. ***Lepidodendron, Lepidocarpon***

Sub-division. **Sphenopsida**
(1) Stem branched, articulated, ridged and furrowed with distinct nodes and internodes
(2) Leaves microphyllous, small, scaly and arranged in whorls at nodes

Order. **Calamitales**
(1) Tree-like sporophytes with considerable secondary thickening of stem and branches

Family. **Calamitaceae**
(1) Stem branched, branches in whorls at nodes
(2) Stem shows endarch siphonostele

Example. ***Calamites***

II DIVISION. **GYMNOSPERMAE**
(1) Ovules naked
(2) Seeds attached to a scale
(3) Scales forming a strobilus

Class. **Cycadopsida**
(1) Wood manoxylic
(2) Large frond-like leaves
(3) Seeds with radial symmetry

Order 1. **Pteridospermales**
(1) Leaves large, frond-like, pinnately compound
(2) Large leaf traces with one or more strand
(3) Spores formed in sporangia, aggregated in synangia

Family 1. **Lyginopteridaceae**
(1) Stem monostelic
(2) Petioles with single vascular strand
(3) Seeds small

Examples. ***Heterangium, Lyginopteris***

Family 2. **Glossopteridaceae**
(1) Leaves with a strong midrib
(2) Stelar structure unusual, showing several plates of vascular tissues
(3) Reproductive structure cupulate and bisexual

Example. ***Glossopteris***

Order 2. **Bennettitales**
(1) Tree trunk covered by a mantle of persistent leaf-bases
(2) Microsporophylls in groups, at the tip, leaves frond-like
(3) Megasporophylls in cone-like organization

Family 1. **Williamsoniaceae**
(1) Stem delicate, branched
(2) Inflorescence stalked or sessile, not sunk in the scales of persistent leaf bases

Example. ***Williamsonia***

Family 2. **Cycadeoideaceae**
(1) Trunk columnar
(2) Trunk covered by mantle of leaf bases
(3) 'Flowers' sunk in the distal part of the trunk

Example. ***Cycadeoidea***

PTERIDOPHYTES

Rhynia

Classification

Division	—	**Pteridophyta**
Sub-division	—	**Psilophytopsida**
Order	—	**Psilophytales**
Family	—	**Rhyniaceae**
Genus	—	***Rhynia***

Exercise 1

***Object* : Study of external features of the plant.**

Work procedure

Study the reconstruction of plant. Observe the differentiation of plant body into rhizoids, rhizome and leaf-less aerial branches.

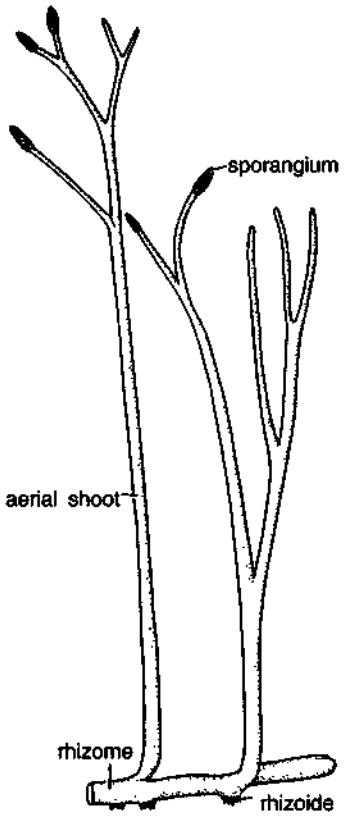


Fig. 1. ***Rhynia.*** External features of the plant.

Comments

1. *Rhynia* is a fossil member (not found living in the present age), discovered from Rhynichert Beds (or upper Devonian era) in Aberdeenshire of Scotland, by Kidston and Lang in 1917.
2. The two species *R. major*, about 40-50 cms in height and *R. gwynne-vaughani*, about 20 cms in height, found at this station, were well preserved, hence their form and structure are well known.
3. The plant grew in swampy marshes. It was differentiated into horizontally creeping rhizome and an upright branched shoot without leaves.
4. There were no roots. Unicellular rhizoids were borne in patches, on underside of the rhizome.
5. The upright branches were dichotomously branched and gradually tapering. The sporangia terminated these branches.

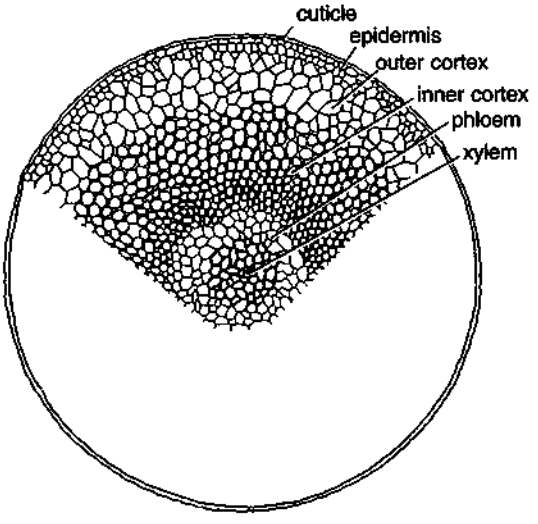


Fig. 2. ***Rhynia.*** T.s. of rhizome (a part is shown cellular).

Exercise 2

***Object* : Study of anatomy of rhizome and aerial shoot.**

Work procedure

Study the prepared slides of transverse section of rhizome and aerial branch.

Comments

1. Both aerial branches and rhizome were differentiated into epidermis, cortex and stele.
2. **The epidermis** was cuticularized with stomata scattered on the aerial shoot. They were absent from the rhizome.
3. **The cortex** was differentiated into outer and inner zone.
4. **The outer cortex** was only 1-4 layered and had compact parenchymatous cells.
5. **The inner cortex** had spherical cells with large intercellular spaces. The inner cortex is believed to be the chief photosynthetic region of the plant.
6. **The stele** was a typical protostele with xylem completely surrounded by phloem.

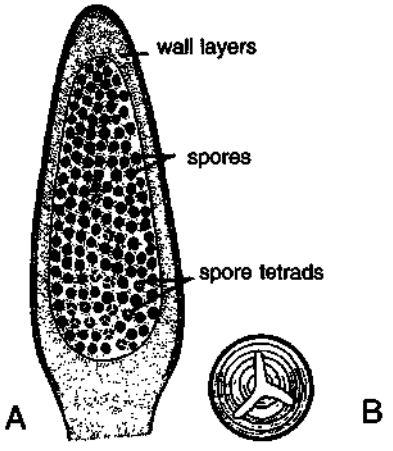


Fig. 3. *Rhynia.* Reproductive structures : **A.** A.L.s. sporangium, **B.** Single spore.

Exercise 3

***Object* : Study of reproductive organ.**

Work procedure

It is sporangium borne at the tip of the branch. Study a slide of L.s. of sporangium.

Comments

1. It was nearly oblong in shape, broad at the base and pointed at the apex.
2. The wall of the sporangium was several layered, of which two could be easily distinguished.
3. The outer wall was cuticularized and the innermost acted as tapetum.
4. Inside the sporangium were spores, all of which were of the same size. Spores in tetrads were also seen in some specimens.
5. Columella was absent from the sprangium.

Identification

Division—**Pteridophyta**. (1) Generally true roots present. (except in Psilopsida), (2) True vascular strand present.

Sub-division—**Psilophytopsida**. (1) True roots absent, (2) Shoot differentiated into subterranean rhizome and apical portion, (3) Sporangia borne terminally, (4) Homosporous.

Order—**Psilophytales**. (1) Sporophyte dichotomously branched, (2) Sporangia generally borne singly.

Family—**Rhyniaceae**. (1) Rhizoids unicellular, on rhizomes, (2) Aerial portion leafless.

Genus—***Rhynia***. (1) Subterranean portion not corm-like, (2) No columella in sporangia.

Horneophyton lignieri

Classification

Division	—	**Pteridophyta**
Sub-division	—	**Psilophytopsida**
Order	—	**Psilophytales**
Family	—	**Rhyniaceae**
Genus	—	***Horneophyton***

Exercise 1

***Object* : Study of the external features of the reconstructed plant.**

Work procedure

Study the features from a drawing of a reconstructed plant.

Comments

1. *Horneophyton* with one species *H. lignieri* was found with *Rhynia* in the Rhynichert bed of Aberdeenshire, Scotland. It was previously named as *Horneo.*
2. The rhizome was a lobed parenchymatous body bearing non-septate rhizoids but with no continuous vascular strand of its own.

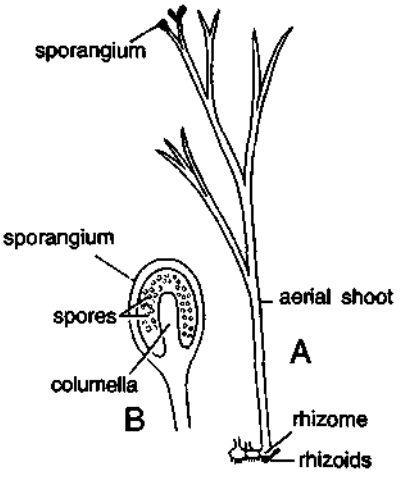


Fig. 1. *Horneophyton lignieri.* **A.** Restoration. **B.** L.s. sporangium.

3. The rhizome gave rise to upright shoots which ranged from 1 to 2 mm. in diameter and were dichotomously branched.
4. Sporangia were borne on the tips of these branches and were 1 to 2 mm in diameter and 2 or more mm in length.

Exercise 2

***Object* : Study the fossil slide of L.s. of sporangium.**

Work procedure

Slide of fossil of sporangium is available. Study various characters using microscope.

Comments

1. The sporangium was oval or slightly cylindrical spore sac, somewhat pointed distally.
2. The sporangial wall consisted of a cuticularised epidermis followed by several layers of thin walled cells. The innermost layer was a well defined tapetum.
3. The most striking feature was the presence of central columella projecting into the spore cavity from the base. The columella was continuous with the phloem of the main stem.
4. Surrounding the columella and within the sporangial wall were many spores.
5. The spores were about 50 m in diameter and occur as tetrads.

Identification

Division—**Pteridophyta**. (1) Generally true roots present (except Psilopsida), (2) True vascular strand present.

Sub-division—**Psilophytopsida**. (1) True roots absent, (2) Shoot differentiated into subterranean rhizome and apical portion, (3) Sporangia borne terminally.

Order—**Psilophytales**. (1) Sporophyte dichotomously branched, (2) Sporangia generally borne singly.

Family—**Rhyniaceae**. (1) Rhizoids unicellular, (2) Aerial portion leafless.

Genus—***Horneophyton***. (1) Rhizome—a lobed parenchymatous body, (2) Rhizome without a continuous vascular strand of its own, (3) Presence of columella in the sporanigum.

Lepidodendron

Classification

Division	—	**Pteridophyta**
Sub-division	—	**Lycopsida**
Order	—	**Lepidodendrales**
Family	—	**Lepidodendraceae**
Genus	—	***Lepidodendron***

Exercise 1

***Object* : Study the external features of the plant.**

Work procedure

Study the reconstruction of the plant. Observe the differentiation into stigmarian root system, Lepidophylloids leaves and *Lepidostrobus* strobili.

Comments

1. *Lepidodendron* with over 100 species, is the largest known genus. It is found in the shales and sandstones of carboniferous coal bearing formations.
2. The root system is included in the form genus *Stigmaria*, leaves in form genus *Lepidophylloides* and the strobili in the form genus *Lepidostrobus*.
3. *Lepidodendron* was a tall tree reaching 40 meters. The trunk was straight that branched dichotomously only at the top. The branches were shorter.
4. The branches were covered with spirally arranged leaves, placed in the form genus *Lepidophylloides*. These were simple, ligulate, acicular to linear. A single vein traversed the length of a leaf.
5. Leaves were attached to the summit of pyramidal cushion-like leaf bases which were rhombic or diamond shaped. The leaf scars formed oblique or spiral rows on the stem. Actual leaf scar was above the middle line of rhombus. In the leaf scar, the bundle scar mark

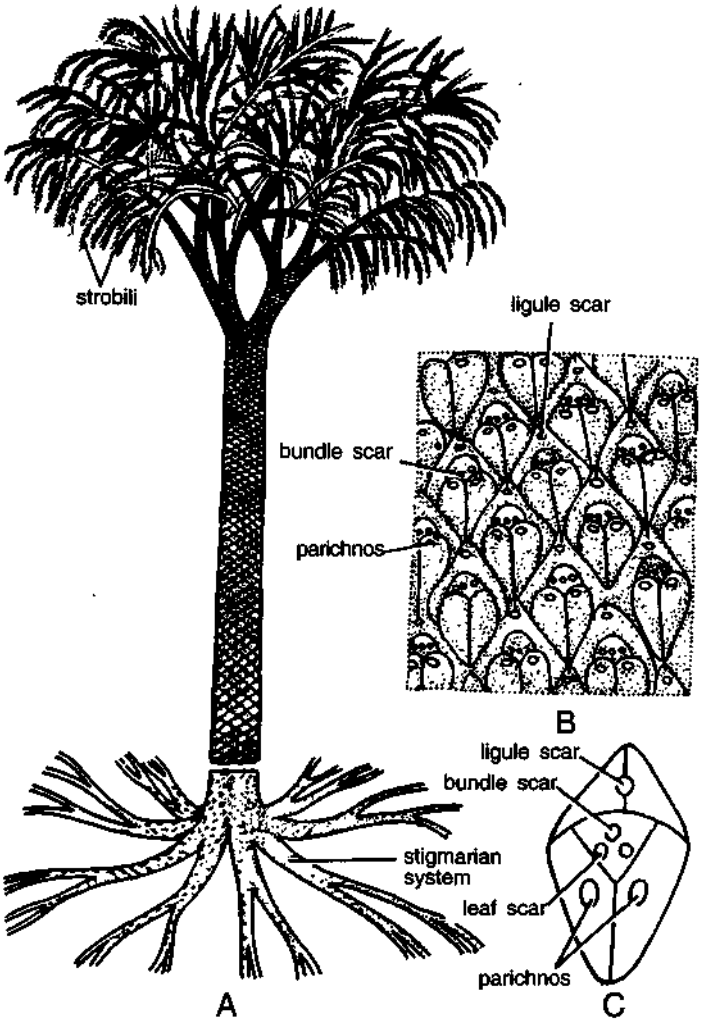


Fig. 1. ***Lepidodendron.*** **A.** Reconstruction of tree. **B.** Surface of the trunk showing scars formed by the leaf bases **C.** A leaf scar.

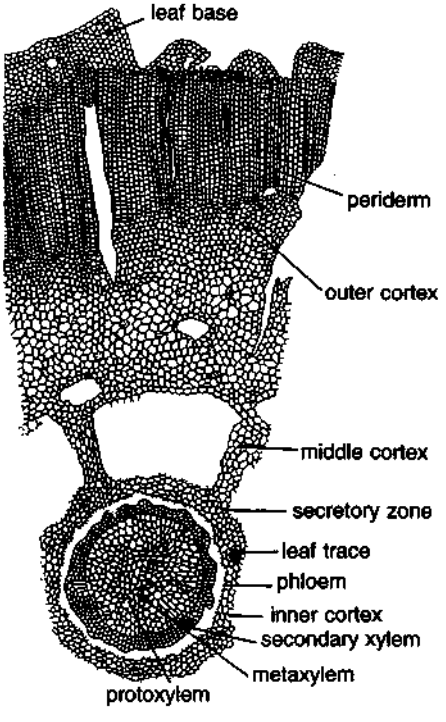


Fig. 2. ***Lepidodendron. L. selaginoides*** (= *L. vasculare*). T.s. of stem.

was flanked by two scars and at the lower level by two more large scars which represented parichnos scars (strands of loosely arranged parenchyma).

6. Typical *Lepisdodendron* trunk was attached to a typical stigmarian root system. The base of the trunk was divided into four massive rhizophores which later again divided dichotomously.
7. The strobili borne terminally were found attached to a branch identical to *Lepidodendron* and are placed under the form genus *Lepidostrobus.*

Exercise 2

***Object* : Study of the anatomy of stem.**

Work procedure

Study the prepared slide of transverse section of the main trunk or a branch.

Comments

1. It shows a protostele or siphonostele with exarch and polyarch protoxylem.
2. Metaxylem was present in the centre with many protoxylem points on periphery.
3. A ring of cambium situated outside produced a narrow zone of secondary xylem. Both primary

and secondary xylem were made of scalariform and spiral tracheids.

4. A large cortex surrounded the vascular tissues. It showed four regions-
   (i) Inner cortex : homogeneous and made of parenchyma except for leaf traces.
   (ii) Secretory zone made of intermingled large and small cells, many of which were filled with a dark coloured substance.
   (iii) Middle cortex that consisted of delicate cells which were often destroyed.
   (iv) Outer cortex made of alternate radial masses of thick and thin walled elements.
5. Outermost was the periderm formed by phellogen. It consisted of many elements on its inner side forming endophelloderm than on the outer side that formed exophelloderm.

Exercise 3

***Object* : Study the strobilus.**

Work procedure

Study the structure of a strobilus by observing and studying the slide of L.s. of strobilus.

Comments

1. The strobili borne by Paleozoic lepidodendrids are placed in organ genus *Lepidostrobus*. All known species are heterosporous.
2. Strobili occurred on terminal parts of certain smaller branches. The strobili were elliptical, 1 to 7.5 cm in diameter and 2.5 to 30 cm or more long.
3. Each consisted of a central axis around which sporophylls were found in spirals or whorls (in some cases verticillate).
4. The sporophyll was peltate with the upper terminal lobe overlapping the sporophyll above. The sporophylls were attached at right angles to the axis.
5. Each sporophyll bore a single sessile elongate sporangium on its adaxial face. Just beyond the sporangium, the sporophyll had a small ligule.
6. There was also a shorter downward prolongation of the lamina called heel, completely covered by the lamina of the sporophyll below.
7. The sporangium was a large sac-like structure wider than the sporophyll. The wall was of a single layer of prismatic cells. Some radiating flaps of tissue called trabeculae extended upward from the base of the sporangium.
8. The microsporangia and megasporangia are of the same size.
9. Microsporangium enclosed several hundred microspores. Megasporangium enclosed 4, 8, or 16 megaspores.
10. Megaspores showed gametophytic development while still within the megasporangium.

Identification

Division—**Pteridophyta**. (1) True roots present, (2) Plant body differentiated into stem, roots and leaves, (3) True vascular strand present.

Sub-division—**Lycopsida**. (1) Leaves microphyllous, (2) Sporangia borne singly on adaxial face of the sporophyll or in its axil, (3) Sporophylls borne in strobili.

Order—**Lepidodendrales**. (1) Plants tree-like, (2) Secondary tissues formed by means of a cambium, (3) Leaves microphyllous, ligulate, (4) Strobili heterosporous.

Family—**Lepidodendraceae**. (1) Aerial portion freely branched, (2) Strobili at the tips of branches, (3) Trunk and branches with spirally arranged leaf scars.

Genus—***Lepidodendron***. (1) The vertical diagonal of the rhombus longer than the tranverse, (2) Cones borne on short lateral branches.

Calamites

Classification

Division	—	**Pteridophyta**
Sub-division	—	**Sphenopsida**
Order	—	**Calamitales**
Family	—	**Calamitaceae**
Genus	—	***Calamites***

Exercise 1

***Object* : Study the reconstructed plant.**

Work procedure

Study reconstruction from the standard books.

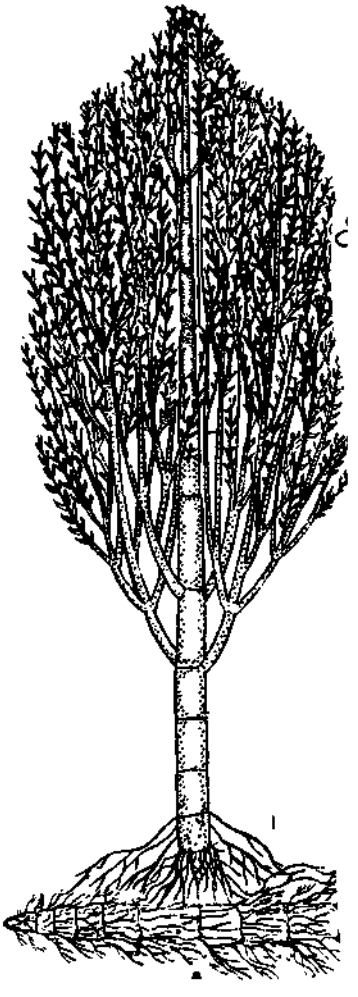


Fig. 1. ***Calamites.*** Reconstruction of the plant.

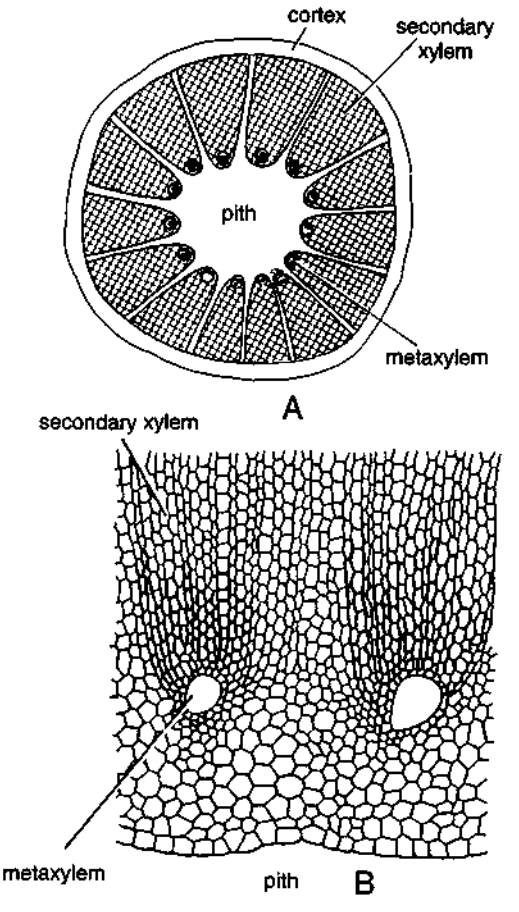


Fig. 2. ***Calamites.*** T. s. of stem. **A.** Outlines, **B.** A part cellular.

Comments

1. Genus *Calamites* appeared in Upper Devonian, and was most abundant during Carboniferous and became extinct early in the Triassic.
2. The plant was 20 to 30 meters tall tree.
3. The tree was arborescent with horizontal rhizome, aerial shoots and whorls of leaves.
4. Rhizomes were differentiated into nodes and internodes. Nodes bore whorl of adventitious roots.
5. Aerial branches were borne on the upper side of rhizome. These wee generally constricted at the place where these joined the thizome.
6. The lowermost nodes of the erect branches produced whorls of adventitious roots.
7. The aerial branches were highly articulated. The leaves were borne in whorls at the upper nodes. These also had branches borne in pairs.
8. Each node had a single whorl of leaves. The leaves were smaller and perhaps were photosynthetic organs. These were lanceolate, linear or spathulate with a single vein.
9. Genus *Calamites* is divided into subgenera on the basis of mode of branching and general growth pattern.
   (i) *Eucalamites*—bore one to many branches at the node.
   (ii) *Calamitina*—bore branches in whorls which were separated by a series of branchless nodes.
   (iii) *Diplocalamites*—2 to 3 branches produced with branches alternating from node to node.

(iv) *Crucicalamites*—large number of branches produced at each node.
(v) *Stylocalamites*—wihout branches or branches fewer and irregularly scattered.

Exercise 2

***Object* : Study of the stem anatomy.**

Work procedure

Study the prepared slide showing stem anatomy.

Comments

1. The petrified calamitean stem of three form genera viz. *Arthropitys, Calamodendron* and *Arthroxyulonn* have been recognised. They have been established to belong to *Calamites* and their special names are used only when necessary.
2. Petrified stems of *Calamites* are frequent in the coal balls and other carboniferous petrifactions.
3. The stem was ridged and furrowed which alternate at each successive internodes.
4. The transverse section of internode shows endarch siphonostele with secondary xylem produced by vascular cambium.
5. There was a large hollow central pith cavity. It became solid at nodes forming a diaphragm.
6. Surrounding the pith was a ring of more than a dozen primary collateral vascular bundles.
7. The protoxylem was endarch and was represented by carinal canal formed due to dissolution of many elements.
8. The metaxylem was very less in amount. It was composed of scalariform and pitted tracheids.
9. Cambium occurred in between xylem and phloem.
10. Secondary xylem was formed on the inner face of cambium. It was made of tracheids and rays. Tracheids were arranged in radial rows. These showed scalariform thickenings or multiseriate bordered pits on the radial walls. Secondary xylem formed wedge-shaped zones separated by interfascicular rays.
11. The rays show considerable diversity in structure and serve as the basis for generic distinction.
12. The tissues outside the secondary xylem showed inner cortex made of thin walled parenchyma with resin canals.
13 The cells of the outer cortex were also thin walled but were much smaller than the cells of the inner zone.
14. The cortex was as wide as xylem and formed thick bark (also termed periderm) that was smooth externally.

Identification

Division—**Pteridophyta**. (1) True roots present, (2) Plant body differentiated into stem, roots and leaves, (3) True vascular strand present.

Sub-division—**Sphenopsida**. (1) Stem branched, articulated, ridged and furrowed with distinct nodes and internodes, (2) Leaves microphyllous, small, scaly and arranged in whorls at nodes.

Order—**Calamitales**. (1) Tree-like sporophytes with considerable secondary thickening of stem and branches, (2) Strobilus with central articulated axis which bore alternate whorls of sporangiophores and sterile bracts.

Family—**Calmitaceae**. (1) Stem branched, branches in whorls at nodes, (2) Stem shows endarch siphonostele.

Genus—***Calamites***. (1) Suberranean rhizome present, (2) Lower nodes producing adventitious roots, (3) Vallecular canal absent, (4) Periderm may or may not be formed.

GYMNOSPERMS

Lyginopteris

Classification

Division	—	**Gymnospermae**
Class	—	**Cycadopsida**
Order	—	**Pterdospermales**
Family	—	**Lyginopteridaceae**
Genus	—	***Lyginopteris***

Exercise 1

***Object* : Study of external morphology of the stem.**

Work procedure

Study the diagrammatic representation of the stem genus from standard books. Summarise the major points of significance.

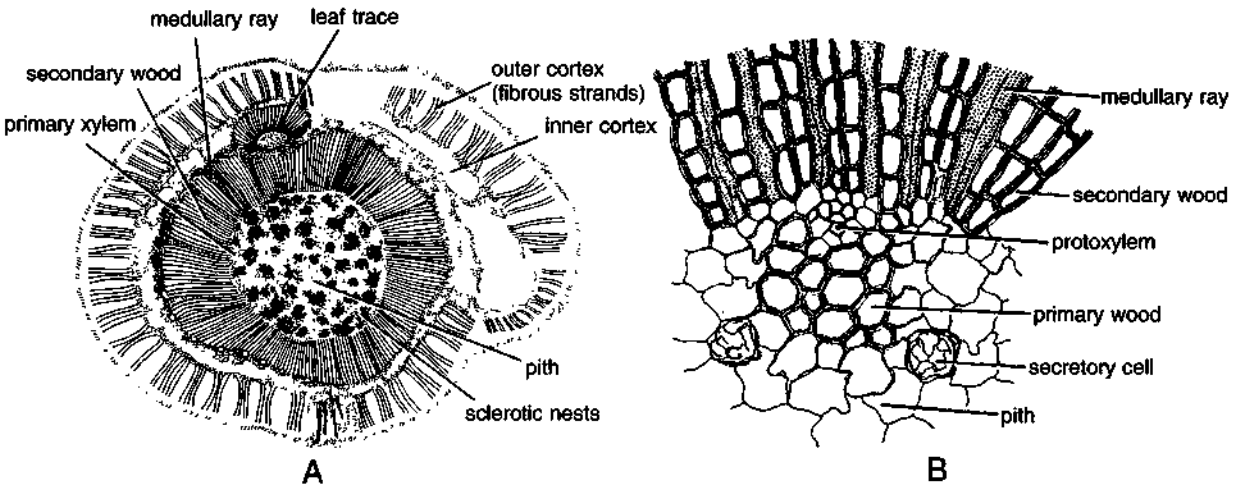


Fig. 1. ***Lyginopteris.*** **A.** T.s. of stem (outlines), **B.** T.s. stem— a part cellular.

Comments

1. *Lyginopteris* is a palaeozoic pteridosperm. It is a stem genus of *Calymatotheca Hoeninghausi.* The descriptions of *Lyginopteris Oldhamia* are available.
2. The genus was described under *Dadoxylon oldhamium* by Binney in 1886. Later t h e genus was transferred to *Lyginodendron* on the basis of cortical impressions. Genus *Lyginopteris* was established by Potonie in 1899.
3. Petrifications and compressions of the stem were found in the lower and middle. Coal measures of Britain, continental Europe and north America.
4. The stem was long and generally slender. Diameter varied from 2 mm to 40 mm, sometimes up to 4 cms . Some specimen showed branching. The branches were axillary when present. These were arranged spirally.

Exercise 2

***Object* : Study the anatomy of stem.**

Work procedure

Study the slide of T.s. of fossil stem or alternatively study the diagrams from the books and draw a list of important features of anatomy.

Comments

1. The section shows three distinct regions—
   (i) central pith,
   (ii) centrally located vascular tissue and
   (iii) outer region of cortex.
2. A large parenchymatous pith was present in the centre. Many sclerotic nests were present scattered in this region.
3. Along the margins of the pith were present many strands of primary xylem. Protoxylem was mesarch .
4. Primary xylem was made of tracheids with bordered pits on their radial walls.
5. The strands of primary xylem were surrounded by a wide region of secondary xylem. It was made of tracheids with multiseriate bordered pits. Wide medullary rays which alternated with groups of primary xylem were also present.
6. Continuity of secondary xylem was interrupted by outgoing leaf traces giving an appearance of four large and unequal masses.
7. Outside the secondary xylem were present cambium and secondary phloem. Pericycle was situated outside the vascular tissues and was represented by groups of stone cells.
8. A band of internal periderm was present outside pericycle.
9. The cortex situated outside was divisible into inner cortex and outer cortex.

10. The inner cortex was poorly preserved and, therefore, the tissues were not distinct. However, it gave an impression as if made of large parenchymatous cells.
11. Outer cortex was made of a wide region of radially arranged fibrous strands. These were anastomosed and formed a distinct reticulum.
12. Numerous glands were present on the stem surface.The tip of the gland was spherical and was made of small cells.These were sessile as well as stalked.

Identification

Division—**Gymnospermae**. (1) Ovules naked, (2) Seeds attached to scales, (3) Scales forming a strobilus.

Class—**Cycadopsida**. (1) Wood manoxylic, (2) Large frond-like leaves, (3) Seeds with radial symmetry.

Order—**Pteridospermales**. (1) Leaves large, frond-like, pinnately compound, (2) Large leaf traces with one or more strands,(3) Spores formed in sporangia, aggregated in synangia.

Family—**Lyginopteridaceae**. (1) Stem monostelic, (2) Petioles with single vascular strand, (3) Seeds small.

Genus—***Lyginopteris***. (1) Presence of stone cells in pith, (2) Wide fibrous bands in outer cortex.

Cycadeoidea

Classification

Division	—	**Gymnospermae**
Class	—	**Cycadopsida**
Order	—	**Bennettitales**
Family	—	**Cycadeoidaceae**
Genus	—	***Cycadeoidea***

Exercise 1

***Object* : To study the external features of stem.**

Work procedure

Study the external features of the reconstructed plant from the figures and text available from standard text books. List various important features.

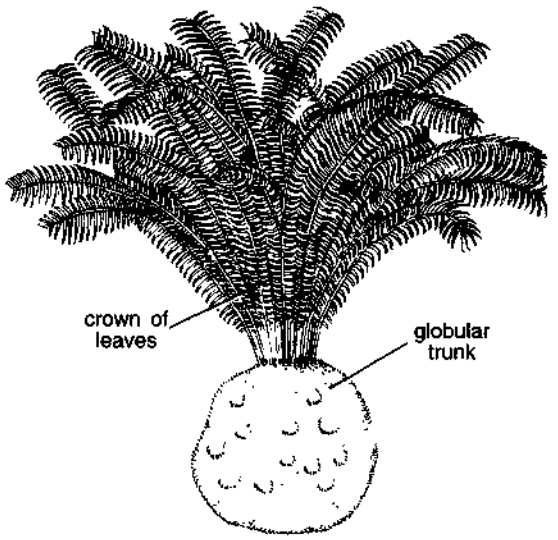


Fig. 1. ***Cycadeoidea.*** External features.

Comments

1. *Cycadeiodea* (= *Bennettitis)* is a fossil that includes many species. Many petrifications have been found of which some are complete plants. This fossil has been found in Jurassic and cretaceous strata of Dakota, America.
2. The stems were generally small (less than three feet in height, sometimes 10 to 12 feet,) and thick (about 2 feet). It remained covered with persistent leaf bases. A few specimen were branchless (though in some 3 to 4 small branches arose from in a group from a basal stalk).
3. Persistent leaf bases were closely placed and formed a thick mantle. In between them were present flat scale-like hairs called ramentum.
4. Only young leaves have so far been found. These were present close to the apex. Leaves were pinnately compound and the venation was parallel.
5. The flowers were borne in the axils of leaves and completely embedded in the armour of persistent leaf bases.

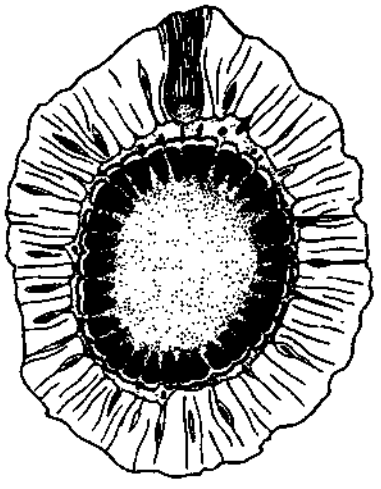


Fig. 2. ***Cycadeoidea.*** T.s. stem.

Exercise 2

Object **: Study of anatomy of transverse section of stem.**

Work procedure

Study the slide of T.s. of stem or study the diagrams available in the standard books.

Comments

1. The section is differentiated into three regions central pith, middle region consisting of wood and outer cortex.
2. Centrally located pith is smaller in diameter. It was surrounded by wood from all the sides.
3. Wood formed a small region that surrounded central pith. The region appeared broken by ray-like extensions projecting from central pith.
4. Endarch protoxylem was situated on the inner side of the wood , close to the pith. Vascular bundles were arranged in a ring and the xylem was arranged centrifugally.
5. Secondary xylem was made of scalariform tracheids and small rays. Rays were uniseriate or biseriate.
6. Medullary rays extended beyond cambium up to phloem. These alternate with parenchyma and vertical vascular tissues.
7. Cortex was made of parenchyma where gum canals and leaf traces were abundant.
8. Leaf trace occurred singly at the place of their origin but broke into many mesarch strands to arrange itself into horse-shoe shaped structure. The mouth of hose-shoe was directed outwards.

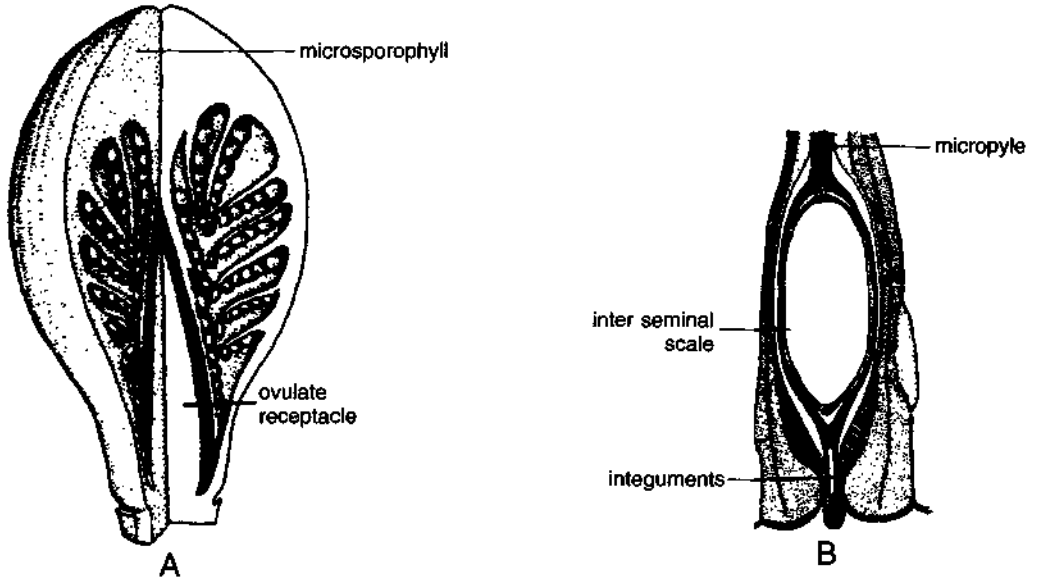


Fig. 3. ***Cycadeoidea.*** **A.** L.s. of cone, **B.** L.s. of Ovule.

Exercise 3

***Object* : To study the reproductive parts.**

Work Procedure

Study the diagrams from the book and prepare the list of main features.

Comments

1. Fruiting bodies were produced on the axillary shoots (In some species more than 100 fruiting bodies).
2. These appeared in a group between leaf bases. Fructifications were bisexual.
3. Many spirally arranged bracts were present on fertile shoots. These kept fructifications covered till they matured. On maturity the bracts of the flower opened and formed saucer-shaped perianth. The structures were modified androecium and gynoecium.
4. The pollen bearing structures bore a whorl of about 20 microsporophylls.. These were almost fused at the base. Each microsporophyll consisted of main rachis which bore two rows of trabeculae which in turn held two lateral rows of multicellular synangia.Each synangia was pear-shaped bearing 20 to 30 longitudinal pollen sacs.
5. The ovule bearing structure was made of conical or spherical receptacle with many stalked ovules and interseminal scales .
6. The ovule was orthotropous with a long micropylar beak. The integument of the ovule was fused with the nucellus except at the apex where it formed micropyle.
7. The seeds were small and invested with a basal cupule.It was somewahat elongated or oval in shape and possessed two cotyledons.

Identification

Division—**Gymnospermae**. (1) Ovules naked, (2) Seeds attached to scales, (3) Scales forming a strobilus.

Class—**Cycadopsida**. (1) Wood manoxylic, (2) Large frond-like leaves, (3) Seeds with radial symmetry.

Order—**Bennettitales**. (1) Tree trunk covered with mantle of persistent leaf bases, (2) Microsporophylls in groups, at the tip, leaves frond-like, (3) Megasporophylls in cone-like organization.

Family—**Cycadeiodaceae**. (1) Trunk columnar, (2) Trunk covered with mantle of leaf bases, (3) Flowers sunk in the distal part of the trunk.

Genus—***Cycadeoidea***. (1) Small, globular trunk,(2) Bisexual strobilus, (3) Orthotropous ovules.

Williamsonia

Classification

Division	—	**Gymnospermae**
Class	—	**Cycadopsida (Bennettitopsida)**
Order	—	**Cycadeoidales (Benettitales)**
Family	—	**Williamsoniaceae**
Genus	—	***Williamsonia***

Exercise 1

***Object* : To study the external features of the plant.**

Work procedure

Study the morphological features of the reconstructed plant, note the significant features and list them from standard books.

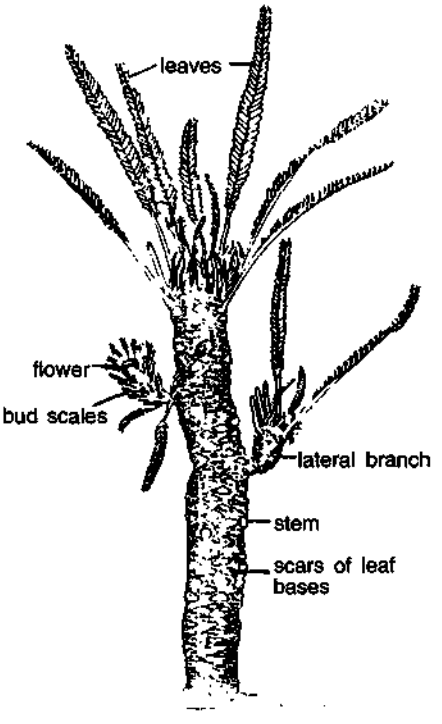


Fig. 1. ***Williamsonia***. External features. Reconstruction.

Comments

1. Many species have so far been reported from upper Triassic and Jurassic beds of India, Europe and north America.
2. It was earlier placed under Zamia gigas by Williamson (1868). Later it was named in honour of its discoverer. *Williamsonia sewardiana* is the best known species described by late Professor Birbal Sahni from Rajmahal Hills, Bihar (India). Gupta (1953) later described another species from Rajmahal Hills and named it after Professor sahni.
3. *W. sewardiana* had a study columnar trunk similar to that of *Cycas*. It had a crown of pinnately compound leaves. The stem was covered with alternating areas of large (foliage) and small (scaly) leaf bases.
4. The leaf was placed in from genus *Ptilophyllum*. It has linear and parallel veined leaflets similar to those found in *Zamia*.
5. The lateral branches were borne through leaf bases and possessed flowers. These branches were also covered with scales and bracts.
6. The flowers were unisexual.

Identification

Division—**Gymnospermae**. (1) Ovules naked, (2) Seeds attached to the scale, (3) Scales forming a strobilus.

Class — **Cycadopsida**. (1) Wood manoxylic, (2) Large frond-like leaves, (3) Seeds with radial symmetry.

Order — **Bennettitales**. (1) Tree trunk covered by a mantle of persistent leaf bases, (2) Microsporophylls in groups, at the tip, leaves frond-like, (3) Megasporophylls in cone-like organization.

Family —**Williamosniaceae**. (1) Stem delicate, branched, (2) Inflorescence stalked or sessile, not sunk in the scales of peristent leaf bases.

Genus—***Williamsonia***. (1) Stem study and columnar, (2) Leaves pinnately compound, (3) Lateral branches with flowers.

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Appendix

Fixing Agents and Preservatives

1. **Carnoy's fluid**

100% ethyl alcohol	...	30 cc
Glacial acetic acid	...	5 cc
Chloroform	...	15 cc

It is used for root tips, anthers, etc. and is preferred for its great penetrating power.

2. **Formalin-Aceto-Alcohol**

50% or 70% ethyl alcohol	...	90 cc
Glacial actic acid	...	5 cc
Formalin	...	5 cc

It is popularly known as FAA and is a standard universal fixative. It is the most extensively used fixing and killing agent.

3. **Formalin-Propino-Alcohol**

In the preparation of FAA use propionic acid instead of acetic acid.

4. **Randolph's modified Navashin fluid**

Solution A.	Chromic acid	...	5 gm
	Glacial acetic acid	...	50 cc
	Distilled water	...	320 cc
Solution B.	Natural formalin	...	200 cc
	Saponin	...	3 gm
	Distilled water	...	175 cc

At the time of use, mix solutions A and B in equal amounts. Recommended for buds, roots tips and similar objects.

5. **Bouin's fluid**

Picric acid (1.5% aq. solution)	...	75 cc
Formalin	...	25 cc
Glacial acetic acid	...	5 cc

This fixative is more useful than those with chromic acid.

Stains

1. **Acetocarmine**

Dissolve 1 gm of stain in 100 cc of boiling 45% acetic acid (or propionic acid). Cool and decant. Add a few drops of saturated aqueous solution of ferric acetate. Cool by keeping in ice for at least twelve hours. Filter and store the stock in refrigerator. For storage, use dropping bottle that is dark or covered with a black paper.

2. **Aniline blue (Cotton blue, China blue, Water blue)**

Aniline blue	...	1 gm
Alcohol 90% or water	...	100 cc

For better results stain or alcohol should be slightly acidified with hydrochloric acid.

3. **Crystal violet (Gentian violet)**

Crystal violet	...	1 gm
Distilled water	...	100 cc

4. **Erythrosine**

(a)	Erythrosine	...	1 gm
	Alcohol 90%	...	100 cc
(b)	Erythrosine	...	1 gm
	Absolute Alcohol	...	5 cc
	Clove oil	...	95 cc

5. **Fast green**

(a)	Fast green	...	0.5 gm
	Alcohol 90%	...	100 cc
(b)	Fast green	...	0.5 gm
	Absolute alcohol	...	25 cc
	Clove oil	...	75 cc

6. **Gram's iodine**

Iodine	...	2 gm
Potassium iodide (KI)	...	3 cc
Distilled water	...	300 cc

7. **Hematoxylin**

It is a chromogen derived from logwood *Haematoxlyon coampechianum* of Leguminosae. Two types of hematoxylins are commonly employed (a) Heidenhain's and (b) Delafield's hematoxylin.

(a) *Heidenhain's hematoxylin.* Half per cent solution of the stain is prepared in warm and distilled water. It is then stored in dark and

closed bottle to ripen for at least four days before use.

(b) Delafield's hematoxylin.

1. A saturated aqueous solution (100 cc) of ferric ammonium sulphate is prepared.
2. One gram of stain is dissolved in 6 cc of absolute alcohol.
3. Mixture of solutions 1 and 2 is prepared. Add to this solution 25 cc of glycerine and 25 cc of absolute alcohol.
4. The solution thus prepared is allowed to remain for sufficient time till the colour becomes dark red.

8. Safranin

(a) Safranin	...	1 gm
Alcohol 95%	...	50 cc
Distilled water	...	50 cc
(b) Safranin	...	1 gm
Distilled water	...	100 cc

Mounting Media

1. Glycerine jelly

Soak some gelatin for 2 to 3 hours in cold water, pour off the excess water and heat until melted. To 1 part of this, add $1\frac{1}{2}$ parts of glycerine and filter while still hot. Add 2 or 3 percent phenol. Still keeping the mixture hot and fluid, add drop by drop a saturated solution of methyl green in 50 percent alcohol, until the glycerine becomes fully as dark as green ink.

2. Lactophenol

Mix equal parts of phenol crystals, lactic acid, glycerine and distilled water. Cotton blue may be mixed to stain fungi.

Recommended Stains and Mounting Media

1. Algae :

For study, mostly temporary or semi-permanent mounts are prepared. However, sometimes permanent preparations may also be made but extreme care, is necessary, not to allow any shrinkage while dehydrating. This is done by passing the material through a very close dehydrating series e. g. alcohol 5%, 7%, 10%, 12%, 15%, and similar grades.

If a single stain is to be used in any of these preparations, the following are some of the most commonly used—

Stains :	**Mounting media :**
(a) Aniline blue	(a) Glycerine jelly
(b) Aceto-carmine	(b) Glycerine 10%
(c) Cotton blue	(c) Formo-glycerine
(d) Delafield's hematoxylin	(d) Lactophenol
(e) Safranin	

2. Fungi

Temporary and semi-permanent preparations; single-staining:

Stains :	**Mounting media :**
(a) Aniline blue	(a) Lactophenol
(b) Cotton blue	(b) Glycerine10%
(c) Hematoxylin	

3. Bryophytes

Temporary, semi-permanent and permanent preparations; single staining :

Stains :	**Mounting media :**
(a) Delafield's hematoxylin	(a) Glycerine jelly
(b) Fast green	(b) Glycerine 10%
(c) Safranin	(c) Canada balsam.

4. Pteridophytes

Temporary, semi-permanent and permanent perparations; double staining.

Stains and combinations :

Principal Stain :	**Counter Stain :**
(a) Delafield's hematoxylin	— Safranin
(b) Safranin	— Fast green
(c) Crystal violet	— Erythrosine

Mounting media :

(a) Glycerine 10% (b) Canada balsam

5. Gymnosperms and Angiosperms

Temporary, semi-permanent and permanent preparations; double staining;

Stains and combinations :

Principal Stain :	**Counter Stain:**
(a) Safranin	— Fast green
(b) Crystal violet	— Erythrosine
(c) Delafield's hematoxylin	— Safranin

Mounting media :

(a) Glycerine 10% (b) Canada balsam.

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