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B.Sc. BOTANY

SECOND YEAR

PAPER – III : PTERIDOPHYTES, GYMNOSPERMS AND PALEOBOTANY

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Pteridophytes:

UNIT I

General characters of Pteridophytes. Classification (K. R. Sporne). Stelar evolution in Pteridiophytes. Homospory and Heterospory. Economic importance of pteridiophytes.

UNIT II

Detailed study of the following genera:

Lycopodium, Selaginnela.

UNIT III

Adaiantum and *Marsilea*.

UNIT IV

General characters of sporophytes and gametophytes of Gymnosperms. Classification (K.R. Sporne) of Gymnosperms. Detailed study of the following genera- *Cycas* and *Pinus*.

UNIT V

Geological time scale. Types of fossils. Brief study of the following fossils- *Lepidodendron* and *Williamsonia*.

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BLOCK INTRODUCTION

We are in the block of course three Pteridophytes, gymnosperms and paleobotany. In this book we will discuss about the first land plants, the pteridophytes and their succession by gymnosperms. We are going to see how the plants have been evolved themselves to the land habit and their progressive evolution to the modern day flowering plants.

The first unit mainly comprises of the introduction of pteridophytes, their general characters, the different types of steles seen in them. Their classification and different types of sporophyte and gametophytes seen in pteridophytes and their commercial importance to man is also discussed.

In the second unit of this block you are going to study the details of two important pteridophytes genera, of which, the *Lycopodium* is a homosporic form and *Selaginella* a heterosporic form. You are also going to see how *Selaginella* heterospory must have been a pioneer in the seed habit to the present seed plants.

In the third unit, you will learn about two advanced forms of ferns, a homosporic *Adiantum* and a heterosporic *Marsilea*, their advanced characters and life cycle.

In the fourth unit you will acquire knowledge about gymnosperms, and their general characters which will be further supported by the detailed study of two widely distributed present day gymnosperm *Cycas* and *Pinus*.

In the last unit of this block, you are going to explore the past history of plants in ‘paleobotany’, how this study is carried out, and what are the types of evidence seen about the extinct plants of pteridophytes and gymnosperm. In addition, you will have a look on fossil pteridophyte *Lepidodendron* and fossil gymnosperm *Williamsonia*.

UNIT - I

General characters of Pteridophytes. Classification (K. R. Sporne). Stelar evolution in Pteridiophytes. Homospory and Heterospory. Economic importance of pteridiophytes.

Introduction:

In the block two, you have studied about amphibious Bryophytes, and how in the advanced forms, have evolved towards the adaptation to land habit. You have learnt that, especially in Anthoceros, the sporophytic generation is independent and of unlimited growth. In the present unit, you will be enlighted about the gametophytes and sporophytes of pteridophytes, their classification, and their importance to man.

1.1. **General characters of Pteridophytes**:

The Pteridophytes are generally called as *vascular cryptogam* (the group of seedless plants with well developed conducting system; due to the presence of true xylem), constitute a significant and important group in the plant kingdom. It is the most primitive group of vascular plants and so offers a very favorable material for the study of various adaptations. The group has a long fossil history, as far back as 380 million years, and flourished well during the Silurian age of the late Paleozoic era. Today the group is represented by a smaller number of plants.

The life cycle of typical member comprises a regular heteromorphic alternation of generations and the most characteristic feature of Pteridophytes is "the presence of independent gametophytes and sporophytes at maturity". Nevertheless the sporophyte is the predominant generation, being a more robust body, suitable to effectively meet the challenges of a terrestrial environment.

Occurrence

1.1.1 They are found in great majority of habitats, ranging from aquatic to xerophytic one. However most plants grow luxuriantly in cool, damp and shady places. The group is strongly mesophytic; but *Selaginella lepidophylla* and *S. rupestris* are xerophytic; and *Marsilea*, *Salvinia* and *Azolla* are hydrophitic.

The plant body (adult sporophyte)

1.1.2 The main plant body is sporophyte which is differentiated into root, stem and leaves. Some primitive members lack true roots and well developed leaves e.g., Psilophytales and Psilotales.

1.1.3 The sporophyte develops from the zygote, a diploid cell which results from the fertilization of the egg and antherozoid, and is the conspicuous plant body.

1.1.4 The plants are mostly herbaceous and show dorsiventral or radial symmetry.

1.1.5 The normal roots arise from the base of the stem. Adventitious roots arise in acropetal succession from each node and are generally adventitious-rhizoids helping in anchorage of the plant to the substratum.

1.1.6 The branching of roots is either monopodial or dichotomous type.

1.1.7 All the vegetative parts of the sporophyte possess vascular supply.

1.1.8 Roots show a diarch arrangement of xylem in general.

1.1.9 The stem is branched dichotomously or monopodially.

1.1.10 The stem shows protostelic to polycyclic conditions.

1.1.11 The stems bear leaves which may be microphyllous (small leaves) or megaphyllous (large in relation to stem).

1.1.12 In microphyllous types, the leaves are small in relation of stem and the leaf traces leave no gap in the stele. It is represented by club mosses and horse tails. Microphyllous leaves are much simpler, with out petiole and usually only one vein.

1.1.13 The megaphyllous types are represented by ferns. The leaves consist of a petiole and a leaf blade or lamina with many veins.

1.1.14 All the vegetative parts possess vascular tissues (*i.e*., xylem and phloem).

1.1.15 The xylem consists of tracheids and xylem parenchyma. Vessels are absent (the primitive vessels may be present in few).

1.1.16 The phloem consists of sieve-tubes and phloem parenchyma. The companion cells are absent.

1.1.17 The secondary growth does not occur (except in *Isoetes*).

Reproduction.

1.1.18 The plants may be homosporous or heterosporous.

1.1.19 The spores are produced inside the sporangia which may be borne on stem (cauline) or leaves (foliar). The leaves bearing sporangia are called sporophylls.

1.1.20 The sporophylls may be scattered on a plant or may be restricted to particular regions called strobili or cones *e.g., Selaginella, Equisetum* etc.

1.1.21 In certain pteridophytes the sporangia are produced within specialized structures called sporocarps *e.g., Marsilea, Salvinia, Azolla* etc.

1.1.22 The sporangium in all pteridophytes, is initiated by the laying down of a cross-wall in a superficial cell or a group of cells. Since whis wall is periclinal each initial cell is devided into an outer and inner daughter cell. If the sporogenous tissue is derived from the inner daughter cell, the sporangium is descried as “eusporangiate” (as in most pteridophytes) and if from the outer as “leptosporangiate” (in some advanced pteridophytes).

Gametophyte

1.1.23 The spores germinate to produce a haploid multicellular, foliaceous and dorsiventrally flattened gametophytic plant- the prothallus.

1.1.24 The gametophyte in homosporous are subterranean and in heterosporous are retained within the resistant wall of the spore.

1.1.25 The gametophytes of homosporous species are monoecious, and the plant bears archegonia at the anterior end and antheridia at the posterior end.

1.1.26 In heterosporous species, the larger megaspores give rise to female prothalli which bear only archegonia, and the smaller micorspores give rise to male protahlli which bears only antheridia.

The antheridia

1.1.27 The homosporous plants produce flagellated, motile antherozoids.

1.1.28 The antheridia produce flagellated, motile antherozoids.

1.1.29 The antheridia may be embedded in the gametophyte (as in eusporangiate) or they may project from it (as in leptosporangiate ferns).

1.1.30 The mature antheridia are globular and consist of an outer sterile wall inside which are found a large number of androcyte. Androcyte metamorphoses to antherozoid.

The archegonia

1.1.31 The archegonia are flask shaped. They have a basal swollen embedded portion, the venter and a short neck. The venter encloses egg and venter canal cell. The neck has 4 longitudinal rows of neck cells. They bear non-motile eggs or oospores.

1.1.32 At maturity the apical cells of archegonium separate, the neck canal cell disintegrate forming a passage for antherozoids to reach the egg.

The fertilization

1.1.33 The fertilization takes place in presence of water.

1.1.34 The male gamete and female gamete fuse to form a diploid zygote.

The embryo (the young sporophyte)

1.1.35 The zygote develops into a young sporophyte which remains attached to the gametophyte by means of a foot and gets nourishment from the prothallus during early stages until it develops its own stem, roots and leaves.

1.1.36 The plants exhibit heteromorphic type of alternation of generation.

1.2. **Classification in Pteridophytes**.

Sporne has classified pteridophytes based on the classification of Reimers in 1954 and has modified it to the present classification. He has classified petidophytes into 6 divisions. His classification is as follows:

Pteridophytes

A. **Psilopsida***

- Extinct plants.
- Only sporophytes are known.
- Rootless, with rhizome and more or less dichotomous aerial axes either naked or bearing small lateral appendages
- Protostelic
- Sporangia thick walled, homosporous, terminal or lateral
- Psilopsida has 3 orders:
    1. Rhyniales*
    2. Trimerophytales*
    3. Zosterophyllales*

B. **Psilotopsida**

- Sporophytes rootless, with dichotomous rhizomes and aerial branches.
- Lateral appendages spirally arranged, scale-like or leaf-like.
- Protostelic (either solid or medullated).
- Sporangia thick walled, homosporous, terminating very short lateral branches.
- Antherozoids multiflagellate
- This division is represented by a single
    1. order Psilotales

C. **Lycopsida**

- Sporophytes with roots, stems and spirally arranged leaves (microphylls).
- Protostelic (solid or medullated). Sometime polystelic (rarely polycyclic).
- Some with secondary thickening.
- Sporangia thick-walled. Homosporous or heterosporous, borne either on a sporophyll or associated with one.
- Antherozoids biflagellate or multiflagellate.
- This division consists of 5 orders, of which 2 include extinct forms

1. Protolepidodendrales*
2. Lycopodiales
3. Lepidodendrales*
4. Isoetales
5. Sellaginellales

D. **Sphenopsida**

- Sporophyte with roots, stem and whorled leaves.
- Protostelic (solid or medullated).
- Some with secondary thickening.
- Sporangia thick-walled, homosporous (or heterosporous), usually borne in a reflexed position on sporangiophores arranged in whorls.
- Antherozoids multiflagellated.
- Sphenopsida is divided into 4 orders, of which only Equisetales is represented by living genera.
    1. Hyeniales*
    2. Sphenophyllales*
    3. Calamilates*
    4. Equisetales.

E. **Pteropsida**

- Sporophytes with root, stem and spirally arranged leaves (megaphylls) often markedly compound and described as fronds (although some early members showed little distinction between stem and fronds).
- Protostelic, solenostelic or dictyostelic. Sometime polycyclic (rarely polystelic).
- Some with limited secondary thickenings.
- Sporangia thick or thin walled; homosporous or hetero sporous; borne terminally on an axis or on the frond, where they may be marginal or superficial on the abaxial surface.
- Antherozoids multiflagellated
- As this is a large group, this division has been sub-divided into 4 sub-divisions.
    1. Primofilicales*
        a. Cladoxylales*
        b. Coenopteridales*
    2. Eusporangiate
        a. Marattiales

b. Ophioglossales

3. Osmundidae
    a. Osmundales
4. Leptosporangiatae
    a. Filicales
    b. Marsileales
    c. Salviniales

F. **Progymonspermopsida***

- Extinct plants, mostly of middle and upper Devonian age, with certain anatomical characters, normally associated with gymnosperms, but without seeds.
- Some known to have been tall trees with stout trunk made up of dense, secondary wood.
- Ultimate branch system either naked of bearing small lateral appendaged showing varying degree of flattening
- Sporangia homosporous or heterosporous.
- Has been divided into 3 orders
    1. Aneurophytales*
    2. Protopityales*
    3. Archaeopteridales*

(Names with '*' shows that they are extinct)

1.3. **Stellar evolution in Pteridophytes**.

The vascular tissues as a whole together with the associated tissues making up the central column of the root, stem and leaf constitute a stele (stele=column). Stele includes all the tissues from the centre, including vascular tissues, to the pericycle.

Depending on the relative position of xylem and phloem and on the presence or absence of pith different types of stele have made their appearance during the course of evolution.

The theory of the stele was formulated by Van Tieghem, and modified by Jeffery in 1866. The gradation of stellar evolution is as given below.

There are mainly three main types of steles in pteridophytes. They are

1.3.1. Protostele

1.3.2. siphonostele

1.3.3. dictyostele

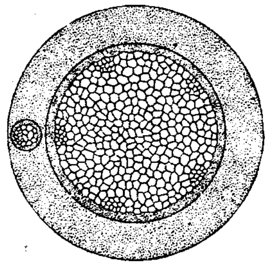
protostele (first) is the simplest and the most primitive type of stele. It has vasculature (xylem) occupying the central region of the stele. There is no pith.

Siphonostele with the development of the pith and presence of leaf gaps the pattern of distribution of xylem and phloem changes, and stele has the vasculature like a tube or siphon. Here the central region consists of non vasculated cells (parenchyma) forming the pith.

In a **dictyostele** (dictyo= net), the siphon is dissected or breaks up into a number of individual bits called meristele. It is the most advanced type of stele.

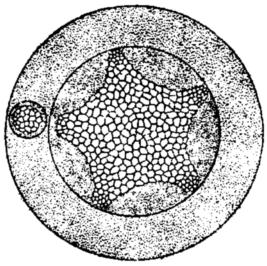
1.3.1. **Protostele**: basically all protostele are alike in not having a pith. They may be classified into the following types based mainly on the configuration of the xylem.

1.3.1.1. **Haplostele**:



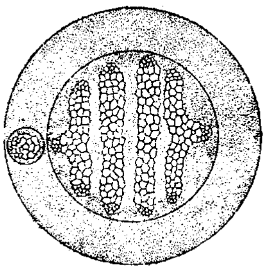
This is the simplest of stele consisting of a central smooth core of xylem surrounded by phloem. This type is seen in *Rhynia*.

1.3.1.2. **Actinostele**:



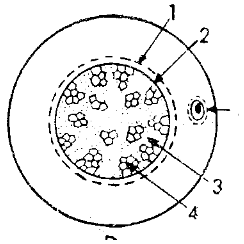
The xylem is star shaped and the phloem completely surrounds the xylem. The contour of the stele is smooth. It is seen in *Psilotum, Lycopodium phlegmaria* etc.

1.3.1.3. **Plectostele**:



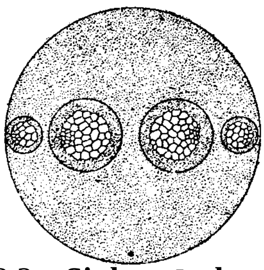
The xylem breaks up into a number of bands or plates arranged parallely. The phloem not only surrounds the xylem but is distributed between the xylem plates also. It is seen in *Lycopodium wightianum*.

1.3.1.4. **mixed protostele**:



In this type the xylem breaks up into a number of small masses. The phloem is intermixed with the xylem. Eg. *Lycopodium cernuum*.

1.3.1.5. **Polystele**:

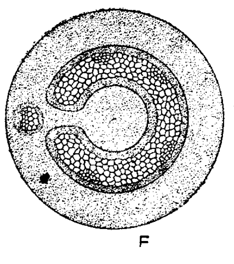


generally the ststem is traversed by a single stele. But in some cases as in some species of *Selaginella* several independent stele run parallelly in the stem. Each stele has its own endodermis. The individual steles are haplostelic.

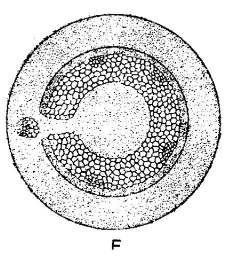
1,3,2. **Siphonosteles**: The steles having a pith in the centre are refered to as an siphonosteles. They are classified further into three types.

1.3.2.1. **Simple siphonostele** or medullated siphonostele or cladosiphonic stele: here, the central region of the stele consists of a parenchymatous or sclerotic pith. Leaf traces that depart from the main vascular clinder do not leave any leaf gaps (parencymatous cavity fround immediately above the leaf trace in the vascular cylinder). E.g. *Psilotum* species.

1.3.2.2. **Solenostele** or phyllosiphonic stele: siphonostele with leaf gaps are called solenosteles. In solenosteles, the leaf gaps are successive so that there is only one break in the vascular cylinder at any one given point. Solenostele may be further classified into

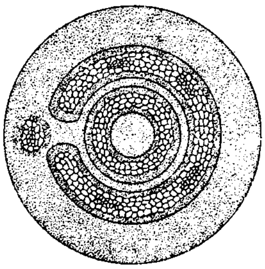


Amphiphloic (amphi= on both sides) solenosteles in which the phloem lines the xylem both on its inner and outer face e.g., *Adiantum, Marsilea.*



Ectophlloic(ectos = outside) soleno stele in which phloem lines the xylem only on its outer face e.g., *Osmunda*.

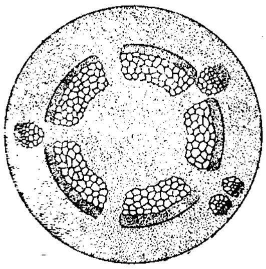
1.3.2.3. **Polycyclic** solenostele:



In this type there will be more than one concentric ring of vasculature.

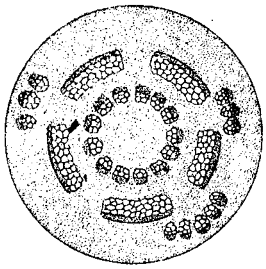
1.3.3.1. **Dictyostele**: Basically dictyosteles are similar to solenosteles in having a pith and leaf gap. In dictyosteles however the leaf gaps overlap. As a result the vascular ring breaks up into many arcs. Each arc is known as a meristele. All the meristeles however are surrounded by a common endodermis.

1.3.3.2. **simple dictyosteles**:



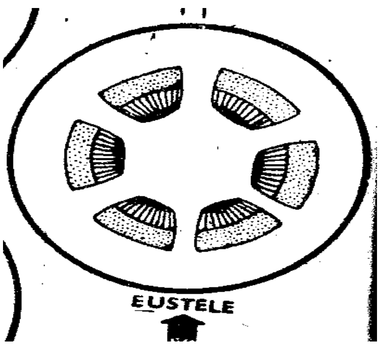
Here only one ring of dictyostele is seen.

1.3.3.3. **polycyclic dictyostele**:



Here there will be at least two concentric rings of vasculature. E.g., *Pteridium aquilinum*

1.3.3.4. **Eustele**:



this is one more modification of the siphonostele were the vascular system consists of a ring of collateral or bicollateral vascular bundles situated on the periphery of the pith in such steles the interfascicular areas and the leaf gaps are not distinguished

from each other very clearly. E.g., *Equisetum*.

1.4. Homospory and Heterospory.

In some members of pteridophytes all spores produced by the sporangia are of one type, such a plant is known as homosporous pteridophytes *e. g., Lycopodium, Equisetum* etc.

On the other hand, in heretosporous pteridophytes *e.g., Selaginella, Marsilea* etc. the spores are of two kinds-the smaller spores are known as microspores or male spores and are developed in micosporangia, while the larger spores are called megaspores or female spores and are formed in megasporangia.

The microspores on germination produce the male gametophytes on which, the sperms are produced. The megaspores produce female gametophytes on which eggs are produced.

In homosporous pteridophyte, the prothalli are subterranean while in the heterosporous forms, they are retained within the resistant wall of the spore and thus able to survive in a much wider range of habitats. In homosporous, the prothalli bear both the sex organs and are thus monoecious whereas the heterosporous forms are dioecious. The larger megaspores give rise to female prothalli which bear only archegonia and the smaller microspores giving rise to male prothalli which bear only antheridia.

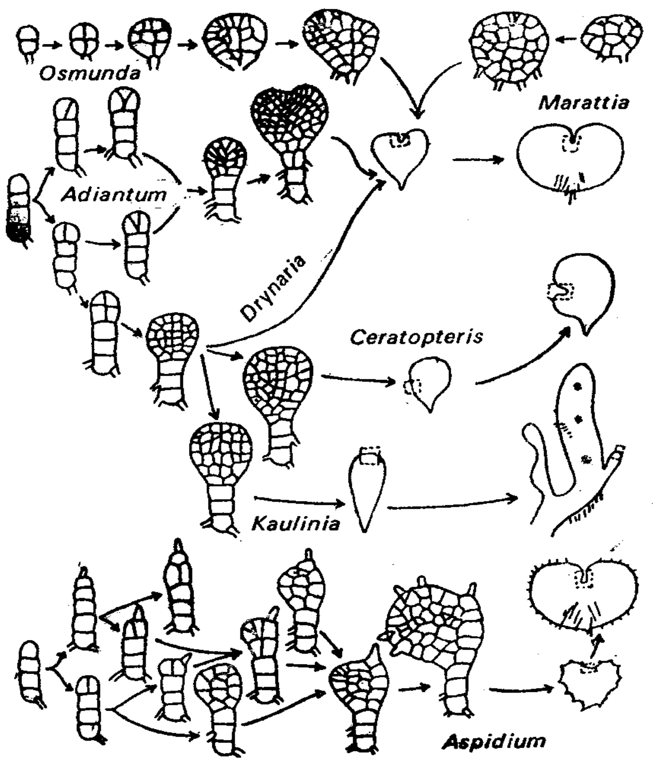
Sl.no.	**Character**	**homosporous**	**hererosporous**
1	Spore germination	exosporic	endosporic
2	Spore development	Under the control of external condition	Independent of external control
3	Life span of gametophyte	Long-lived (in certain *Lycopodium* may require years to attain maturity; in some *Vittaria*-gametophyte remains as a permanent phase)	Life span ranges from a few hours to a few days.
4.	Differentiation of gametophyte	Well differentiated	Highly reduced; (in some *Selaginella* and *Isoetes* male gametophyte consist of a single prothallial cell and an antheridium; rhizoids absent)
5.	Vegetative propogation	Frequent by adventitious branching; gemmae (*Psilotum, Lycopodium*	Female gametophyte poor development. No vegetative propogation

		species), tubers (*Gymnogramma*).	seen.
6.	Special contrivances for water holding	No Special contrivances, except the formation of lobes in the gametophyte of *Lycopodium* and *Equisetum*	Hydrophytes *Azolla* and *Salvinia* have no Special contrivances but stand chances of being washed away if not shed in a mass, the massula.
7.	sexuality	monoecious	dioecious
8.	example	*Lycopodium, Equisetum*	*Salaginella, Isoetes, Marsilea*

Gametophyte development in homosporous ferns:

Prothalli of homosporous fern follow a definite pattern of development and attain a characteristic adult form. Seven different patterns are recognized after Nayar and Kaur (1971). They are *Osmunda* type, *Marattia* type, *Adiantum* type, *Drynaria* type, *Kaulinia* type, *Ceratopteris* type and *Aspidium* type.

The pattern of spore germination and successive cell division of the above mentioned seven types is as depicted in the below given diagram.



Gametophyte development in heterosporous ferns:

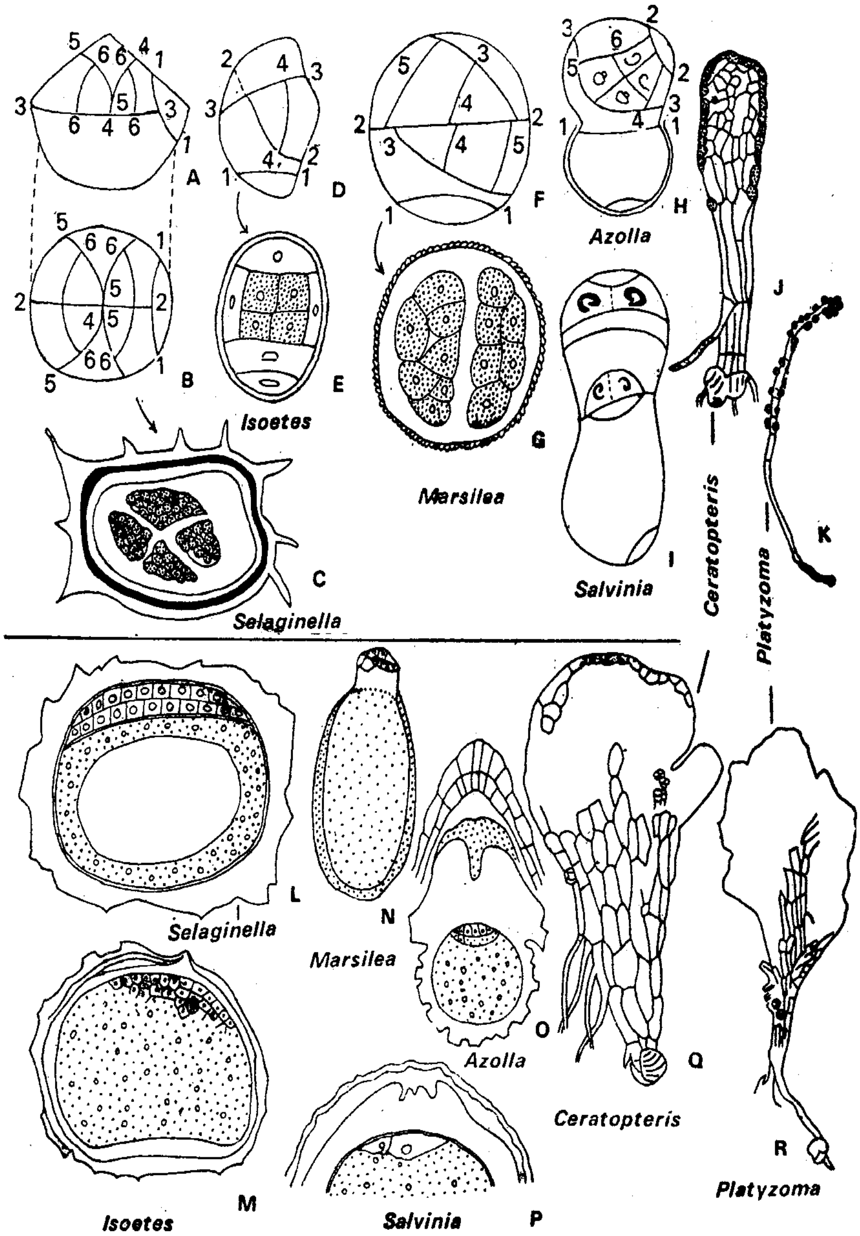


Fig. 6.3 Heterosporous pteridophytes, patterns of gametophyte development. *Ceratopteris* (homosporous) and *Platyzoma* (heterosporous) are connecting links between homosporous and heterosporous forms; the former shows incipient heterospory and the latter shows latent homospory.

In contrast to homosporous pteridophytes which form exosporic gametophytes, the gametophytes of heterosporous pteridophytes are endosporic. The germinating microspore in heterosporous ferns (except *Platyzoma*), produce a lenticular cell and the larger cell. From the latter by a series of divisions, differentiate spermatogenous cells anda variable number of sterile jacket. The development of female gametophyte initiates with a series of free-nuclear divisions in selaginella and isoetes, followed by wall formation, beneath triradiate ridge, and on this tissue differentiate archegonia. The megaspores in *Marsilea*, *Salvinia* and *Azolla* divide to from a small papillate cell and the larger cell occupies the rest of spore storing abundant food material.

1.5. **Economic importance of Pteridophytes**.

Very little is known about the economic importance of Pteridophytes because not enough attention has been paid towards harnessing the potentialities of pteridophytes towards human welfare.

Pteridophytes were handled for a very long time by academicians only, and was much sought for, as it were the first land plants, and to study the origin of land plants and their evolution.

Food and fodder: *Pteridium aquilinum* (ostrich fern), *Matteuccia struthiopteris*, Osmunda cinnamomea (cinnamon fern), and *Diplazium esculentum* is used by some tropical peoples as food.

1.5.1 *Pteridium aquilinum* (bracken), the fiddleheads used as a cooked vegetable in Japan and are believed to be responsible for the high rate of stomach cancer in Japan. It is also one of the world's most important agricultural weeds, especially in the British highlands, and often poisons cattle and horses.

1.5.2 *Matteuccia struthiopteris* (ostrich fern), the fiddleheads used as a cooked vegetable in North America.

1.5.3 *Diplazium esculentum* (vegetable fern), a source of food for some native societies

1.5.4 *Polypodium glycyrrhiza* (licorice fern), roots chewed for their pleasant flavor

1.5.5 sporocarps of *Marsilea salvatrix* are used as a source of nutrition.

1.5.6 sporocarp of *Marsilea drummondii* is cooked into cakes and used by the natives of Australia.

1.5.7 The fiddleheads of *Osmunda cinnamomea* is used as a cooked vegetable.

1.5.8 Ceratopteris are also taken as vegetables.

1.5.9 Pteridium is generally used as a cattle food.

Landscaping ornamental and decoration:

1.5.10 Many ferns are grown in horticulture as landscape plants, for cut foliage and as house plants, especially the Boston fern (*Nephrolepis exaltata*).

1.5.11 *Rumohra adiantoides* (floral fern), extensively used in the florist trade.

1.5.12 The Bird's Nest Fern, *Asplenium nidus*, is also popular, and the stag-horn ferns, genus *Platycerium*, have a considerable use.

1.5.13 The foliage of *Lycopodium obscurum* is used for decorations.

1.5.14 *Selaginella willdenovii* and S. caesia are used as ornamental plants for their metallic and many-hued tints ranging from bronze to bluish tinge.

1.5.15 *Selaginella seprens* has periodic changes in the colour of leaves from deep green-in the morning to paler in the day, to deep green again in the evening.

1.5.16 Most of the pteridophytes (especially ferns) are cultivated in green houses and gardens as ornamental plants.

Medicines

1.5.17 The dusty spores of *Lycopodium* have been used in pharmacy as water repellants, as a protective dusting powder for tender skin, in the compounding of pills and the preparation of suppositories.

1.5.18 Extracts of *Lycopodium* have been used in the past as kidney stimulants.

1.5.19 *Equisetum arvense* is used as a diuretic agent in German pharmacopoeia. It is also known as a haemopoietic and haemostatic agent.

1.5.20 *Equisetum debile* is used as a cooling medicine.

1.5.21 The rhizomes and frond bases of *Dryopteris* are used as vermifuge in pharmacy under the name FiIix-mass.

1.5.22 Marsilea plant is used medicinally for soothing nervous system.

Horticulture

1.5.23 *Selaginella lepidophylla* and *S. pilifer* are xerophytic and are sold under the name resurrection plant.

1.5.24 the fibres of *Osmunda* root and stem are used for growing orchids.

1.5.25 Osmunda regalis (royal fern) and *Osmunda cinnamomea* (cinnamon fern), the root fiber being used horticulturally.

Biofertilizer

1.5.26 dry fronds of ferns are used as a source of potash.

1.5.27 *Azolla* are used as a biological fertilizer in the rice paddies of southeast Asia, taking advantage of their ability to fix nitrogen from the air into compounds that can then be used by other plants.

Mineral prospecting

1.5.28 Some species of *Equisetum* act as mineral indicators of soil and are of value in ore prospecting.

1.5.29 *Pteris vittata* (brake fern), used to absorb arsenic from the soil.

Construction works

1.5.30 Dry fronds of many ferns as used as thatching material for cottages.

1.5.31 Tree ferns, used as building material in some tropical areas.

Miscellaneous uses

1.5.32 The spores of *Lycopodium* are highly inflammable “vegetable brimstone” and are used in the manufacture of fire works and to produce stage lightining in the stage.

1.5.33 Earlier *Equisetum* stem were used for polishing wood and scouring pewter dishes.

1.5.34 The important fossil fuel coal consists of the remains of primitive plants, including ferns.

Destructive pteridophytes

1.5.35 Several ferns are noxious weeds or *invasive species*, including Japanese climbing fern (*Lygodium japonicum*), mosquito fern and sensitive fern (*Onoclea sensibilis*). Giant water fern *(Salvinia molesta*) is one of the world's worst aquatic weeds.

SELF ASSESSMENT QUESTIONS

1. Exosporic germination is seen in heterospory (True/False).

2. Solenostele is a type of siphonostele (True/ False).

3. Psilopsida includes extinct forms (True/ False).

4. *Salvinia molesta* is used in mineral prospecting (True/False).

Summary

In pteridophytes sporophytic generation is independent of gametophytic generation.

Clear cut alternation of generation is seen.

Sporopohytes are of two types: homosporous and heterosporous.

The development of sporangia may be eusporangiate (group of initials) or leptosporangiate (for a single superficial cell)

NOTES

UNIT - II

Detailed study of the following genera.

Lycopodium, Selaginella.

Introduction:

Many taxonomists have divided the Division Lycophyta into two classes depending upon the presence and absence of ligule. Ligule is a special membranous structure which arises fro a depressed pit at the base on adaxial surface (upper surface) of the leaf.

Eligulopsida: the members are homosporous and leaves are with out ligule. It includes a single order Lycopodiales.

Ligulopsida: the members are heterosporous and have ligule bearing leaves. It consists of two orders: *Selaginellales and Isoetales*.

Lycopodium

Systematic position

Divison: Lycopsida

Order: Lycopodiales

Family: Lycopodiaceae

Genus: Lycopodium

2.1.1. **Occurrence**:

The plant is world wide in distribution. The plant is found most commonly on humus soils in moist shady places.

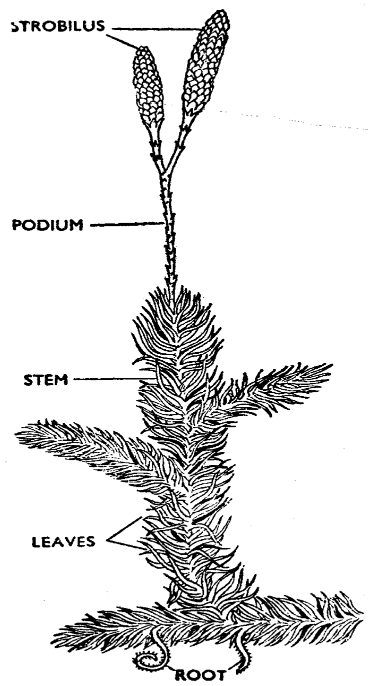
The genus is commonly known as “club mosses”, “ground pines”, “trailing evergreens” or “creeping pines”. Most of them are terrestrial but few are epiphytes on higher plants.

The genus includes 200 species out of which only 33 species have been reported from India, all from hills.

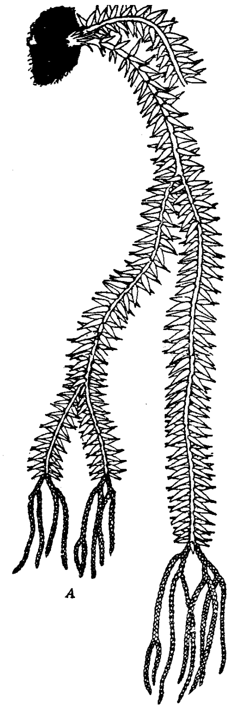
The most common species are *L. clavatum, L. cernuum, L. phlegmaria, L. serratum, L. phyllanthum and L. wightianum.*

2.1.2. 1. The plant body

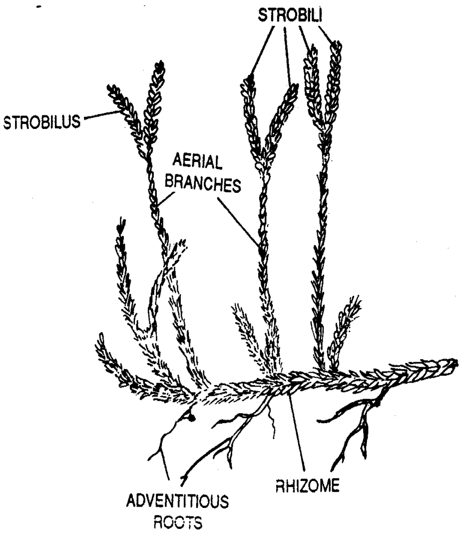
The plant is small, herbaceous or shrubby sporophytes.



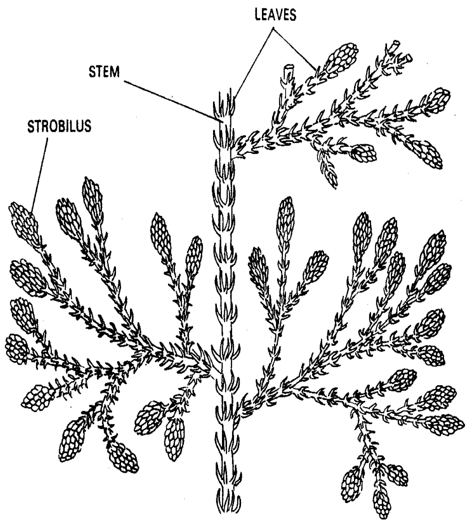
L. clavatum



L.phlegmaria



L. wightianum



L. cernuum

Stem is slender and delicate. It is differentiated into creeping rhizome and elongated aerial branches from the upper side and adventitious roots from the lower. The aerial branches vary from 3-8 inches in length. *L. cernuum* is exceptional in attaining a height of 2 feet or more.

Most of the species are terrestrial and the sporophyte, may either have an upright stem or a horizontal creeping stem.

Some species grow as epiphytes on higher plants and in them a pendent habit is found *e.g., L. phlegmaria, L. squarrosum*.

This genus is divided into two sub-genera *Urostachya* and *Rhopalostachya*.

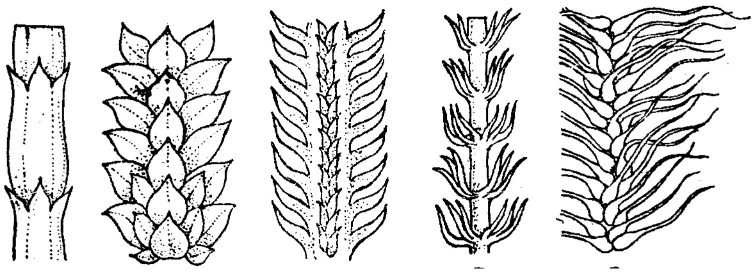
2.1.2.2. Stem:

Urostachya posses branched or unbranched stem, that are erect or pendant but never creeping. If branched, it is dichotomous at right angles to one another. This sub-genus does not bear adventitious roots along the stem.

Rhopalostachya posses prostrate stems bearing upright branches. Stem is freely dichotomously branched. Branches arise almost at right angles to each other. But, in some species, the later developed branching may be monopodial.

2.1.2.3. Leaves:

Stem is thickly covered with abundant small leaves. Leaves may be present in close spirals(*L. clavatum, L. annotium*) or whorls (*L. verticillatum, L. cernuum*) or in opposite pairs (*L. alpimum*) or irregular.



Different leaf forms and arrangement in the species of *Lycopodium*

Leaves are entire, small (2-10 mm. long), simple, sessile, membranous and lanceolate with broad bases. In some the margin of lamina may be slightly serrate.

Each leaf is supplied by a single mid-vein which runs almost unbranched right up to the apex.

Generally the leaves are alike in size and shape, however, in some species like *L. complanatum, L. volubile* and *L. chamaecyparissus* the leaves are dimorphic, arranged in four vertical rows on the stem two being smaller and two larger in size.

Leaves have no ligules

The walls of the epidermal cell or the leaf are sinous and stomata are more or less parallelly oriented to the midrib.

The stomata are equally distributed on both surface of the leaf.

2.1.2.4. Roots

The first formed root is short lived, so majority of the plant has many adventitious roots arising singly or in groups along the underside of stem. Roots arise acropetally (only at the base, primary roots are present).

The species of subgenus *Urostachya* do not possess adventitious roots along the stem. The species of subgenus *Rhapalostachya* with a creeping stem generally have their adventitious root borne along the entire length of the prostrate portion.

In some species, *e.g.*, *L. selago, L. phlegmaria* and others the roots that arise on the outside of the stele do not penetrate the cortical region of the stem at once. These roots turn downward and penetrate the soft middle cortex making canals through it, and ultimately they emerge only at the stem. Such roots are known as 'cortical roots' or 'inner roots'.

The roots may be or may not be branched. Branching is strictly dichotomous.

2.1.2.5. Spore bearing organs

The sporophyll may or may not be restricted to the terminal portion of branches and organized into definite strobili.

In subgenus *Urostachya, L. selago* has alternate sterile and fertile regions thorughout length of stem and branches. In L. . *phlegmaria* the strobili are terminal. In subgenus *Rhopalostachya, L. clavatum* strobili are borne on special modified branches.

The sporophylls and simple vegetative leaves may be similar or dissimilar. In subgenus *Urostachya L. phlegmaria*, the sporophylls, although green are comparatively much smaller than the foliage leaves. In subgenus *Rhopalostachya*, *L. clavatum* and *L. complanatum* remain covered with minute scaly leaves.

Strobilus may or may not be restricted to the terminal portion of erect lateral branches. They are usually in pairs.

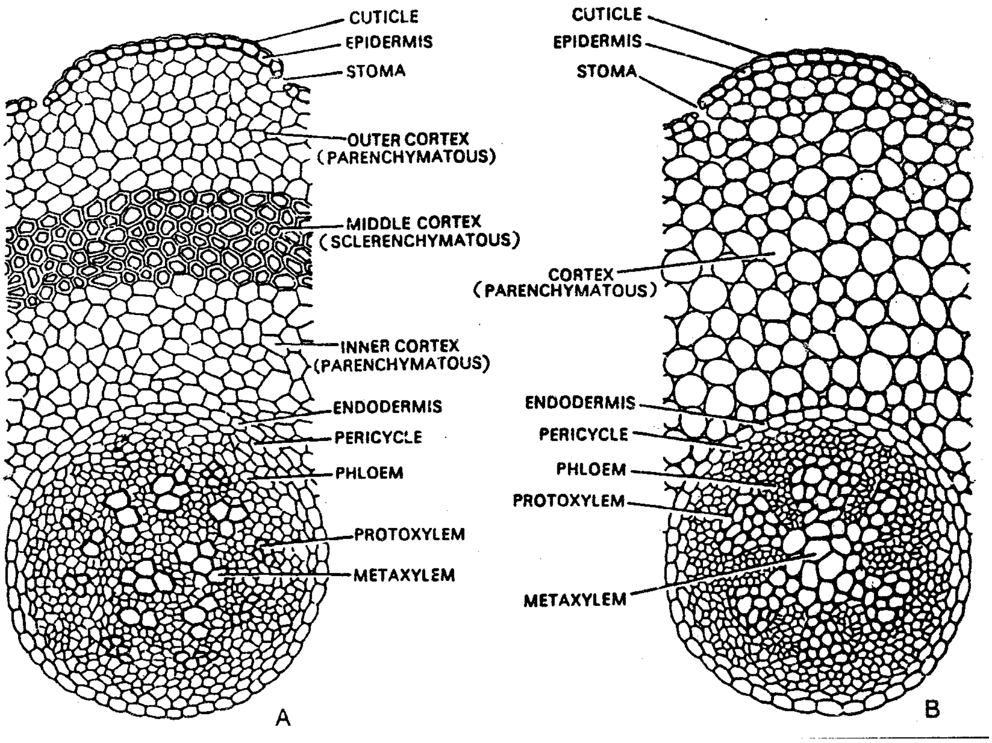
Below the strobilus a long portion of stem is without leaves. It is known as stalk or the podia. However, in *L. inundatum, L. alpinum* the strobilli are sessile at the apices of ordinary leafy shoots.

Each strobilus is long, slender and cylindrical. The sporangia are arranged on adaxial (upper) surface of sporophyll or in its axil.

They possess homosporous sporangia.

2.1.3.1. Internal structure of stem

The superficial layer is epidermis. It is one cell thick with highly cutinized outer wall. It is interrupted with stomata.


CUTICLE
EPIDERMIS
STOMA
OUTER CORTEX (PARENCHYMATOUS)
MIDDLE CORTEX (SCLERENCHYMATOUS)
INNER CORTEX (PARENCHYMATOUS)
ENDODERMIS
PERICYCLE
PHLOEM
PROTOXYLEM
METAXYLEM
A
CUTICLE
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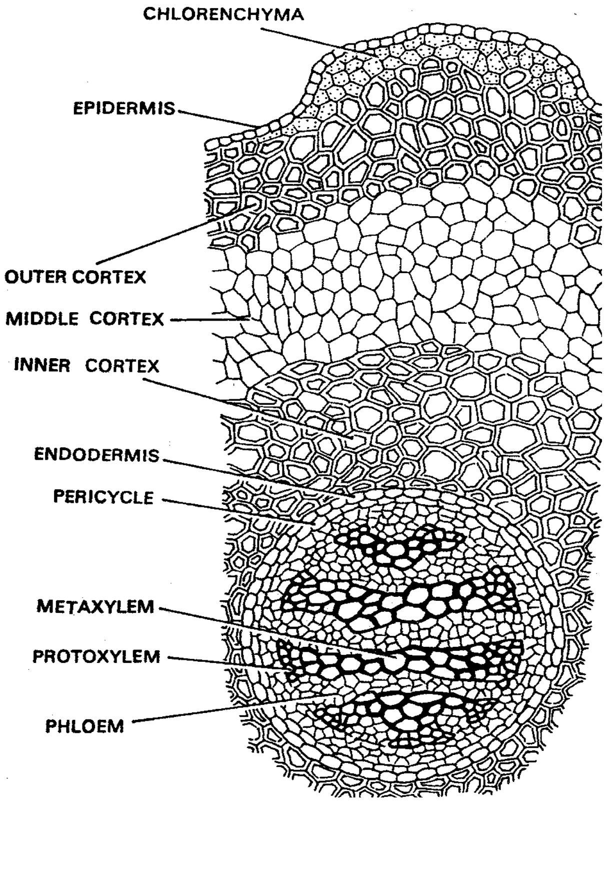

CHLORENCHYMA
EPIDERMIS
OUTER CORTEX
MIDDLE CORTEX
INNER CORTEX
ENDODERMIS
PERICYCLE
METAXYLEM
PROTOXYLEM
PHLOEM

A broad cortex is present below epidermis. It may be homogenous (e.g. *L. selago, L. inundatum* - parenchymatous); or heterogenous with three distinct regions.

Outer cortex is made up of sclerenchymatous cells arranged in several layer. (In some cases but only in younger regions and in *L. cernuum* few C. layers are of parenchymatous *A. L. cernuum;B. L. selago; C. L.clavatum* cells)

Middle cortex is several layered thick and consists of compact parenchymatous cells.

Inner cortex of few layers of sclerenchymatous cells

Endodermis is single layered. The cells are ill defined but show characteristic thickenings of casparian strips on radial and end walls. Pericycle present below endodermis is one or two layered.

Stele is protostelic and centrally situated. Xylem shows peculiar radiating arrangements. The protoxylem strands 3-12 in number are situated at the periphery. The xylem bands consist of trachieds pointed at both ends i.e., centripetal. Protoxylem shows spiral and annular trachieds.

Phloem is present in between the xylem bands. The phloem consists of narrow cells. These represent sieve-tubes which have no sieve plates.

This type of protostele is known as plectostele.

In different species or even in the different regions of the stem large number of variations are seen *e.g*., cortex may be homogenous or heterogenous showing two or some times three distinct regions.

Similarly the arrangement of xylem in stele varies from species to species and following three important conditions are seen.

The simplest structure represented in *L. serratum* and *L. selago is* Actinostele (star-shaped).

A slightly evolved arrangement, Plectostele is seen in *L. volubile.*

In between actinostele and mixed type of stele is stellate condition found in *L. annotianum*.

In forms higher than these, such as, *L. cernuum, the xylem elements occur as scattered groups embedded in the tissue of phloem*- Mixed protostele.

No secondary growth has been noticed in any species of *Lycopodium*.

2.3.3.2. Internal structure of root

The superficial outermost layer is epidermis or epiblema. It is single layered and thin walled.

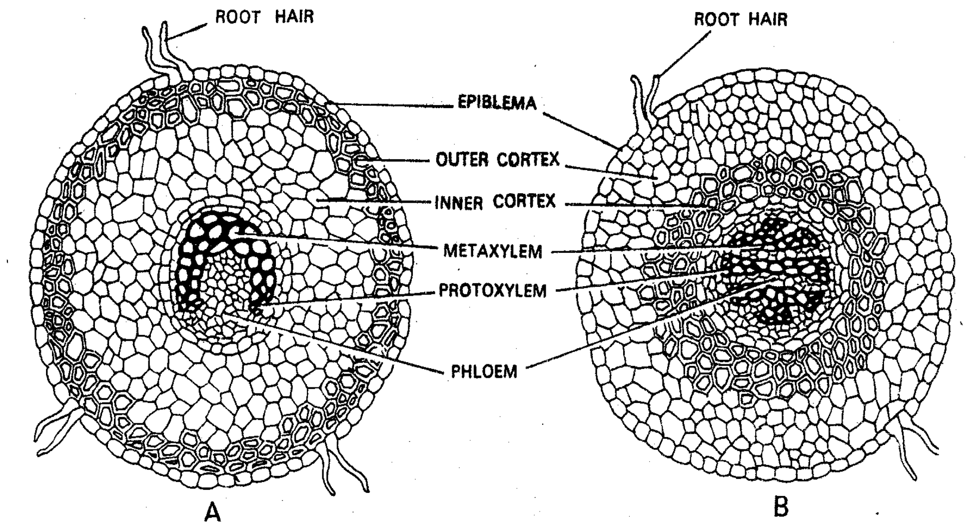
Few cells of epidermis divide by oblique walls (or anticlinal walls) giving rise to unicellular paired root hairs.

Cortex is many layered present bellow the epidermis and shows two marked regions.

Outer cortex consists of thick walled cells which serve to give mechanical strength in *L. selago* and *L. pithyoides*. Whereas in *L. clavatum* the outer cortex in parenchymatous.

Inner cortex consists of simple parenchymatous cells in *L. selago* and *L. pithyoides*. Whereas in *L. clavatum* the inner cortex in sclerenchymatous.

Stele is present in the centre.



T.S. of root of A. *L. pithyoides;* B. *L. clavatum*

The stele is diacrh. Metaxylem is present in between two protoxylem patches in a characteristic crescent or C-shaped fashion *e.g., L. selago.* Whereas the stele in *L. clavatum* is plectostele.

Phloem occupies the remaining space.

2..3.3.3. Internal structure of **leaf**

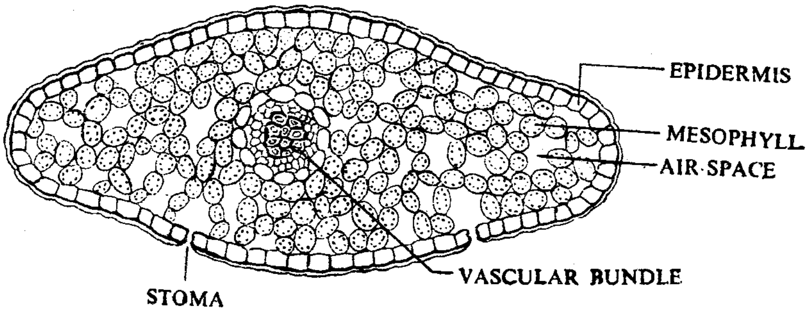
T he epidermal cells are usually elongated and are interrupted by simple types of stomata and guard cells.

Stomata are present on both surface (*L. clavatum*) or only on the lower surface (*L. volubile*).

Next to epidermis mesophyll cells are present. These cells are of two types.

Angular cells with small intercellular spaces. They are present around the stele.

Round cells with small intercellular spaces. These occupy the remaining space.



T.S. of leaf of *Lycopodium*

Single, concentric median amphicribral vascular bundle (with small xylem in the centre, surrounded by phloem) is present in centre.

There is no differentiation of proto and meta xylem.

The phloem is composed of narrow sieve-tubes and phloem-parenchyma.

The mid rib bundle is surrounded by sclerenchymatous pericycle.

Endodermis is not well defined.

The xylem is present in centre but without any differentiation into proto and metaxylem.

The xylem is surrounded by phloem.

2.1.4. 1 Vegetative propagation

Besides fragmentation, it occurs by several means as follows:

1. **Adventitious buds**.

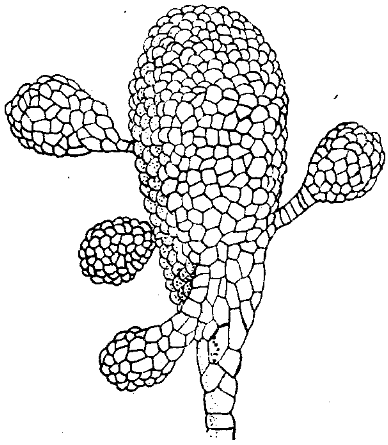
These develops at the base of the stem, as in *L. aloifolium, L. reflexum* etc. These are capable of developing into new plants when detached.

2. **Bulbils**.

These may develop in tropical epiphytic plants or in erect forms from roots, leaves, or from the fragment of the plants. These grow directly into new plants.

3. **Death and decay** of older portion of the branches leading to the survival of young dichotomous branches which develop as individual plant. A single plant thus gives rise to a number of separate plants.

4. **Gemmae**. These are branches of peculiar kind and are formed annually



on new stem tips in place of a leaf as in *L. selago, L. phlegmaria etc*. There gemmae have few leaves and a rudimentary root. They are shortly-stalked pear-shaped bodies and develop in clusters. Since gemmae are provided with stored food material they tide over unfavourable periods.

Gemma of Lycopodium with Secondary gemmae.

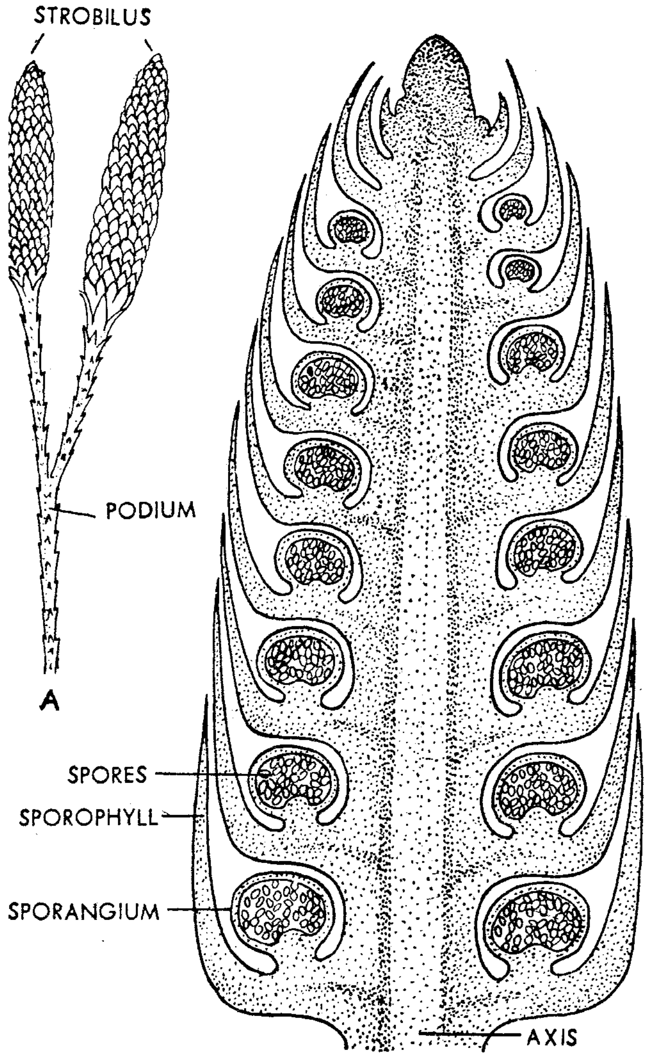
When detached, the gemmae are capable of producing new plants.

5. **Resting buds**. These develop during winter in *L. inundatum* where entire plant, except the tip of rhizomes dies. This tip behaves as a resting-bud and on the return of favourable season it unfolds itself into a new-plant.

6. **Tubers**. These are developed at the apices of the roots and are capable of germinating into new plants.

2.1.5.1. Reproduction.

The fertile region, in majority of cases, and in creeping species, is represented by strobili.



The entire strobilus and L.S of the strobilus of *Lycopodium*

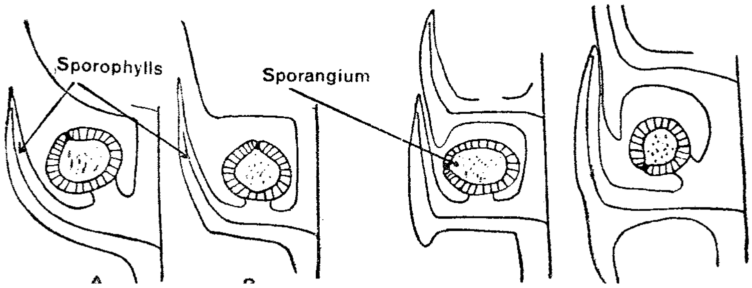
The strobilus is made up of a central axis on which a large number of acutely-pointed, yellow sporophylls are closely arranged.

The kidney shaped sporangia are borne singly, close to the base, on the upper surface of the sporophylls.

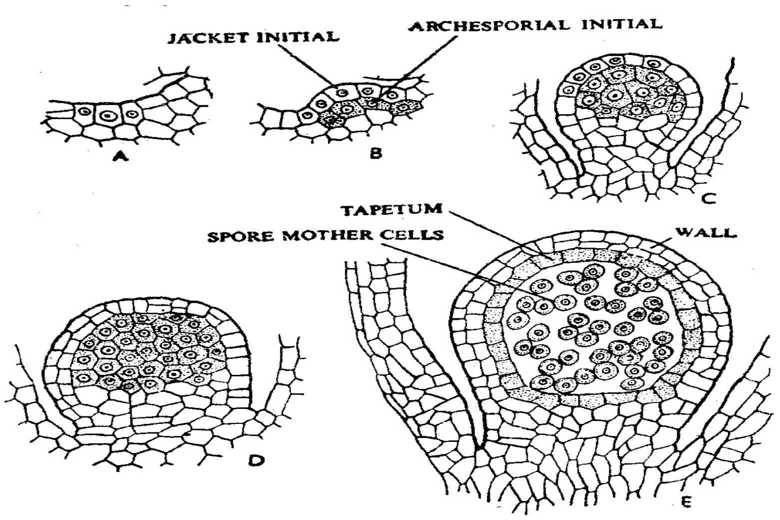
Sporangia.

The large yellow-sporangia are borne singly, close to the base, on the upper ventral surface of the sporophylls. All the sporangia are alike. They are non-septate sacs, more or less reniform, having a short, broad stalk, and a large number of spores.

The position of sporangial attachment varies from species to species. The shape of sporophylls also varies. Four important variations are shown in the figure.



Development of sporangia.



Successive stages of development of sporangium of *Lycopodium*

The development of sporangia is of eusporangiate type. The sporangia develop from a transverse row of superficial cells. These divide transversely to from three layered thick wall, the inner most layer of this forms a nourishing layer for the spores, the tapetum. The central archesporium consists of three tangential rows of twelve cells each, which divides and produces spore mother cells. These divide meiotically producing tetrads of spores.

Dehiscence.

The mature sporangia may reach a diameter of 1 t o2.5 mm. The sporangium opens by a slit or pore called 'stomium' which runs in the direction transverse to the median plant of the leaves. It divides the sporangium into two valves scattering the yellow spores. At this stage the tapetum collapses.

Large numbers of spores are produced from each sporangium.

All spores are of uniform size and shape, thus the plant is homosporous.

Spores.

The production of spores marks the end of diploid sporophytic generation and the beginning of haploid gametophyte. Each spore is small (0.03-0.05mm in dia.) with thick spiny outer wall (exine) and an inner granular intine. They may contain chlorophyll in small amount.

On the basis of marking, *Lycopodium* spores are divided into three types.

1. Netzporen- with reticulate ridges *e.g. L. clavatum.*
2. Tupfelsporen – with knob-like outgrowth *e.g., L. selago*.
3. a transitional form with a ridged pattern *e.g. L. cernuum*.

The mature spore escapes through a slit in the wall of sporangium and are disseminated by air.

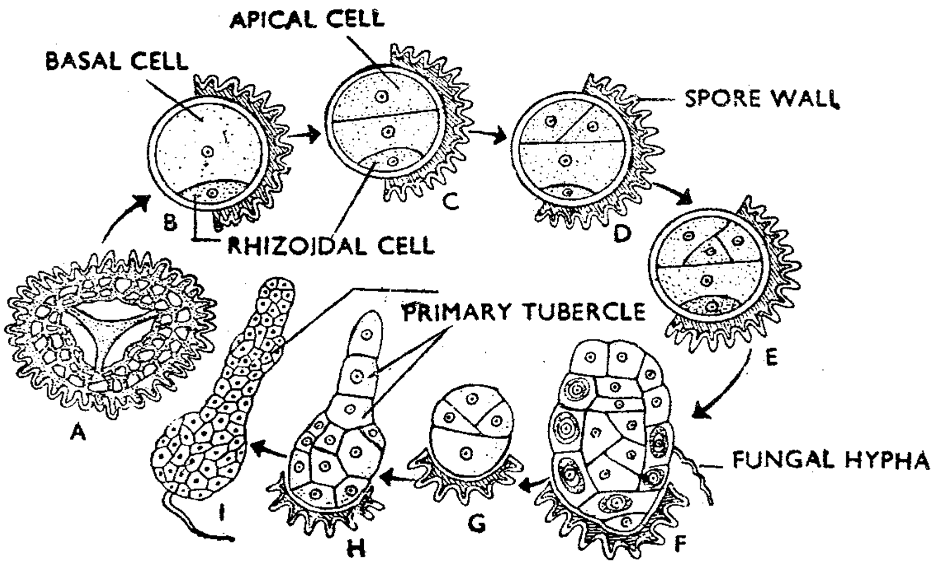
Germination of spore.

The germination of spore shows a wide range of variation. It may take place within few days and short lived *e.g., L. cernuum, L. inundatum.*

In certain cases, it can be slow and takes about 3-8 months.

In other cases, which have a colourless subterranean gametophyte nourished by a symbiotic mycorrhiza, it may take even fifteen years to mature.

Development of gametophyte or prothallus.



Spore germination and development of gametophyte in *Lycopodium*.

During germination of spores, the exine opens by three valves and intine comes out in the form of spherical vesicle. This divides by a transverse wall into an inner basal cell, which suffers no further change except the formation of a small lens-shaped rhizoidal cell. And another cell which develops as an apical cell and forms two rows of segments. Further development of this 4-5 celled gametophyte is arrested unless it is infected by a symbiotic phycomycetous fungus at the basal cell. After infection the basal cell and apical cell cuts off about six segments which develop a group of meristematic cells. Each segment is divided by a periclinal wall into an inner and an outer cell. The latter gets infected with symbiotic fungus. From the apical group of these cells arise the major portion of the adult gametophyte, which shows great diversity in form and structure.

The mature prothalli.

The prothalli of this genus are distinguished into a number of types as follows;

1. **First type *e.g., L. cernuum, L. obscurum and L. inundatum*.**

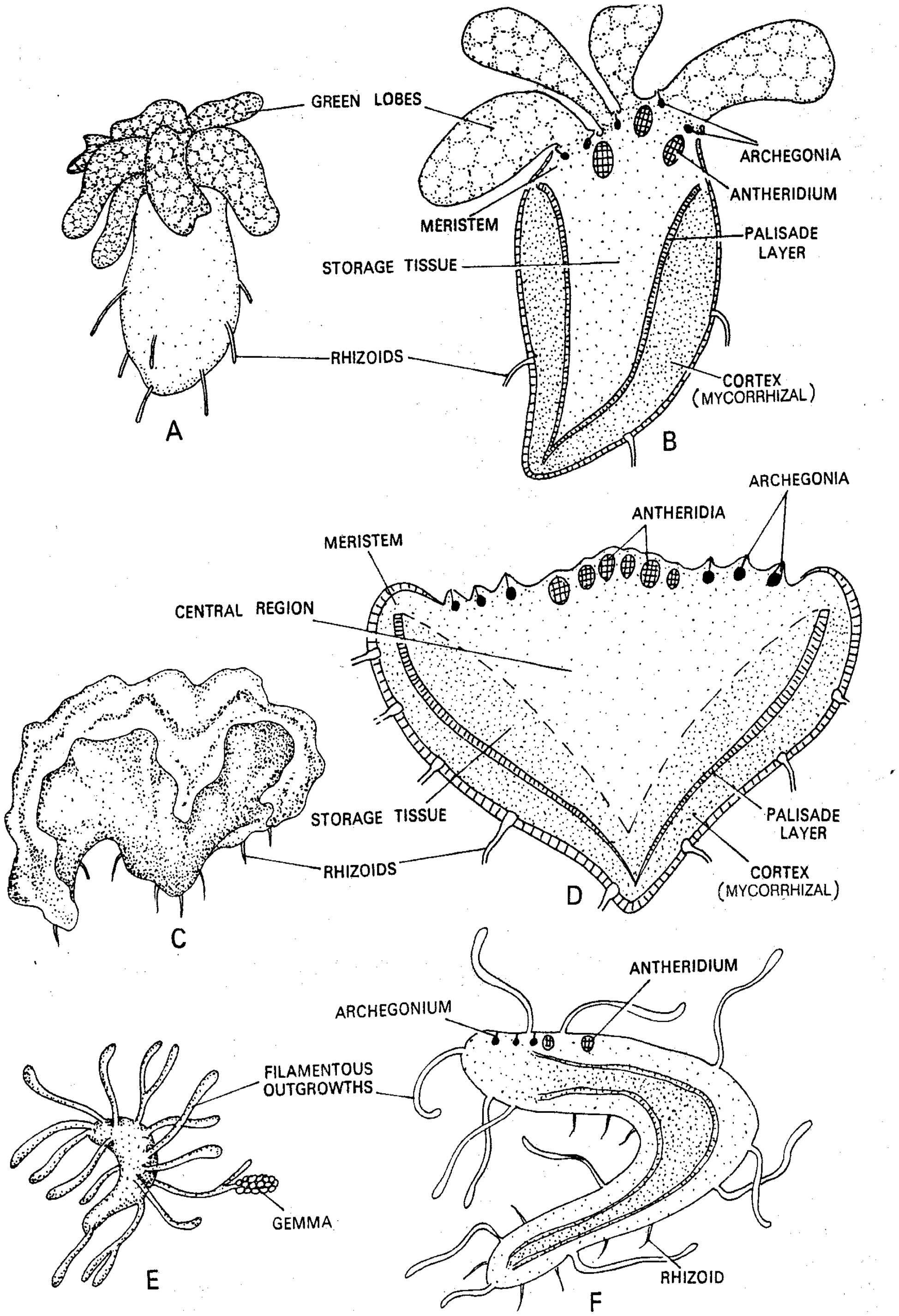
   The gametophyte is an aerial, green upright, fleshy-structure 2-3mm in diameter whose lower-portion is embedded in the soil. On its upper part develop greenlobes with meristamatic strands. The sex-organs develop at the base of these lobes. In spite of the constant pressure of the symbiotic mycorrhizal fungus, the prothallus is autophytic. The presence of the fungus, however, makes it partially sporophyte.

2. **Second type *e.g. L. clavatum***

   The large-prothalli are completely subterranean, tuberous, non-green, without lobes and incompletely saprophytic. This type of prothallus is larger and more massive than the aerial types and lies buried at depth of 1-4 inches. Depending upon the species, they are cylindrical like carrot, convoluted or lobed. The sex organs develop in the hollow (cup-like) upper surface. Here the nutrition is completely saprophytic.

3. **Third type. *E.g., L. phlegmaria*.**

   The large saprophytic protahlli are attenuated in form and branch monopodially into colourless cylindrical branches. These may become independent as a result of an apical growth and posterior decay. The sex organs are developed on the upper surface of the



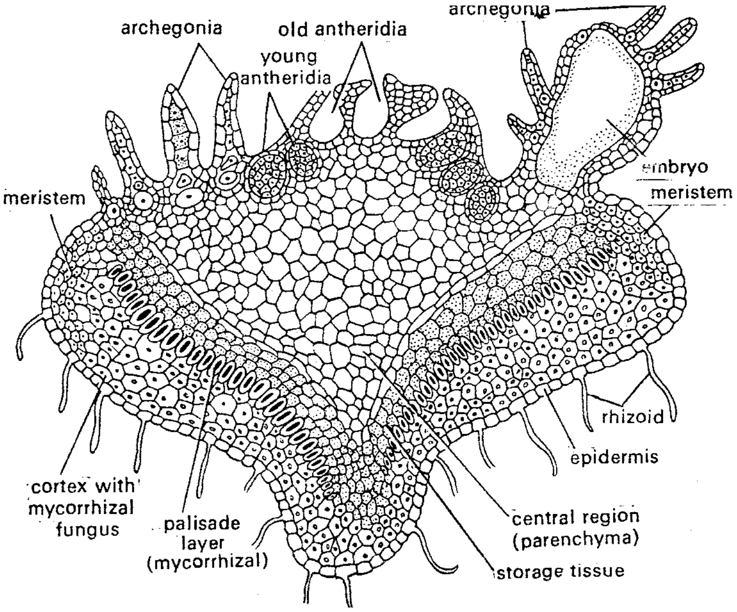
Types of gametophyte in Lycopodium.A-B. *L. cernuum*; C-D *L. clavatum*; E-F *L. phlegmaria*(external feature and L.S. of gametophyte side by side).

enlarged branches. The presence of the paraphyses is an anomalous feature.

2.1.6. Gametophyte of *L. clavatum*

The prothallus is a flattened body showing distinct storage, mycorrhizal and assimilatory regions. A row of palisade cells is quite prominent.

The lower epidermal cells show the formation of rhizoids.



V.S. of mature prothallus of *L. clavatum*

The meristematic zone or generative tissue is present in the anterior-lateral region.

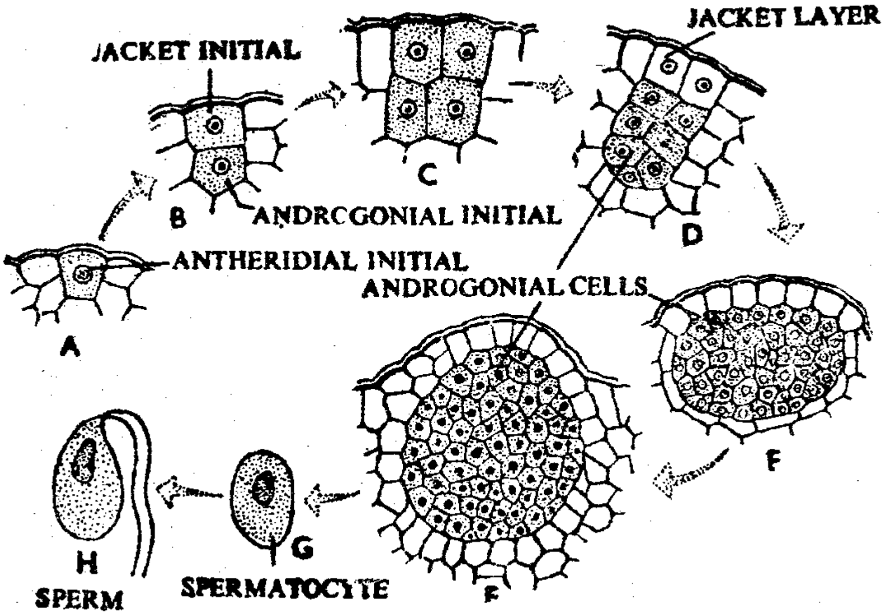
The anterior region of prothallus shows large number of lobes. These lobes bear sex-organs.

Antheridia are sunken in the mid-anterior region where as archegonia on either side.

Each antheridium is a sub-spherical body surrounded by single layer of jacket and contains large number of antherozoids (or antrocytes sometimes).

Each archegonium is a narrow elongated structure. It consists of 4-6 neck canal cells, an egg and venter canal cell.

Development of antheridium:

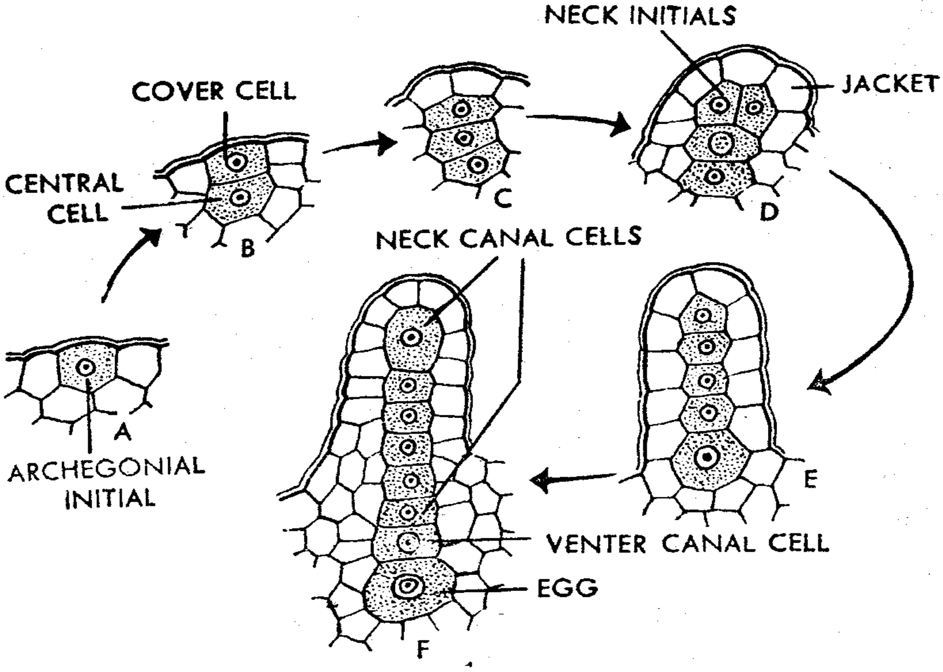


Stages showing development of antheridium in *Lycopodium*.

The antheridium initial is an epidermal cell of the prothallus just behind the apical meristem. The cell divides periclinally into an inner androgonial initial and an outer jacket initial. The latter divides anticlinally to form an outer jacket layer one cell in thickness, whereas the former undergoes a number of divisions to develop a large number of sperm mother cells which are surrounded by the jacket layer.

The sperms are biciliate and fusiform and are similar to those of Bryophytes. When mature, a triangular opercular-cell of a few cells becomes mucliagenous. This results in the absorption of water which causes the dehiscence of the antheridium thus liberating the bicilate sperms.

Development of an archegonium:



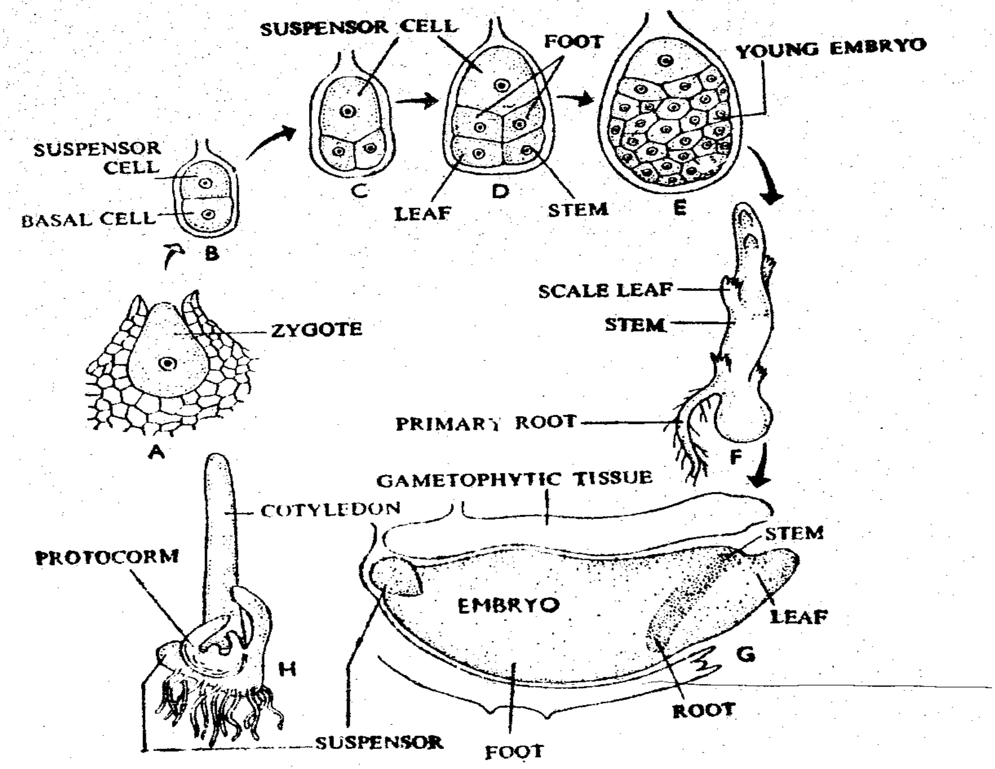
Stages showing developmentof an archegonium in *Lycopodium*.

The development of the archegonium may be traced to a single superficial cell. The archegonial initial divides periclinally into an outer cover-cell and an inner central cell. The former divides anticlinally to form four neck initials which undergo transverse division to form a long and straight neck, 3-4 cells in height and composed of four vertical rows of cells. The latter undergoes a periclinal division to form a primary canal cell and a primary venter cell. The former divides transversely to form about six neck canal cells, whereas the latter directly behaves as an oosphere.

Fertilization.

When mature, the neck-cells separate, the neck canal cell disorganizes forming a mucilaginous product which draws the chemotactic biciliate sperms to the orifice of the archegonium. A number of sperms enter the neck but only one fuses with the oosphere to form an oospore.

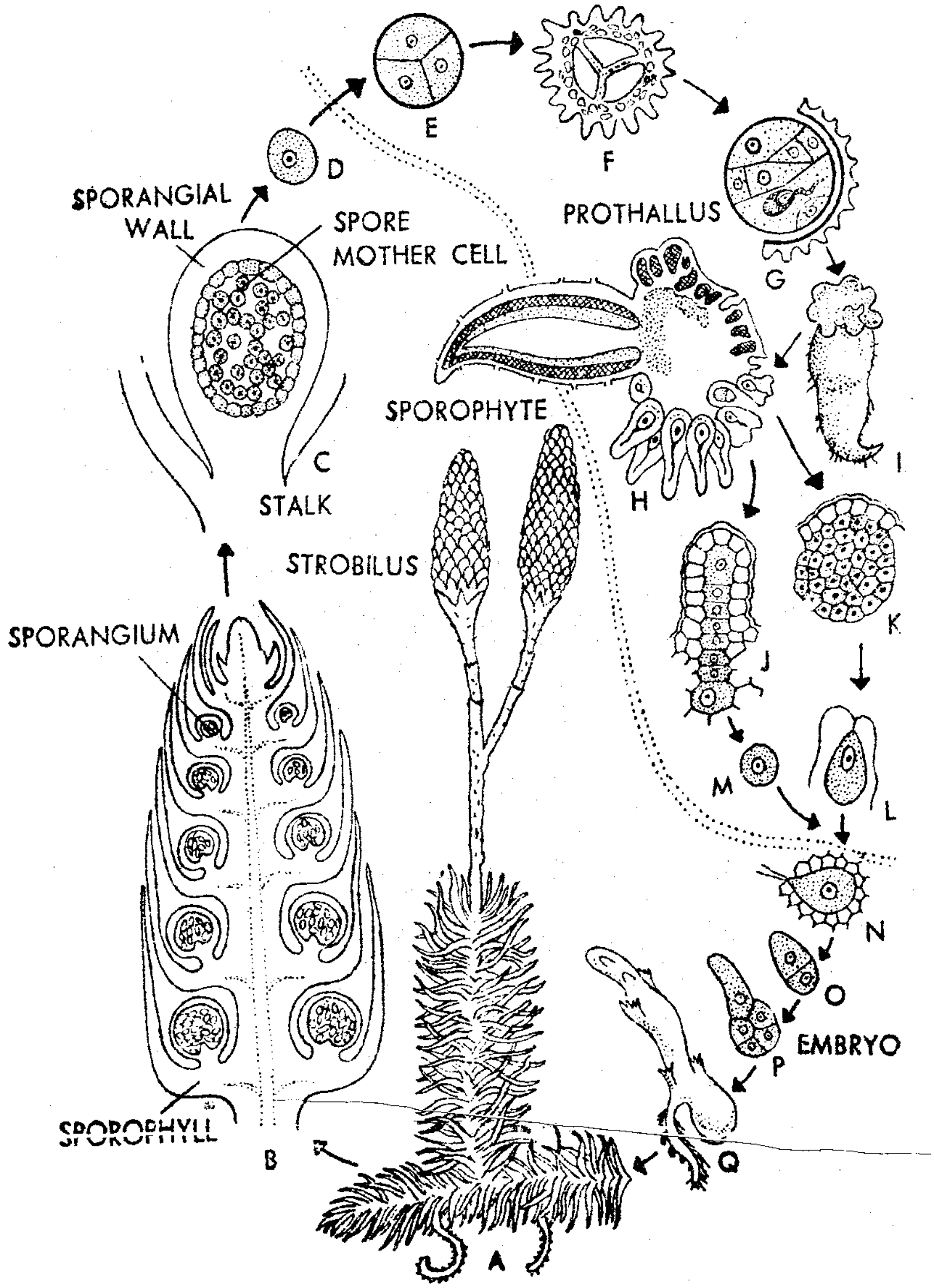
2.1.7. Development of embryo:



Stages of development of embryo in *Lycopodium*.

The fertilized egg soon secretes a wall and behaves as a zygote. The whole process of development of the embryo is extra ordinarily slow, so much to that the young sporophyte takes several years before reaching the surface of the soil. The first division of the zygote is always transverse and separates the upper suspensor cell and lower embryonic cell. The former usually does not divide and if it does, it may divide one or twice. The latter divides trice vertically and transversally to form a spherical group of eight cells, arranged in two super imposed tiers of four cells each, forming the octant stage of the embryo. From the lower tier, two cells form the stem and two form the first leaf and primary root. The upper tier branches obliquely, forming a tuberous foot which serves as an intra-prothallial haustorium for deriving food from the prothallus until the embryo leads an independent life. The first root shows an exogenous development though subsequent roots are endogenous in development and have been called cladogenous. As the stem grows, it emerges from the prothallus and develops many leaves on it. The first leaves differ from those on the mature plants in their scale like habit as well as in the absence of vascular tissue and chlorophyll.

The primary stem lives for a short period and is soon replaced by an adventitious outgrowth from its base which finally becomes the horizontal stem of the adult plant. The prothallus now begins to degenerate so that the young embryo gets the opportunity to develop more roots and leads an independent life. The young stem shows a protostelic structure whereas the adult shows the furrowing of xylem mass into several bands between which phloem enters.



Life cycle of *Lycopodium*.

Selaginella

The Selaginella are distinguished from the Lycopodium by the ligulate laves and by the fact that the sporangia are heterosorous. Their sporophytes are haeraceous and usually without an;y indication of secondary growth. The roots are borne on leafless-branches, the rhizophores. The micro and megasorophylls are aggregated to form strobili. The male and female gametophytes are morphologically and physiologically different. The sperms produced by the male gametophyte are bicilate.

SELAGINELLA

Systematic position

Divison: Lycopsida

Order: Selaginellales

Family: Selaginellaceae

Genus: *Selaginella*

2.2.1. **Occurrence**:

The genus *Selaginella* includes more than 700 species, out of which about 70 are reported from India.

They have world wide distribution. Most abundant in tropical rain-forests, temperate regions and a few are adapted to xeric environment.

The plants are perennial though delicate annual forms are not uncommon *e.g., S. pygnaea* and *S. gracillima.*

Most of them grow on moist and shady places in the hills while a few others are xerophytes or epiphytes.

S. kraussiana, *S. adunca* are the most common Indian species which are also commonly grown in green house.

S. lepidophylla and *S. rupestris* are xerophytic species and S. oregano is an epiphyte.

The xerophytic species *S. lepidophylla, S. pilifera* and *S. rupestris* are sold as novelties. These plants coil and assume a shape of ball when dry but when dipped in water they become normal green plants.

S. oregano is an epiphytic species which grows on the branches and trunks of moss-covered trees.

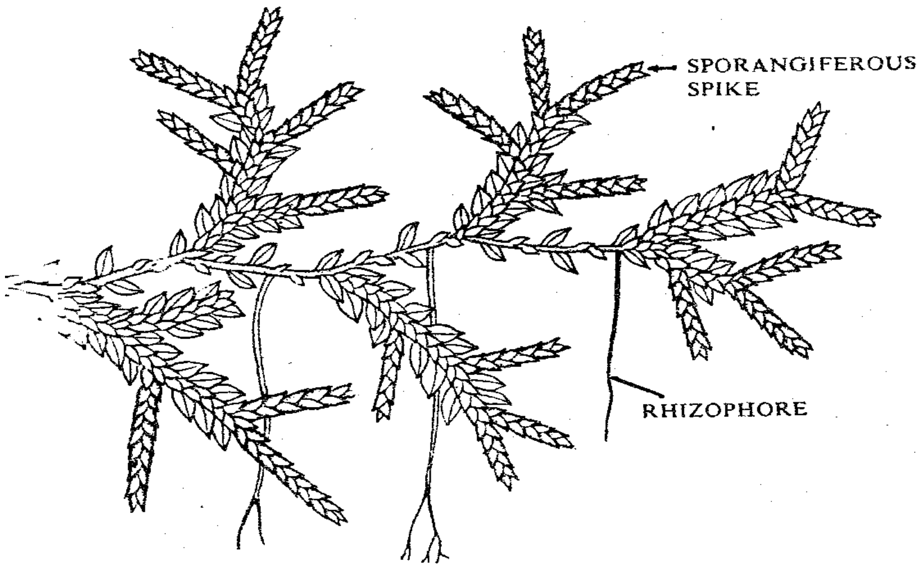
2.2.2. The plant body

Various species of *Selaginella* are highly diverse in form.

In some species the branching stem is prostrate growing along the surface of ground e.g., S. krauassiana or may be sub-erect S. trachyphylla, or scandent S. willdenovii.

On the basis of nature and forms of stem and leaves the genus has been divided into two sub-genera the Homoephyllum and the Heterophyllum.

Heterophyllum species: *S. kraussiana, S. lepidophylla*

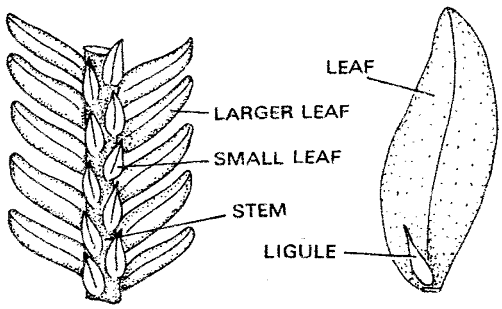


Plant body of *Selaginella kraussiana*.

The sporophytic plant body is prostrate and creeping on the ground. It is differentiated into root, rhizophore, stem and leaves.

The stem is slightly dorsiventral, flat and dichotomously branched. The branches grow erect or sub-erect scandant.

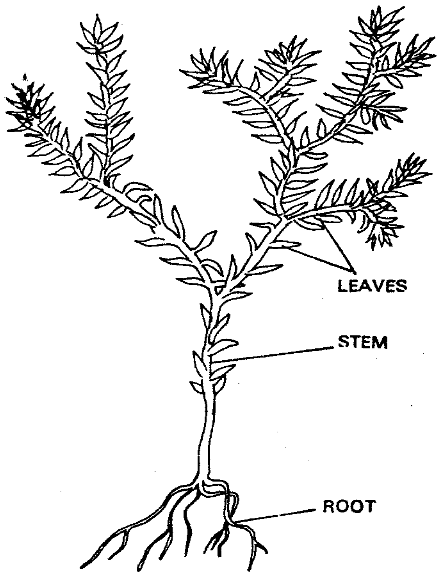
The stem gives rise long, colourless, cylindrical, prop like leaf less rhizophores from the points of dichotomy. The rhizophores penetrate into the substratum and terminate into adventitious roots.



The leaves are dimorphic attached laterally on the dorsiventral stem. Two rows of larger ventral leaves and two rows of smaller dorsal leaves form four vertical rows. The larger and smaller leaves alternate with each other. Each leaf is sessile, simle, lanceolate or obovate, and has a distinct unbranched midrib.

Each leaf possesses small tongue-like, laminar outgrowth, the ligule attached at the base towards adaxial (upper) surface of leaf.

Homoeophyllum species: *S. spinulosa*, *S. rupsetris*



The plants are differentiated into root, stem and leaves.

The stem grows upright, erect and shows dichotomous branching.

The leaves are of only one type. They are simple, small, and sessile and arranged spirally on the stem. Each leaf possesses ligule.

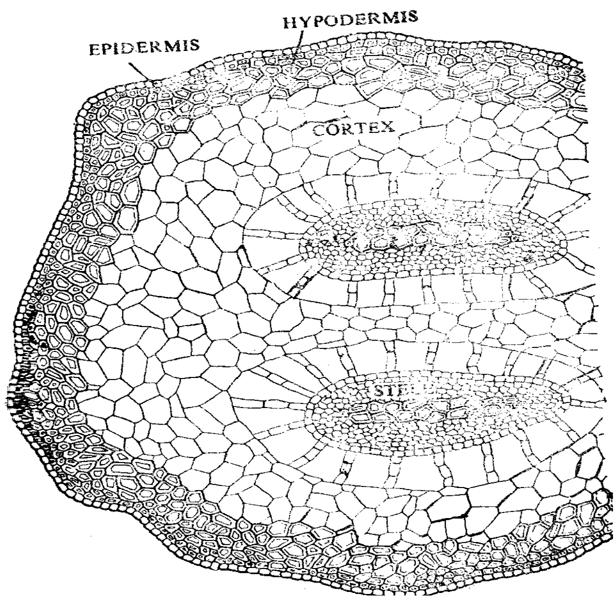
Plant body of *Selagineglla spinulosa*

The adventitious roots arise from the swollen base of hypocotyl (stem).

2.2.3. Internal structure

Stem

The outer most layer is epidermis. It is made up of prosenchymatous cutinized cells.



Next to epiderm is is 4-6 layered hypodermis of scelrenchymatous cells. The sclerenchyma may be absent in younger regions of the stem.

Hypodermis is followed by many layered parencymatous cortex.

The central part of stem is occupied by meristele.

Number of steles varies from to species and some times even in the same plant from

T.S. of Selaginella stem through distelic condition species region to region. If the section passes through nodal region, it may show single stele and if from internode, double stele are seen. Hence the stem can be mono, di, tri or polystelic(*S. spinulosa*- it is endarch polystelic).

Meristele has interspaced and trabeculated endodermis with characteristic casparian strips. Trabeculated endodermis is absent in some xerophytic specie, such as, *S. lepidophylla* and *S. rupestris*.

These trabeculae are either one celled or multicelled. When multicelled, the extra cells are derived either from pericycle or from cortex.

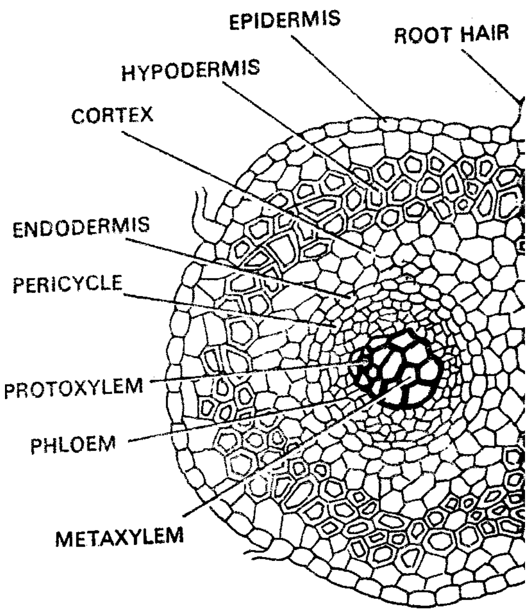
Thus single or double layered pericycle forms the outer binding portion of stele mass.

The xylem is solid band-shaped consisting of tracheids only. A few species have been reported to have true-vessels (*e.g., S. oregano, S. rupestris* and *S. densa*). It shows diarch and exarch condition. Protoxylems are on tips and metaxylem occupies the central portion.

The xylem mass is surrounded by phloem. Companion cells are absent in phloem.

Root:

The outermost layer is a piliferous layer from which root hairs are given of.



A few layered scelernchymatous hypodermis may be present in a few species.

Otherwise the cortex is homogenous, made of thin walled parenchymatous cells.

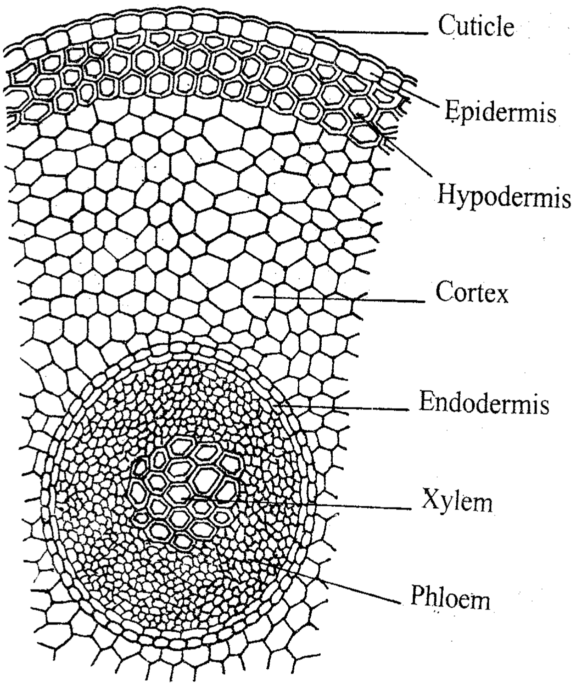
Endodermis is not well defined.

Pericycle is present.

Stele is a protostele with monarch structure.

The protoxylem is exarch. Xylem is surrounded by phloem in a horse-shoe shaped manner.

Rhizophore:



The structure of rhizophore is similar to that of root, but it differs from root in possessing a thick-walled epidermis, and sclerenchymatous hypodermis.

Wide variation is seen in the stele.

In *S. kraussiana, S. poulteri* and *S. delicatissima* the protoxylem is in the centre. *i.e.,* centroxylic.

In *S. martensii* the stele is monarch and exarch.

In *S. atrovirdis,* a number of strands form a crescentric metaxylem.

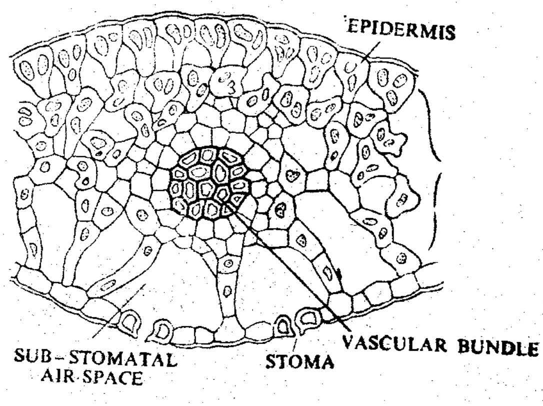
Theories in relation to the morphological nature of rhizophore:

Capless-root theory: van Tieghem(1902) and Uphof(1920) support this hypothesis. The positive geotropic nature and leafless-form support this theory of capless root organ.

Leafless-shoot theory: Treub, pfeffer, Bruchmann and Troll support this theory. The absence of root-cap, root-hairs and their formation from angle-meristem giving a dichotomous nature support this shoot organ hypothesis.

Organ *suigenesis*: Williams (1958), Goeble and Bower regard rhizophore as an intermediate structure between root and shoot and hence proposed the organ *suigenesis* theory.

Leaf:



The upper and lower epidermis is one cell thick and contains chlorophyll.

The stomata are present on only lower epidermis, near the midrib only.

Mesophyll is not well differentiated and forms a loose net-work (except S. *lyalli, S.*

concina where it is differentiated into palisade parenchyma).

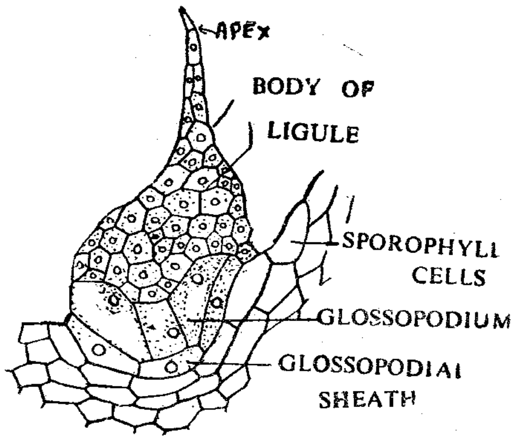
Near the vascular strand, the intercellular spaces are absent but the remaining part of the leaf is traversed by large intercellular spaces.

Single median concentric amphicribral-vascular bundle is present in the centre.

Few cells of xylem are placed in centre. A layer of elongated parenchymatous cells of phloem surround the xylem.

Ligule:

Ligule is best seen only on the bases of very young leaves or sporophylls. In mature leaves, it is shriveled off and disappears shortly.



The ligule is small tongue shaped outgrowth present at the base of each young leaf on its adaxial side.

Each ligule is differentiated into two parts- glossopodium and the glossopodial sheath.

The lower most basal hemispherical portion is glossopodium. It consists of vertically elongated thin walled cells.

At the base, glossopodium is surrounded by sheath cells which are 3 celled, tubular cup-shaped and are dead.

The body of ligule consists of large number of polygonal parenchymatous cells filled with dense protoplasm, arranged in a single layer.

The apical region covering the distal half portion is made up of smaller cells with free single celled margin.

The function of ligule is not known.

Vegetative reproduction:

1. **fragmentation**- vegetative reproduction is of rare occurrence and may take place by fragmentation. (*S. rupestris*).
2. **Bulbils**: it is seen in *S. chrysocaulos*

3. **Tubers**: small tubers are developed underground in *S. chrysorrhizos* and are called underground tubers. In *S. chrysocaulos* the tubers are formed at the surface of the ground and are called 'surface tubers'.

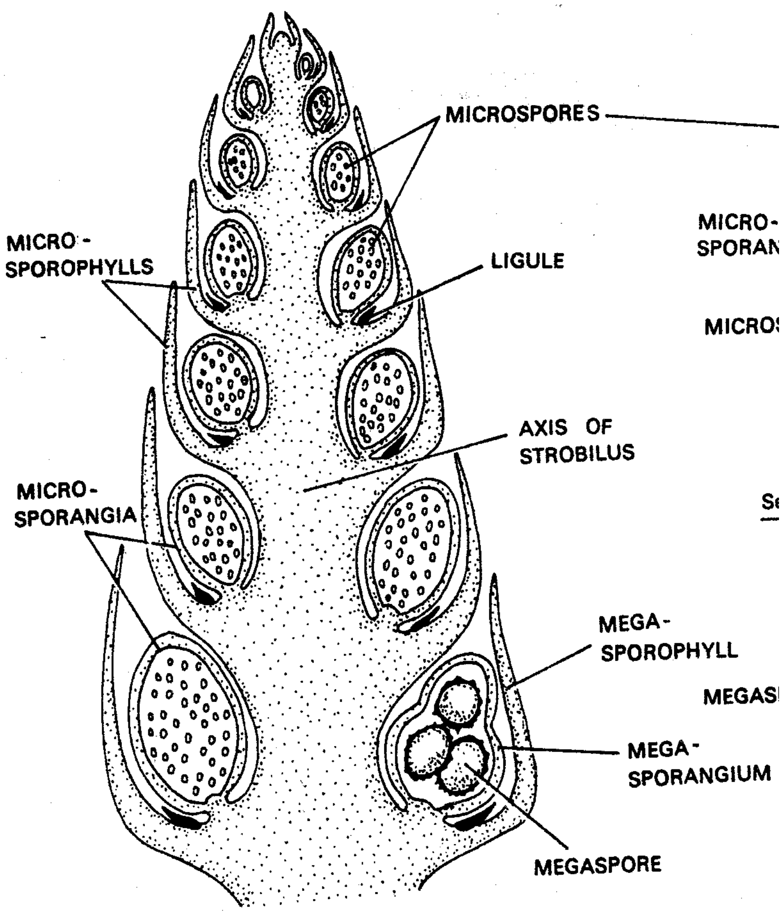
Reproduction:

The spore producing organ is called as strobilus or spike. It is sessile and borne at the apices of the branches.

The strobilus may be either erect or horizontal.

Each strobilus appears like slender, sub-cylindrical region where sporophylls are compactly arranged.

It has a large central axis on which several pointed sporophylls are borne.



The sporangia are borne singly in the axil of sporophylls. Sporangia may be cauline (on the main axis) or foliar (on adaxial base of sporophyll).

In *S. pallisissima*, sporangia are borne in the axil of normal leaves. Fertile leaves or sporophylls are not aggregated at the apex to form a strobilus.

In *S. patula* and *S. cuspidate,* the terminal portion of the branch continues vegetative growth beyond the spike.

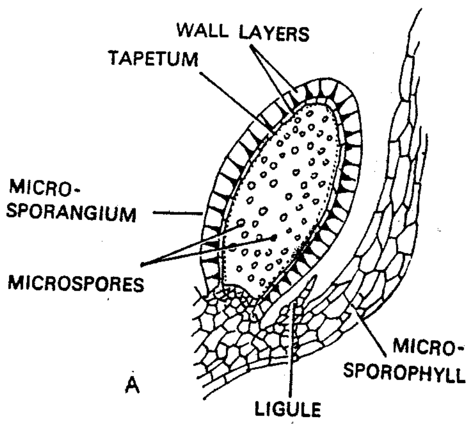
In *S. erythropus,* a second strobilus is produced on the fertile-branch after an intercalary sterile portion.

The wall of sporangium is made up of two layers- the outer thick wall of columnar shaped cells and inner thin wall of elongated and flattened cells. The third inner layer, *i.e.,* tapetum may not be present.

Sporangia are of two types. One: large megasporangium, with 4 mega spores, borne on a megasporophyll; and other microsporangium, with many small spores, borne on a microsporophyll. This dimorphic nature of spore is known as heterospory.

The sporangium are eusporangiate.

Microsporangia;



They are present on the terminal portion of strobilus.

It is eusporangiate. Numerous spore mother cells divide meiotically to form a tetrad of spore, resulting in numerous, small haploid microspores in each sporangium.

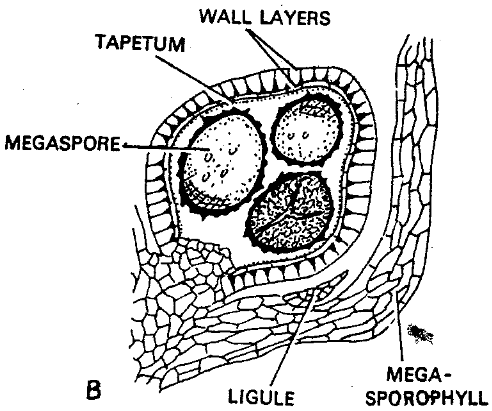
Microspores are either arranged in tetrad or lie freely within sporangium.

Each microspore has thick exine and thin membranous intine wall.

At maturity the microsporangium is red, yellow or brown on account of the contained microspores.

Megasporangia:

Megasporangium are present towards the base.

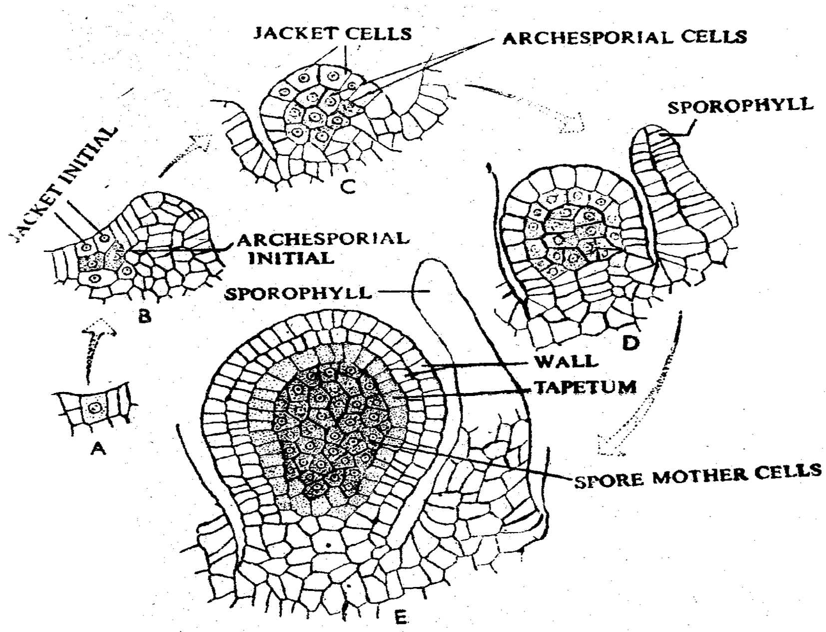


It is eusporangiate. All the spore mother cells except one usually disintegrate. The remaining functional spore mother cell divides meiotically to form four Megaspores and is arranged in tetrad. Only 3 can be seen from one side.

Exceptionally 24 megaspores are seen in *S. wildenovii*; and only one megaspore in *S. rupestris*.

Megaspores are large in size covering not only the entire space but exert pressure on the walls so as to give a four lobed shape to sporangium.

The sporangial initial divide periclinaly into an outer jacket initial and inner archesporial initial. The archesporial initial further divides to form sporogenous tissues.



The jacket initial further divides' to produce two or three layered spore walls: thick outer and sculptured exine, a mesine and a thin intine.

The sporangia are broader at the base and narrow at the distal end.

Ligule is present at the adaxial base of each sporophyll.

The mature megasporangia are pale-greenish and contain chalky white, yellow or orange megaspores.

Spore germination:

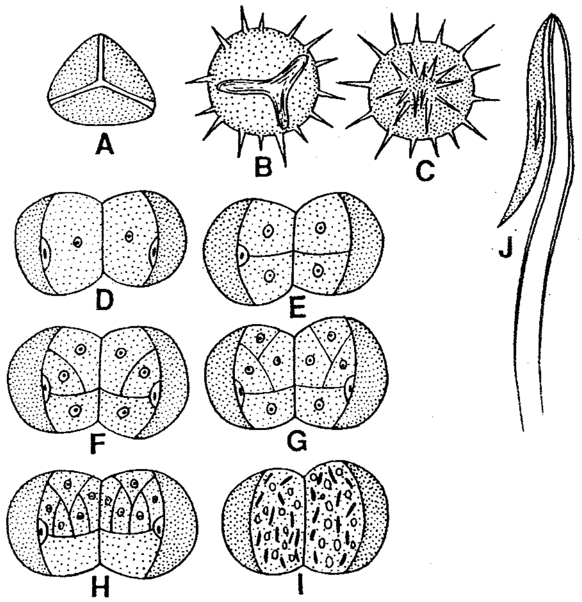
It is endosporic showing intrasporangial germination called 'precocious germination'.

Megasore develops into female gametophyte and microspore into 13-celled male gametophyte.

Mature sporangium splits open vertically only in the upper part into two valves (due to hygroscopic changes) which gape apart. The unsplitted lower portion dries up and becomes boat-shaped, forcing out the spores violently to a distance of few centimeter.

This and the protandrous nature of strobilus facilitate cross-fertilization in *Selaginella*.

Germination of microspore:



Schematic representation of stages of development of microgametophyte The first division results in the formation of a large and a small cell both of which lie within the microspore wall. The smaller cell corresponds to the vegetative tissue of the fern porthallus called prothallial cell.

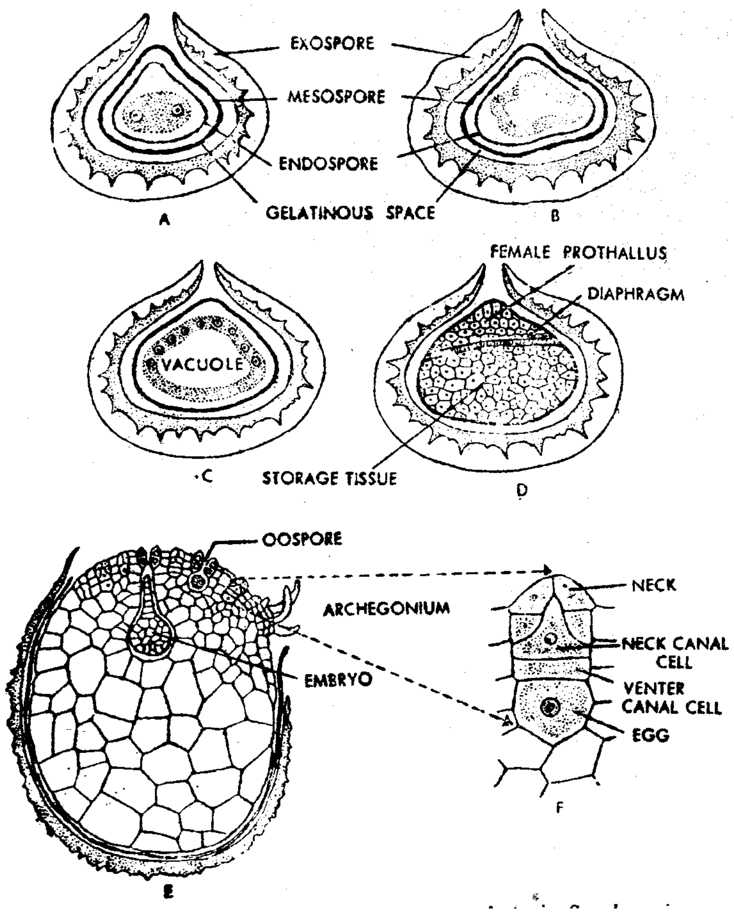
The large cell is the mother cell of the antheridium which by further divisions develops a central group of 6-8 primordial cells surrounded by a single layer of jacket cell.

Each primordial cell is transformed into a spirally coiled antherozoid with two flagella, while the jacket cell disintegrates.

At maturity about 256 sperms lie free in the spore wall which liberates them when it bursts open.

Germination of megaspore:

Each megaspore has a characteristic well marked triradiate ridge prolonged into a beak-like portion. In this region the spore ruptures.

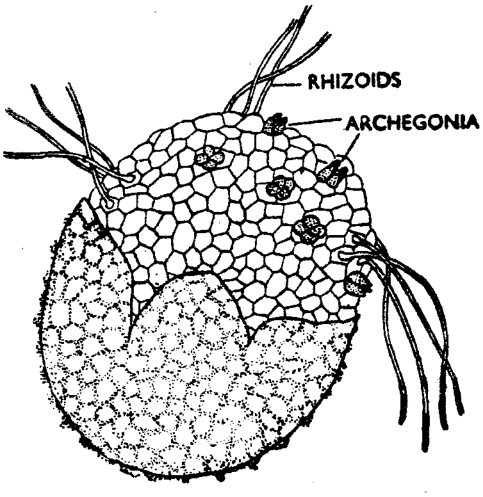


Schematic representation of development of megogametophyte.

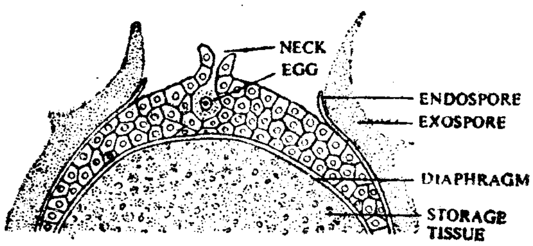
The megaspore germinates in situ, and shed at various stages in different species. For e.g., in some cases they are liberated immediately after the first division; in *S. kraussiana*- after the development of first archegonia; in *S. apoda* and *S. rupestris*- after fertilization and development of embryo.

During the development of female gametophyte, first the protoplasm contracts into a small sac-like structure which is accompanied by the rapid expansion of the wall so that the two become separated by a wide space. This is followed by the bursting of the outer wall into two layers- the exospore and mesospore which are separated with each other by a gelatinous membrane. The megaspore at this stage contains a haploid nucleus which divides producing numerous nuclei around the protoplasmic-layer. At this stage the protoplasm increases in size and volume thus establishing contact with the exospore and mesospore and obliterating the central vacuole. Wall formation takes place at the beak-like portion in the centre of the triradiate ridge. This results in the development of a small celled meniscus-shaped cellular tissue. This is one cell thick at the sides and three cells thick in the middle and is called the female prothallus. Below this there is a large celled tissue of hexagonal cells called the diaphragm formed by free cell formation.

Certain superficial cells toward the apical side enlarge and behave as a potential archegonial initals and form the archegonia. At this stage the megaspore bursts along the ridge exposing the female prothallus. Soon vestigial rhizoids develop from the three lumps. The archegonial initial divides into two which further divide into four and each of these redivides by oblique transverse divisions into cells that lie one above the other. Thus the next consisting of four rows of cells with tow cells in each row is formed. The lower cell divides thrusting a narrow prolongation in between the neck cell. This is separated into a neck canal cell and a large cell the central cell. This cell further divides and forms a venter canal cell and an egg. When the archegonium is mature, the neck canal cell and venter canal cell disorganize forming a mucilaginous product. This oozes out from the neck attracting the sperms to the egg.



Dehiscence of megaspore exposing prothalial tissue with three rhizoidal humps and archegonia scattered between them.

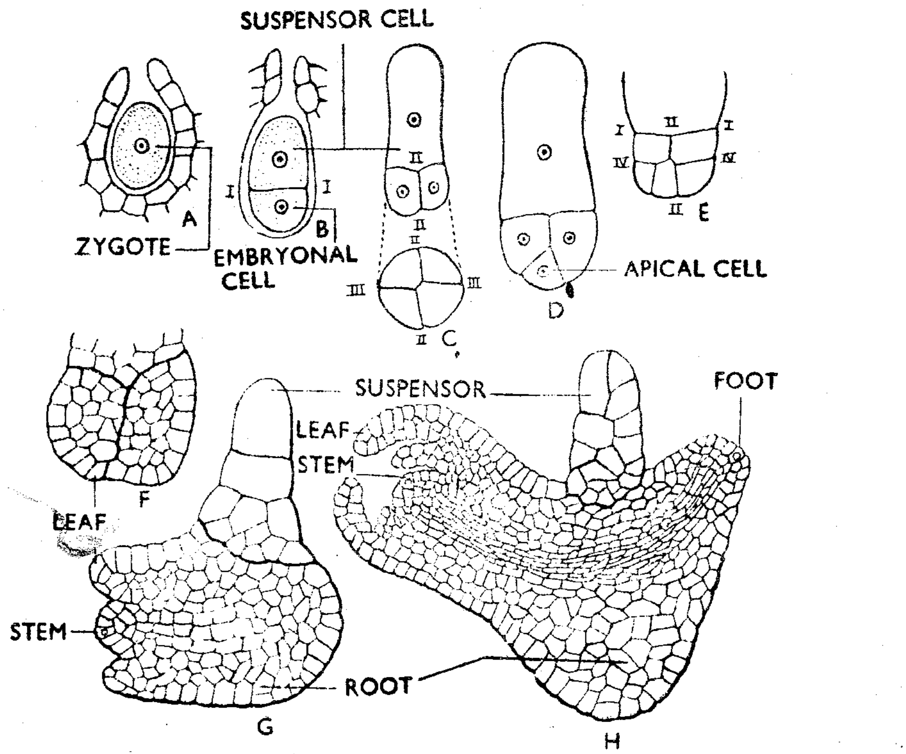


Megagametophyte showing an archegonium ready for fertilization.

Generally in *Selaginella* the megasporangia break open at this stage thus liberating the female gametopyte which falls to the ground.

Fertilization:

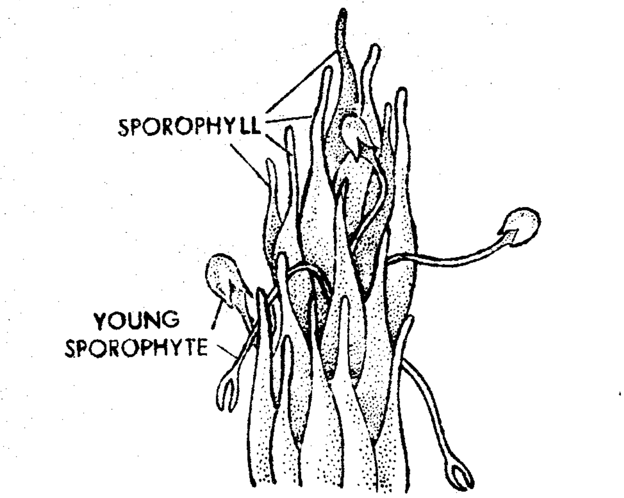
Male gametophyte sheded on the ground, complete their development and produce spermatozoid. If this falls near the female gametophyte, and moisture is present, the sperms swim from the male gametophyte to enter archegonia. The sperm ultimately fuses with the egg resulting in its fertilization.



In *S. apoda* and *S. rupestris*, seed habit is seen. Here, the megasporangium is matured, it cracks open, just to permit the escape of developing female gametophyte. When male gametophyte falls on the partly open megasporangium, the two gametophytes complete their development, side by side, and in the presence of moisture, fertilize the egg. The young embryos develop within the wall of the megasporangium and drop out as soon as they develop a root and primary shoot.

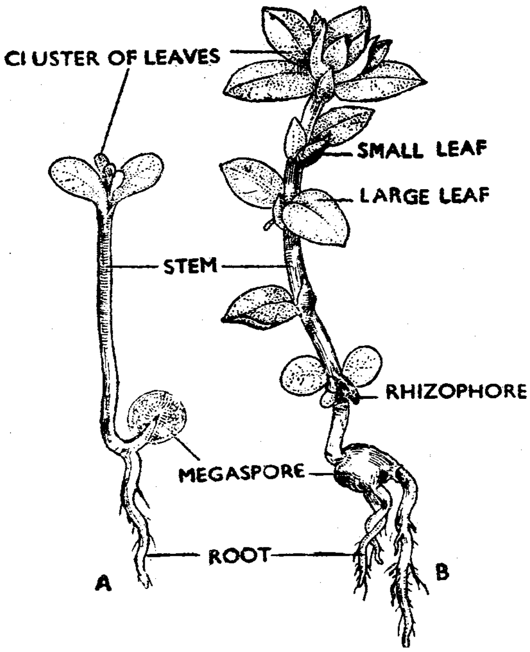
Development of embryo or sporophyte:

The oosphere after fertilization gets surrounded by a wall and becomes an oospore. It divides transversally into two cells, the upper epibasal and the lower hypobasal cell. The epibasal cell forms suspensor cell which elongates and thrusts the hypobasal cell into the embryo. The



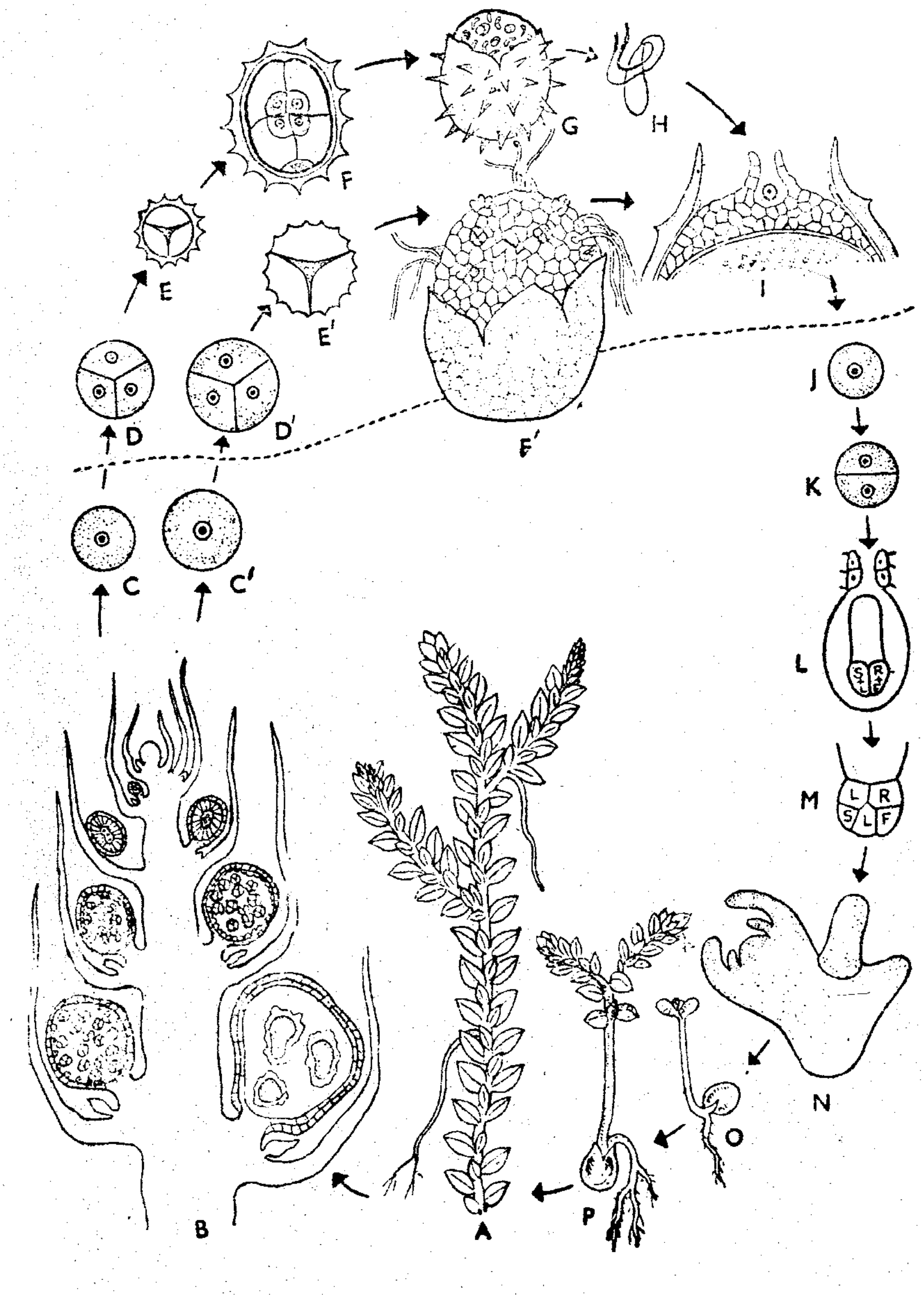
Sporelings from megaspores when still within the strobilus.

embryo is thrust down into the tissue of the female gametophyte. The embryo differentiated into foot, root, primary stem and two rudimentary



Older sporophyte still attached to megasporophyte sembling seed habit.

leaves and rhizophore. Thus young sporophyte becomes independent of the gametophytic tissues within the old megaspore wall.



Life cycle of *Selaginella*.

SELF ASSEMENT QUESTIONS;

1. Name an epiphytic species of *Lycopodium*?
2. How many types of prothalli are found in *Lycopodium*?
3. Name the xerophytic species of *Selaginella* sold as Resurrection plant?
4. What is a ligule? What is its function?
5. Which organ of Selaginella is called as ‘organ suigenesis’? Why?

Summary

In the second unit you have studied two eusporangiate pteridophtes.

The determination of sex is carried by the gametophyte in homosporous pteridophyte.

In heterosporous pteridophyte, the sex is determined in the sporophyte itself, during the differentiation of sporangia.

Endosporic germination is seen in heterosporous, and so ensures the survival of sporophyte under varied environmental conditions prevailing on land.

Heterospory leads to seed habit.

NOTES

UNIT - III

ADIANTUM AND *MARSILEA*

Introduction:

Ferns are advanced forms of pteridophytes, and dominate today's pteridophyte. In the present unit you are going to study a homosporous and heterosporous form of pteridophyte in detail. *Marsilea* is considered to be more advanced due to the presence of heterospory and a complicated sporangial organization- the sporocarp.

ADIANTUM

Systematic position

Division: Pteropsida

Sub-division: Leptosporangiate

Order: Filicales

Family: Adiantaceae

Genus: A*diantum*

Occurrence:

It includes 200 species.

It is widely distributed. It grows luxuriantly in both tropical and sub tropical climate.

It is commonly seen in moist and shady places.

It is cultivated in gardens for its ornamental beauty

It is also known as maiden hair fern, for its black shining petioles fanciful resemblance to the hair of a maiden.

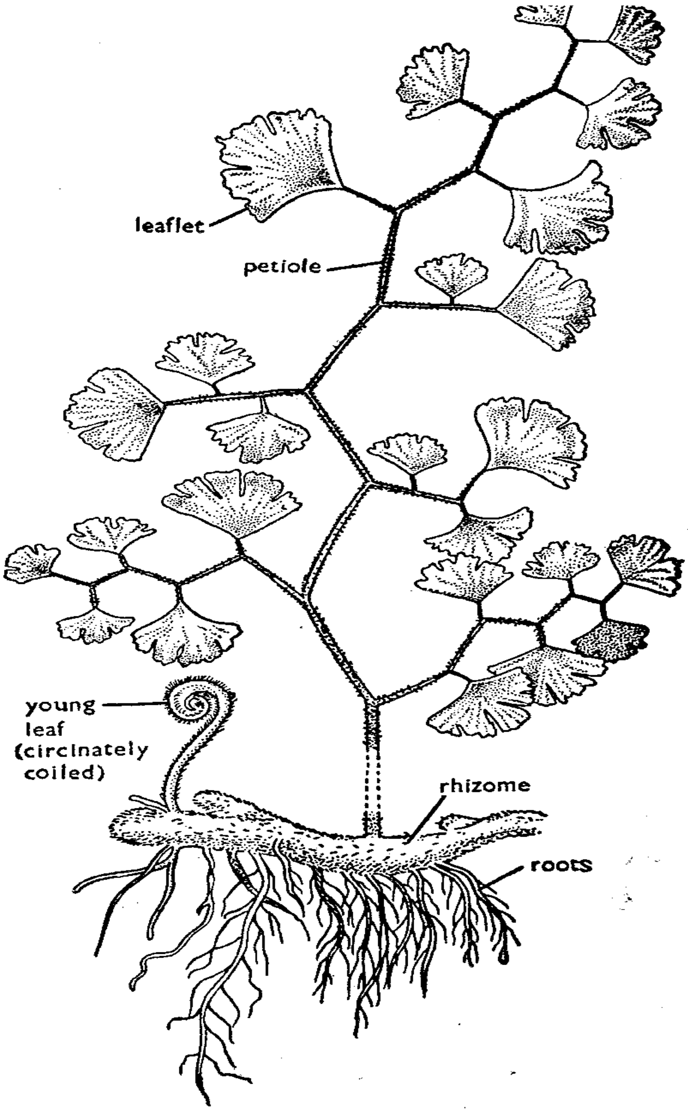
The common species seen in India are *A. capillus-veneris, A. pedatum, A. incisum, A. caudatum, A. venustum etc.*

3.1.2. The plant body:

The sporophytic plant body consists of underground rhizome, from which are produced leaves and roots.

It may be erect (*A. caudatum*), semierect (*A. pedatum),* or creeping (*A. capillus-veneris*).

The rhizome may be hard or soft and brown in colour.



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The rhizome is covered with chaffy scales (paleae) which vary in shapes and sizes.

Roots are given out on the lower side of the rhizome. Primary roots are short-lived. Adventitious roots arise from the under surface of the rhizome.

The roots are stiff and black in colour. Occasionally they may be branched.

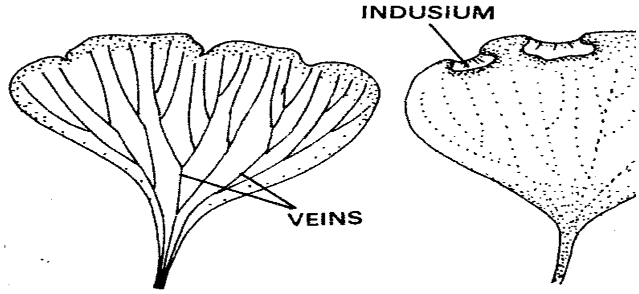
The leaves are produced in acropetalous succession on the creeping rhizome. Leaves are spirally or alternately arranged on the rhizome with a long petiole. Young leaves show circinate vernation typical of ferns.

The rachis of the leaf is hard, wiry, shiny and black or dark brown in colour thus giving the name maiden hair fern.

Leaves are often dichomomously branched into many leaflets. The leaves may be unipinnate (*A. caudatum*) or bi or tripinnate (*A. capillus-veneris).*

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.

The rachis has a median dorsal groove and is covered with paleae at the basal region. In addition to this, glandular hairs may also be present.



The pinnae are stalked and have dichotomous venation. The rachis may terminate in a pinna or may bear a bud.

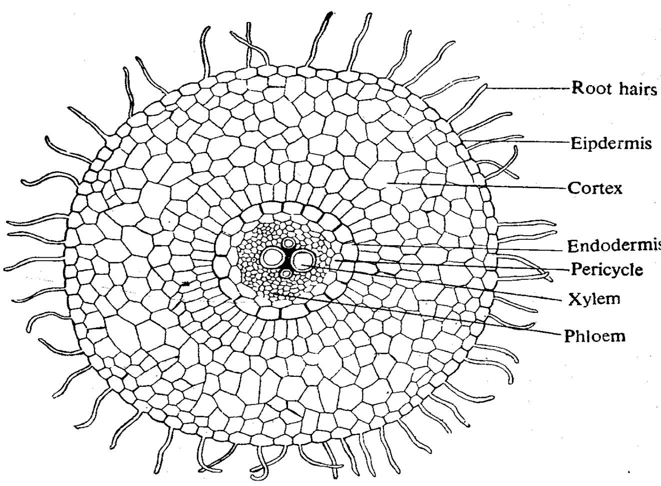
There is no distinction between fertile and sterile leaves in Adiatnum. The whole leaf may be sporangiferous or only certain pinnae may bear sporangia.

Soral organization is seen. Sori are borne on the ventral surface of the pinnae.

3.1.3. **Internal structure**:

Root:

These are white fine, thread-like structures arising from the rhizome. These may be many and well developed. In a T.S. of the root shows the following structure.



Epidermis: it is single layered and outermost. It has many unicellular root hairs and hence piliferous.

Cortex is heterogenous with outer parenchymnatous zone and an inner sclerotic zone.

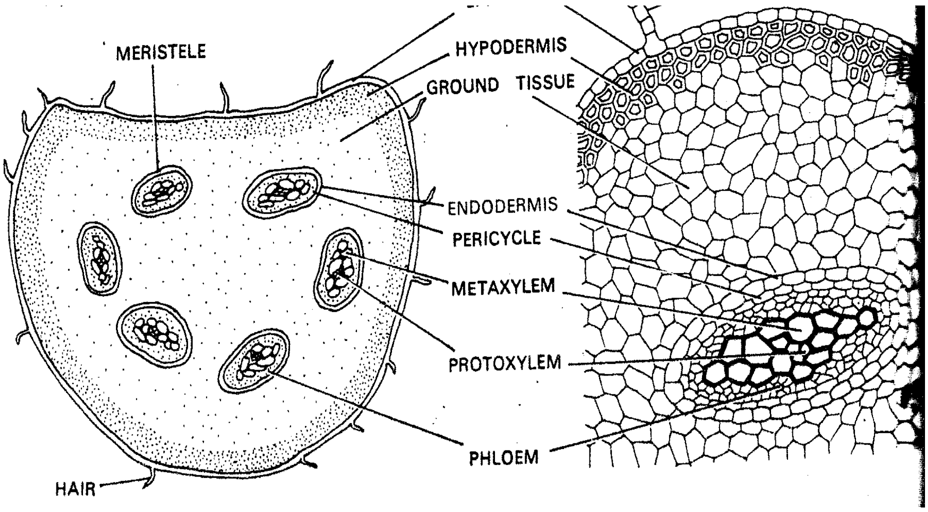
Endodermis is very prominent having cells quite enlarged with prominent thickenings.

Pericycle it is a single layered situated below the endodermis.

Stele: it is a protostele with are xylem pointing exarch and diarch surrounded by phloem from all sides.

Rhizome:

The species with elongated rhizome exhibits actual solenosteles (*A. pedatum*) but in a T.S. it appears as a structure having several meristeles arranged in a ring on account of overlapping leaf gaps.



Epidermis: it is single layered, slightly circular or gutter-shaped, thin or thick walled and has distinct cuticle. It is not continuous because of many leaf gaps. Epidermis bears multicellular hairs.

Cortex: it may be homogenous parenchymatous (*A. rubellum*) or heterogenous. If heterogenous it may be differentiated into hypodermis and ground tissue or with scattered mass of sclerenchyma in the parenchymatous ground tissue (*A. caudatum*).

Hypodermis: it is scelerenchymatous, 4 to 6 layered and situated below the epidermis. Cells are double walled.

Ground tissue: is made up of spherical cells having intercellular spaces. It possesses starch;

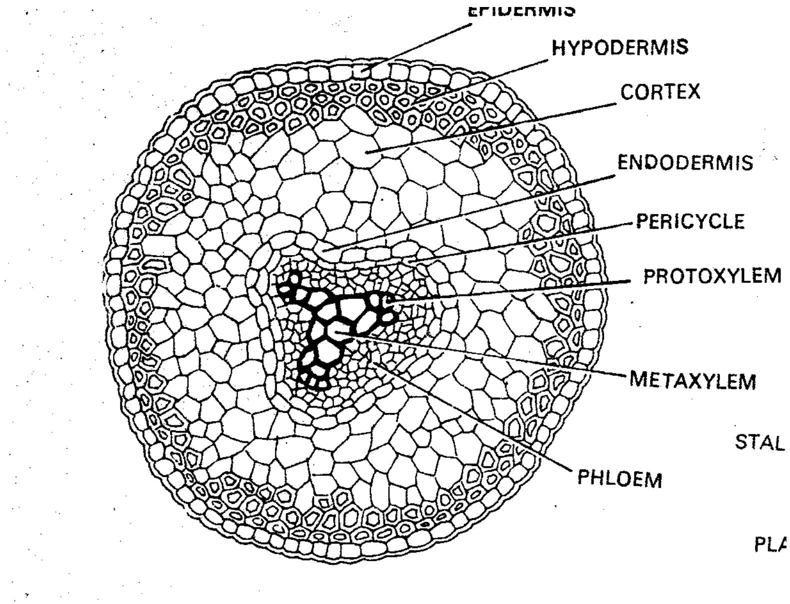
Steles: many steles are embedded in the ground tissue. Great variation is seen in the steler structure between species, or at different stages in the same species.

Stele may be a dictyostele (*A. capillus-veneris*) with a ring of meristele; each stele has single layered endodermis, one layered pericycle and xylem surrounded by phloem.

Or it may be a typical amphiphloic solenostele (*A. rubellum*); with outer endodermis, outer pericycle, outer phloem, xylem, inner pericycle and inner endodermis lining the parenchymatous pith.

Petiole:

Epidermis is single layered, parenchymatous and continuous with a definite cuticle.



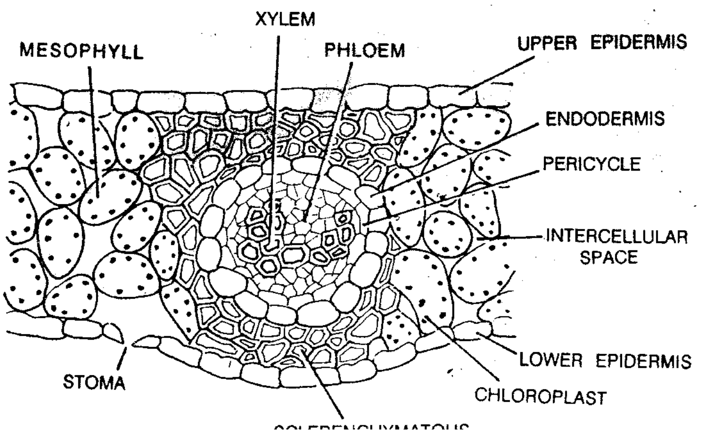
Hypodermis is few layered with thick walled sclerenchymatous tissue.

Ground tissue is made up of parenchymatous cells which may contain starch.

Stele: two big steles are embedded in the ground tissue. Both are facing each other. Each stele has its own endodermis, pericycle, xylem is triarch 'Y' shaped, exarch and surrounded by phloem from all sides. Protoxylem points are many.

Leaf:

The lamina shows both upper and the lower epidermis.



The mesophyll is generally undifferentiated. It is highly reduced (*A. cappillus-veneris, A. pedatum*) with only two layers of cells. In *A. pedatum*, in some regions the mesophyll is totally absent and the two epidermal layers are closely appressed to each other.

The mesophyll (when present) and epidermis are chlorophyllous.

Stomata are scattered throughout the surface of the leaf. Palaeae may be borne even on the epidermis of the lamina.

Veins may or may not have bundle sheath. The vascular tissues show the characteristic protostele consisting of xylem surrounded by phloem. The protoxylem faces towards adaxial side of the leaflet.

Reproduction

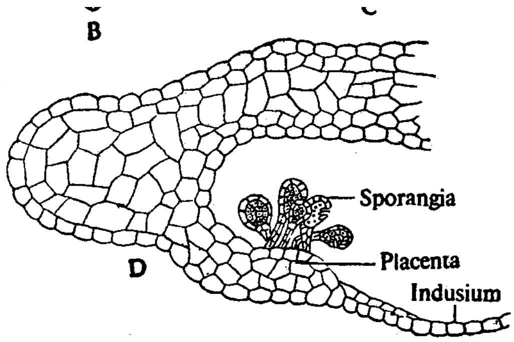
Vegetative reproduction is brought about with the aid of underground rhizome which forms an excellent perenating body.

'Walking habit' is seen in *A. caudatum*. Here, the buds are produced at the leaf tip, which, when the leaf bends, enters the ground and develop into a new individual. This in turn may repeat the process leading to walking habit.

Sexual reproduction:

When the plants are mature sori begin to develop on the distal end of the leaves which are called sporophylls. These sori are apparently marginal but really superficial in origin. In fact these are covered by reflexed leaf margins which give an appearance of an induisum which is membranous and brown at maturity. True indusium is lacking. Sorus or the fertile region of the leaf is reflexed at the proximal end. Sharply reflexed region is highly specialized as it encloses fertile cells which remain protected also.

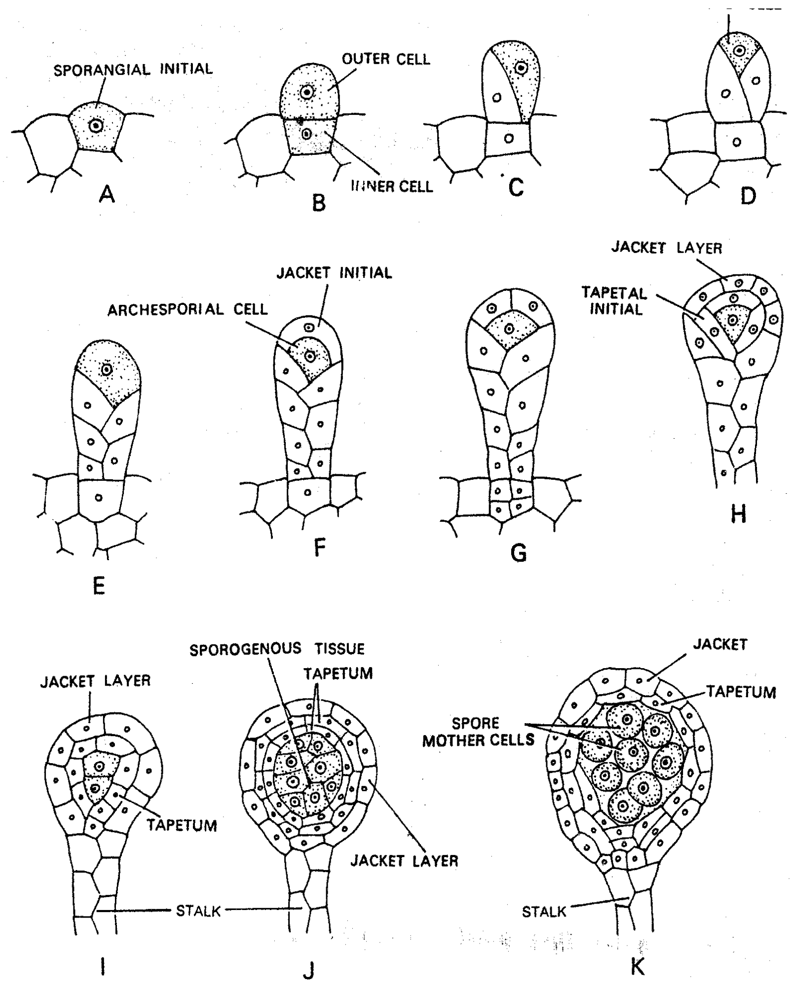
Sporophyll in a section it shows the usual leaf portion and slightly swollen placenta on which many sporangia are present.



The development of sporangia:

The development is of leptosporangiate type. A single superficial cell arises from the receptacle and functions as the sporangial initial. This divides transversely to form up upper cell and a lower cell. The lower cell does not contribute to the sporangium.

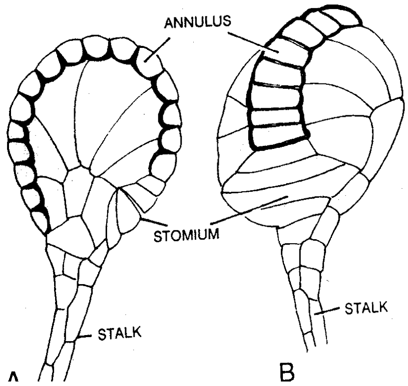
The upper cell by intersecting oblique walls gets differentiated into an apical cell with three cutting faces. This cell cuts off segments along its three faces which give rise to the stalk of the sporangium.



The stalk has three rows of cells. After some time, the apical cell divides periclinaly to form an outer jacket initial and an inner archesporial cell. The jacket initial contributes to the jacket of the sporangium which is one celled thick. The jacket at the base of the sporangium is derived from the segments cut off by the original apical cell. The archesporial cell cuts off one cell each on all its four sides to form four primary tapetal cells surrounding a sporogenous cell. The primary tapetal cells divide one periclinally and several times anaticlinally to form a double layered tapetum. Meanwhile the sporogenous cell divides to form about twelve spore mother cells. The tapetal cells disorganize and provide nutrition to the spore mother cells the spore mother cells divide meiotically and produce haploid spores.

Sporangia.

A mature sporangium has a long sporangiophore, made up of three rows of cells and spherical, globose or biconvex capsule or sporangium.

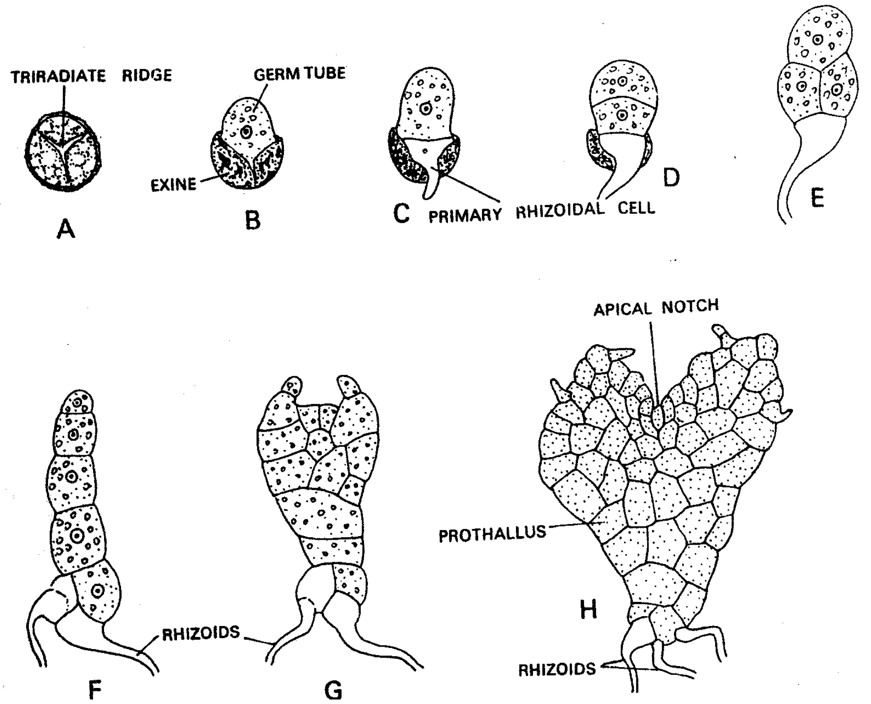


The wall is single layered characteristic and has special thickenings which help in its rupture. There is an obliquely vertical annulus of 12-24 cells long. After the breaking of sporangia stomium is formed. The stomium is separated from the stalk and annulus. The rest of the sporangial wall is composed of few large cells.

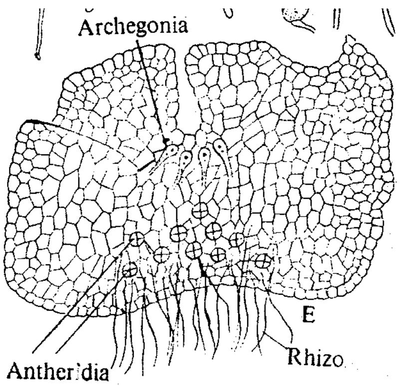
In the mean time the spore mother cells divide meiotically and thus many haploid spores are formed. These spores are liberated through the stomium. The sporangium dehisces transversely liberating the spores. All the spores are of the same type. Each spore is uninucleate with two walls- an outer exine and an inner intine.

Germination of spores:

Spores are tetrahedral in shape. The wall is two layered. The exine is thick and smooth and has a brownish tinge. It ruptures and the intine comes out in the form of a germ tube. The germ tube undergoes several



transverse divisions to form a short filament. The lowest cell forms a lateral rhizoid. The terminal cell becomes an apical cell with three cutting faces. By the division of the apical cell, first a spatulate prothallus is formed.

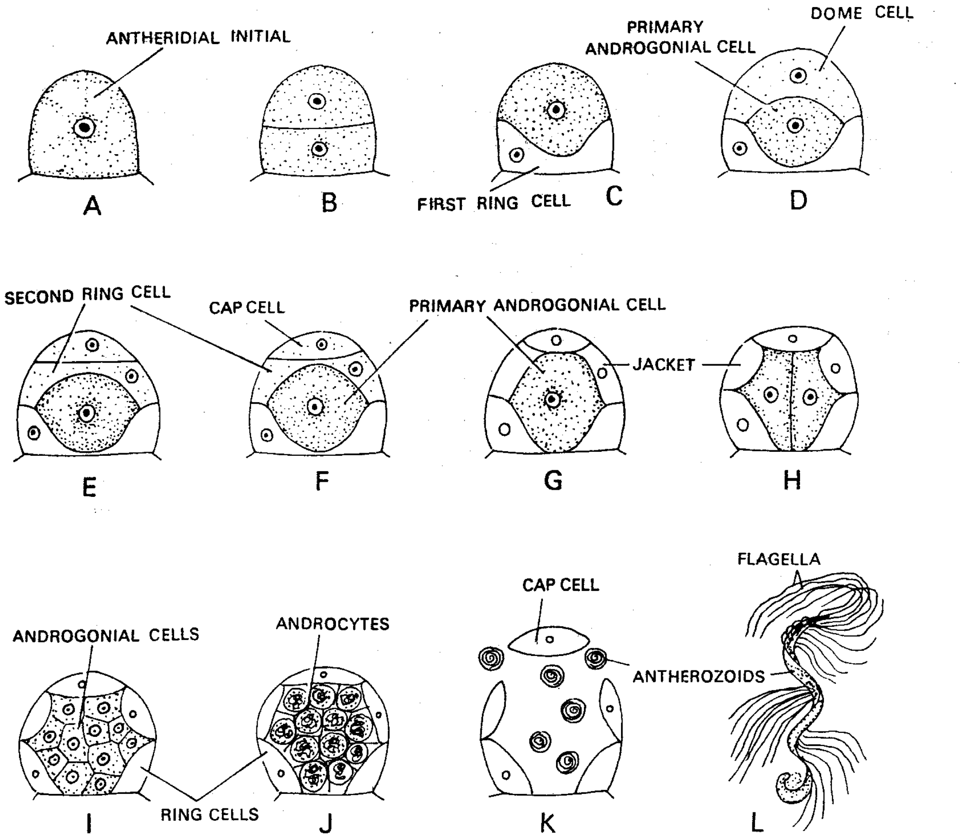


Later on the characteristic dorsiventral, photosynthetic, heart shaped prothallus is formed with a definite notch. The growing point is situated in the apical notch. The prothallus is one celled thick towards the margins but many celled thick towards the centre. In some species collenchyma may be found at the conners. Rhizoids are produced from the ventral surface.

The prothallus is monoecious. Sex organs, archegonia and antheridia develop on the prothallus. Archegonia develop near the notch and antheridia near rhizoids, on the ventral surface.

The development of male organ:

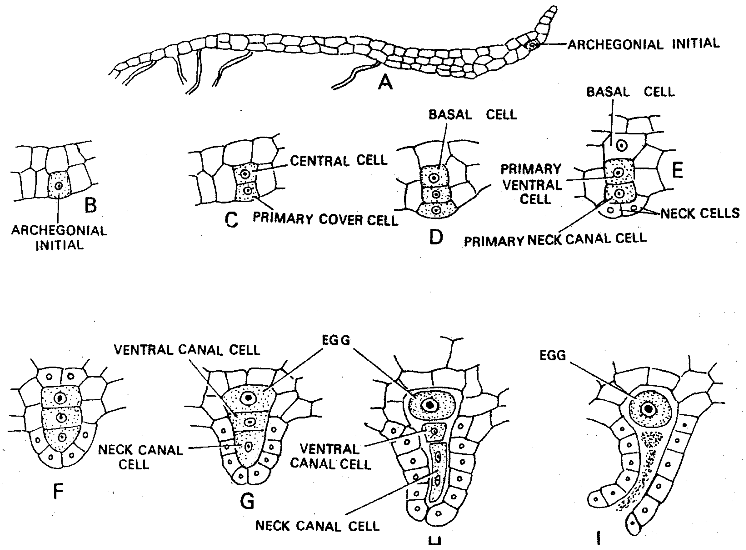
One of the superficialcells on the prothallus towards the ventral surface projects out a little and unctions as an antheridial initial. This undergoes a transverse division to form two superposed cells. Due to the increase of turgor pressure in the upper cell the cross wall bulges down and ultimately touches the wall of the lower cell. The upper cell now divides to form a dome cell and the primary androgonial cell. At this stage the youg antheridium consists of a dome cell, a primary androgonial cell and a ring cell the dome cell divides transversely to form a cap cell and the second ring cell. The cap cell may or may not divide to form two cover cells. Meanwhile the primary androgonial cell divides to form 20-25 androcyetes.



Antheridia: the mature antheridia are discoid having two ring cells, and one or two cover cells with many antherozoids inside surrounded by a sterile jacket. The antherozoids are coiled and multicilliate. At maturity the antheridia absorb water and finally rupture liberating antherozoids which are uninucleate and multiciliate.

The development of female organ;

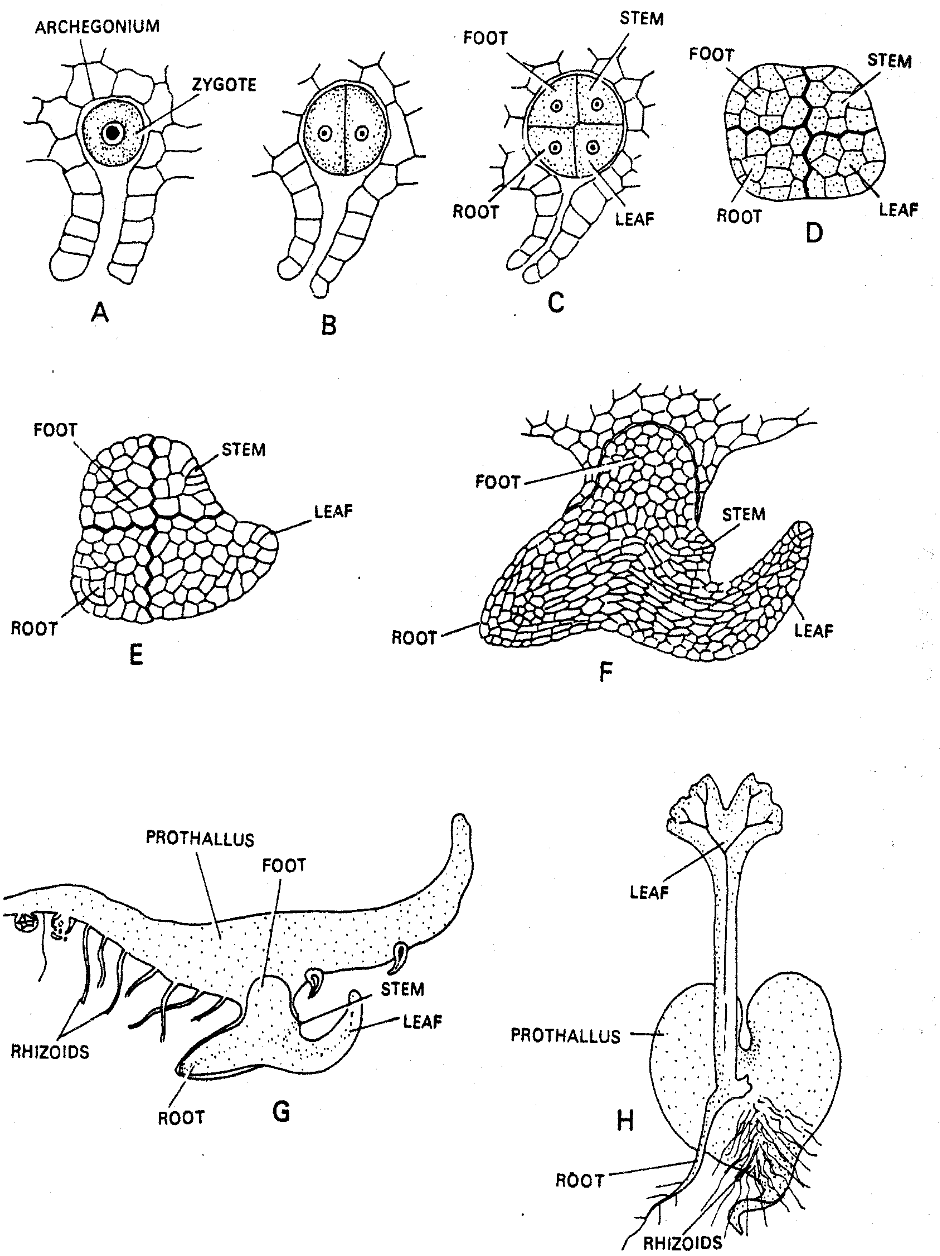
A superficial cell functioning as the archesporiral initial divides periclinally and forms an upper primary cover cell and a lower cell. The lower cell divides again to form a basal cell and a central cell. The primary cover cell forms a neck of 3-4 cells in height. The basal cell will not contribute to any part of the archegonium. The central cell divides, and its derivatives develop into a neck canal cell (with two nuclei) a venter canal cell and an egg cell.



Archegonia: the mature archegonium are flask shaped with a long neck and swollen venter. The neck has many neck canal cells while the venter encloses a venter canal cell and an egg. When ready for fertilization neck canal cells and venter canal cell disintegrate and convert into mucilage. The latter absorbs water which facilitates the rupture of cover cells thus making a clear passage for the entry of the antherozoids. Many of them are attracted but finally it is the one of which unites with the nucleus of the egg resulting in the formation of zygote.

Post fertilization changes and formation of a new plant

The zygote soon divides into two by a transverse wall and then into four by another wall at right angles to the first. Thus a quadrat is formed. The epibasal half (next to the archogonial neck) forms the leaf and root while the hypobasal half forms the stem apex and foot. The young embryo soon emerges from the prothallus and leads an independent existence.



Stages of development of embryo in *Adiantum*.

Life cycle of *Adiantum***.**

A. sporophyte, B. fertile frond; C. sorus; D. mature sporangium;E.Spore; F. meiosis to spore terrad. G-J. liberation and germination of spore to mature gametophyte;K-L anthredium and antherozoid; M-N. archegonium; O. oospore P-R-germination of oospore to sporophyte

Marsilea

Division: Pteropsida

Sub-division: Leptosporangiate

Order: Marsileales

Family Marsileaceae

Genus: Marsilea

Occurrence:

The genus consists of 53 species of which about 9 are recorded from India.

The genus is aquatic (*M. quadrifolia*) or semiterrestrial (M. condensata). A few species grow in dry soil.

As the name indicates, the plants are found at marshy places. It is amphibious in nature found growing throughout India.

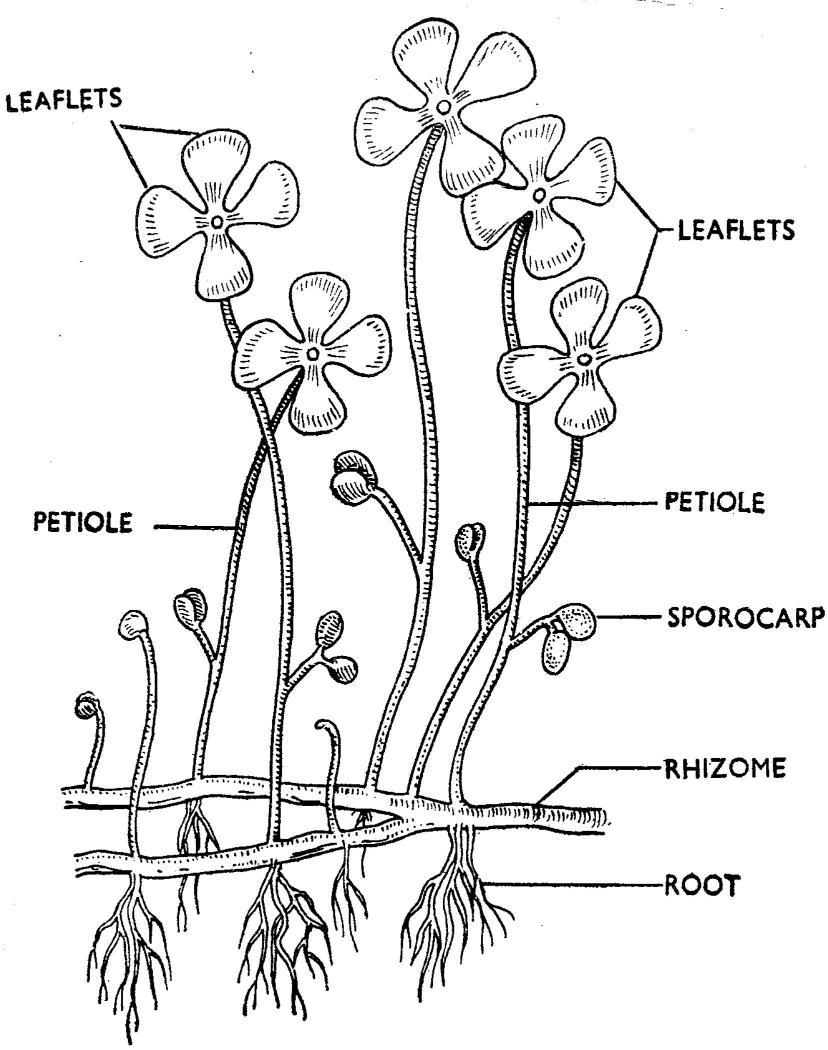
The plant body:

The plant body is differentiated into a rhizome, roots and leaves.

The slender creeping rhizome is branched and may either grow in water or just below or on the surface of soil attached by roots in the damp soil.

The rhizome has indefinite length and under luxuriant growth conditions may reach a length of 25 meters.

It bears nodes and internodes. Nodes are slightly swollen and internodes are longer in aquatic species and shorter in terrestrial species. It is from the nodes that the leaves and roots arise. Both leaves and roots are borne in



Habit of *Marsilea*.

acropetal succession (youngest towards the apex or rhizome). Whereas the adventitious roots grow downwards, the leaves grow upwards. Roots are mostly unbranched but they may be branched. The leaves when young are circinately coiled, a characteristic of most fern.

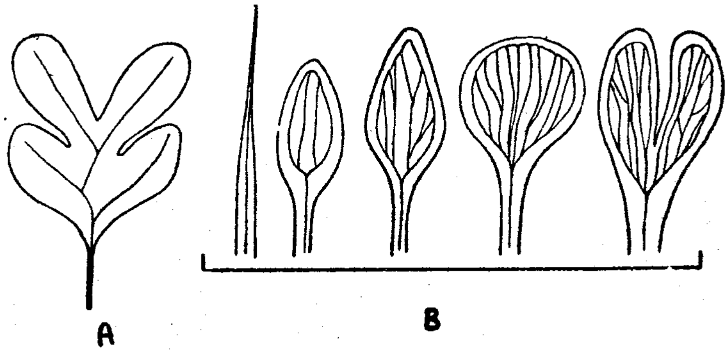
The leaves present at the nodes are two ranked i.e., present in two rows, one on the either side of the mid-line of the rhizome.

Each leaf consists of a long, delicate, cylindrical 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.

The vascular supply in leaflets is peculiar and characteristic. All the four leaflets are supplied by separate traces from a single vascular trace.

The division of the 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.

Each leaflet is obovate, obcuneate or elliptical and the venation is peculiar.



Venation in the juvenile leaves of *Marsilea.*

Two veinlets after fusion give rise to three sub-veinlets. *i.e.*, anastomosing type. The free veinlets at the apex of the leaflet are tied up with marginal loops.

If the leaves are examined in the night or early morning, they may show the well known sleeping movement during which the leaflets fold up.

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

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

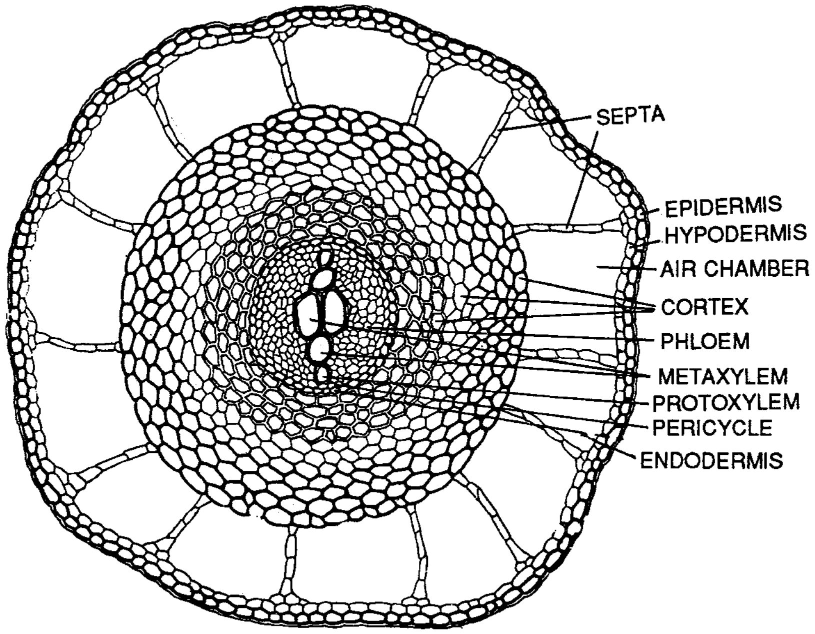
Each sporocarp is bean shaped or squarish shaped and has a short stalk called peduncle or pedicel. They are soft and green in the beginning but become hard and brown at maturity.

Internal structure:

Root:

The epidermis is single layered with tangentially elongated cells.

The cortex is differentiated into an outer and an inner cortex. The outer cortex has many large air chambers separated by radial septa or trabeculae, the inner cortex has either all the parenchymatous cells or some of the cells towards the inner side may become thick walled.



T.S. of *Marsilea* root

The vascular bundle is surrounded by a single layer of endodermis followed by a single layer of pericycle.

Stele: The mass of xylem is situated in the centre which is diarch and exarch, the protoxylem elements are situated opposite to one another.

The phloem has smaller cells and forms two bands, one on either side of the xylem mass.

Stele is surrounded by a single layer of pericycle and endodermis

(The aerenchyma in the outer cortex is a hydrophytic character).

Rhizome:

The epidermis is single layered without stomata. The epidermis of plants, growing in water, does not possess cuticle, but of those growing in mud or soil, develops a cuticle.

The cortex is differentiated into three regions- the outer, the middle and inner cortex.

The outer cortex has well-developed air spaces, separated by radially arranged one cell thick parenchymatous cells called trabeculae. This tissue is known as aerenchyma. The outermost cells of the cortex contain chloroplast.

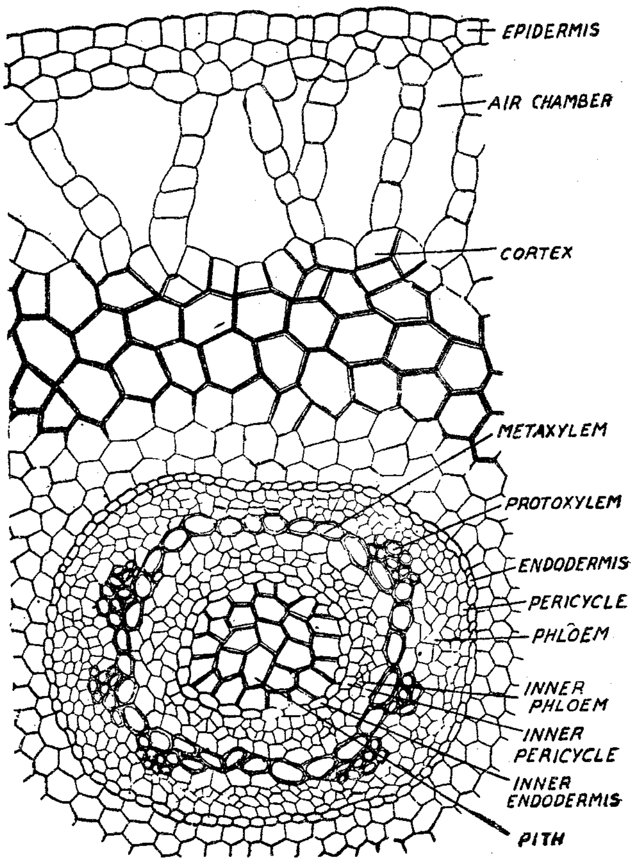
The middle cortex is thick walled, made up of sclerenchymatous cells and is only a few celled thick.

The inner cortex is composed of compactly arranged thin walled parenchymatous cells. These cells contain starch.

The stele is an amphiphloic solenostele.

In the centre is the pith which is parenchymatous in rhizomes growing in water and sclerotic in the rhizomes growing in mud.

Outer to the pith is a layer of inner endodermis, followed externally by the inner pericycle and then by the inner phloem.



T.S. of *Marsilea* rhizome through older portion

There is a ring of xylem surrounded by outer phloem, outer pericycle and outer endodermis toward the periphery.

Protoxylem groups may or may not be distinct, and if distinct, they are generally exarch, but in some cases mesarch too.

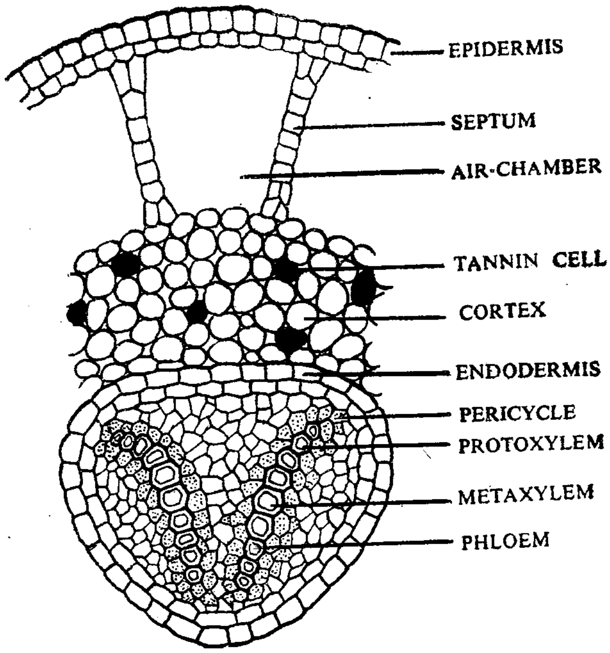
(Marsilea has both hydrophytic - aerenchyma and xerophytic – scelern-chymatous middle cortex and pith in them.)

Petiole:

The petiole is circular in outline.

Epidermis is single layer made up of rectangular cells.

Cortex differentiated into outer and inner cortex.



Portion of T.S. of petiole of *Marsilea*

The outer cortex is parenchymatous (aerenchymatous), enclosing large air chambers separated by septa are trabeculae.

The inner cortex is made of compact parenchymatous cell. Scattered in this region are few starch cells and tannin cells.

The stele is more or less triangular. It is protostele.

Endodermis is single layered followed by single layered pericycle.

The xylem consists of two 'V' shaped strands arranged in such a way that they look 'Y' spahed when seen together.

Each xylem strand has larger one or two tracheids in the middle and smaller trachieds at either ends. Thus, the protoxylem is exarch.

The xylelm is surrounded by phloem.

Leaflet:

The leaflet show upper and lower epidermis

The stomata are generally present on both the surfaces but in floating leaves they are found only on upper epidermis.

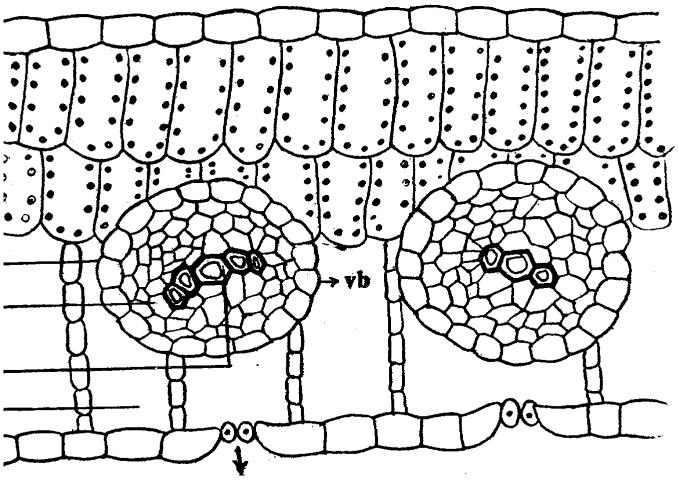
Epidermis

Palisade parenchyma

Endodermis

Phloem

Xylem



Aerenchyma

Stomata

T.S. of a leaflet of *Marsilea*. (vb-vascular bundle)

The mesophyll consists of upper palisade and lower spongy parenchyma.

The spongy parenchyma has large air chambers separated by transverse septa.

The vascular bundles are concentric type. Each vascular bundle consists of central reduced xylem surrounded by phloem.

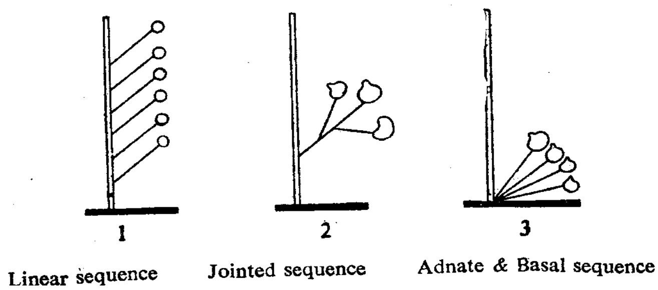
The vascular bundles are enclosed within endodermis and pericycle.

Vegetative propagation:

Vegetative propagation is by means of tubers (*M. hirusta*). These are small, condensed side branches having leaf primordial. The tubers persist even after a plant dies during unfavourable conditions and on the availability of favourable conditions, develop into a new plant.

Reproduction:

The spore bearing structure is called as sporocarps. It is heterosporous. Each sporocarp has a short stalk-the pedicel. The mode of attachment of the pedicel to the plant is varied. Three distinct types are found. They are:



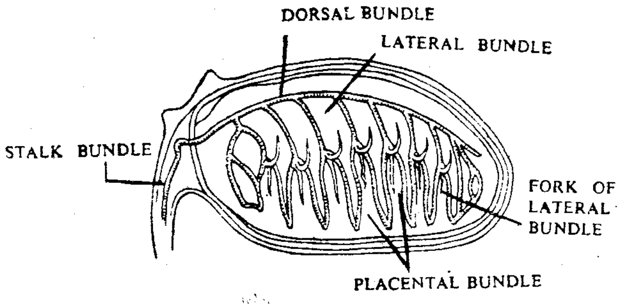
Diagrammatic representation of three possible types of attachment of the pedicels to the petiole.

Linear sequence: In *M. polycarpa* and *M subangulata* the pedicels are directly attached to the petiole in a linear sequence.

Joint attachment: In *M. quadrifolia* the pedicels of many sporocarps join together and have a common stalk joined to the petiole.

Adnate and basal attachment: In *M. vestita* a pedicel are free of slightly connate with an attachment to the base of the petiole.

The vascular supply of the sporocarp consists of a single vascular trace called the dorsal medium bundle (DMB) or dorsal bundle, along the narrow



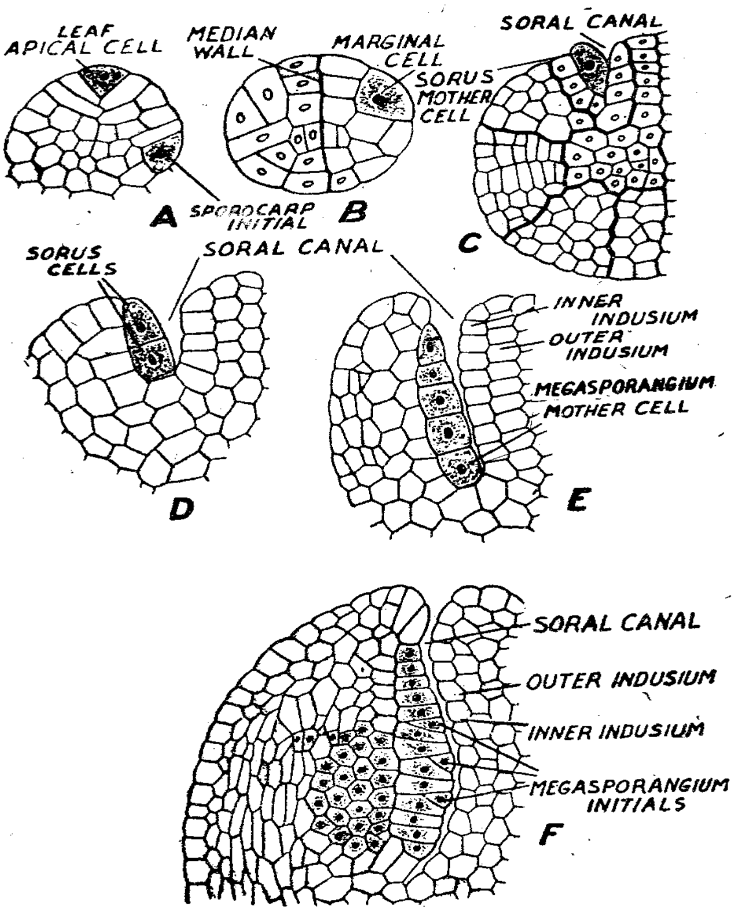
Vascular supply of *Marsilea* sporocarp.

side facing the peduncle, from which are given off alternately right and left dichotomously branched lateral-vein at right angles to the dorsal bundle. A receptacle develops at the region where each lateral vein forks. Receptacles on the half of the sporocarp alternate with those on the opposite half. A flap-like outgrowth, two celled in thickness, develops in a hood-like manner over the entire receptacle.

The soporocarp is bisporangiate. At the point of attachment of the pedicel to the body of the sporocarp there are one to two teeth like projections called tubercles. The end of the stalk which is fused laterally to the back of the sporocarp is called raphe.

Development of the sporocarp:

Sporocarp development originates early in the ontogeny of the leaf. In a young leaf one of the transversely placed apical cells gives rise to the sporocarp long before the appearance of the lamina. In a young growing sporocarp the tip enlarges and is directed horizontally. With the



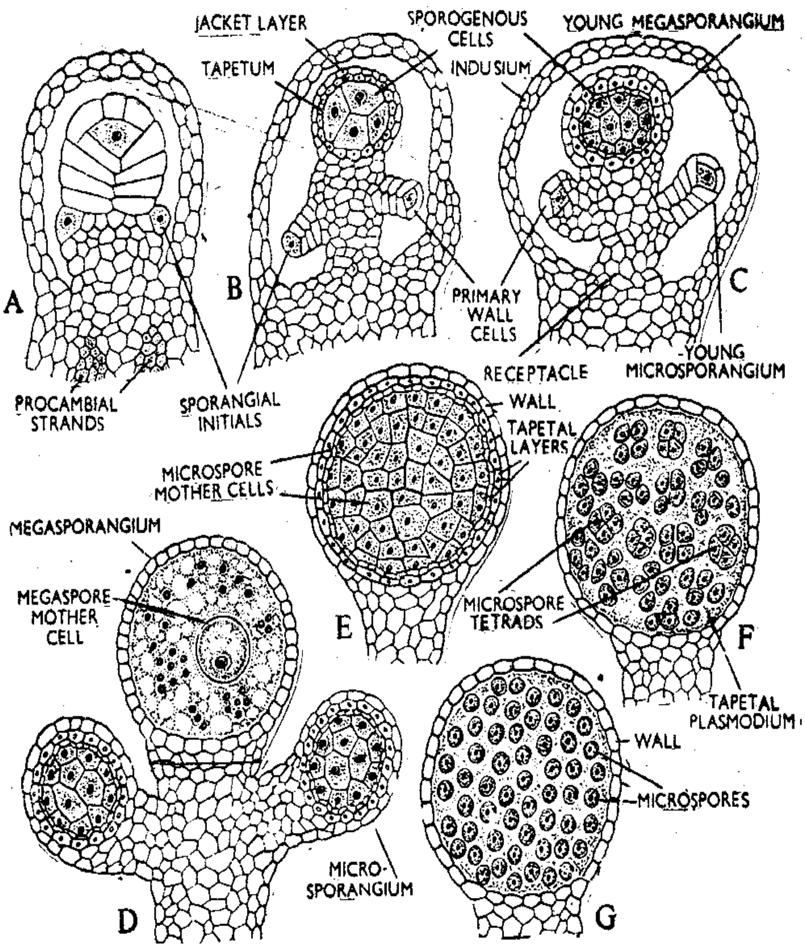
Stages of development of sporocarp in *M. quadrifolia.*

A. young leaf; B. T.S. of young sporocarp; C. development of one half of leaf; D-F stages of development of sorus and soral canal.

enlargement of the tip two rows of soral mother cells appear on the ventral side. These give rise to two rows of sori. When sori are developing, the marginal cells withdraw and form spaces called the soal canals. The soral canal is lined at its inner face by a tissue called indusium. Each sorus consists of a band of fertile tissue called the receptacle. From this the sporangial initial arises.

Development of sporangia:

Both the mega and micro sporangia develop by leptosporangiate method. The sporangial initial develop first at the apex of each ridge-like receptacle.



Stages of development of sporangium of *Marsilea.*

A. T.S. of young sorus with 1 terminal megasporangial mother and 2 microsporangial initial; B-D. later stages of development; E. young microsporangium; F. mature microsporangium; G. mature microsporangium

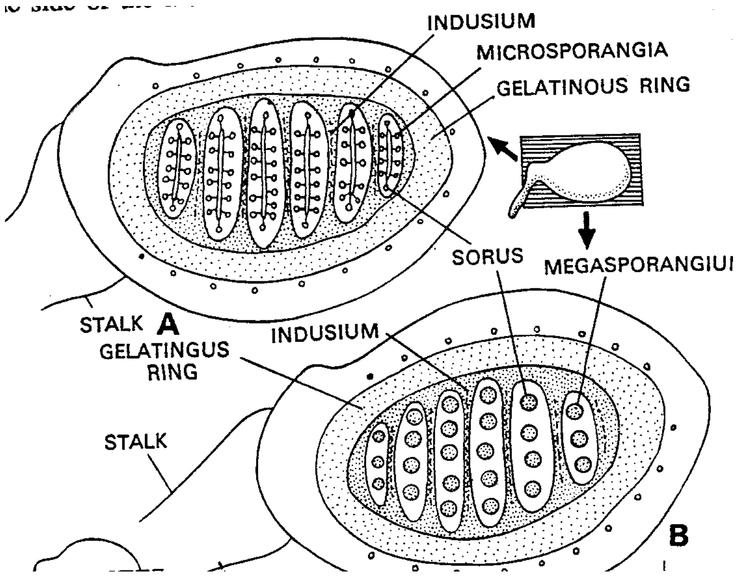
This sporangial initial divide periclinally to form an outer cell and a lower cell. The inner cell does not contribute to any part of the sporangium. The outer cell cuts off a tetrahedral apical cell by three intersecting divisions. Segments that are cut off from the three sides develop into stalk and basal portion of the jacket. The apical cell, then divides periclinally to form an outer jacket initial and an inner primary archesporial cell. The jacket initial by anticlinal division builds up a single layered jacket. The primary archesporial cell on each of its side cuts off tapetal initials. The tapetal initials develops a two to three layered tapetum. The central cell is now called the sporogenous cell and divides repeatedly to form 8-16 spore mother cells. These divide meiotically to form 32-64 spores.

At this stage, in megasporangium, all the spores except one degenerate. Their contents mingle with those of the tapetal cells forming a multinucleate plasmodium. The functional megaspore absorbs large quantities of food material, increase in size and become somewhat ellipsoidal.

In microsoporangium, all the spores are functional, arranged in tetrads, hence show faint triradiate ridge. Unlike *Selaginella*, the spores of *Marsilea* do not germinate until they have been shed from the sporocarp.

Internal structure of the sporocarp:

Dorsiventral section: the sporocarp, when cut dorsiventrally reveals, an outer thick epidermis formed of broad, columnar-cells with stomata. Below this lies a two-celled thick hypodermis. The first layer consists of much elongated columnar cells, supposed to contain the controversial ‘linea lucida’ or linea obscura’. The second layer is formed by thick walled elongated brick shaped palisade cells. These lie at right angles to the epidermis and provide mechanical strength to the wall. This layer is followed by a layer of gelatinous tissue. The sporocarp seems to be modified

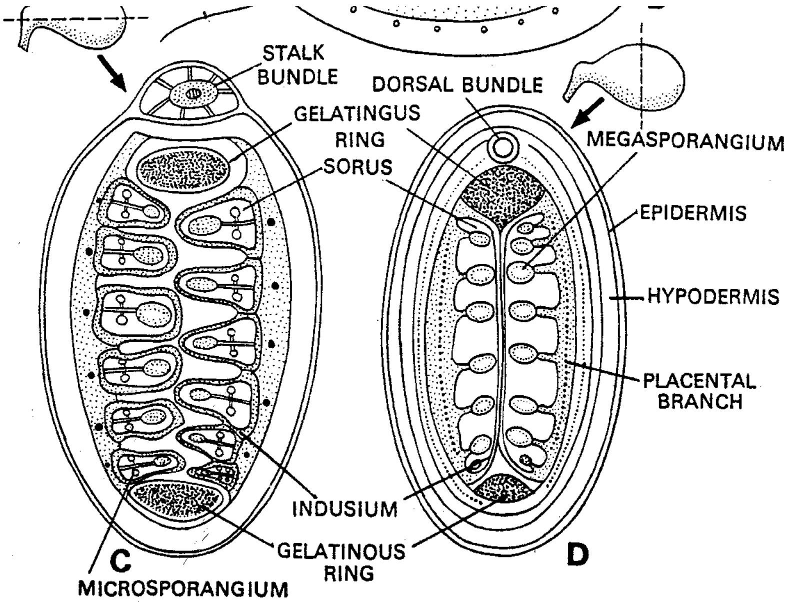


Dorsiventral section of *Marsilea* sporocarp plane showing A. microsporangia B. megasporangia.

leaf or blades enclosing a group of sori. Each sorus is formed in a cavity that extends dorsiventrally and the latter is lined with a delicate indusium completely investing the sours which contains micro and mega sporangia. The receptacle of the sorus is ridge like and gears along its top a row of megasporangium and around its side many microsporangia. Thus the sporocarp shows two rows of chambers which alternate with one another and run from above downwards.

Transverse section: It shows two chambers or sori surrounded by their indusial. Each sorus contains a receptacle which possesses only one kind of sporangia either micro or megasporangia.

Longitudinal section: It has two alternating rows of sori, surrounded by a two layered indusium. The receptacle possesses a single terminal megasporangium and the microsporangium are laterally arranged on the



Marsilea sporocarp C. longitudinal section; D. transverse section

side. There is only one megaspore in the mega sporangium whereas the microsporangium contains many microspores.

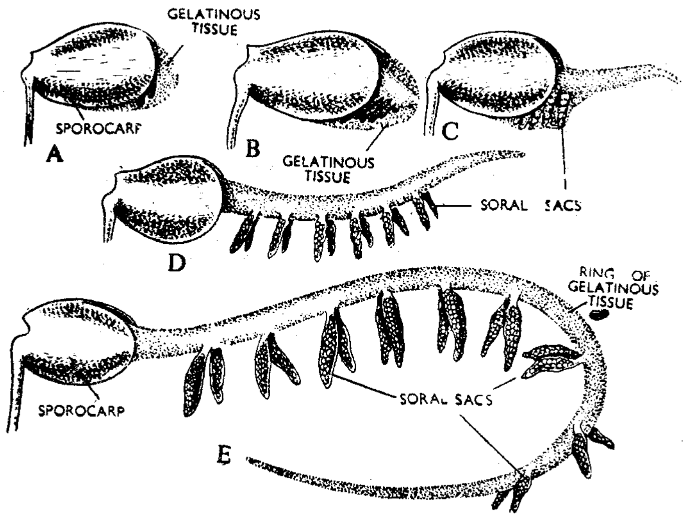
Morphological nature of the sporocarp:

Two main hyphothesis have been seen

1. Laminar hypothesis: Bower *et al.* proposed this hypothesis. According to this hypothesis, the sporocarp is regarded as a modified fertile-segment from the lower parts of the leaf.
2. Petiolar hypothesis: Jhonson proposed this theory. According to his view, sporocarp is homologous with the swollen end of the petiole one of the sterile branch of the leaf, in which the marginal cells are developed for the formation of the sporangia instead of lamina. This is supported by the fact that the apical growth of the sporocarp resembles that of an entire leaf rather a pinna.

The laminar hypothesis is more accepted, and sporocarp is considered as a lateral fertile modified segment.

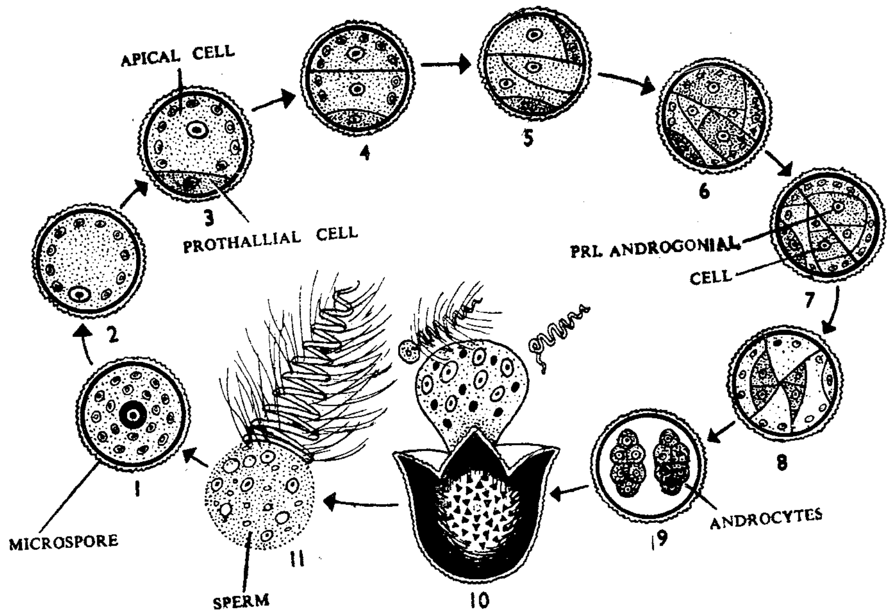
Dehiscence and liberation of sori from sporocarp:



Liberation of sori from *Marsilea* sporocarp

The sporocarp wall is very thick. So by either mechanical injury or by the bacterial rotting, the dehiscence is initiated. The sporocarp opens only in the water. The sporocarp absorbs water and splits open along the ventral suture. The ring of gelatinous tissue which extends around the cavity expands and protrudes out. A break occurs in the ring and ring extends out like a long gelatinous band carrying sori called sorophore. The sorophore bears two rows of soral sacs one on either side alternating with one another. The sorus breaks connection with the sorophore, so also the sporangia with the sori. Ultimately the sporangial wall ruptures liberating the spores.

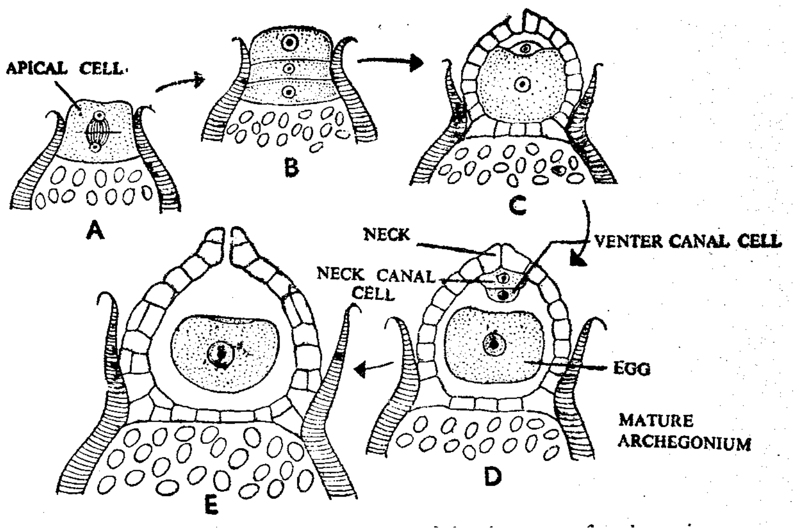
Microspore and development of male gametophyte:



Sequence of male gametophyte development: 1. microspore; 2. germinating microspore; 3. division into small prothallai and large apical cell; 4. apical cell into two anthredial initial; 5-6 later stage; 7. formarion of two androgonial cells; 8-9 formation of androcytes; 10 ruptured microspore; 11. multicillate sperm.

A microspore is globose in shape, and 0.06 to0.075 mm in diameter. It is surrounded by a thick outer-wall consisting of the outermost transparent epispore and exospore, and a delicate thin endospore. It has a single central nucleus and dense cytoplasm containing starch grains. The spores germinated at once when set free. The first evident change in the germination of spore is the migration of the starch grains to the periphery. The nucleus of the microspore moves to a side where it undergoes a division to cut off a small porthallial cell and a large primary antheridial cell. The primary antheridial cell divides by an oblique or diagonal wall to form two antheridial cells, each of which forms an antheridium. Each antheridial cell cuts off a periclinal cell to form a central cell and a jacket cell. The central cell cuts off a small sterile cell and a large cell. The sterile cel forms the second jacket cell. The large cell divides periclinally and forms the third hjacket cell and a central primary androgonial cell. At this stage the antheridium has one prothallial cell and two primary androgonial cells and six jacket cells. Each primary androgonial cell gives rise to 16 anthrozoids (totally 32 in a gametophyte) which are cork screw shaped and multiflagellate. At maturity the jacket cells disintegrate liberating the antherozoids.

Megaspore and development of female gametophyte:



Sequence of development of archegonium in *Marsilea*.

The megaspore are ellipsoidal with a small rounded protuberance at the anterior pole. Size varies from 0.41X0.36 to 0.8X0.05 mm. They are sufficiently large enough to be visible to the unaided eye. The mucilaginous spore wall round the protuberant portion is relatively thin and the triradiate ridge is visible. Like the male gametophyte the female gametophyte also develops rapidly on liberation.

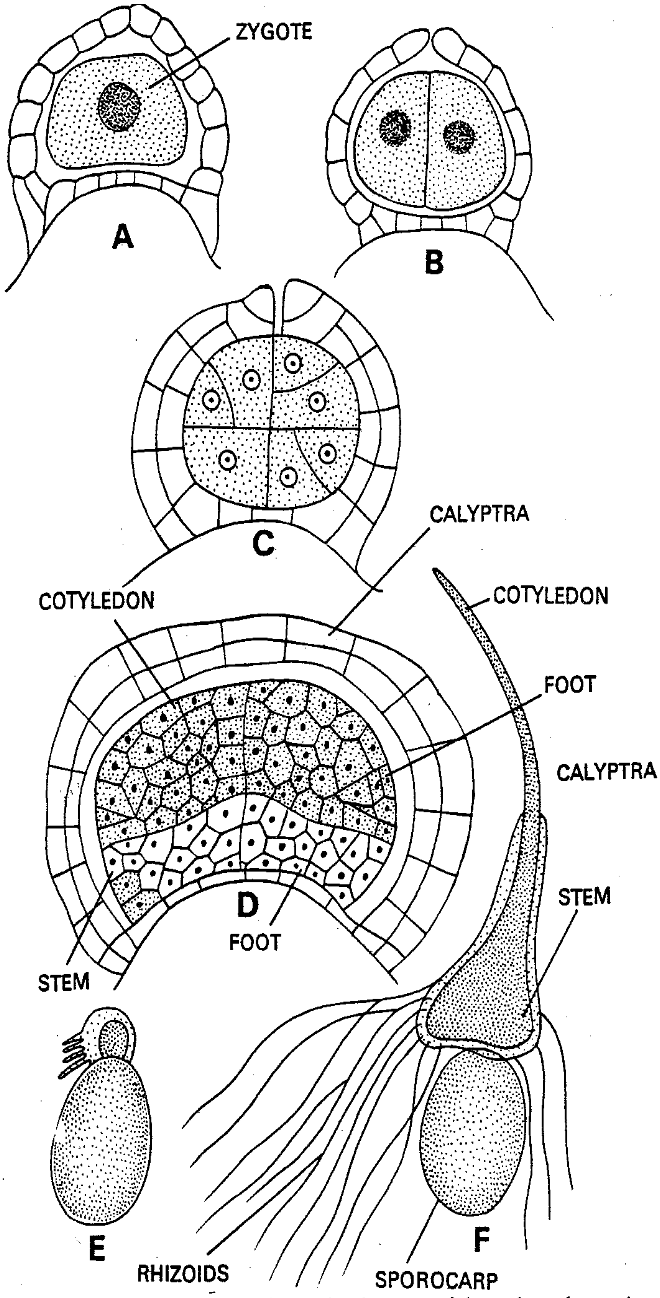
The nucleus lies in the dark coloured anterior protuberant apical portion having dense granular cytoplasm. The remaining basal protoplasm contains large starch grains, oil, albuminous matter embedded in a watery cytoplasm. The first division is transverse and it cuts off a small cell limited to the papilla region and a large bsal cell occupying the remainder of the cavity. The entire gametophyte is derived from the papilla cell. The basal cell does not divide further. Subsequent divisions in the papilla cell result in the formation of a central cell surrounded by three peripheral cells this cuts off a basal cell and functions as the archesporial initial. The remaining cells divide transversely as well as vertically to build a small amount of vegetative tissue. The archegonial initial divides periclinally to form an upper primary cover cell and a lower central cell. The primary cover cell divides to form a neck of two tiers of four cells each. The central cell divides to form a primary canal cell and a primary venter cell. The primary canal cell may or may not divide. Primary venter cell divides to form a venter canal cell and an egg cell.

A mature gametophyte has a cap of tissue enclosing the single archegonium and a basal unicellular portion. The nucleus in the basal nutritive portion of the gametophyte may divide amitotically. The female gametophyte is surrounded by a gelatinous layer which has a funnel shaped opening above to receive the antherozoids.

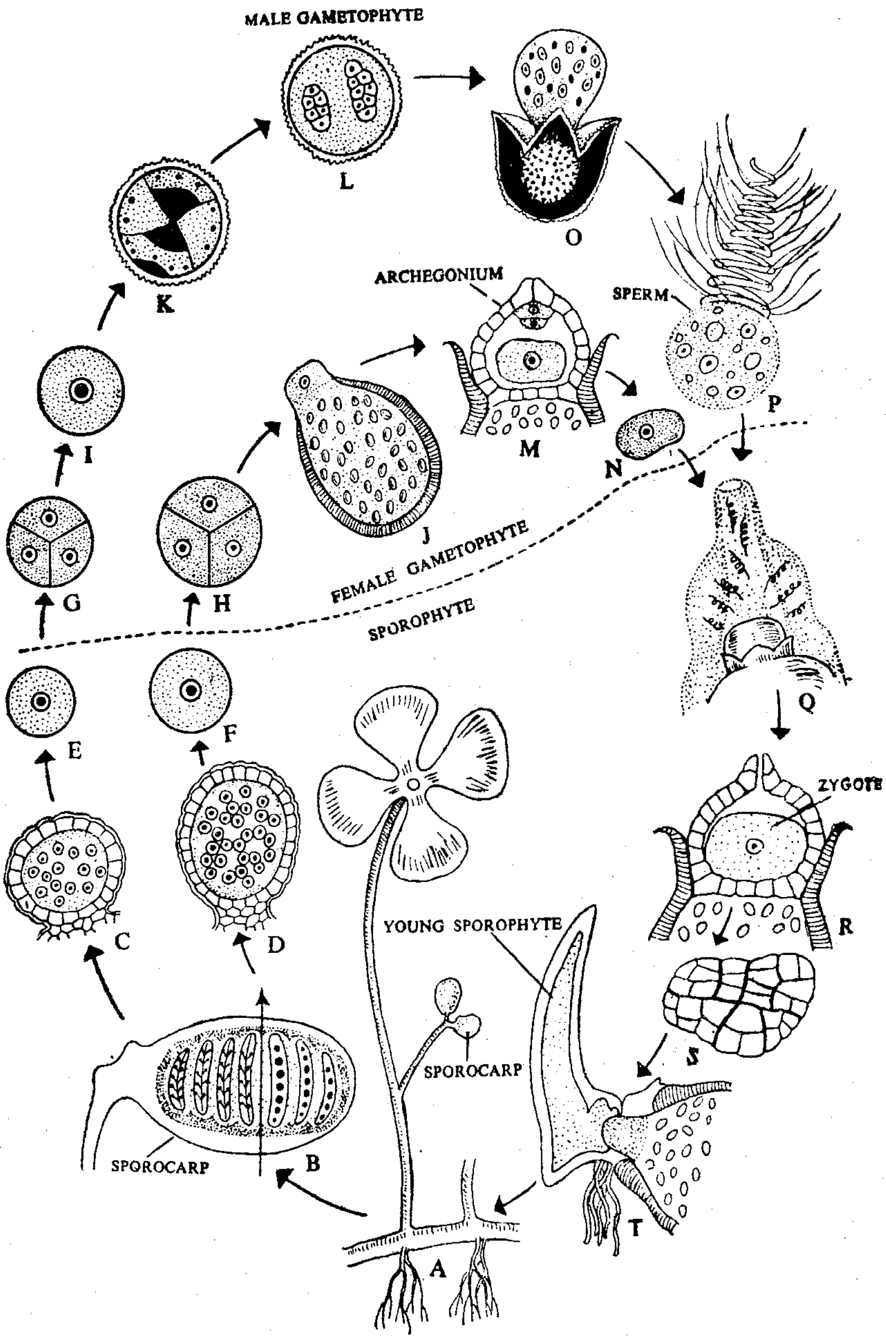
Fertilization

The chemotactic sperms are attracted towards the gelatinous envelope and most of them enter it, some reaching the archegonium while others failing to do so. Only one fuse with the egg and the others become trapped in the gelatinous material nearby. The sperms are greatly stretched out as they die. The orientation of the sperms becomes reversed, as it penetrates the egg nucleus. The result of the fertilization is a diploid zygote.

Development of embryo:



A-D. Successive stages in development of embryo; E. sporocarp with young embryo; F. advanced stage of embryo in median longitudinal section.



Diagrammatic representation of the life history of *Marsilea*.

The development of the embryo takes place rapidly and a sporophyte with the first leaf several mm long is formed within 2 to 4 days after fertilization. The first division of the zygote is parallel to the long axis of the archegonium *i.e.,* vertical. Later on the two daughter cells of the zygote undergo a division in a plane perpendicular to that of the first division thus a quadrat embryo is formed. The outer segments of this embryo form leaf and root, while the inner segments give rise to the stem and foot. With the development of embryo, the cells of the venter are stimulated to divide periclinally and form a growing-sheath, the calyptra which surrounds the young sporophyte. A few rhizoids develop from some of the lowest cells and the upper tissues become green. Growth of the calyptra keeps pace with that of the embryo for the first four or five days but this disappears about the same time when the primary root penetrates the soil or substratum. The embryonic sporophyte grows rapidly.

SELF ASSESSMENT QUESTIONS:

1. The spore bearing organ of Marsilea is __________.
2. ___________ of sporangial development is seen in Adiantum.
3. Coiling of young leaves in pteridopytes is called as ____________.
4. Xerophytic characters are exhibited by _________ species of Marsilea.
5. the sorus of Adiantum are protected by __________.

Summary:

In the last unit you learnt two eusporangiate pteridophytes, whereas in the present you understood two leptosporangiate pteridophytes.

Many species of Adiantum is seen widely distributed in India.

It is a homosporous form, and sori are grown on the reflexed outgrowth of fertile pinna.

Marsilea is an advanced heterosporous form. Eventhough the development is endosporic, the seeds are liberated in an early stage of embryo development than seen in Selaginella.

NOTES

UNIT - IV

General characters of sporophytes and gametophytes of Gymnosperms. Classification (K.R. Sporne) of Gymnosperms. Detailed study of the following genera- *Cycas* and *Pinus*.

Introduction:

In this unit you are going to study the next divisions of plants, the Gymnosperms. Unlike pteridophytes, they are true seeded plants, but the seeds are naked. Two widely distributed, and cultivated genera are discussed in this unit in detail.

General characters of sporophytes and gametophytes of Gymnosperms.

The gymnospoerms (gymnos-naked; sperma-seed) are naked seeded plants.

The group includes about 70 genera and 725 living species. Besides it includes a large number of extinct fossil plants.

Habit:

They are represented by the plant bodies which are diploid (sporophyte). They are perennials of usually arboreal evergreens (*Sequoia* up to 125 meters height and 30 meters girth), shrubby habits, or rarely climbers (Gnetales) occurring mostly under xerophytic conditions of life. No herbs are seen.

Roots:

The radicle forms the tap root. The tap root system is exarch and diarch to polyarch.

The tap roots may contain fungus (mycorrhiza) or algal cells (coralloid root of *cycas*).

Stem:

Stems are tall erect. In some it is underground tuberous- *Zamia pygmia*. Tht stem is generally branched. But it is unbranched in cycas. Mostly they are woody. They bear characteristic leaf scars.

In some genera (*Pinus*) two types of branches are seen: Long shoots and dwarf shoots that bear at their apices a clusters of green leaves collectively known as spur.

Majority of the gymnosperms are monostelic with distinct pith, though a few may be polystelic.

Vascular tissue is well developed. Stem possess collateral, endarch and open vascular bundles. Due to the presence and activity of cambium, secondary growth is present.

Xylem consists of xylem parenchyma and trachieds. The trachieds are homoxylous with bordered pits in their radial walls. Vessels or wood fibres are absent except in Gnetales.

Phloem consists of sieve tubes, phloem parenchyma and sometimes fibres. Companion cells are absent. Resin ducts are abundant.

The secondary wood may be either manoxylic or pycnoxylic.

The manoxylic wood is without any commercial value; it is soft and relatively thinly distributed with very wide rays made of parenchyma cells. *E. g*., Cycadales.

The pycnoxylic wood is of much commercial importance, as it forms the most important constituent of the total timber output of the world. This type of wood is dense, compact and possesses very narrow wood-rays. *E. g.*, Coniferales.

Leaves:

Leaves are mono or dimorphic.

If dimorphic, two widely different types of leaf are found- the microphyll and megaphyll.

Microphyll are usually small, deciduous leaves with only one or two veins; but sometimes rather larger leaves with parallel venation are also meant by the same. In *Pinus* they are needle like.

Megaphyll is meant to relatively larger type of cutinized leaves with a fern-like branching and having branched veins. They may be pinnately compound as in *Cycas*.

Leaves are mostly evergreen and possess resin passages (Pinus), or lacks resin passage (e.g., Gnetales) and posses' latex tubes.

Usually the leaves are arranged in a spiral manner except in Cupressaceae and Gnetales where their arrangement is cyclic(*Cedrus*) or opposite decussate (*Gnetum, Weltitschia*, *Ephedra*). Forking of rachis and that of leaflets is seen in *Cycas circinalis*.

The venation may be reticulate (*Gnetum*), parallel (*Welwitschia*) or even dichotomous (*Ginkgo*).

The leaves of conifers and cycads possess a transfusion tissue.

Stomata may be syndetocheilic or haplocheilic. The stomata may be on both surface (*Ginkgo biloba*) and on lower epidermis alone (*Cycas, Taxus).*

The mesophyll may (Cydacs, *Gnetum*) or may not (*Pinus*) be distinguished into palisade and spongy parenchyma.

Leaves may be triangular (*Pinus roxburghii*), semi circular (*Pinus sylvestris*), circular (*Pinus monophylla*) and bifacial (*Cycas, Gnetum*).

Reproduction:

Gymonosperms reproduce both asexually and sexually, though sometimes vegetative reproduction may also take place. *E. g.,* bulbils in cycads.

The reproductive parts are generally arranged in the form of compact and hard cones or strobilli. The cones are unisexual. Hermaphrotide cone in certain members occur sometimes as an abrnormality. In certain genera like *Cycas*, however, reproductive structures are not present in the form of compact cone like structures.

Male cones are usually smaller and short lived than female cones.

The sporangia are borne upon their respective sporophylls *viz*., microsporophyll or anther and megasporophyll or carpels.

The sprophylls may form compact cones or strobili or may remain in loose aggregations.

In male cones, many microsporophylls are arranged on the central axis, each having many microsporangia containing microspores or pollen. The microporophyll may be broad (e.g., *Cycas*) or peltate as in *Dioon* and *Taxus.*

The sporangial development is like the eusporangiate ferns.

The sporophytic plants produce spores (microspore or pollen grains and megaspores) within sporangia of two types- microsporangia or anthers and megasporangia or ovules.

The microsporangia are arranged in soral groups or 3-5 as in *Cycas* or their number is reduced to only a pair as in *Pinus*, whatever the number be, the microsporangia are always on the lower (abaxial) surface of the microsporophyll.

The microspore on germination, gives rise to the pollen tube (male gametophyte) bearing the flagellate or nonflagellate male gametes.

The male gametophyte has only one (*Cycas*) or two (*Pinus*) porthallial cells.

Ovules are unitegmic or rarely bitegmic and arthortropous and are formed on the surface of megasporophyll without any covering over them.

The integument consists of an outer fleshy, a middle stony and an inner fleshy layer, and surrounds the nucellus. Both these outer structure represents the sporophyte.

At the tip of nucellus, there is a minute opening the micropyle. Within the nucellus the female gametophyte (endosperm) containing two or more archegonia which have a tendency to eliminate the venter canal cell and neck canal cell.

Archegonium is without neck canal cells. Each archegonium has one egg cell.

The female gametophyte or embryo sac developed from megaspore bears egg the female gamete. They are non green, simple and dependent on sporophyte.

The female gametophyte follows the same sequence of development which occurs in heterosporous pteridophytes. But *Gnetum* is an exception in this, the eggs mature at the stage of free nuclear division, the most embryonic stage of female gametophyte.

The pollen tube grows through the tissues of the female prothallus and reaches the archegonium which awaits fertilization.

An outer structure form an aril, is often present in Taxus.

Pollination is anemophilous (wind) type. The pollen grains come in contact with the ovule directly.

The zygotes (oospore) is produced as a result of fertilization, which gives rise to the embryo, which later develops meroblastically (i.e., develops from a small part of zygote) into a new sporophytic plant.

The proembryo differentiates into three zones; outer rosette or haustorial, middle suspensors and the basal embryonal cells.

The cells of suspensors grow out into long tubes, thus pushing the lower part of the archegonium. The elongated suspensors make their way to the nutritive endosperm which is formed before fertilization.

Sometimes the adjoining tubes of the suspensors, separate from one another and each produces at its apex a rudimentary embryo. Thus several rudimentary embryos are seen in an immature seed. Thus polyembryony is present in many members e.g., *Pinus*. When mature only one embryo develops, the others degenerate.

During development of an embryo, endosperm increases considerably in size and finally supplants the surrounding tissue of the nucellus. It is here a straight embryo distinctly differentiated into stem, leaves and root lies. The radicle lies toward the micropylar end whereas the plumule towards the basal end. There are either two cotyledons as in *Cycas* or many as in *Pinus*. Usually, the cotyledons are green even though they remain within the seed. The integuments now transform itself into a fleshy or stony seed-coat.

True fuits are lacking because of the absence of the ovary.

Mature and ripened ovule forms the seed. Seed coat is being formed by the integuments of ovule. In cycads, the seeds are fleshy due to the outer fleshy layer.

The seed on germination ruptures the seed-coat through which the radicle comes and gradually a young sedling plant unfolds itself. It consists of an erect stem which passes without any dintinct line of demarcation into strong primary tap-root which forms an extensive root system. The young stem grows vertically upwards and its growth is unlimited though it ceases in case of *Welwitchia*.

There is very distinct alternation of generations in the life cycles of the gymnosperms.

The diploid or sporophytic stage is dominant and independent while the haploid or gametophytic stage is dependent and reduced.

Representatives of orders like Cycadofilicales, Bennettitales and Cordaitales are altogether extinct and occur only as fossils while that of

Cycadales, Ginkoales and Coniferales are living as well as extinct. Members of Gnetales are living

Sporne (1965) Classification of Gymnosperms:

Fossil plants presents problem to the taxonomist, but living plants are classified based on the totality of characters. But for fossil plants, it is most convenient to have a separate classification for stem, leaves, and seeds and so on. Sporne has adapted Engler's method of classification.

lasses	Orders	Families	Examples
1.Cycadopsida	1.Pteridopermles*	1.Lyginopteridacea	*Lygnopteris*
		2.Meulosaceae	*Medullosa*
		3.Calamopityceae	*Calamopitys*
		4.Glossopteridaceac	*Glossopteris*
		5.Peltaspermaceae	*Lepidopteris*
		6.Corystospermaceae	*Xylopteris*
		7.Caytoniaceae	*Caytonia*
	2.Bennettitales*	1.Williamsoniaceae	*1.Williamsonia*
		2.Wielandiellaceae	*2.Wielandiella*
		3.Cycadeoideaceae	*3.Cycadeoidea*
	3.Pentoxylales*	1.Pentoxylaceae	*1.Pentoxylon*
	4.Cycadales	1.Cycadaceae	*1.Cycas*
		2.Nilssoniaceae	*2.Nilssonia*
2.Coniferopsida	1.Cordaitales*	1.Erytophytaceae	*1.Erytophyton*
		2.Cordaitaceae	*2.Cordaites*
		3.Poroxylaceae	*3.Poroxylon*
	2.Coniferales	1.Lebachiaceae	*1.Lebachia*
		2.Voltziaceae	*2.Voltziopsis*
		3.Palissyaceae	*3.Palissya*
		4.Pinaceae	*4.Pinus*
		5.Taxodiaceae	*5.Taxodium*

		6.Cupressaceae	*6.Cupressus*
		7.Podocarpaceae	*7.Podocarpus*
		8.Cephalotaxaceae	*8.Cephalotaxs*
		9.Araucariaceae	*9.Araucaria*
	3.Taxales	1.Taxaceae	*1.Taxus*
	4.Ginkgoales	1.Trichopityaceae	*1.Trichopitys*
		2.Ginkgoaceae	*2.Ginkgo*
3.Gnetopsida	1. Gnetales	1.Gnetaceae	*1.Gnetum*
		2.Welwitschiaceae	*2.Welwitschia*
		3.Ephedraceae	*3.Ephedra*

Order1. Pteridospermales:

Plants with relatively slender stems. Primary xylem mesarch (rarely exarch) in the form of a solid or a medullated protostele or reduced to circum-medullary strands. Sometimes polystelic. Secondary wood limited in amount, manoxylic and composed of trachieds with multiseriate piting, especially on the radial walls. Leaves mostly large and fern-like, often many times pinnate. Ovule and seed borne either on the frond or on a specially modified frond (megasporophyll) which is not part of a cone.

Order 2.Bennettitales:

Stem with wide pith, stout and pachycaulic or relatively slender and forking. Leaves compound (rarely simple) with open (rarely closed) venation. Stomata syndetocheilic. Reproductive organs in hermaphrodite or unisexual 'flowers', protected by numerous bracts. Ovules stalked, very numerous, scattered over a conical, cylindrical or dome shaped receptacle, along with interseminal scales, more or less uinted at the distal end to form a shield, through which the micropyles protruded. Seeds with two cotyledons. Pollen bearing organs in a whorl, free or united, pinnate or entire, with numerous microsporangia, usually in capsules.

Order3. Pentoxylales :

Fossil plants, habit unknown, but probably shrubs or very small trees. Long and short shoots, the latter bearing reproductive organs terminally and spirally arranged leaves. Stems- polystelic. Wood rays uniseriate. Leaves thick, simple, lanceolate. Venation open (anastomoses very rare). Female organs like stalked mulberries; seeds sessile, united by fleshy outer layer or integument. Male organs consisting of a whorl of branched sporangiophores, fused basally into a disc.

Order4. Cycadales:

Woody plants with stems unbranched or with occasional adventitious branching. Manoxylic. Mucilage canals in pith and cortex. Some genera with additional co-axial vascular cylinders. Leaves large, pinnate (rarely bi-pinnate). Leaf trace diploxylic (except in Nilssoniaceae). Dioecious. Reproductive organs in cones (except female *Cycas*) cones terminal or lateral. Megasporophylls with sterile tips and 8-2 orthotropus ovules. Seeds large. Microsporophyll scale-like or peltate with pollen-sacs on the abaxial side. Sperms with spiral band or flagella.

Order5 Cordaitales*

Mostly tall trees with slender trunks and a crown of branches. Primary wood scanty. Secondary wood mostly pycnoxylic. Leaves spirally arranged, simple, up to 1 meter long, grass like or paddle-shaped, with parallel venation. Cones compound, unisexual, consisting of a main axis with bracts subtending secondary fertile shoots bearing sterile and fertile appeanages. Female fertile appendages with one to four ovules. Male fertile appendages with four to six terminal pollen sacs. Seeds bilateral.

Order6. Coniferales:

Branching woody plants, often with long and short shoots. Secondary wood pycnoxylic, made up of tracheids with large uniseriate (rarely multiseriate) pits on the radial walls, and small wood rays. Resin canals in leaves, cortex and (sometimes) in wood. Leaves spirally arranged form opposite, rarely whorled, needle- like or scale-like, rarely broad. Reproductive organs unisexual cones. Female cones fundamentally compound; a main axis with infinite to few bract scales each subtending, or fused with one ovuliferous scale bearing infinite to 2 ovules (rarely one). Male cones simple, usually with many scale-like microsorophylls with 2 to infinite fused or free pollen sacs. Embryo with two to infinite cotyledons.

Order7. Taxales:

Profusely branching, evergreen shrubs or small trees, with spirally arranged small linear leaves. Wood pyconxylic, tracheids with abundant tertiary spirals, no resin canals in wood or leaves. Ovules solitary, arillate, terminating a dwarf shoot, with decussate bracts microsporangiophores in small cones, scale-like or peltate, with two to eight pollen sacs. Embryo with two cotyledons.

Order8. Ginkgoales:

Branching trees with long and short shoots (except in the earliest fossil members). Wood- pycnosylic. Leaves leathery, strap-shaped or fan shaped, often deeply divided, with dichotomous venation. Ovules two to ten, terminal on axillary branching or almost unbranched, axes. Seeds large, with fleshy outer layer and stony middle layer. Male organs axiallary, unbranched, catkin-like, bearing micro sporangiophores each with two to twelve pendulous microsporangia. Sperm with spiral band of flagella.

Order9. Gnetales:

Woody plants; trees, shrubs, lianes or stumpy turnip-like plants with stem partly below ground. Leaves opposite or whorled, simple, broadly elliptic or strap shaped or reduced to minute scales. Secondary wood with vessels. 'Flowers' unisexual and normally dioecious (except some *Gnetum sp.*). Flowers organized into compound strobili or 'infolorescence'. Female flowers with a single erect ovule, the nucellus of which is surrounded by two to three enveloped, the micropyle projecting as a long tube. Male flowers with a perianth and antherophores with one to eight synangia. Fertilization by means of a pollen-tube with two male nuclei. Embryo with two cotyledons.

Cycas

Systematic Position:

Class: Cycadopsida

Order: Cycadales

Family: Cycadaceae

Genus: *Cycas.*

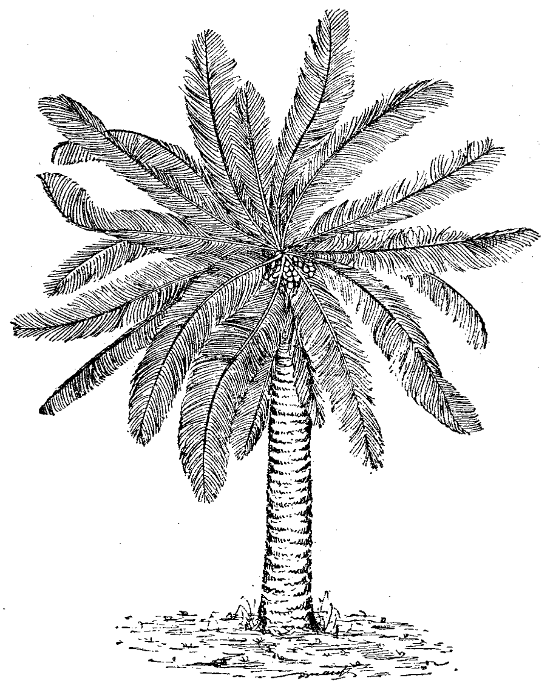
Occurrence:

The plant is widely distributed throughout the world; it grows well in tropical climate nearly on all types of soils.

They are planted in parks and botanical gardens.

The species common in India are *C. circinnalis, C. revolute, C. siamensis etc.*

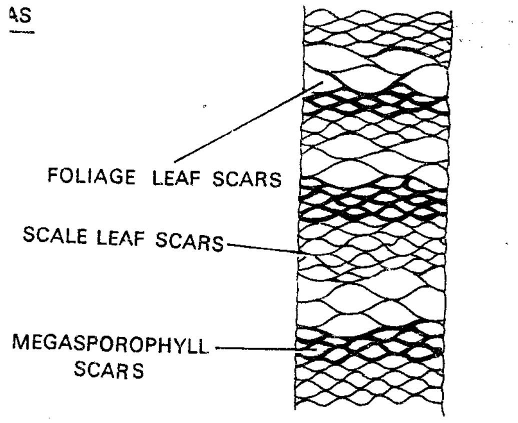
The plant body:



The plant body is differentiated into root, stem and leaves. They are slow growing, long lived and evergreen.

The plant of *cycas* is palm-like and consists of evergreen leaves.

The stem is usually unbranched, stout and tuberous 0.5 to 4 (sometimes 13-15) meters long. The old stem shows armour of leaf bases.



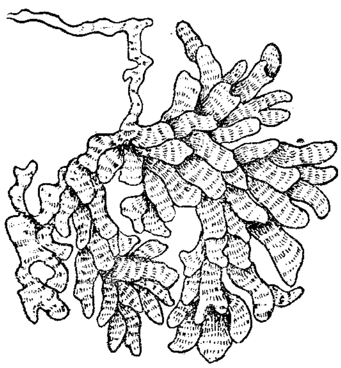
The root is tap in young stages but in older plants it is replaced by adventitious type.

The roots of *Cycas* are of two types-normal and coralloid roots.

The leaf bases are covered with woody scales.

Bulbils may be present in axil of these scales.

Coralloid root:



Some of the ultimate branches of the primary roots grow vertically into coralloid roots.

These roots are dichotomously branched negatively geotropic arising from main root and coming out on the surface of the soil.

Their tips become swollen and do not bear the root caps.

There are several lenticel like apertures found on the surface of roots.

Coralloid roots resemble with corals (body of coelenterate animals) hence are called coralloid roots.

These roots are blue green in colour and are inhabited by myxophycean algae.

Normal roots:

They are positively geotropic, well developed and bear conical root caps at their tips. Some times they are as thick as the stem.

Stem:

The stem is woody erect, stout, columnar and arborescent with a crown of leaves at the apex.

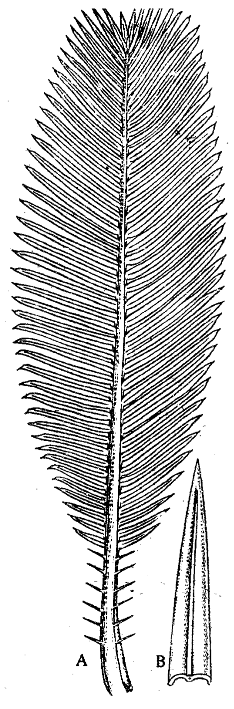
Stem is usually unbranched (rarely branched). It is covered with hard armour of leaf bases.

The leaf bases are large, representing foliage leaves; and small representing scale leaves. They alternate with each other and used as an index of age.

Leaves:

Leaves are spirally arranged at the apex of stem.

Two types of leaves are found: green assimilatory leaves and scales or cataphylls; both of these are arranged around the axis in closely set spirals. The assimilatory leaves are circinately vernated in young condition. On maturation leaves are large (up to 2.5 meters) having stout rachis and are unipinnately compound and arranged spirally on the stem to form corwn. The rachis is hard, spiny and thick tapering towards apex.



Leaf of *Cycas revoluta*. Assimilatory leaf scaly leaf

The assimilatory pinnae are sessile, spine tipped, leathery and are arranged in two rows along both the sides of rachis. When young, they are covered with ramenta (hairs).

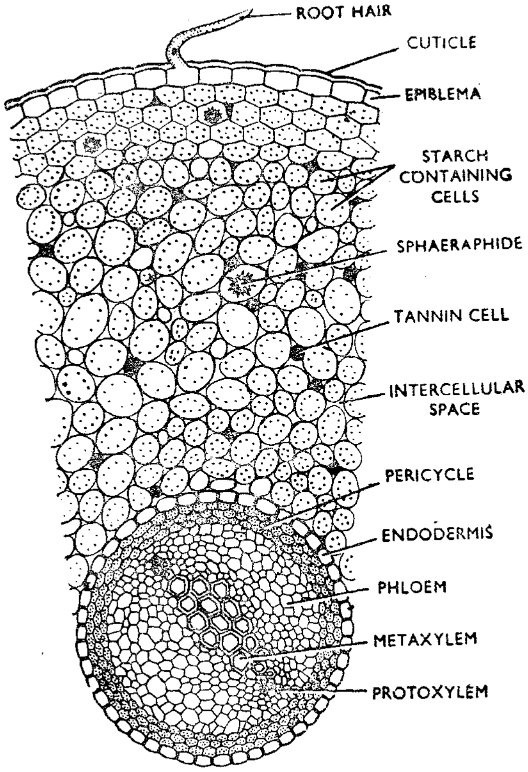
Each assimilatory pinna (leaflet) is with entire margin and a conspicuous mid rib. Lateral veins are absent.

The scale leaves or cataphylls are smaller, dry, and brown in colour, trianglar structure and are covered with rementa.

Internal structure:

Normal young root:

The outline is nearly circular.



Outer most layer is epiblema, is single layered and made up of thin walled parenchymatous cell with root hairs.

Cortex is parenchymatous with cells with starch grains. Dark brown, tannin cells, are scattered in the cortex.

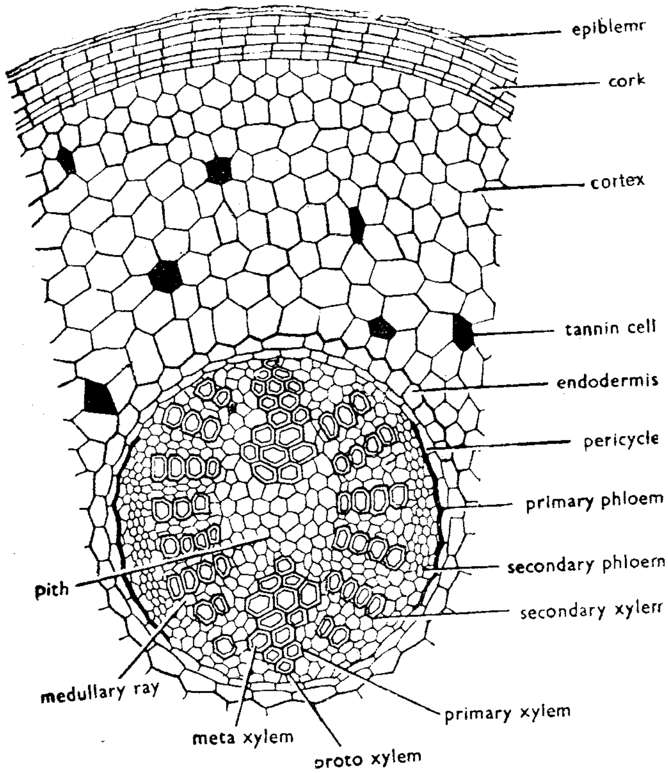
Single layered endodermis is not well demarcated but pericycle is multilayered and distinguishable.

Stele is radial, diarch, exarch.

The pith is small and parenchymatous.

Normal old root:

Periderm is the outermost region and is constituted of suberised cork cells. It is produced by cork cambium.



Cork cambium consists of radially elongated cells and gives rise to parenchymatous cells (phelloderm) towards inner side. The phellodermal cells are identical to those of primary cortex.

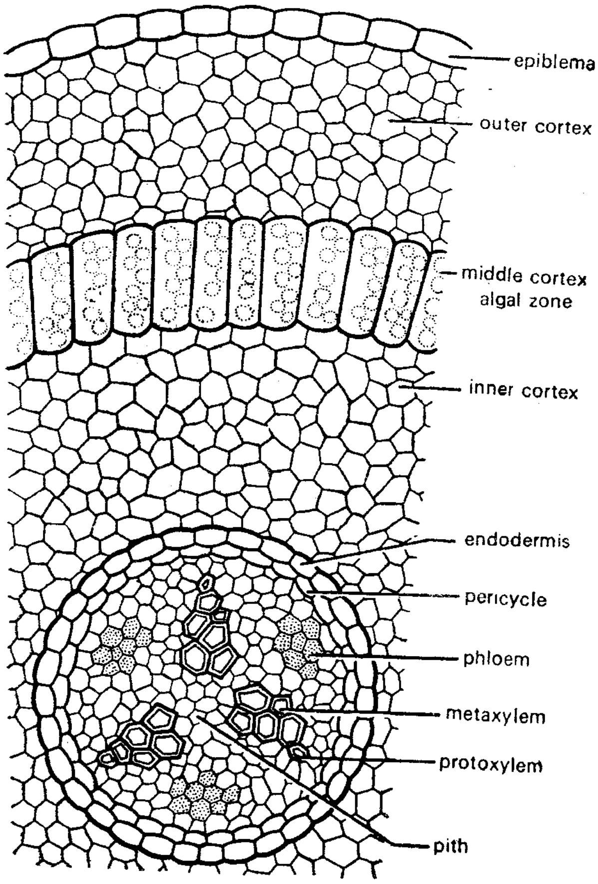
Primary cortex is multilayered and parenchymatous. It may contain mucilaginous canals, and dark brown tannin cells scattered.

Endodermis and pericycle are not very conspicuous after secondary growth.

Vascular cylinder consists of xylem and phloem. The secondary vascular tissues are produced due to the activityof the fascicular cambium formed in a ring. Secondary phloem consists of sieve cells while the secondary xylem is made up of only longitudinal rows of tracheids. Medullary rays are parenchymatous. Primary medullary rays ae formed opposite to proto xylem and secondary medullary rays between the secondary xylem.

Primary vascular zone shows diarch structure showing two patches of exarch xylem alternating with the phloem. The primary phloem is crushed after secondary growth and so not visible in older roots.

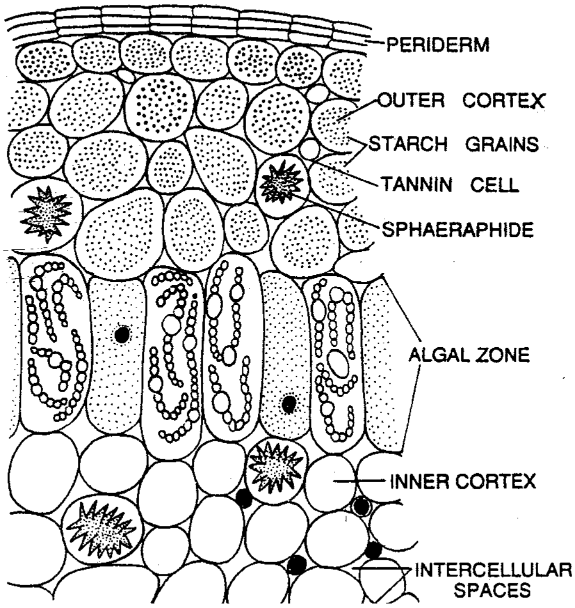
Coralloid roots:



Periderm constitutes the outermost layer. It is made up of suberised parenchymatous cork cells.

Cork cambium phellogen is present below cork cells.

Cortex is much wider, multilayered and made up of rounded parencymatous cells with smaller intercellular spaces. The cells contain dark depositions.



Cortex is differentiated into 3 zones:

Outer parenchymatous

Middle algal zone; the algal zone consists of mainly myxophycean algae, *Anbaena cycadeae* or *Nostoc*.

Inner: parenchymatous.

This algal zone is supposed to serve two important functions of aeration and nitrification. So, some consider the alga as symbiotic in nature.

The mucus of the intercellular spaces of the root provides nourishment to the alga, which are regarded as "innocuous parasites" of *cycas*. There are no conditions present in the root, which can favour free nitrogen assimilation by *Anabena* and hence the root cannot profit in nitrogen by their presence.

Endodermis is single layered.

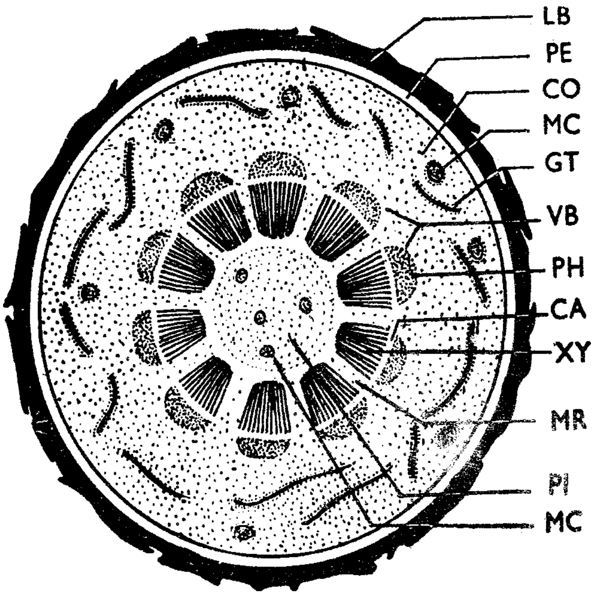
Pericycle is uniseriate.

Stele is triarch or tetrarch siphonostelic. Xylem consists of traceids and the phloem consists of sieve tubes.

Secondary vascular tissues are poorly developed or absent.

Young Stem:

The outline of the section is irregular due to the presence of several persistent leaf bases.



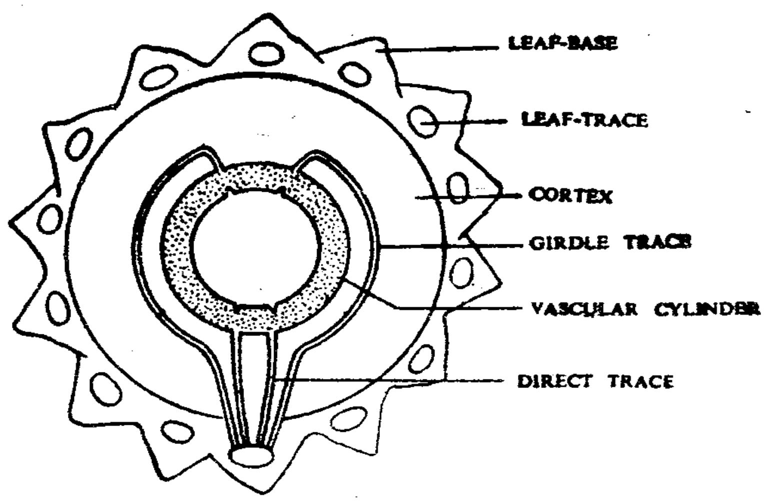
LB=Leaf base
PE=periderm
CO=cortex
MC=mucilaginous canal
GT=girdle trace
VB=vascular bundle
PH=phloem
CA=cambium
XY=xylem
MR=medullary ray
PI= pith

Epidermis is not clearly demarcated.

Cortex is multilayered large parenchymatous. The cells have large intercellular spaces and filled with abundant starch; mucilage ducts are present in cortex and pith regions.

Numerous leaf traces are seen cut into small piece in cortical region. These pieces belong to direct and indirect leaf traces.

The leaf traces are the branches of the central stelar cylinder to the encircling whorl of leaves. For each leaf, there are usually four traces. Two of them appear directly in fron the the leaf-bases and are called direct traces; opposite to these ditect traces on the other side of the central cylinder, is the



place of the origin of the girdle traces which girdle round the central cylinder in the cortex, hence the name given. The reason, that these traces are seen in pieces in transverse section, is that, each whorl consists of number of leaves; and the leaf-traces run obliquely to the longitudingal axis of the stem and thus it is impossible to get a complete section of any trace in transverse plane.

The leaf traces are endarch but become mesarch when enter into the leaf. At the tip of the rachis it is exarch.

Stele is eustelic enclosed within parenchymatous endodermis.

Vascular bundles are conjoint, collateral, open and endarch.

The phloem is made up of sieve tubes and phloem parenchyma. Companion cells are totally absent.

Cambium is present in between xylem and phloem. The cambium cells are radially elongated.

Xylem is homoxylous *i.e.,* made up of polygonal lignified tracheidal cells. Vessels are altogether absent. Protoxylem is endarch.

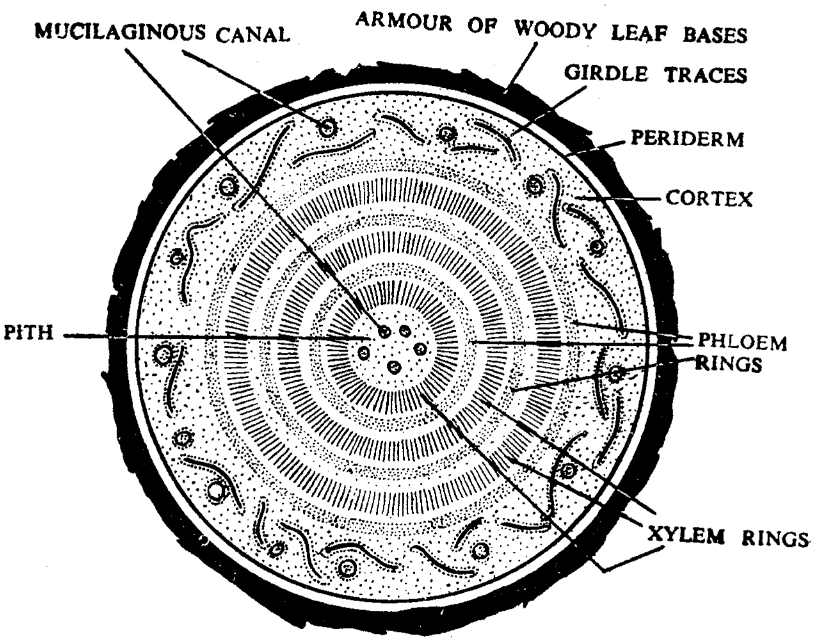
Medullary rays are wide, deep and parenchymatous connecting cortex and pith. Some of these parencymatous cells may contain calcium oxlates.

Wide pith is present in the centre of stem consisting of large celled parenchyma which extends into the medullary rays. The cells or pith may contain calcium oxlates.

Old stem:

Outer most layer of the stem is periderm, produced as a result of meristematic activity of cork cambium (phellogen) arising in the upper region of cortex.

The epidermal cells are suberised and lack intercellular spaces. In older stem the epidermis is peeled off.



Cork cambium is followed by parenchymatous zone called secondary cortex (phelloderm), the cells of which are identical with those of primary caotex. These are also produced from cork cambium.

Cortex is parenchymatous with abundant starch grains. This zone contains simple and girdled leaf traces and numerous mucilagenous ducts.

Secondary growth in vascular bundles takes place by means of fascicular cambium present initially in the vascular bundles. Due to this cambium, a little amount of secondary xylem and secondary phloem are produced on the inner and outer sides respectively. However, the vascular bundles do not show any appreciable change except that they slightly increase in size.

After sometime, the vascular cambium dies and may be superseded by a second cambium. The latter arises in the pericyclic region and produces a vascular cylinder as prominent as the primary one. This after sometime becomes inactive and a third vascular-cambium arises outside the second vascular ring and this process is repeated.

Many rings of vascular cylinder (having xylem and phloem) are produced in the region of cortex due to abnormal accessory cambia.

Usually, a vascular ring arises when a new crown of leaves is produced by the terminal bud. Thus on maturation the whole stem becomes polyxylic structure. The wood is manoxylic.

The secondary xylem is made up of tracheids and parenchyma. The tracheidal walls possess small pits radially in two or three series.

Secondary phloem is made up of sieve tubes and parenchyma.

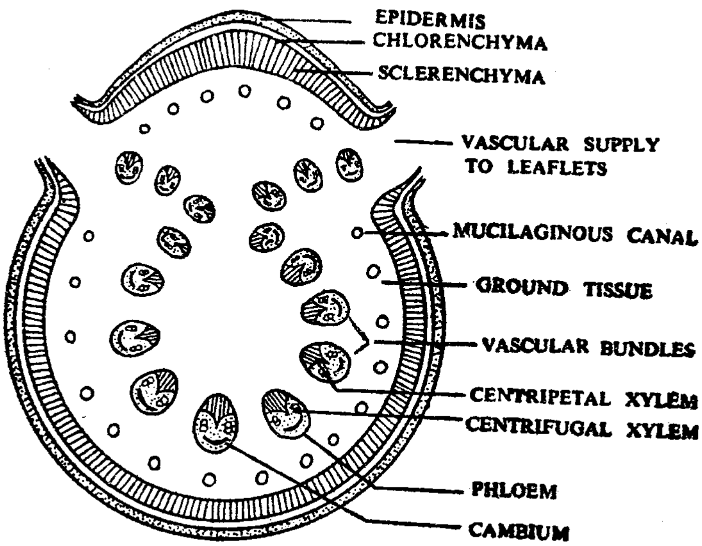
Primary and secondary meduallary rays are present.

Pith is broad and parenchymatous, and similar to cortex.

Lenticels have also been observed among cork cells.

Rachis:

The outline os the T.S. is roughly cylindrical bearing two arms on either side. The arms pass into the leaflets (pinnae).



The outermost layer is a thick cuticle followed by uniseriate and stomated epidermis. The epidermal cells are thickened.

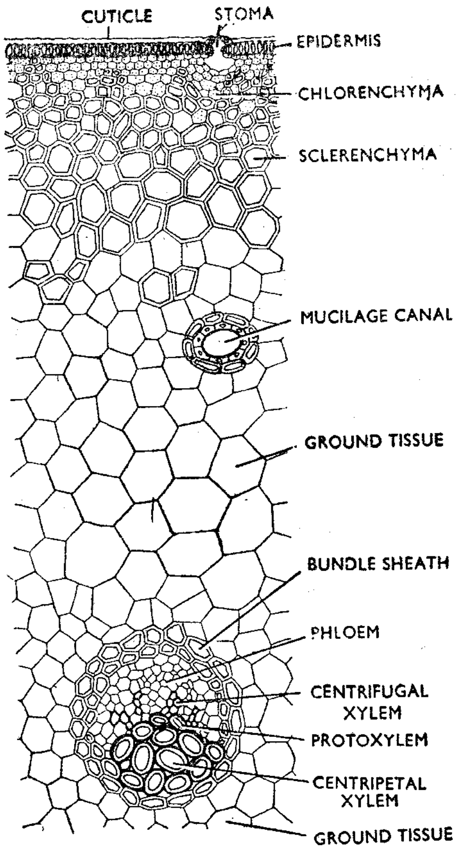
Hypodermal region is differentiated into outer green chlorenchymatous and inner thick walled compact scelrenchymatous layers.

The ground tissues are thin parencymatous with intercellular spaces. Numerous mucilaginous canals are present in this region.

The mucilaginous canal consists of secretory epithelium.

Vascular bundles are arranged in inverted 'Ω' manner enclosed in bundle sheath. They are collateral, conjoint and open.

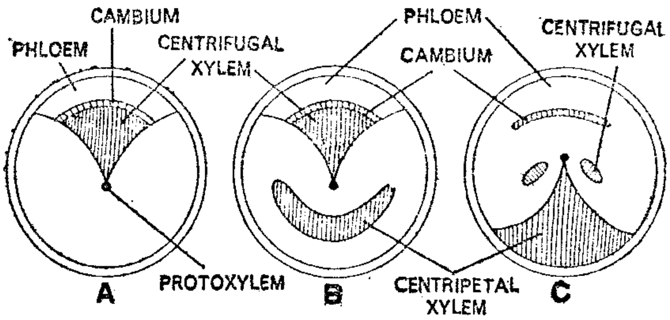
Each vascular bundle is diploxylic *i.e.,* there are two types xylem. One is the exarch centripetal xylem having protoxylem pointing towards the periphery and other is endarch centrifugal xylem having two tracheidal patches on either sides of portoxylem point of centripetal xylem. Both of these tracheidal patches are separated from each other by few layers of parenchymaouts cell.



Phloem faces towards centripetal xylem.

Few cells of cambium are present in between xylem and phloem.

In the basal portion of rachis, centrifugal xylem is well developed and endarch. The protoxylem element points towards the centre of vascular bundle. Centripetal xylem is not developed.

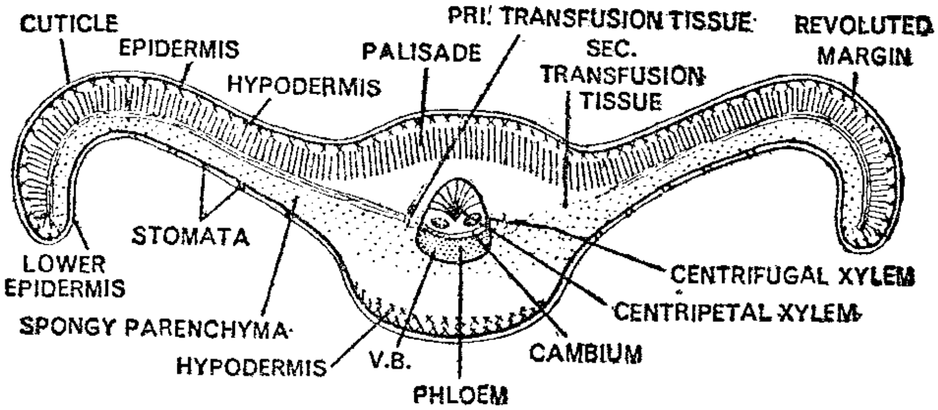


In the middle rachis: opposite to protoxylem of centrifugal xlem, the centripetal xylems (metaxylem trachieds) are developed. Thus the vascular bundles become diploxylic. The condition is called pseudomesarch.

At the apex of rachis: centripetal xylem is well developed and becomes exarch facing the periphery. Centrifugal xylem is reduced to patches and lie on either sides of protoxylem of centripetal xylem.

Leaf let:

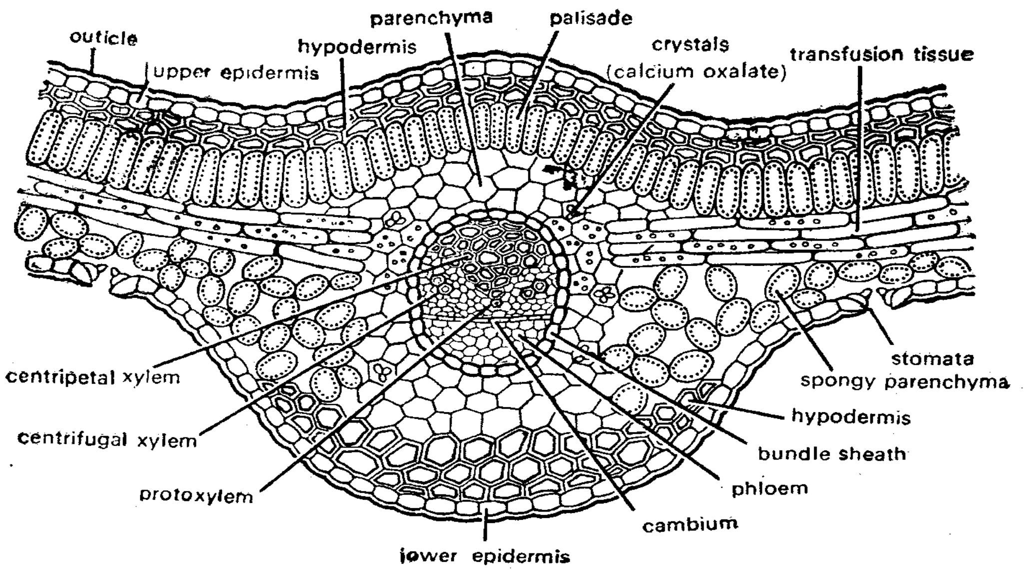
The leaflet is usually dorsiventral and hypostomatic but may be amphistomatic in *C. comorensis*.



Upper epidermis is continuous and consists of thick walled cells. It is covered from outside by a thick laminated cuticle.

Hypodermis consists of 2-3 layers of highly cutinized and lignified cells. The mesophyll cells are well developed and are differentiated into green lignfied palisade cells and 2-3 layered spongy parenchymatous cells.

The central part of arms of the pinna is constituted by transversely placed flattened cells with a narrow lumen and numerous pores. These are transfusion parenchyma cells.



The transfusion tissue is said to compensate for the unbranched nature of the mid rib. Its morphological nature has been controversial. According to Worsdel – it is an extension of centripetal xylem; Carter regards it as a modified leaf parenchyma. Whereas, Takeda regards it as a physiological modification of mesophyll cells for food storage.

Some thick walled lignified tracheidial cells called transfusion tracheids are scattered near the mid-rib vascular bundle.

Midrib vascular bundle is surrounded by a bundle sheath of thick walled cell.

The xylem is the vascular bundle shows diploxylic structure (two types of xylem).

Centripetal xylem: it is well developed situated towards upper side with its protoxylem facing towards the centre of the vascular bundle.

Centrifugal xylem: it is poorly developed and situated in patches with protoxylem facing towards periphery and metaxylem towards the centre.

Phloem lies towards the lower side,

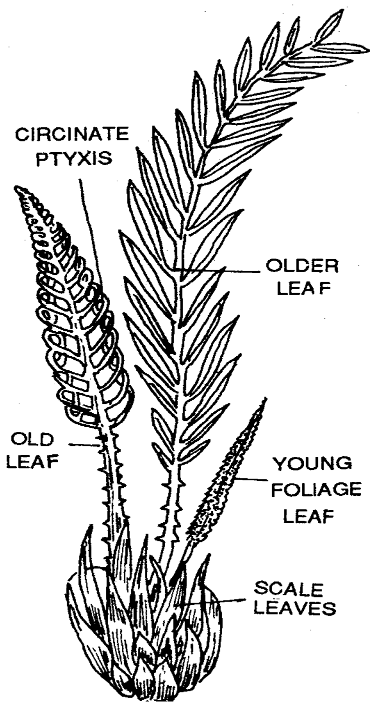
A strip of cambium is present between xylem and phloem.

The lower epidermis is cuticularised and discontinuous due to presence of numerous sunken stomata.

Stomata are situated 1-2 layers below on the lower epidermis and are amphicyclic. Each stomata consists of two subsidiary cells and two guard cells. Hypo and epistomatal cavities are formed due to typical arrangement of the guard cells.

Reproduction

Bulbils of *Cycas*:



Bulbils are the structures of vegetative reproduction in *Cycas*.

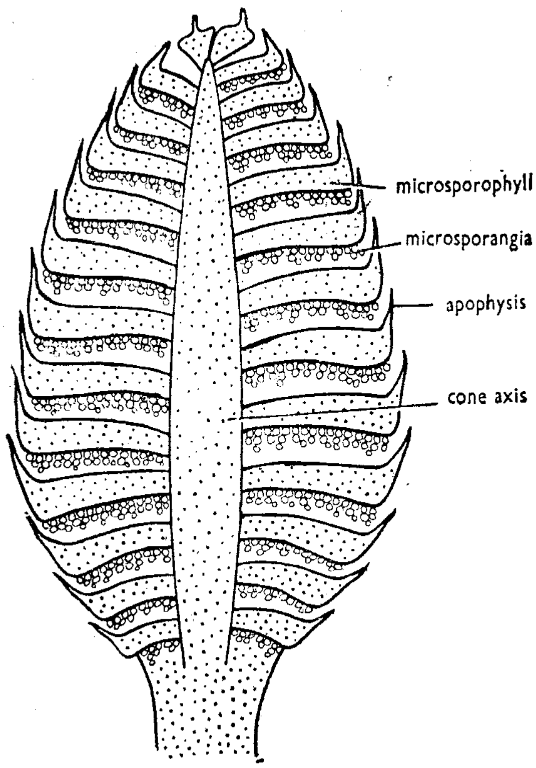
These bulbils are produced all over the stem from the apex to the base on fairly old plants. Uusally in crevices of the lower fleshy portions of old leaf bases and germinates under favourabale condition to produce a new plant after falling on the soil. Female plants are produced from the bulbils of the femal plants which are common in north India.

Suckers have been reported in *C. circinallis* as a vegetative mode of reproduction. These develop from the roots which traverse the soil horizontally to a distance of several meters.

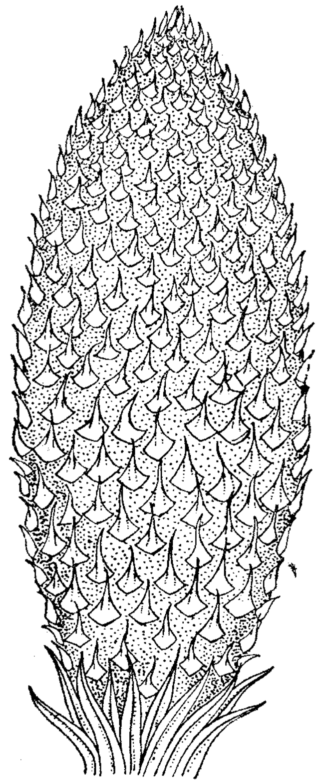
Sexual reproduction:

They are heterosporous and dioecious. Reproductive structures in *Cycas* are male cones and megasporophylls. These structures develop after the plant has acquired about 10 years of age. Male plants are branched sympodially while female plant monopodially.

Male cone of *Cycas*:



L.S. of male cone of *Cycas*



C*ycas* male cone-entire

Male cone develops singly at the apex of stem, but due to the activity of lateral bud arising from base of peduncle the male cones are pushed on to one side, thus the plant appears sympodial.

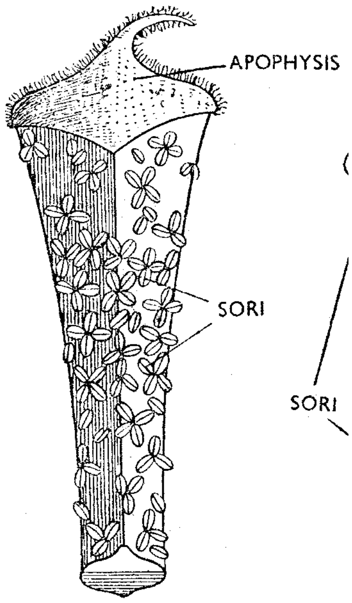
The male cone is shortly stalked, compact and oval structure.

Mature cone appears woody in texture and nearly 20-60 cms long.

The cone consists of several microsporophylls (stamens) arranged in spiral in acropetally on the central axis. The microsporophylls towards the base and apex of the cone are smaller in size. The microsporophyll attains nearly 30-35 mm length.

Microsporophyll of cycas:

The microsporophyll arising as a small outgrowth on central axis appears as triangular and flattened structure nearly 3-3.5 cms in length, woody and wedge shaped at maturity.



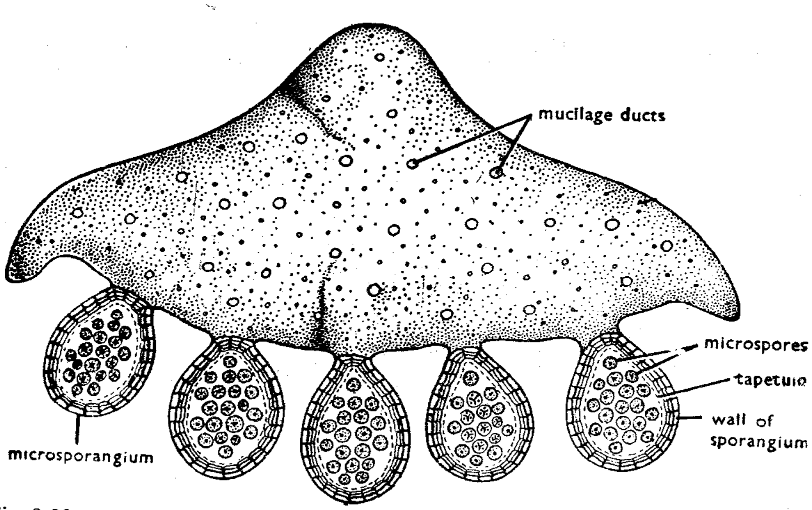
The basal part of each microsporophyll is narrow and sterile. The basal part gradually becomes broader and bears microsporangia (pollen sacs) on its abaxial (lower) side. The fertile part terminates into an expanded sterile disc with a short upward projection called apophysis.

The microsporangia are present on the lower side of microsporophylls in quite large number, arranged in definite sori. These sori are forund in two depressed zones on either sides of a median ridge.

The number of sporangia in each sorus is 2-6. Indusial hairs are mixed with sporangia.

T.S. of microsporophyll of *Cycas*

It is almost triangular shape with a median ridge on the lower side.

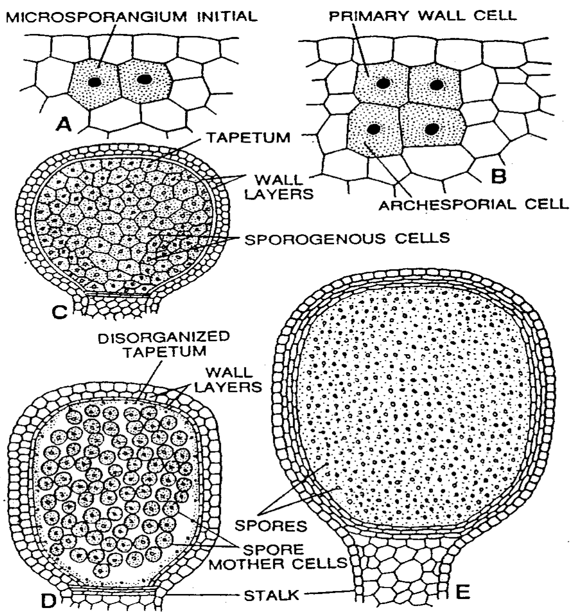


Body of the microsporophyll is surrounded b a single layered epidermis. Stomata are present on the lower side. The epidermis surrounds many layered parenchymatous cells which are traversed by many mucilage canals and vascular strands arranged in row.

Microsporangia grouped in sori are attached on the abaxial (lower) side of the microsporophylls.

Each microspore is boat shaped and with a median furrow. It is double walled and at the time of dehiscence, the microspores are three celled (prothalial, generative and large tube cell).

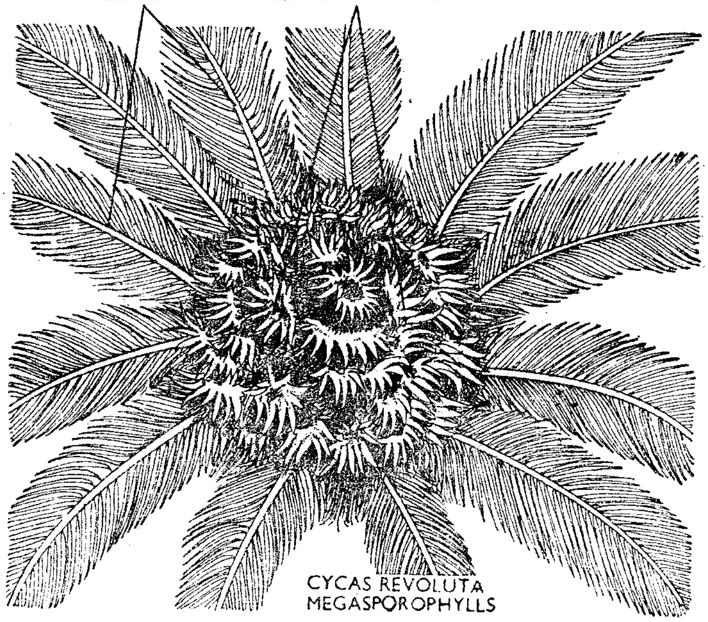
Development of microspores and germination up to pollination stage:



The microsporangia are eusporangiate in development *i.e.*, they develop form hypodermal cell of the microsporophyll. The mature microsporangium is oval and attached by a short stalk at one end. The microsporangial wall is massive and four to seven cells thick. The surface cells of the microsporangium are large and very thick-walled (annulus) except at the point where dehiscence will occur. There is a scanty tapetum below it. The archesporium of the microsporangium develops a number of microspore mother cells which divide meiotically to give rise to tetrada of spores (*i.e.*, the initiation of gametophytic phase).

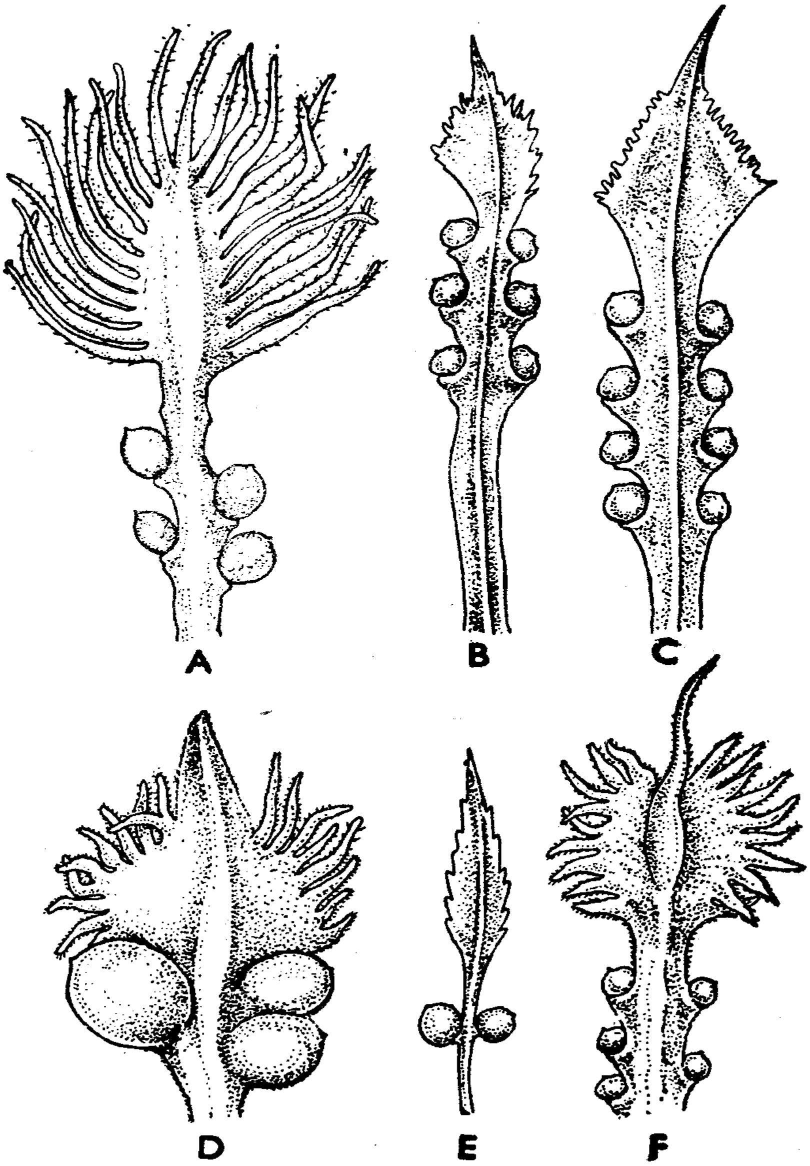
The microspores germinate, *in situ*, much before the sporangium dehisces. Each has two coverings- the outer thick exine and inner thin intine. The spore divides into a small prothalial cell at the lower end leaving a large anthreidial cell. The antheridial cills divides forming a large tube cell and a small generative cell. Thus the male gametophyte is strictly endosporic. Due to dehydration, the sporangial wall breaks-open along the lower side. So the microsporangium becomes boat shaped and with a median furrow. Microspore is double walled and at the time of dehiscence, the microspores are three celled (prothalial, generative and large tube cell). When this takes place the axis of the male cone elongates and the microsporophylls get separated from one another.

Megasporohyllls of *Cycas:*



The megasporophylls differ in shape and size in different species and are of great systematic value in the characterization of species

They are female reproductive structure and develop spirally in acropetral manner around the stem terminally.



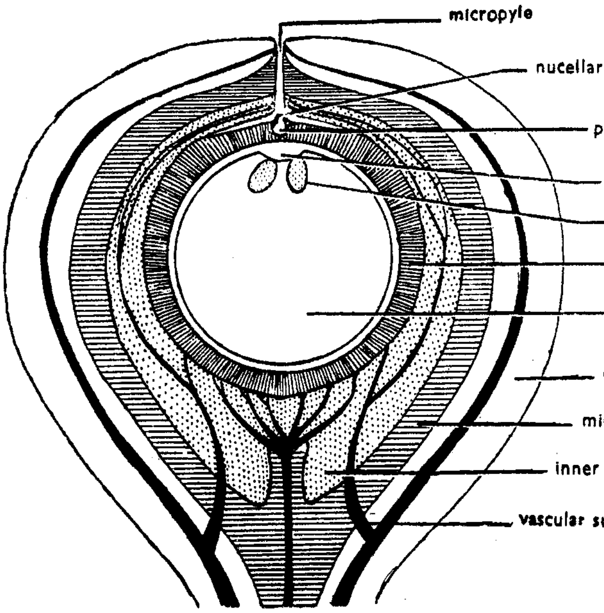
Mega sporophyll of A. *C. revolute;* B. *C. rumphii;* C. *C. circinnalis;* D. *C. pectinata*; E. *C. normandiana and* F. *C. siamensis.*

Each megasporophyll is divided into an upper dorsiventral, palmate, flattened sterile part and lower fertile axis bearing two rows of opposite and alternately arranged ovule. Whole megashorophyll is covered with brown wooly hairs.

Ovules are orthotropous and stalked. The micropyle of the ovule is away from the central axis of mega sporophyll. The number of ovules in each megasporoophyll may be 2-12. The ovule is largest in the plant kingdom.

The megasporophyll of *C. revolute* is 10-23 cms long with ovate blade and pinnate segments absent.

L.S. of ovule:



The ovule is stalked having a single integument. The integument is differentiated into outer fleshy layer, middle stony layer and inner fleshy layer.

The integumens leave a passage towards upper side called micropylar canal. This canal communicates with the pollen chamber below. The pollen chamber is surrounded by a rim called nucellar beak.

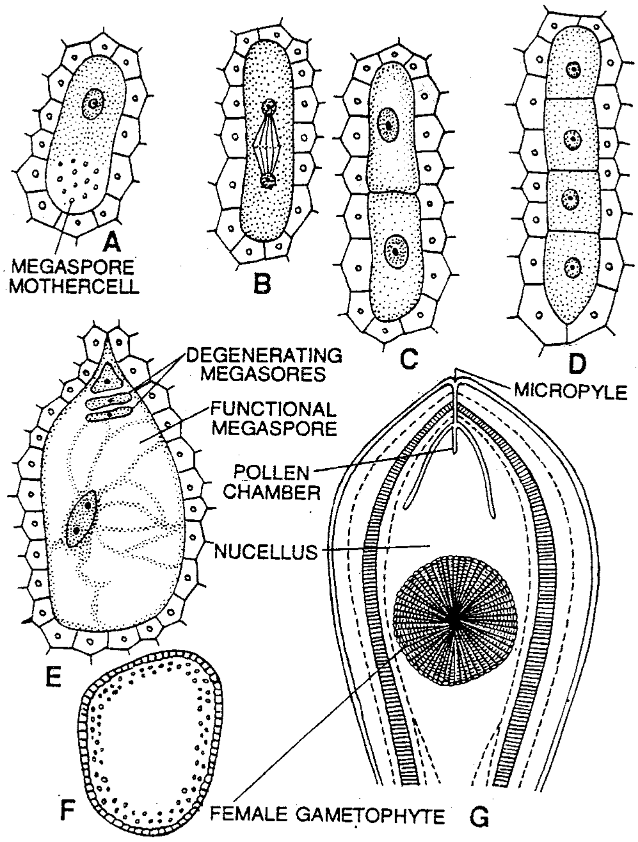
Below the pollen chamber is situated archegonial chamber. At the base of archegonial chamber one or two archegonia are present.

Ovule is centrally occupied by endosperm tissue.

Each archegonium consists of two neck cells and a large egg on maturity.

The inner fleshy layer of integument is jointed with the nucellus (centre part of the ovule) throughout except in the upper part of ovule.

Megaspore and development of the female gametophyte:

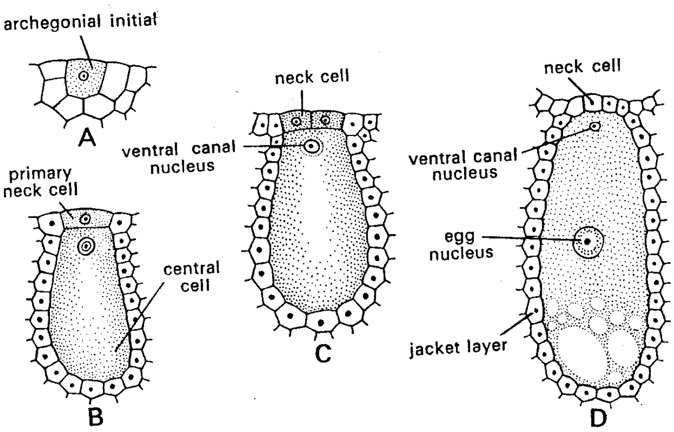


Stages of development: A-D.formation of megaspore tetrad; E. functional megaspore; F. free nuclear division; G. cellular female gametophyte.

At first, the thin walled parenchymatous cells of nucellus are alike, but soon one cell in the central region becomes more prominent- mega spore mother cell. It divides meiotically to give a linear tetrad haploid megaspore. The upper three disintegrates and the basal functional megaspore (initiation of female gametophyte) becomes large in size at their cost.

The functional megaspore is the embryo sac, is retained in the megasporangium or ovule.

The megaspore has a thick papillate exospore and a fibrillar inner endospore. It enlarges considerably and a vacuole appears in the centre which pushes the nucleus to the lower side. The nucleus divides by free nuclear division resulting in the production of more than a thousand nuclei. As free nuclear divisions continue, additional cytoplasm is synthesized and the vacuole is gradually obliterated. At this time wall formation is initiated, at first between the peripheral nuclei and it continues in a centripetal direction until the female gametophyte is entirely cellular. This is known as the female prothallus or endosperm and consists of uninucleate cells which are smaller above and larger below. A well-defined megaspore wall clearly demarcates the gametophyte from the adjacent tissue of the nuclleus. Outside it is a nutritive jacket, two cells thick and is called endosperm jacket. This seems to function like the tapetum.

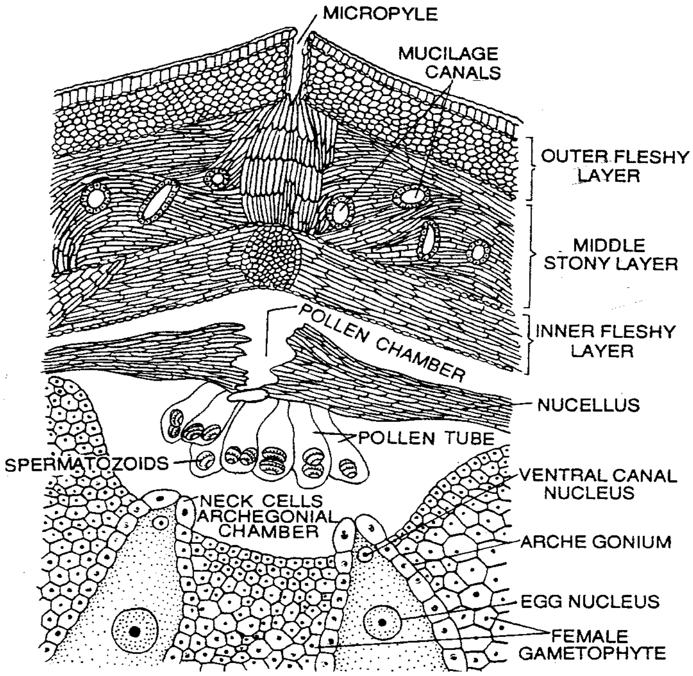


Near the micropylar end of the female gametophyte, few cells enlarge and form 2-5 archegonial initals. Each develops into an extremely large archegonium. The superficial initial divides transversely into a primary neck cell and a central cell. The primary neck cell usually divides once longitudinally to form two neck cells. These lie side by side forming a very small neck. The neck cells become turgid, enlarge and protrude into the archegonial chamber. Neck canal cells are absent in *Cycas*. The central cell, at this stage, enlarges considerably and becomes highly vacuolated. It gets surrounded with a nutritive jacket of cells called the archegonial jacket. After the jacket cells become depleted of its contents, the pores between the central and jacket cells become occluded by the formation of plug-like thickenings.

Next, the central cell divides to form a venter canal cell and a large egg. No wall is produced between these two nuclei. The venter canal cell is short lived and soon disappears.

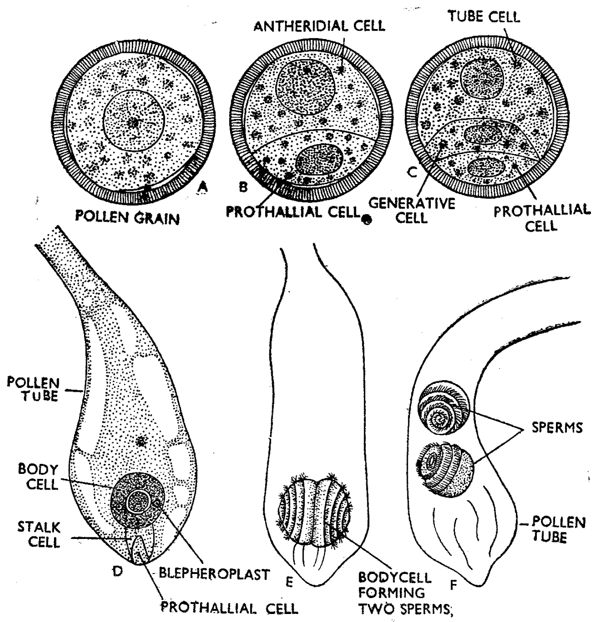
The egg becomes densely cytoplasmed by intake of contents of surrounding cells; the upper portion of the gametophyte which contains the archegonia loses its contact with the nucellus forming a small space, the archegonial chamber.

Pollination:



It is anemophilous. The 3- celled microspore lodges in the micropylar region of the ovule by wind. Some cells of the nucellus disorganize forming a pollen chamber and a mucilaginous drop which fills it and oozes out as a pollination drop. Large numbers of pollens are entangled in this, and as the pollination drop dries, the pollen grains are drawn into the pollen chamber. Further drying seals the pollen chamber and the top becomes very hard.

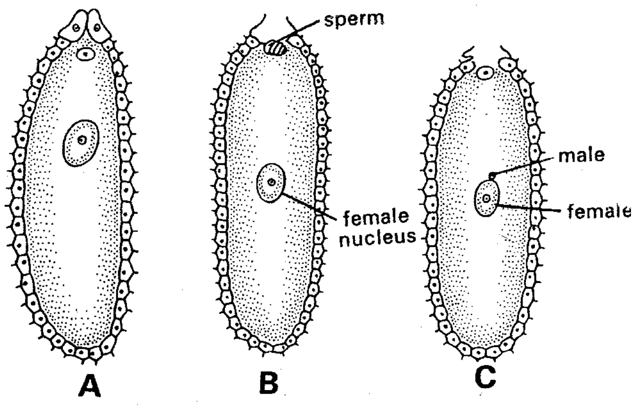
Development of male gametophyte after pollination:



Four months after pollination, the pollen grain germinates in the pollen chamber. The tube cell enlarges; burst opens the exine, the intine comes out in the form of pollen-tube. This end of pollen tube is called haustorial end. It penetrates in the nucellus towards the nucellar beak. The pollen tube is not the pollen carrier. At this stage the generative cell divides into a stalk cell and a body cell. The stalk cell is sterile and remains attacted to the persistent porthalial cell.

No further development takes place until the archegonia are mature. After four months the prothalial cell penetrates into the stalk cell, reducing it to form a ring. When the fertilization time approaches, the body cell enlarges enormously in the direction of the long axis of the elongating pollen tube. In the body cell, two star shaped protoplasmic bodies appear. These are known as blepharaoplasts. They are concerned in the production of cilia and break up into a granular mass forming 5-6 spiral bands. The nucleus completely divides and each of its part is attached to the centre of the ciliated spiral bands. The body cell divides and two antherozoids are formed. These are liberated from the body cell, become motile and swim actively in the pollen tube. The sperms of C*ycas* are the largest known in the plant kingdom and may attain a diameter of 300 microns and are thus visible to the naked eyes.

Fertilization:

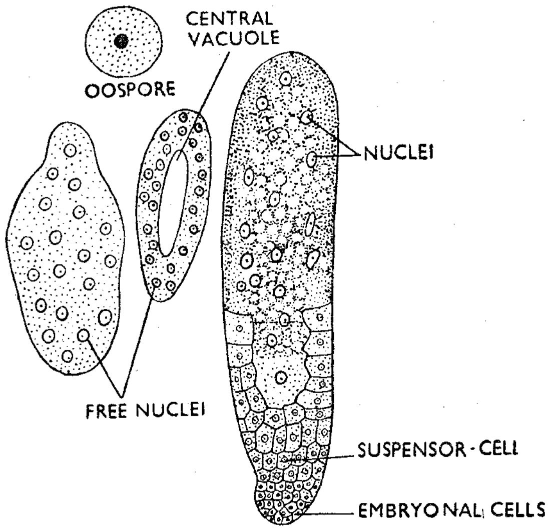


The interval between pollination and fertilization is 4-6 months. During fertilization the pollen tubes are extremely turgid. No liquid water is seen in the archegonial chamber at fertilization time. An orifice is formed at the turgid end of the pollen tube and the sperms are squeezed out by amoeboid movements.

After liberation of the sperms, the pollen tube gives out a liquid that along with the water from neck cell and egg makes the egg cytoplasm protrude into the archegonial chamber. When the sperm touches the neck cell, it is sucked violently with a sufficient force so as to sever the blepharoplasts and the naked male nucleus migrates to the vicinity of the egg nucleus, which is now of tremendous size. The union of male and female nucleus is fertilization. The diploid oospore is the initiation of sporophytic generation. This type of fertilization which is achieved by the help of pollen tube is called siphonogamy.

Development of embryo:

After fertilization, the diploid oospore undergoes repeated free nuclear division, until 256 or more nuclei are formed.



A large central vacuole forms pushing the nuclei towards periphery.

Wall formation initiates at the base and extends gradually towards the neck end of archegonium.

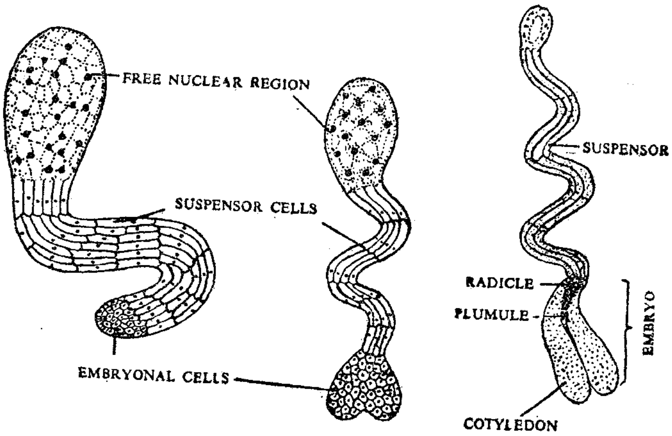
Some of the free nuclei may remain unenclosed by walls and this region is called proembryo; and functions as meristamatic zone.

The meristamatic zone differentiates into

1. Upper haustorial cell region.
2. central suspensor cells
3. Basal embryonal cell.

The haustoraial cell is in direct contact with the free nuclear part of the oospore and helps in nutrition of growing embryo.

The suspensor elongate pushes the embryo cell deep into the tissue of the female porthallus.



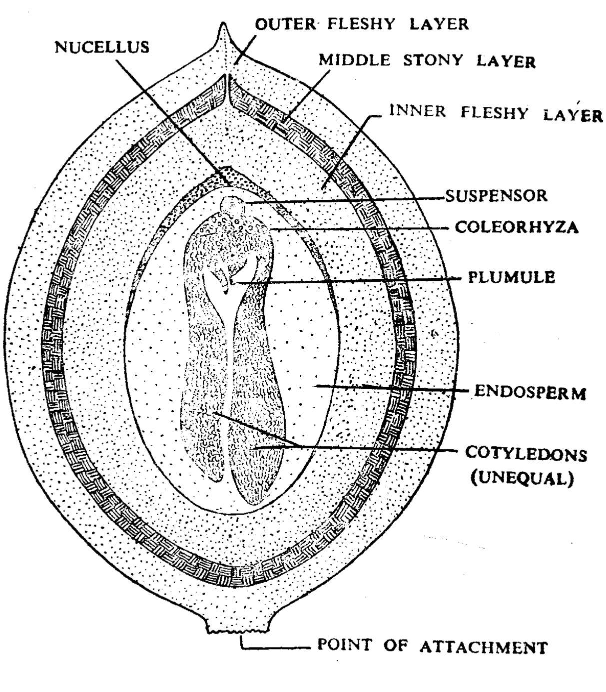
Eventhough all the archegonia of one female gametophyte may be fertilized, only one is functional in mature seed.

All the suspensor from different archegonia twist together to form a compound structure supporting the functional embryo, thrusting it to the nutritive porthallus.

The embryonal cells enlarge and divide rapidly. Soon the growth at the centre ceases, whereas the margins grow rapidly and protrude out forming two or three unequal cotyledons. Between the depressions of the two cotyledons lies the terminal plumule. The cell above the plumule elongates and forms the axis of the embryo which soon differentiates into hypocotyl and a radicle.

Development of embryo is slow; and when mature, the embryo reaches the whole length of the seed. At this stage the suspensors are pushed back against the micropylar end forming a hard pad, called the coleorhizae.

L.S. of seed of *Cycas*



The seed of *Cycas* is fleshy and orange-coloured

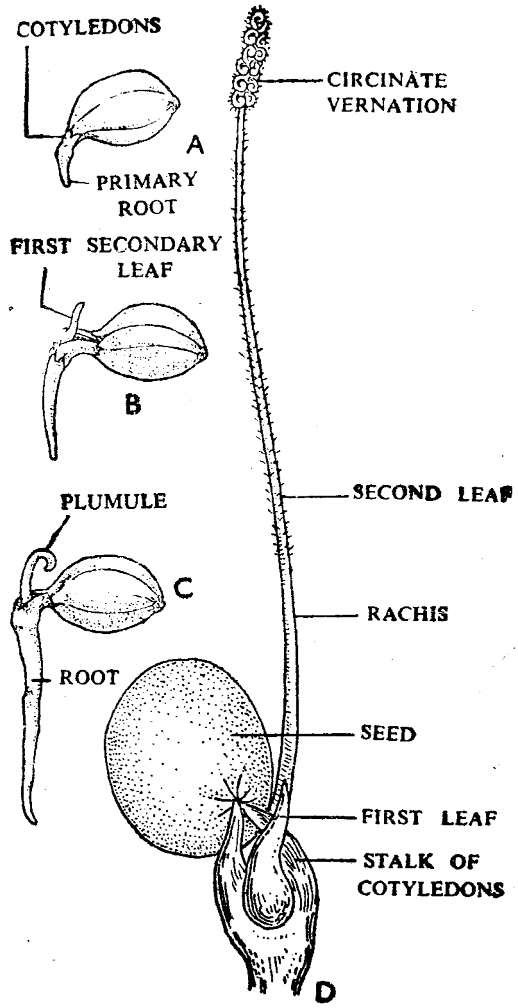
Outer fleshy layer forms sarcotesta, middle stony sclerotesta and inner fleshy layer remains thin and papery. Thus whole of the integument forms seed coat.

Nucellus is reduced and forms a papery layer.

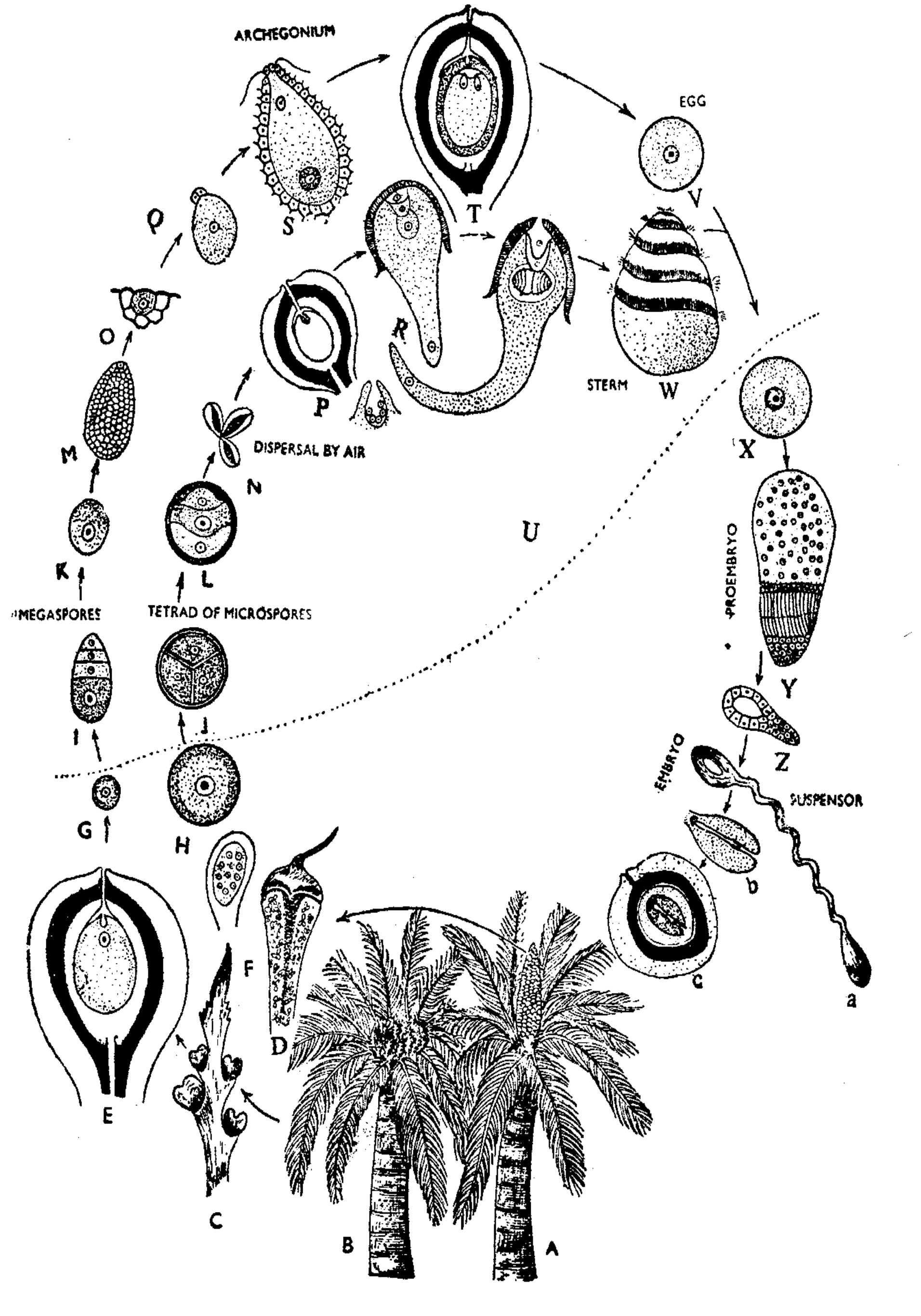
Straight embryo is embedded in the gametophytic tissue.

Germination of seed:

The seed of *Cycas* germinate immediately without resting period. The seed-coat on germination is broken up by the stony coleorhizae, which markes the passage for the delicate radicle. The unequal cotyledons remain within the seed below the ground, where they function in absorbing food stored, in the female gametophyte cells or endosperm. When the food is finished the



cotyledons dry up and is followed by the appearance of the first foliage leaf with a few leaflets. The seedling stem is very short and its vascular system forms a plate rather than a column. The seedling is an autonomous organization.



Life cycle of *Cycas*.

PINUS

Systematic Position:

Class: Coniferopsida

Order: Coniferales

Family: Pinaceae

Genus: *Pinus*

Occurrence:

The plants are gregarious in habit growing wildly as well as cultivated in the gardens.

Usually it grows on shallow soil overlying-rocks.

Some of the Indian species are *P. gerarginan, P. roxburghii*.

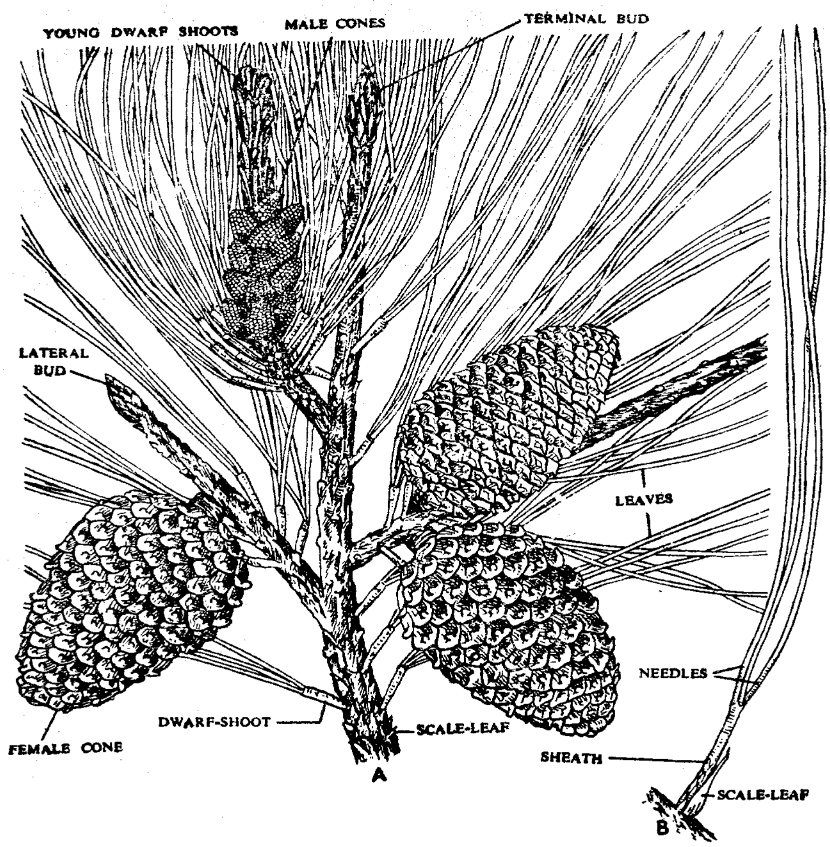
The plant body

The plant body is a large evergreen tree. The branches upto middle is whorled and the crown is pyramidal. The stem branches monopodialy. At the apex of the stem is the large terminal bud which grows more rapidly than the terminal buds of the branches and hence the stem tapers towards the apex forming a conspicuous central trunk. The gradual transition in length of the lateral branches from the longest lower most to shortest gives the tree a conical form.

Bark over the stem is fissured, long striped and red.

The stem is cylindrical and woody. The branches are of two types.

Branches of unlimited growth: these are longer and possess terminal bud. These branch freely and are clothed with scale leaves.

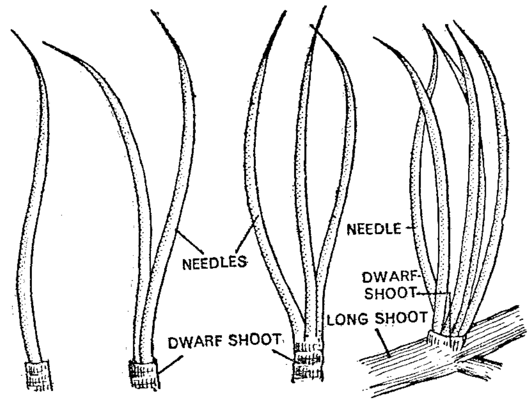


Branches of limited growth (dwarf shoot): these branches develop in axil of scale leaves on the branches of unlimited growth. They terminate into acicular leaves and are not covered with scale leaves. These branches lack apical bud and so their growth is arrested after eleongation to few millimeters only.

The leaves are dimorphic *i.e.* they are of two types:

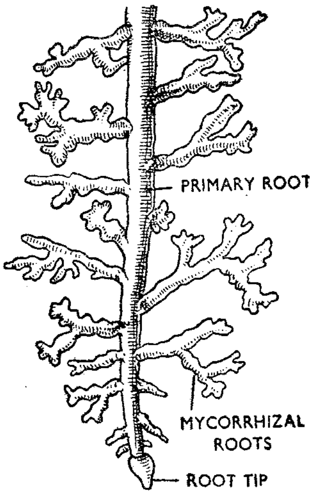
Small **scale leaves** are present all over the stem.

Needle-like leaves are 2-5 in number in different species of *Pinus*. These are borne only on dwarf shoots terminally. These are almost long pointed glaucous, green and triangular. The basal sheeth is persistent.



Variation of needles in different species: monofoliar: *P. monophylla;* bifioliar*: P. sylvestris;* trifoliar*: P. gerardiana;* pentafoliar*: P. wallichiama*

The root is tap with numerous root hairs. Older roots may develop ectotrophic mycorrhiza.

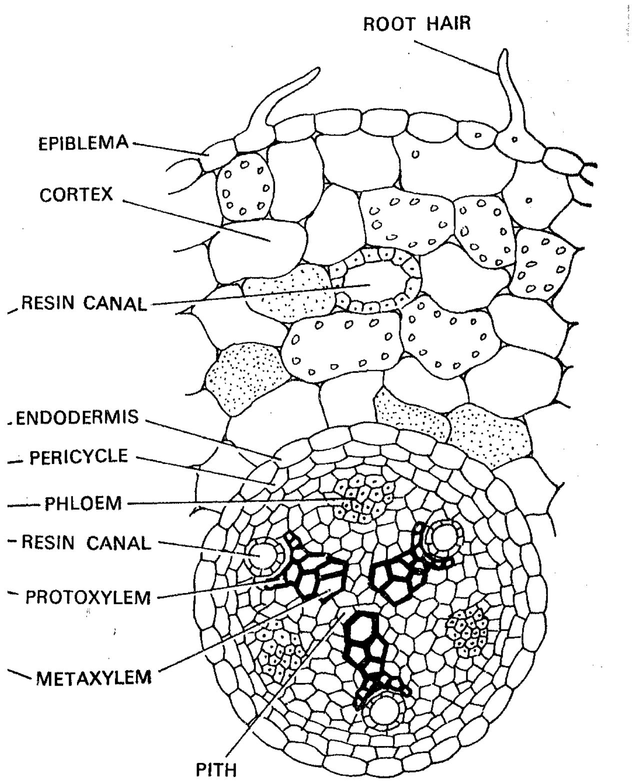


Male and female cones arise at the base of dwarf shoot.

Internal structure:

Root:

A well developed periderm is formed by the activity of the phellogen (cork cambium). The phellogen cuts cork cells towards outer side and parenchymatous phellodermal cells (secondary cortical cells) towards inner side.



Epiblema is uniseriate and may be infected with fungal hyphae.

Cortex is multilayered and is made up of loosely arranged parenchymatous thin walled cells. Sclerotic cells are also present in this region.

Several resin ducts are also present in the region of cortex.

Endodermis and pericycle are prominent in young roots but become inconspicuous after secondary growth. Endodermis is single layered but pericycle is several layered.

Stele: near the centre lies 2 to 6 Y shaped primary xylem which alternates with equal number of phloem bundles. Primary phloem is crushed after secondary growth and is left as a thin layer on the peripheral edges of secondary phloem.

Secondary vascular cylinder consists of secondary phloem towards periphery and secondary xylem towards inner side.

Xylem is made up of longitudinal rows of tracheids.

Phloem is made of sieve tubes and parenchyma.

Phloem and xylem are prominent.

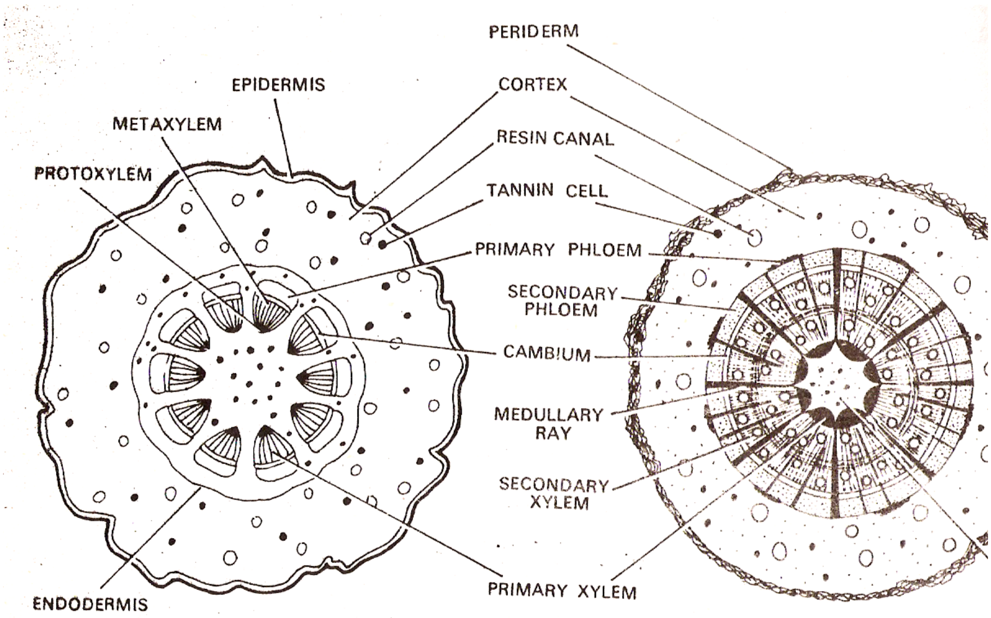
Primary xylem bundles are exarch and join together.

Young stem:

The epidermis is uniseriate and consists of thick walled parenchymatous cells.

The epidermis is surrounded by a thick cuticle.

Epidermis is followed internally by multilayered parenchymatous cortex bearing many resin canals. Few outer layers may be sclerenchymatous. The resin canals form longitudinal pores in the cortex.



Young stem old stem

The resin canal has an epithelium, made up of secretory cells. The epithelium is covered by an outer protective layer of parenchymatous cell.

Stele is eustelic and is enclosed within a paenchymatous endodermis and pericycle.

The vascular bundles are conjoint, collateral and open. The xylem is endarch.

Meduallary rays are thin and are one cell thick.

Phloem is made up of sieve tubes and phloem parenchyma. Albumen cells may also be present in some cases.

Xylem is well differentiated into meta and protoxylem. It is made up of polygonal lignified tracheidal cells. Protoxylem bears bordered or spiral thickenings.

Cambium is present in between xylem and phloem in the form of the strip.

Leaf gaps are present in the stele.

The centre of the stem is occupied by small parenchymatous pith.

Old stem:

The outermost region is periderm made up of cork cells.

The periderm (cork) is produced by the activity of cork cambium. The peridermal cells lack intercellular spaces and have the deposition of suberin in their radial and end walls. These are therefore dead cells.

Cork cambium (phellogen) is 2-3 layered and its cells are parenchymatous and radially elongated.

Cork cambium also produces parenchymatous cells in many layers on the lower side, called phelloderm. The cells are rounded or angular and possess intercellular spaces. The cells are similar to the cells of primary cortex.

Primary cortex is multilayered and parenchymatous. Some of the cells of this region are lignified. The cortical cells also contain sclerotic cells and various inclusions such as crystals etc.

Resin canals are present in the region of cortex.

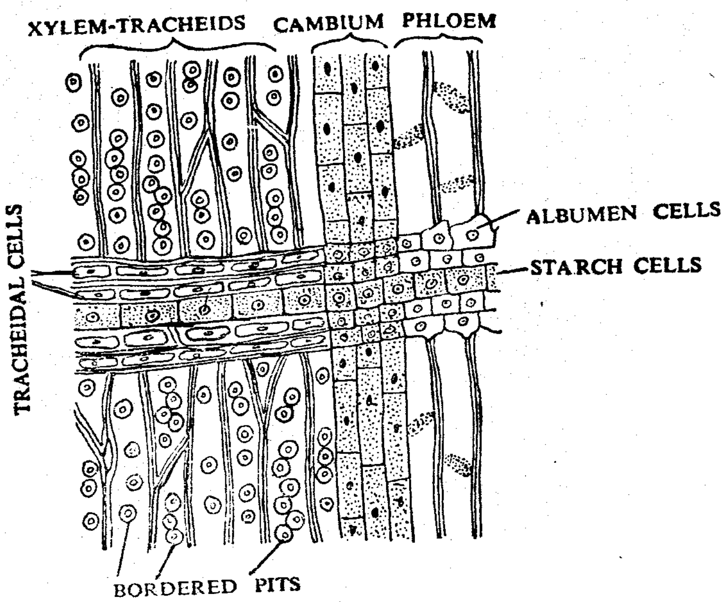
Vascular cylinder consists of primary phloem, secondary phloem, primary xylem, secondary xylem and cambium.

Primary phloem is crushed after secondary growth and so it becomes inconspicuous.

Secondary phloem is made up of sieve tubes and phloem parenchyma. Companion cells are absent.

The vascular cambium is 2-3 layered and the cells are radially elongated and narrower. Intercellular spaces are absent.

Xylem cylinder is thick and consists of trachieds arranged in longitudinal rows. The tracheids have the deposition of lignin and possess bordered pits in their radial walls.



The tracheids of the secondary xylem are elongated cells arranged in regular radial rows. The tracheids display uniseriate bordered pits on their radial walls. Such thickenings are called *Crassulae rims, or bars of sanio.*

The vessels are absent in the xylem.

Medullary rays are uniseriate and parenchymatous. These are interspersed in the xylem.

In the regions of secondary phloem, the medullary ray consists of usual rectangular cells containing starch and somewhat elongated called albuminous cells having a store of proteinaceous matter.

In secondary xylem, certain radially elongated thick walled cells with simple pits in their walls- 'tracheidal cell' are present. They help in the radial diffusion of sap.

Primary xylem of each vascular bundle bears a resin canal characteristically towards the pith.

Xylem parenchyma may be associated with the resin ducts.

The central portion of the stem is pith and made up of angular parenchymatous cells with intercellular spaces. The cells show crystals in them.

Dwarf shoot of pinus:

Dwarf shoots are small branches of limited growth, developing on the branches of unlimited growth in the axil of scale leaves.

These shoots lack any apical bud at their terminal end and so they do not grow beyond few millimeters.

These shoots terminate into needle leaves.

The number of leaves on each shoot varies in different species.

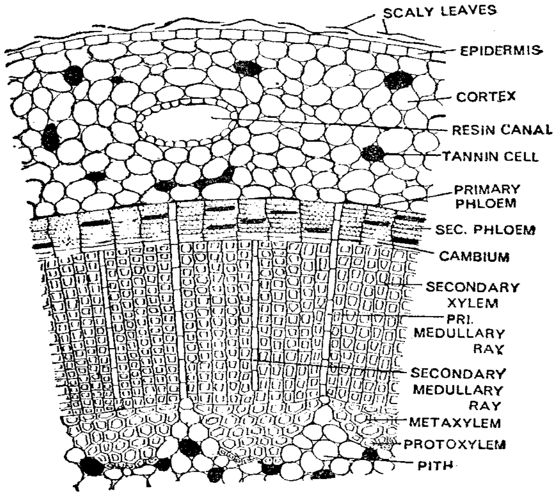
T.S.of dwarf shoot near base

The outline is wavy due to the presence of cataphylls.

Epidermis is uniseriate and consists of thick walled cells.

Cortex is multilayered and differentiated into thick walled and thin walled parenchymatous cells.

Resin ducts and tannin cells are scattered in the cortex.



Stele is polyfascicular siphonostelic.

Endodermis and pericycle are inconspicuous.

Vascular bundles are conjoint, collateral and open.

Xylem and phloem are typically gymnosperous.

Medullary rays are parenchymatous.

Pith consists of thick walled cells.

Secondary growth in dwarf shoot is similar to stem except the cork is not produced in dwarf shoot.

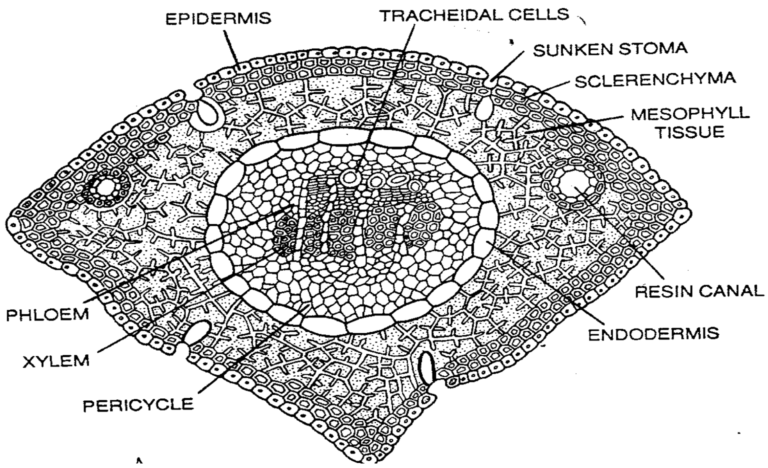
T.S. of mature needle:

The outline of cross section is triangular.

The outermost layer is a thick walled cuticularised epidermis having sunken stomata.

Each stomata has two subsidiary cells and two deeply situated guard cells. Epi and hypostomatal cavities are formed due to the position of guard cells.

Hypodermis consists of thick walled scelerenchymatous cells.



Resin canals are present in sclerenchymatous hypodermal zone. Each resin canal has an inner epithelium layer of secretory calls surrounded by a layer of sclerotic cells.

Mesophyll region is made up of thin walled; polygonal parenchymatous cell having chloroplast. Each parenchymatous cell has few peg-like infoldings in its inner wall towards the lumen of the cell. Thus the photosynthetic area of the cell is increased.

Vascular region is surrounded by a layer of endodermis having barrel shaped cells.

Pericycle is multilayered consisting of parenchymatous cells.

Some parenchymatous cells with denser cytoplasm (transfusion parenchyma) and some thick walled tracheidial cells (transfusion trarheids) are scattered in vascular region. Its morphological nature is much discussed:

'It is considered as to be derived from primitive centripetal primary xylem';

'It represents a modified development of original parenchyma';

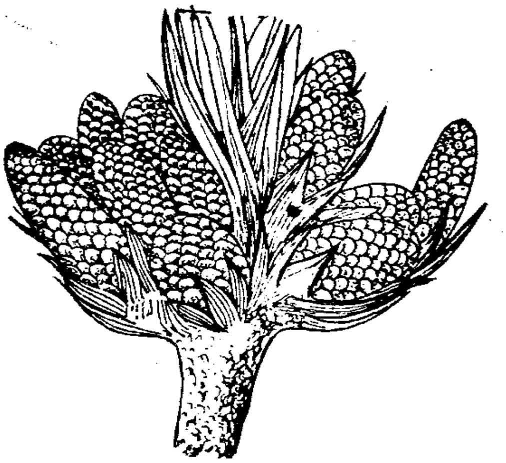
The most common concept is it represents 'an auxiliary conducting system serving to bring the vascular tissue closer to the mesophyll. It is a water storage tissue'.

There are two conjoint and closed vascular bundles. Each vascular bundle has phloem towards outside. Phloem and xylem shows distinct xylem rays.

Reproduction:

The plants are usually monoecious. The male and female reproductive structures are the cones.

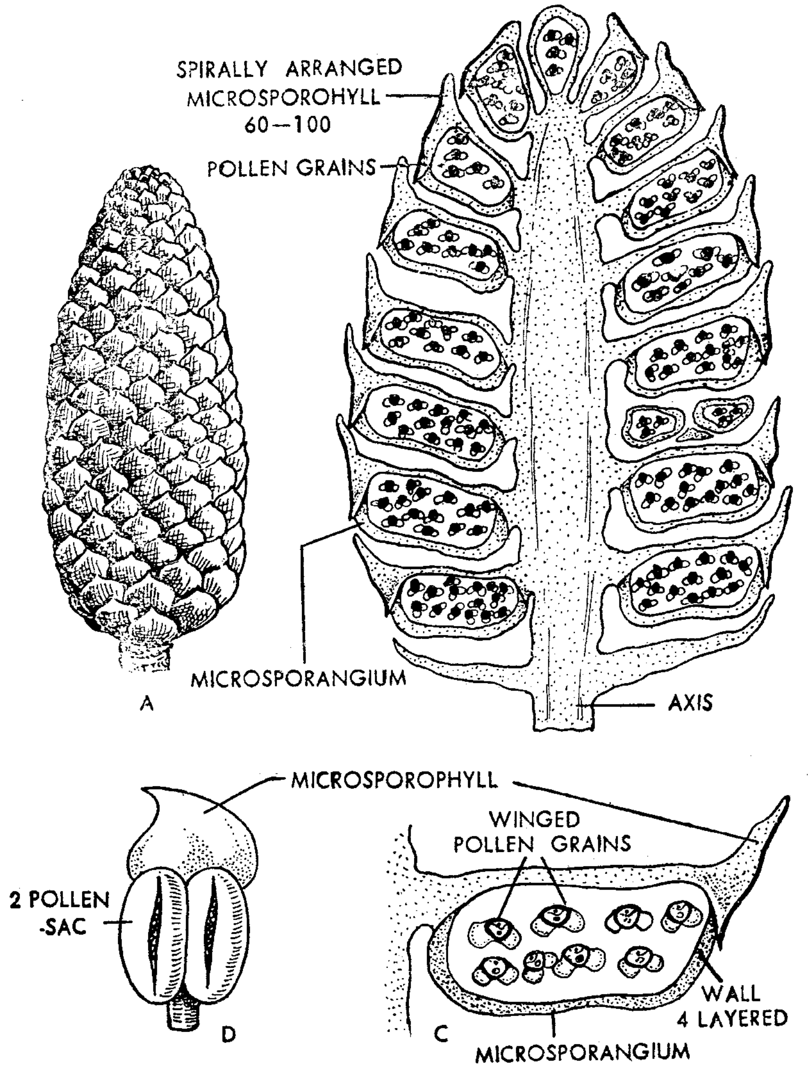
Male cone:



Male cones develop in cluster on dwarf shoots in the place of needle leaves. These are small structures of about 4 cms in length.

Male cone is ovoid subtended by protruding light brown acuminate scales with fimbriate margins grouped on the axis of a new shoot.

L.S.of male cone:



Pinus male cone: A. entire cone; B. L.S. of cone; C. microsporangia; D. a single microsporophyll

It shows central axis with spirally arranged several microsporophylls over it.

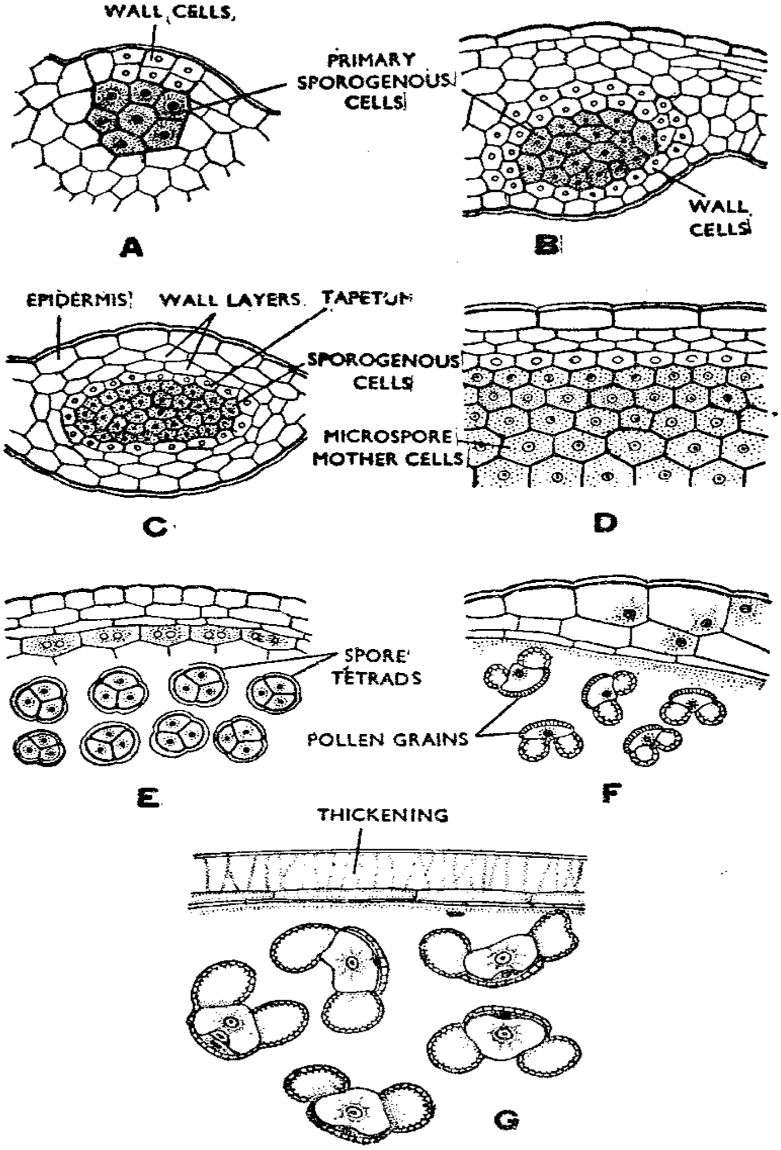
The microsporophyll is small, triangular and scaly structure consisting of a basal narrow stalk attached to the axis of the cone and an upper leaf-like expansion with two microsporangia on the lower side. The expanded woody portion of sporophylls (apophysis) protects the microsporangia.

The microsporangia are eusporangiate in development. The sporangial wall has four layers of cells;

An outer epidermis

Two middle layers and

A glandular tapetum



Development of microsporangium in *Pinus*

Thus the microsporangium when young has a wall, a peripheral tapetum and a central archesporial tissue which produces diploid microspore mother cell, which divide meiotically to produce tetrad microspores (pollen grains).

The microspores (pollen) have two wings on the two lateral sides.

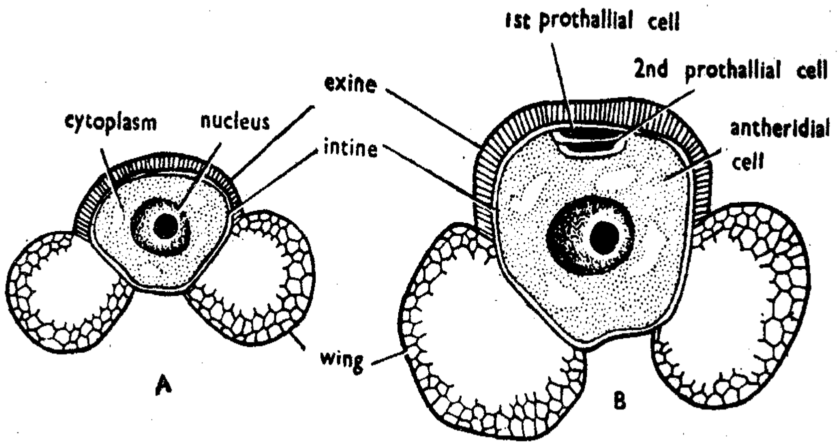
Some of the basal microsporophylls are sterile while the remaining upper ones are fertile.

Microspore and development of male gametophyte:

The microspore has a three layered wall. They are

1. incomplete cuticularised outer exine
2. Middle complete exo-intine with two ballon like extenstion (wings).

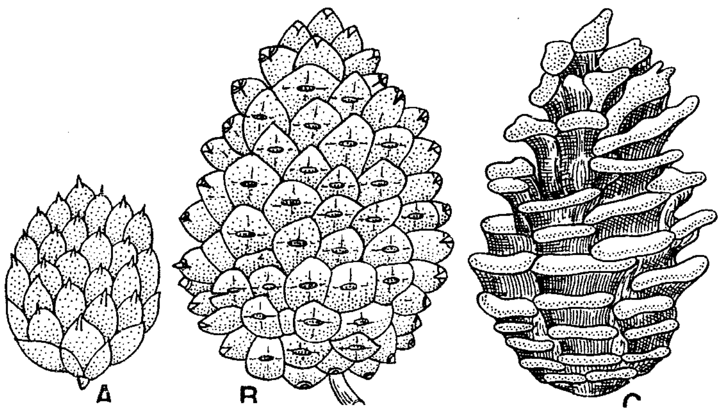
3. Inner very thin and delicate intine.



Pinus microspores (pollen grains) A. young; B. old

Microspore germination is endosporic. The spore divides into a very small flattened prothalial cell and a large tube cell. Thus the pollen is in two celled stage during dehiscence. By the longitudinal fissure on the microsporangial wall, pollens arre liberated to wind.

Female cone:



Pinus female cone: A. first year; B. second year; C. third year cone.

Female cones are pale green in colour, erect, ovoid with scales arranged spirally. They arise in the place of needles on dwarf shoots or in the axil of scaly leaves.

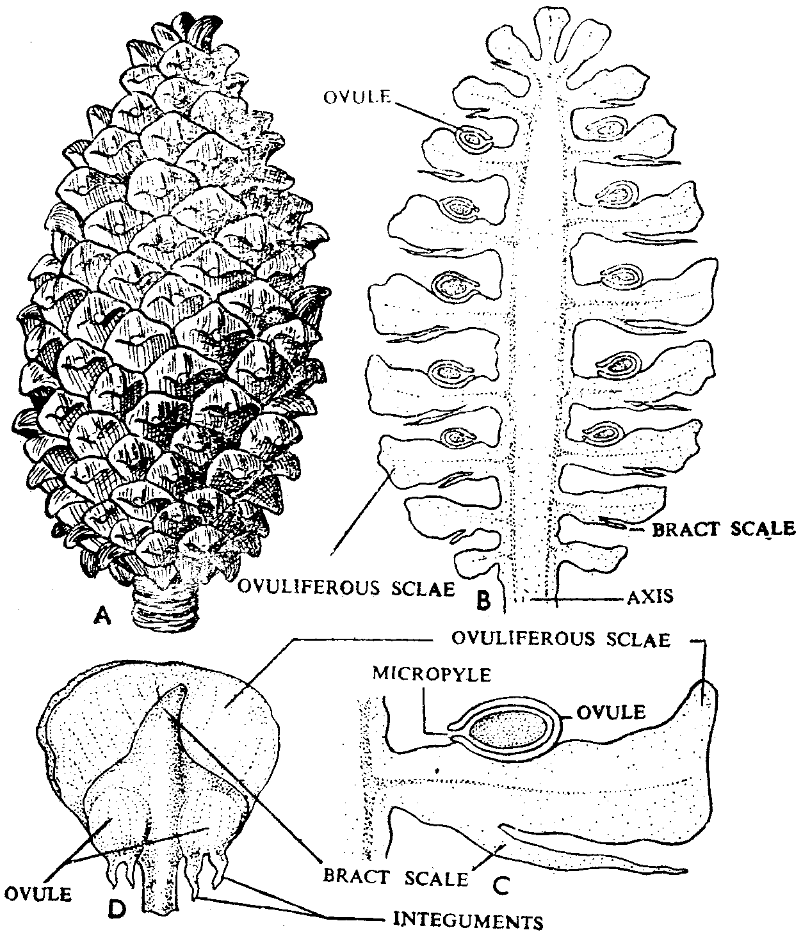
L.S. of female cone:

It has a central axis.

The paired scales are arranged spirally on the central axis.

The paired scale consists of:

1. An upper triangular and woody part called ovuliferous scale. The ovuliferous scale is stout, woody and brownish structure borne on the dorsal side of bract scale. Each ovuliferous scale is triangular with a terminal broader portion, the apophysis. The apophysis appears rhomboidal and possesses a small central point called umbo. Each ovuliferous scale bears two ovules on its dorsal side near the base
2. An adjoining lower thin and membranous part called bract scale or branch scale is sterile. It is small dry membranous structure occurring just below the ovulifereous scale. It has a simple vascular bundle. Both ovulifereous scale and bract scale are fused.



Pinus female cone: A. entire; B. L.S. of cone; C. single megaporgangium; D. a megasporophyll bearing two ovules.

The ovules face towards the central axis.

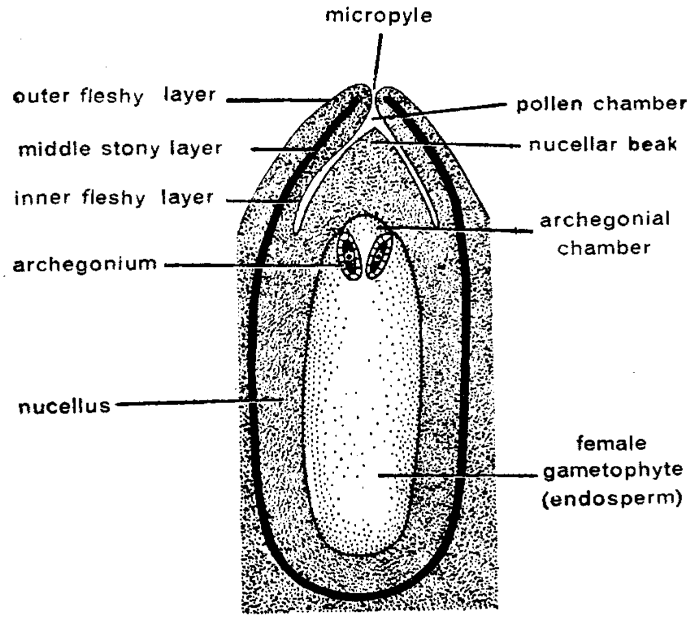
Morphological nature of ovuliferous scale:

Many theories have been putforth. To mention a few important:

- Sachs and Eicher- ovuliferous scale in an outgrowth of the bract scale comparable to the ligule of *Selaginella* or placenta of angiosperms.
- Kubart and Bessey- ovuliferous scale is a combined outgrowth of the ovules and it is similar to aril.
- Delpino- it is formed from two lateral lobes of bract-scale which fuse together.
- Hirmer- ovuliferous scale and bract scale as part of one structure, which has forked vertically.
- Florin compares female cone to the infloresecence of angiosperms. Thus entire cone is a compound strobilus.

L.S. of ovule:

The ovule consists of following structures:



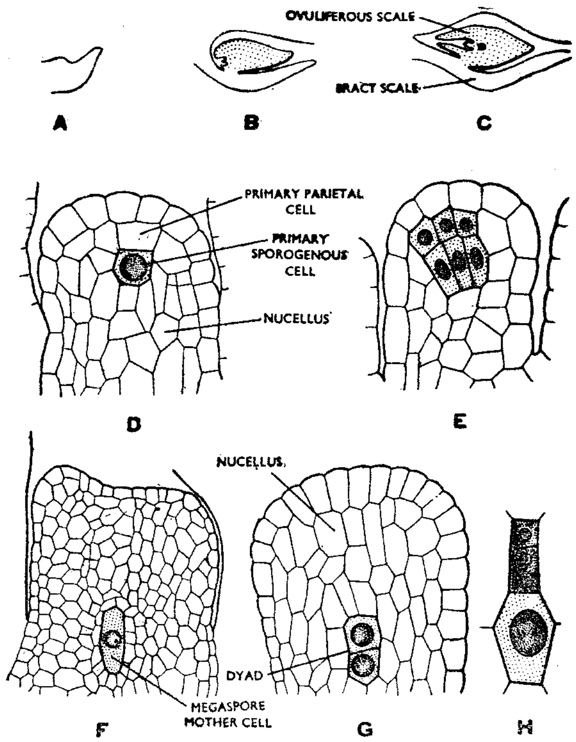
The integument: it is two lipped covering over the nucellus. Both the lips of integument form a narrow canal. The integument is differentiated into outer fleshy, middle stony and inner fleshy layers. The integument is fused with nucellus in the basal region.

Nucellus: it is a homogenous mass of compactly arranged parenchymatous cells.

Micropyle: it is the canal formed by the integuments. The micropyles of ovules are obliquely directed inward towards the axis of the cone.

Pollen chamber: it is a pocket-shaped structure present inside the ovule. The pollen grains are collected in pollen chamber.

Archegonia: at the apex of nucellus, a deep seated cell enlarges and functions as archesporial cell.



This divides to give a tapetal cell and megaspore mother cell. The latter divides meiotically to form a linear tetrad of megaspore. The apical three degenerates and the basal becomes functional megaspore or embryo sac. Soon the megaspore is surrounded by modified nucellus cells.

The development of embryo sac takes place only after pollination takes place.

At maturity, 2-3 archegonia are present at the upper end of nucellus region. Each archegonim consists of a small neck, a venter canal cell and an egg.

Pollination:

It is anemophilous. The female cone axis elongates separating the ovuliferous scales. Pollen is blown by wind inbetween ovuliferous scale and lodged in the micropyle.

The nucellus secretes mucilaginous fluid, entangles pollen and dries up bringing the pollen to the apex of nucellus. Integument growth seals the micropyle; and female cone begins to harden and brown.

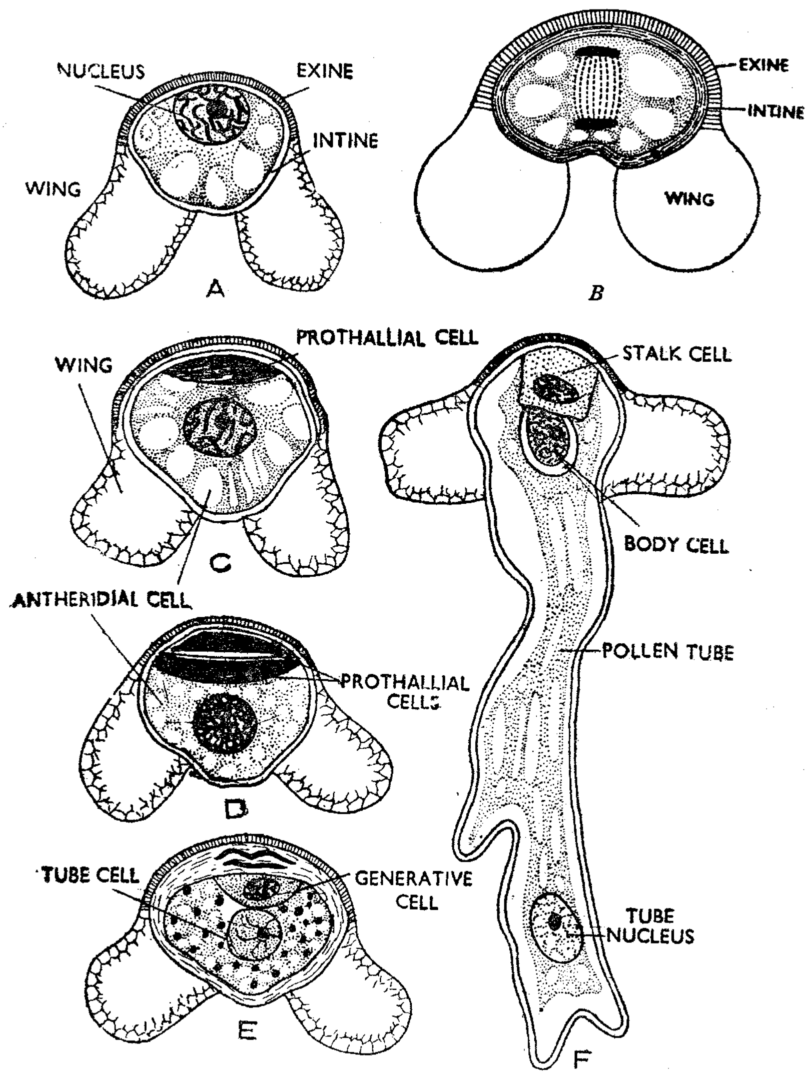
Development of male gametophyte after pollination:

The male gametophyte resumes growth on the surface of nucellus.

The tube cell divides to form a second prothallial cell, on top of the first porthallial cell. Both this prothallial cells disorganize soon.

Tube cell divides to produce a spherical antheridal or generative cell.

The exo-intine wall breaks at the ballon and the delicate intine expands into pollen tube and undergoes a period of rest.



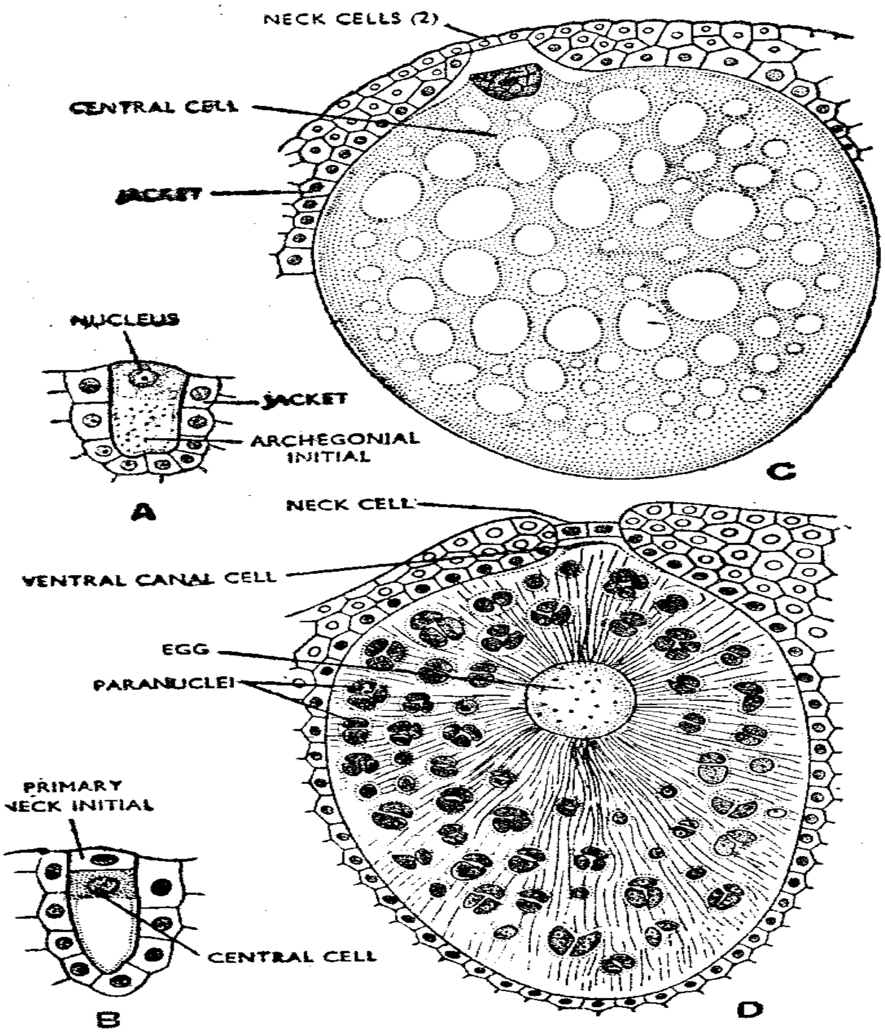
Nearly a year after pollination, at this stage, the generative cell divides into two cells: a stalk cell and a body cell.

The body cell divides to form two male cells of unequal size.

Development of female gametophyte after pollination:

The megaspore undergoes free nuclear division forming 32 nuclei. Later a vacuole is formed in the centre, pushing the nuclei to the periphery.

At this stage the embryo sac undergoes rest, and resumes growth after a year.



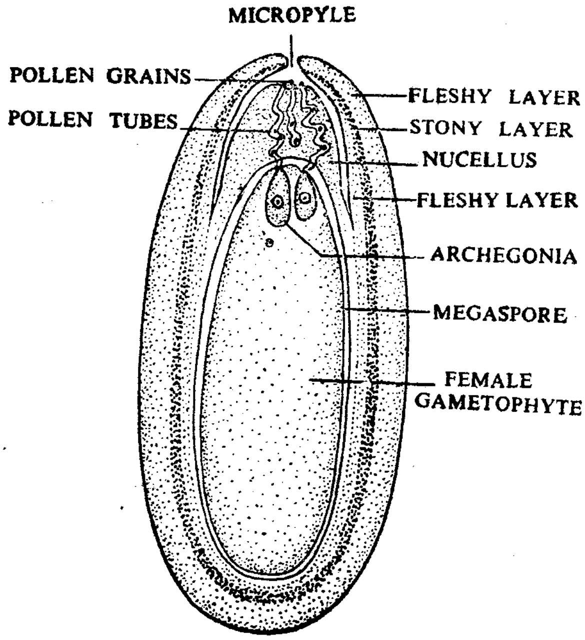
Soon there is free nuclear division, increasing the number to 2000 nucleus.

Wall formation is in centripetal direction, and the cellular tissue forms the endosperm or female prothallus.

Few cells at the micropylar end acts as archegonail initial, and develop 2 to 3 archegonia.

Archegonium gets differentiated into a small neck, a venter canal cell and an egg. The nucleus of egg cell is very large and possesses peculiar protein vacuoles called paranuclei. When mature the ventral canal cell disorganizes.

Faertilization:

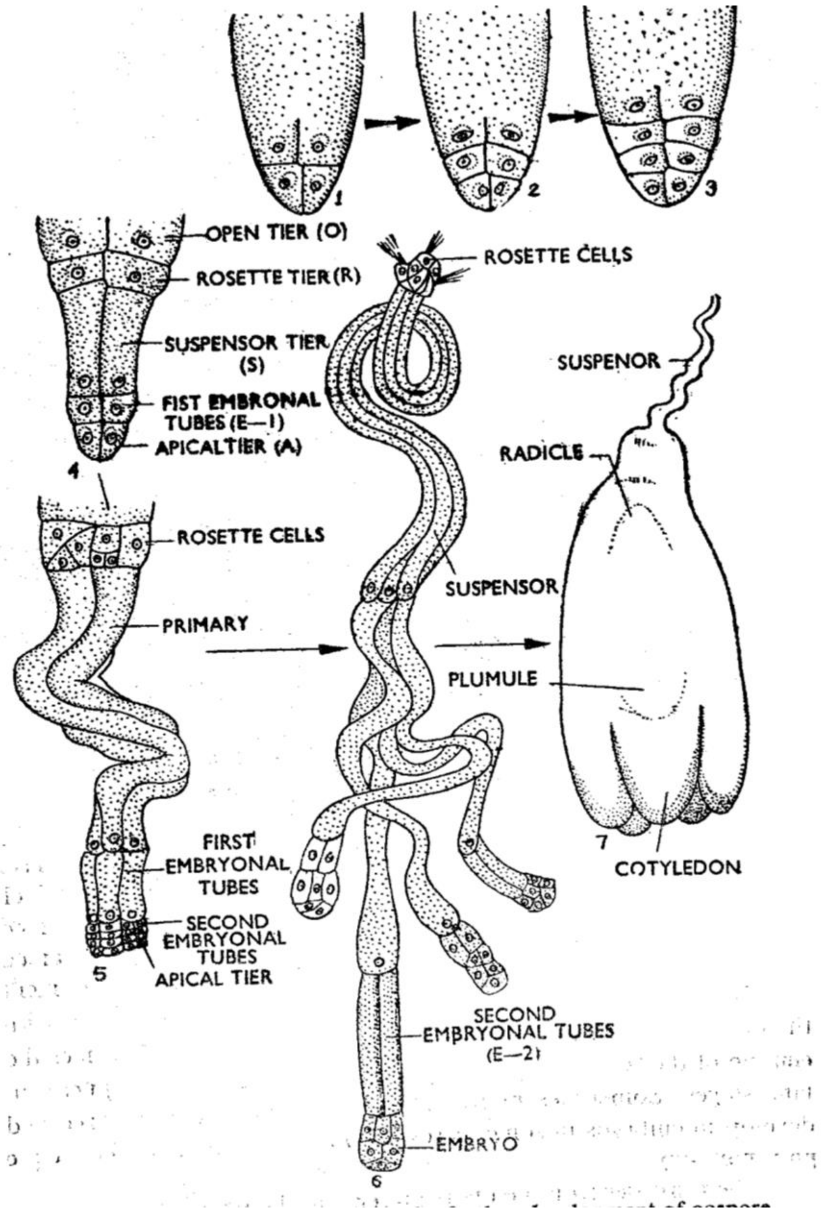


Pollen tube elongates and reaches the archegonium, burst open and throws the two unequal male nuclei, tube nuclei and stalk cell. Only the larger male nuclei fuse with the egg forming a thick walled diploid oospore.

Development of embryo:

The nucleus moves towards the basal region of the oospore, and undergo a meiotic and mitotic division forming 8 cells, in two tiers of 4 each. Again it undergoes one more division, to form 4 superposed tiers and this 16 celled stage is called proembryo.

- The uppermost tier is open-tier as it is in open communication with the oospore. This is short lived.
- Second tier form rossete-tier and is functionless.
- The third tier is of elongated cells and called suspensor tier
- The lowermost tier is the apical or embryonal-tier.



Ultimately the the embryonal cells separate and form four potential embryo and this process is called as cleavage polyembryony

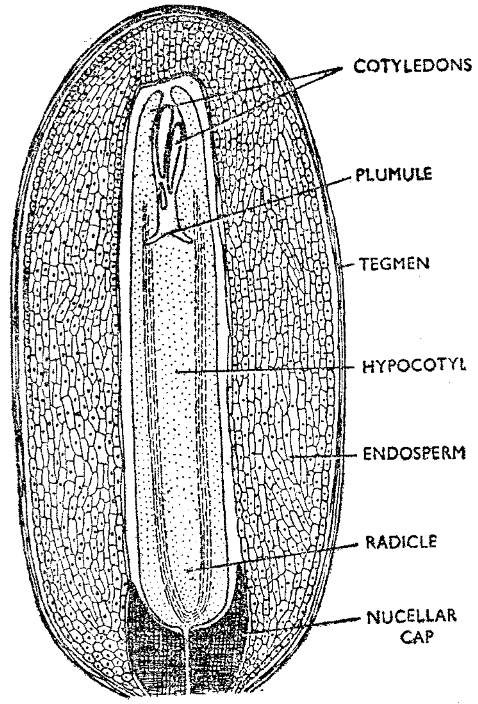
The four embryos derived from the cleavage of one proembryo struggle for existence. Only one, the lower most, becomes organized and well-defined. So it is clear that the embryo formed only from a part of the oospore and such a development is called the meroblastic development.

Seed of pinus:

The ovules in female cone are fertilized *in situ* and are transformed into seeds. The development of seeds takes place on the megasporophylls (ovuliferous scales) which are attached to female cone axis. Seeds are winged.

L.S. of seed:

Outer most covering of the seed is hard and brown called testa.



Inner fleshy layer is membranous and persistent called tegma.

Nucellus persists in the form of a thin layer at the micropylar end of the seed.

Endosperm is oily and highly developed. It acquires maximum space in the seed.

Embryo is situated in the centre of the seed attached to the coiled suspensor.

Embryo is differentiated into plumule (stem tip) radicle (root tip) and cotyledons. The cotyledons may be variable in number in different species of *Pinus*.

Hypocotyl is well developed.

Dissemination of seeds:

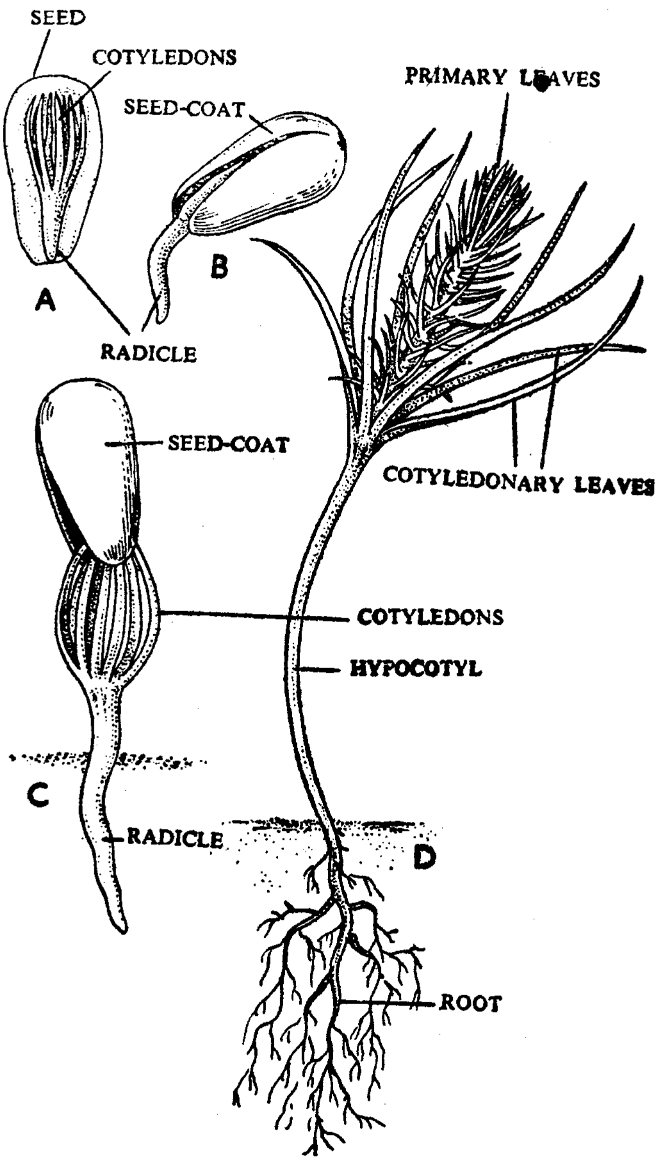
After the seeds are mature, there is renewed growth of the axis of female cone resulting into the gapping of the megasporophylls. Due to this gapping the seeds are detached from the megasporophylls and fly with the wind with the help of their wings. Each scale has a pair of winged seeds.

Seed germination:

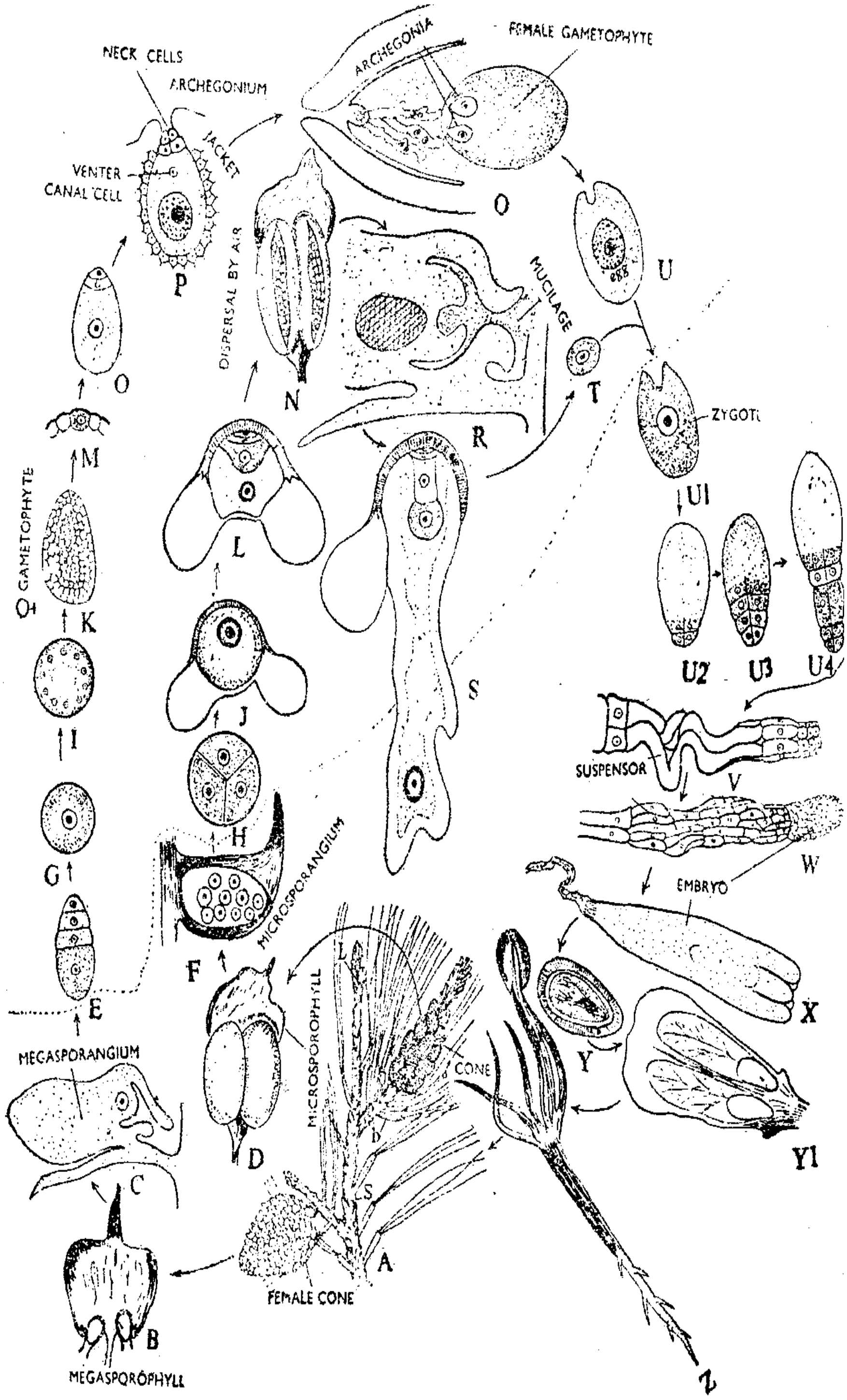
During favourable conditions, the seed absorbs water, splits the seed coat and germinates.

The seed germination is epigeal, and the cotyledons are carried with the seedling until it is 3-4 inch height. This is known as 'juvenile conditions'.

Pinus takes about 3-5 years to complete its life cycle.



Seed germination and seedling development in Pinus



Life cycle of *Pinus*.

SELF ASSESSMENT QUESTION

Match the following

A	B
1. polyembryony	a.water conducting cells
2. transfer cells	b. *Pinus*
3. starch cells	c. needle leaves
4. pegged parenchyma	d. *Cycas*

Summary:

Gymnosperms are first division of seed plants.

Cycas are rich in starch and are economically important.

Cycas is monoecious, the microsporophyll are seen as cones, whereas the megasporophyll lack such organization.

Pinus has two types of branches, and needle leaves.

The reproductive cycle of *Pinus* is very slow and long.

NOTES

UNIT - V

Geological time scale. Types of fossils. Brief study of the following fossils- *Lepidodendron* and *Williamsonia*.

Introduction:

Fossil studies in plants are difficult when compared to animals, as the organs of plants are few and very much similar in diversed groups. The leaves are soft and cannot by easily preserved like animal structure. However many types of fossil plants are obtained, but assembling the parts of a single genus is difficult, and hence plant fossils are studied as individual organ (stem, Root, seed etc.) 'form genera'. In this unit you will also be knowing the details of *Lepidodendron* and *Williamsonia*.

Paleobotany

Paleobotany, also spelled as palaeobotany (paleon(Gr.) = old and "botany", study of plants), is the branch of paleontology dealing with the recovery and identification of plant remains from geological contexts, and their use for the biological reconstruction of past environments, and the evolution of both the plant kingdom and life in general.

Paleobotany includes the study of terrestrial plant fossils, as well as the study of prehistoric marine photoautotrophs, such as photosynthetic algae, seaweeds or kelp. A closely-related field is palynology, which is the study of fossilized and extant spores and pollen.

Paleobotany is important

- in the reconstruction of ancient ecological systems and climate, known as paleoecology and paleoclimatology respectively;
- as fundamental to the study of green plant development and evolution.
- has also become important to the field of archaeology, primarily for the use of phytoliths in relative dating and in paleoethnobotany.

5.2. Plant fossils

Within the preview of palaeobotany comes the observation of the plant remains called fossils. A plant fossil is any preserved part of a plant that has long since died. In a popular sense fossils may be defined as 'imprints of nature, in the womb of earth'. So fossils may be prehistoric impressions that are many millions of years old, or bits of charcoal that are only a few hundred years old.

5.3. Geological time scale:

Macroscopic remains of true vascular plants are first found in the fossil record during the Silurian Period of the Paleozoic era. Some dispersed, fragmentary fossils of disputed affinity, primarily spores and cuticles, have been found in rocks from the Ordovician Period in Oman, and are thought to derive from liverwort- or moss-grade fossil plants .

An important early land plant fossil locality is the Rhynie Chert, an Early Devonian sinter (hot spring) deposit composed primarily of silica found outside the town of Rhynie in Scotland.

Plant-derived macrofossils become abundant in the Late Devonian and include tree trunks, fronds, and roots. The earliest tree is *Archaeopteris*, which bears simple, fern-like leaves spirally arranged on branches atop a conifer-like trunk.

Widespread coal swamp deposits across North America and Europe during the Carboniferous Period contain a wealth of fossils containing arborescent lycopods up to 30 meters tall, abundant seed plants, such as conifers and seed ferns, and countless smaller, herbaceous plants.

Angiosperms (flowering plants) evolved during the Mesozoic, and flowering plant pollen and leaves first appear during the Early Cretaceous, approximately 130 million years ago.

Fossils arranged in a chronological order clearly reveal the relationship between one group and other which are diverse in the present day. The chronological order of the different eras and periods in the history of earth together with fossils round in the period is called as Geological time scale.

It is as represented in the following section:

Geological time scale			
Era	Period	Age in million years	Type of vegetation
Cenozoic era	Quaternary	1	Modern
	UpperTertiary,Pliocene, Miocene	10 20	Modern
Mesozoic	LowerTertiary,Oligocene Ecocene Upper Cretaceous	35 50 75	Modern, with tropical plants in Europe
	Lower cretaceous Upper Jurrassic	100 130	Gymnosperms dominant (conifers and Bennettitales)
	Lower Jurassic (Liassic) Upper Triassic (Rhaetic)	140 160	Luxuriant forests of Gymno-Sperms and Ferns
	LowerTriassic(Bunter)	180	Sparse desert flora with Gymnosperms (Conifers and

	Upper Permian	190	Bennettitales)
Palaeozoic	Lower Permian Upper Carboniferous (coal measures)	200	Tall swamp forests with Early Gymnosperms, tree Lycopods, *Calamites*, Ferns.
	Lower Carboniferous Upper Devonian	250 260	Early Gymnosperms, large Tree Lycopods and Ferns.
	Middle Devonian	275	*Rhynia* vegetation in marshy localities
	Lower Devonian Upper Silurain	300	Herbaceous marsh plants (*Psilophyton, Zosterophyllum*), small shrubs
	Silurian Ordovician	350 425	Marine algae
	Cambrian	500	Marine algae, but some evidence of land plants.
Pre cambian		4500?	Fungi and bacteria reported to have occurred 2,000 million years ago.

Some plants have remained remarkedly unchanged throughout earth's geological time scale. Early ferns had developed by the Mississippian, conifers by the Pennsylvanian. Some plants of prehistory are the same ones around today and are thus living fossils, such as *Ginkgo biloba* and *Sciadopitys verticillata.* Other plants have changed radically, or have gone extinct entirely.

Types of plant fossils:

Fossils of plants are very different from the fossils of animals, and this is in part a result of the different architecture of plants. Animals develop with specific parts, and in both the young and adult animal, those parts exist in fixed numbers and locations. Even animals which undergo metamorphosis have only one head, and will emerge with a fixed body structure. By contrast, plants are continually producing new branches, leaves, and other parts throughout their lives. These parts may fall off without injuring the plant. Thus, plants fossils are often fragmentary pieces such as leaves, branches, or pollen.

Since a leaf, stem, spore, or seed may be found preserved without any physical connection to the plant from which it came, paleobotanists use form taxa (singular form taxon) to name and classify such fossils. When the true identity of such fossils is later discovered, the two form taxa may be merged.

For example, in the 1960s fossil leaves called *Archaeopteris* (literally "ancient fern") were found attached to fossil wood of the tree *Callixylon*. The whole plant is now known to be a Devonian tree with fern-like leaves but with gymnosperm-like wood.

Some form taxa continue to exist even after their identity is determined. This is a matter of convenience for identifying quickly which part was found as a fossil, especially which the fossil may come from more than one kind of plant. Leaves assigned to the form taxon *Sphenopteris* come from both ferns and from seed plants; it usually is not possible to determine from isolated fossils which group the leaves belong to.

5.4.1. **Dead and preserved bodies**: the actual dead and preserved bodies, or parts of bodies, or plants and animals, with the original tissue intact, and enclosed wither in ice or amber or else mummified in various ways, form this class of fossils.

5.4.2. **Petrified fossils**: One of the most spectacular of plant fossils is petrified wood. In these fossils, organic matter has been replaced particle for particle, by mineral matter such as lime, silica, magnesium salts etc., and in such a way that finer structure of the tissue has been very nicely duplicated and rendered permanent. These types of fossils are numerous and important. *E.g.*, in coal mines generally the coal balls are formed by the infiltration of calcium carbonate.

5.4.3. **Casts and molds**: a plant that has been laid in mud or clay long enough to have left its impression; the mud hardens about the body and forms a mould; the organic matter disintegrates and the mould is filled with hard mineral mater; and the matrix may then be removed so as to leave the perfect cast.

5.4.5. **Compressions**: One of the most common kinds of plant fossils is a compression fossil, in which a leaf or flattened part of the plant has been pressed between layers of sediment and often preserved as a carbonaceous film. A compression fossil is a fossil preserved in sedimentary rock that has undergone physical compression. While it is uncommon to find animals preserved as good compression fossils, it is very common to find plants preserved this way. The reason for this is that physical compression of the rock often leads to distortion of the fossil. The best fossils of leaves are found preserved in layers of sediment that have been compressed in a direction perpendicular to the plane of the deposited sediment. Since leaves are basically flat, the resulting distortion is minimal. Plant stems and other three-dimensional plant structures do not preserve as well under compression. Typically, only the basic outline and surface features are preserved in compression fossils. Internal anatomy is not preserved.

Compression fossils are formed most commonly in environments where fine sediment is deposited, such as in river deltas, lagoons, along rivers, and in ponds. The best rocks in which to find these fossils preserved are clay and shale, although volcanic ash may sometimes preserve plant fossils as well.

5.4.5. **Imprints**: These are formed from the burial of plant parts in soils, which harden into rock. The imprint of the organism is left in the rock, after its decomposition. Prints preserve the external features only.

5.4.6. **Actual remains**. Such plant fossils are of comparatively young age and do not decompose completely due to low temperature or vacuum. All materials that are resistant to natural decomposition are preserved like this, *e.g.*, cuticle, cutin, spore, pollen etc. Some time plant material happens to fall in resin or amber extruded by some plants, such as pine trees and others and are resistant.

5.4.7. **Chemical remains**: chemical materials like amino acids and hydrocarbons may be obtained in a natural state or in a modified form from the rocks in which organic matter of the pertified plant part or organ has been incorporated.

5.4.8. **Products of activity of organism**: Sometimes products exerted by living organism are obtained for the excavations, *e.g.*, secreted lime deposits of algae. Such products have been found on pottery and other manufactured goods discovered during excavation.

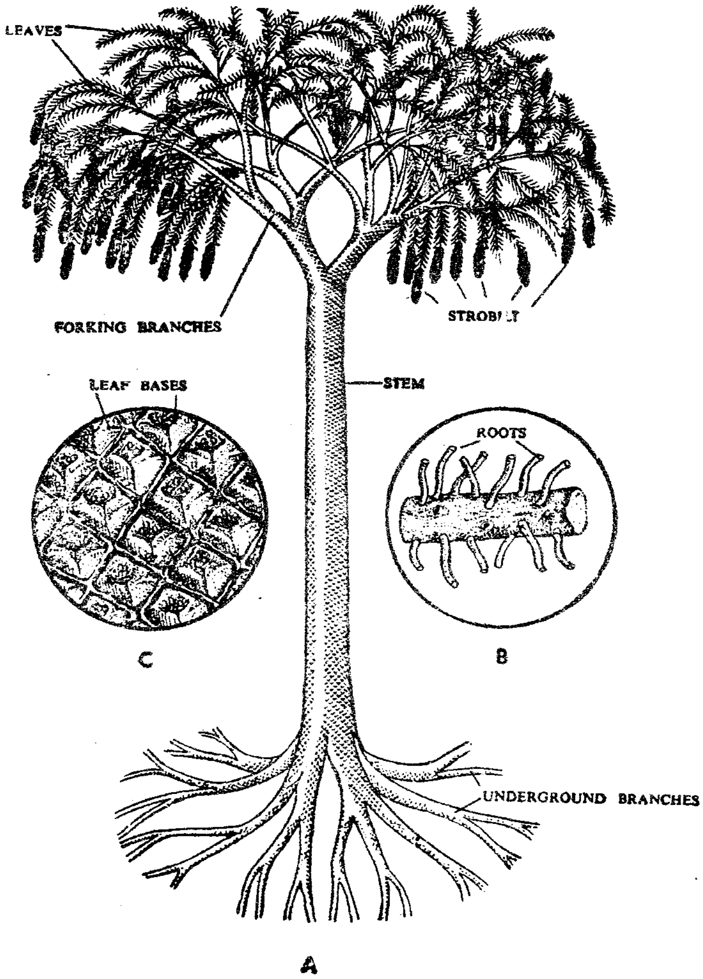
Lepidodendron:

The genus *Lepidodendron* has 100 species. It appeared in the late Devonian, flourished in Carboniferous and underwent degeneration most probably during the late Permian.

They flourished well in the slabs and sand stones of the carboniferous period.

The plant body:

The plant body is tree- like, similar to other ancient lycopods.



Lepidendron reconstruction: A. habit; B. roots from underground branch; c. leaf bases

The petrified trunks were sometimes as long as 100 feet or high and formed swamp forests.

The stem was erect, unbranched for a considerable height and then showed a regular dichotomy in its branches, at its crown.

Root system is typical *Stigmarian* type.

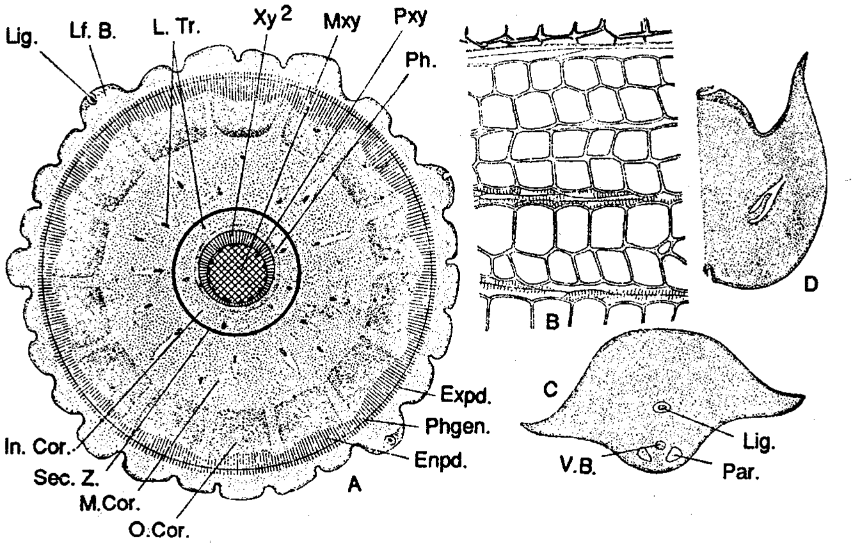
The leaves named as the form genus *Lepidophyllum* were circular to linear in shape, having a length of 5-9 inches, arranged spirally on the branches.

The leaves were ligulate. Each leaf had a single vein with the stomata situated in two bands on the ventral surface.

The leaves were deciduous and persistent leaf bases were pyramidal in outline and formed peculiar leaf cushion.

Internal structure:

Stem:



T.S. of L. vasculare (after Smith) Lig. Ligule; L. tr. Leaf trace; Mxy. Metaxylem;Ph. Phloem; Expd. Endophelloderm; In. cor. Inner cortex; M.cor. middle cortex; Lf. B. leaf blade; xy2. secondary xylem; Pxy. Primary xylem; Expd. Exophelloderm; Phgen. Phellogen; Sec. Z. secretory zone; O. cor. Outer cortex.

The outer most epidermis is very soon (even before secondary growth) replaced by periderm.

The cortex is broad, and differentiated into outer, middle and inner cortex.

The outer cortex consists of alternating bands of sclerotic and parenchymatous cells.

The middle cortex is homogenous parenchymatous. Next to it is a secretory zone consisting of glandular cells which were filled with a dark coloured substance.

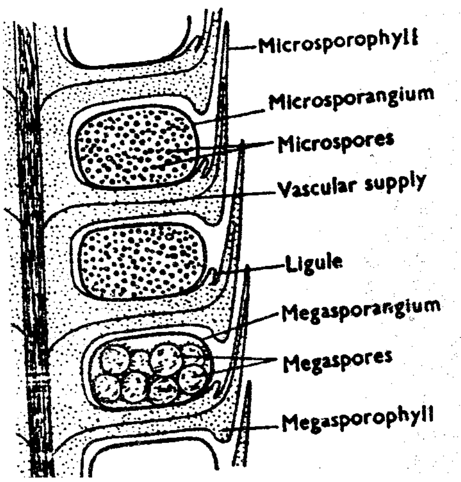
The inner cortex is parenchymatous.

The stem was usually protostele or siphonostele. The protoxylem was exarch and polyarch.

Secondary growth is recorded in a few species. The cambial activity is not uniform. It produces xylem to the interior and secondary phloem to the exterior. Due to cambial activity eccentric rings are formed.

The leaf showed a single vascular bundle flanked on either side by parichnos cavities. These are believed to be aerating oragns.

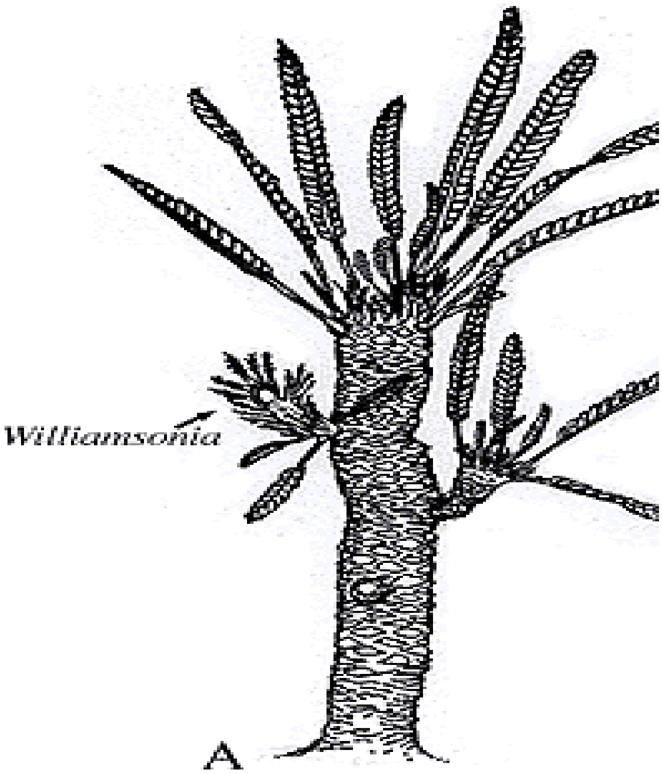
The name of the form genus of the cone or strobilus of *Lepidodendron* is



Lepidendron form genus *Lepidostrobus*

Lepidostrobus. It is an elliptical or cylindrical body bearing both micro and mega sporophyll on the central axis spirally or whorlly. The sporophylls are ligulate and somewhat peltate bearing a single, sessile, elongate sporangium on their adaxial surface. The microsporophylls were placed towards the apex and megasporophyll towards the base of the strobili.

Williamsoina:



Reconstruction of *Williamsonia sewardiana* with spirally arranged leaf scars.

First appear in the upper Triassic, became more abundant in Jurassic and became extinct toward the end of the Cretaceous. Birbal Sahni described *W. sewardiana* for Rajmahal hills.

Williamsonia resembled cycas in appearance. They have upright, slender, branching trunks about 2 meters tall, with monosporangiate strobili. They have woody stems that were heavily armored with persistent rhomboidal scars of leaf bases, much like modern cycads. They produced pinnate compound foliage, like *Pitlophyllum,* in a terminal crown.

Two types of lateral shoots were there. Sterile or vegetative shoots and fertile or reproductive lateral shoots.

At the base of lateral shoots a distinct constriction was present, indicating that probably detached laterals helped in vegetative propagation.

Leaves were of 2 types

1. simple scale like pointed leaves and
2. pinnately compound foliage leaves. Lateral branches bear only foliage leaves.

Internal structure:

T. s. of trunk revealed a circular outline.

Cortex is broad, parenchymatous, with secretory sacs.

Pith is narrow, parenchymatic with secretory sacs.

Primary vasculature consisted of a ring of endarch, conjoint, collateral vascular bundles.

Pith extends between the vascular bundles in the form of pith rays.

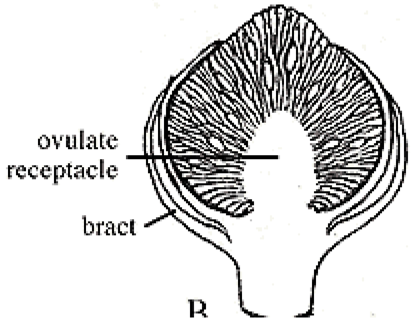
Secondary wood was traversed by uni, bi or triseriate secondary medullary rays. The wood was pycnoxylic, *i.e.*, compact and consisted of scalariformed bordered pitted tracheids.

The cambium was distinct.

Leaf traces were multiple but not girdling.

Reproduction:

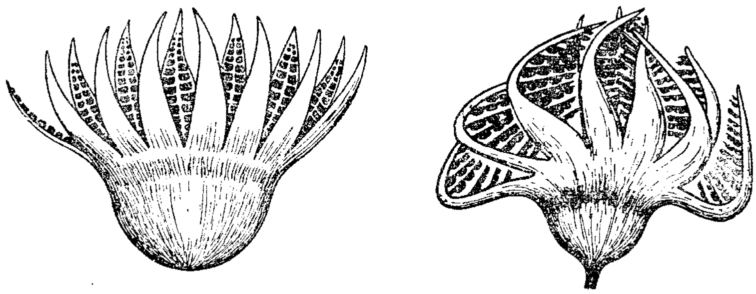
Williamsonia, frutification were large upto 12 cm in diameter and are borne on th long peduncle. Around the baseof the floral axis were present many spirally arranged bracts. In *W. gigas* the cones were present among the crowm of leaf bases where as in *W. sewardiana* they were present on the short lateral branches. The plants are unisexual.



Williamsonia ovulate structure

Female flower: female cones of only *W. gigas and W. sewardiana* have been discovered so far. The female flower had a conical receptacle surrounded by many perianth like bracts. The ovules were stalked. The apex of the receptacle was naked and sterile. The nucellus were surrounded by a single integument. The integument was vascularized and fused with the nucellus. The ncellus has a well marked beak and a pollen chamber.

Male flower:



A B

Pollen bearing organ of A. *W. whitbiensis*; B. *W. spectabilis*.

It consists of a whorl of microsporophylls which were united to form a more of less cup like structure. In most of the species (*W. whitbiensis*) the sporophylls were unbranched while in some specis (*W. spectabilis*) they were pinnately branched. In *W. santalensis*, the microsporophylls were bifid. One of the branches of sporophyll was fertile while other was sterile. The complete male flower of *W. santalensis* was about 20 cm long while a single microsporophyll attained a length of 10 cm. The fertile branch of the bifid sporophyll contained many purse-like capsules, in which were present many pollens.

SELF ASSESSMENT QUESTIONS:

1. Fossil *Lepidodendron* root is called _____________.
2. Fossil *Lepidodendron* leaf is called _____________.
3. Fossil *Lepidodendron* cone is called _____________.
4. *Williamsonia sewardiana* was reconstructued from ________ area.

Summary:

In the earlier units, we have discussed of plants that make the present day flora of the earth. In the present unit we have discussed briefly of some of those that have lived on this plant in previous ages. We have also seen different evidence of preserved plant material, of which, petrifaction and sedimentation are the important and best fossils available in plants. In geological history, major fossil reserves of plants are seen during the Cretaceous period, in the form of sediments.

Birbal Sahani is called the "father of Indian paleobotany".

NOTES