PLANT DIVERSITY-II (PTERIDOPHYTES, GYMNOSPERMS AND PALEOBOTANY)

UNIT I: PTERIDOPHYTES

General characters, Reimer's classification (1954). Telome concept. Sporangium development – Eusporangiate type and Leptosporangiate type. Apogamy, Apospory, Heterospory and Seed habit. Detailed account on stellar evolution.

UNIT II:

Brief account of the morphology, structure and reproduction of the major groups-Psilophytopsida, Psilotopsida, Lycopsida, Sphenopsida and Pteropsida. (Individual type stydy is not necessary). Economic importance of Gymnoperms.

UNIT III: GYMNOSPERMS

General characters – Classification of Gymnosperms (Sporne, 1965), Orgin and Phylogeny of Gymnosperms, Gymnosperms compared with Pteridophytes and Angiosperms-Economic Importance of Gymnosperms.

UNIT IV:

A general account of distribution, morphology, anatomy, reproduction and life cycle of the following major groups – Cycadopsida (Pteridospermales, Bennettitales, Pentaxylales, Cycadales) Coniferopsida (Cordaitales, Coniferales, Ginkgoales) and Gnetopsida (Gneales).

UNIT V: PALEOBOTANY

Concept of Paleobotany= Geological time scale- Fossil- Fossilization- Compressions, Incrustation, Casts, Molds, Petrifactions, Compactions and Caol balls. Detailed study of the fossil forms- Pteridophytes: Lepidodendron, Calamites. Gymnosperms: Lyginopteris, Cordaites. Role of fossil in oil exploration and coa excavation, Paleopaynology.

Prepared by:

Unit I and II
1. Dr. A.Pauline Fathima Mary,
Guest Lecturer in Botany
K. N. Govt. Arts College(W), Auto., Thanjavur.

Unit III and IV
1. Dr. S.Gandhimathi,
Guest Lecturer in Botany,
K. N. Govt. Arts College(W), Auto., Thanjavur.

Unit V:
1. Dr. G.Santhi,
Head and Assistant professor of Botany,
K. N. Govt. Arts College(W), Auto., Thanjavur.

Reference:

1. Rashid, A, (2007), An Introduction to Peridophytes- Vikas Publications, New Delhi.
2. Sporne, K.R. (1975). The Morphology of Pteridophytes, London.
3. Coultar, J. M. and Chamberin, C, J. (1976). Morphology of Gymnosperms. Allahabad.
4. Shukla, A.C. and Mishra, S.P. (1982). Essentials of Paleobotany (2nd ed.). Vikas Publishing, House Pvt. Ltd., New Delhi.

Unit I:

Pteridophytes:

General Characters:

1. Pteridophytes are considered as the first plants to be evolved on land:

It is speculated that life began in the oceans, and through millions of years of evolution, life slowly adapted on to dry land. And among the first of the plants to truly live on land were the Pteridophytes.

2. They are cryptogams, seedless and vascular:

Pteridophytes are seedless, and they reproduce through spores. They contain vascular tissues but lack xylem vessels and phloem companion cells.

3. The plant body has true roots, stem and leaves:

They have well-differentiated plant body into root, stem and leaves.

4. Spores develop in sporangia:

The sporangium is the structures in which spores are formed. They are usually homosporous (meaning: one type of spore is produced) and are also heterosporous, (meaning: two kinds of spores are produced.)

5. Sporangia are produced in groups on sporophylls:

Leaves that bear the sporangia are termed as sporophylls. The tip of the leaves tends to curl inwards to protect the vulnerable growing parts.

6. Sex organs are multicellular:

The male sex organs are called antheridia, while the female sex organs are called archegonia.

7. They show true alternation of generations:

The sporophyte generation and the gametophyte generation are observed in Pteridophytes. The diploid sporophyte is the main plant body.

Life Cycle of Pteridophyta

Pteridophytes show alternation of generations. Their life cycle is similar to seed-bearing plants, however, the pteridophytes differ from mosses and seed plants as both haploid gametophyte and diploid sporophyte generations are independent and free-living. The sexuality of pteridophytic gametophytes can be classified as follows:

1. **Dioicous:** the individual gametophyte is either a male producing antheridia and sperm or a female producing archegonia and egg cells.
2. **Monoicous**: every individual gametophyte may produce both antheridia and archegonia and it can function both as a male as well as a female.
3. **Protandrous**: the antheridia matures before the archegonia.
4. **Protogynous**: the archegonia matures before the antheridia.

Classification of Pteridophytes:

Pteridophyta is classified into four main classes:

Psilopsida

- They are the most primitive.
- The stem is photosynthetic and dichotomously branched.
- Rhizoids are present.
- Leaves are mostly absent.
- The sporophyte is homosporous synangium.
- Examples- *Psilotum and Tmesipteris.*

Lycopsida

- They are commonly known as club moss.
- Well-differentiated plant body with adventitious root, stem, rhizophores and leaves.
- The sporophyte is homosporous or heterosporous.
- Examples- *Selaginella, Lycopodium.*

Sphenopsida

- Commonly known as horsetail.
- Well-differentiated plant body with roots arising from nodes of the underground rhizome, stem and scaly leaves.
- Homosporous, sporangia are borne on strobili.
- Examples- *Equisetum.*

Pteropsida

- Commonly known as a fern.
- Well-differentiated plant body with roots, stem and leaves.
- The sporophyte is homosporous or heterosporous.
- Antherozoids are multiflagellate.
- Examples- *Pteris, Dryopteris, Adiantum*

TELOME THEORY

Introduction to Telome Theory:

It is now widely accepted (on the basis of overwhelming amount of evidence) that the land-dwelling plants evolved from aquatic ancestors. Ail organisms known in the Precambrian, Cambrian and Ordovician periods of Paleozoic Era lived in aquatic environment.

The evolutionary conquest of land probably occurred sometimes between the late Cambrian and early Silurian. The concrete evidence of early vascular land plants came from the Silurian in the form of fossil plant Cooksonia of Rhynia group of plants.

A number of theories on land-plant evolution exists of which the Telome theory of Walter Zimmermann (1930, 1952) is the most comprehensive. This theory is based on fossil record and synthesises the major steps in the evolution of vascular plants.

According to this theory, all vascular plants evolved —either directly or indirectly — from a simple leafless Rhynia type ancestral form made up of sterile and fertile axes (the telomes). Evolutionary modification of its parts produce more advanced vascular plants with roots, stems, leaves, more complex vascular systems and protected sporangia.

Meaning of Telome Theory:

A telome is defined as "the single-nerved ultimate terminal portion (at base or apex) of a dichotomising axis" i.e., it is the point of the most distal dichotomy to the tip of a branch. The connecting axes between dichotomies are called mesomes (Fig. 7.134). Functionally, telomes are of two types viz., fertile telome and sterile telome.

If the ultimate branch is terminated by a sporangium then it is a fertile telome (Fig. 7.134), whereas those terminal branches without sporangia are called sterile (vegetative) telomes (Fig. 7.134). Several

vtelomes, either fertile or sterile, becomes grouped together by connecting mesomes to form a more complex structure, called syntelome or telome truss (Fig. 7.134).

A syntelome is designated as phylloid truss if composed of only sterile or vegetative telomes, or as fertile truss when composed of only fertile telomes, or a mixed telome truss when com-posed of both sterile and fertile telomes.

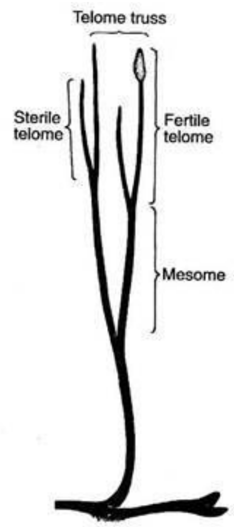


Fig. 7.134 : A primitive *Rhynia* plant showing telome and mesome

Telome and the evolution of the independent sporophyte among pteridophytes:

Processes of Telome Theory:

According to Zimmermann, these telomes or telome trusses of primitive Rhynia type of vascular plants have been subjected to certain evolutionary processes in varying degrees among the various taxonomic groups.

These evolutionary processes are:

(i) Overtopping

(ii) Reduction,

(iii) Plantation,

(iv) Syngenesis or webbing, and

(v) Curvation.

(a) Overtopping:

In this process, one of the two dichotomising branches of the primitive axis produced by the apical meristem outgrows or overgrows the other. The larger axis thus produced becomes the stem, while the shorter or overtopped branches represent the beginnings of lateral branches or leaves (Fig. 7.135A-C). Now the earlier dichotomy will be transformed to pseudomonopodial branch.

(b) Reduction:

In this process, the activity of terminal meristem of each telome of the truss becomes suppressed resulting into much shorter branches by decreasing the length of telomes and mesomes (Fig. 7.135B, C). This process is responsible for the formation of microphyllous leaves of the Lycopsida and Sphenopsida as well as the needle-like leaves of conifers.

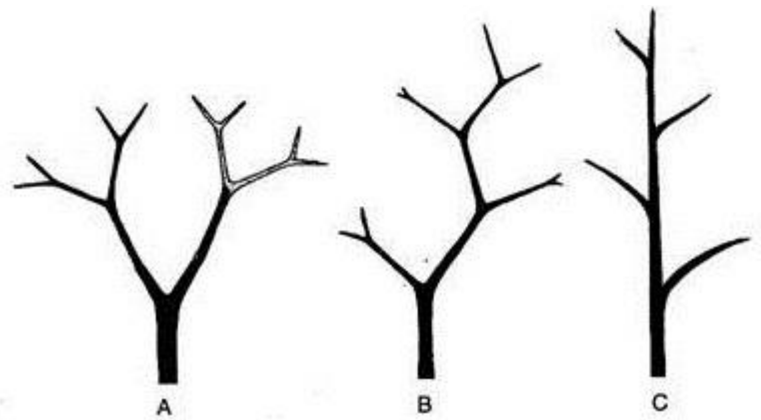


Fig. 7.135 : Telome concept : A–C. Evolutionary process of overtopping and reduction

(c) Planation:

The process of planation caused the telomes and mesomes of the truss to shift from a three-dimensional pattern (cruciate dichotomy) to a single plane (fan-shaped dichotomy) (Fig. 7.136A, B).

The process of infilling with photosynthetic and other tissues between the planated branches is called webbing which have led to the evolution of flattened leaf-like structure with a dichotomously veined lamina.

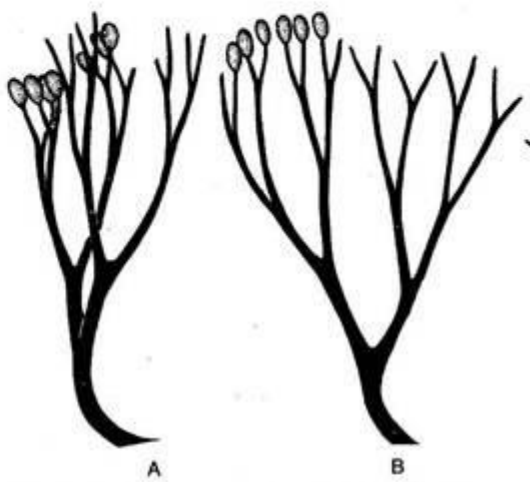


Fig. 7.136 : Telome concept : A–B. Evolutionary process of planation

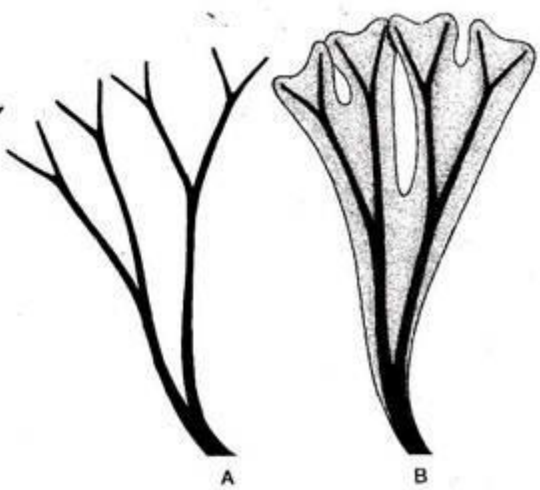


Fig. 7.137 : Telome concept : A–B. Evolutionary process of webbing

(d) Syngenesis:

This is an evolutionary process where tangential fusion of mesomes and telomes takes place (Fig. 7.137A, B). The lateral fusion of sterile vegetative telomes and mesomes resulted into complex anastomosing vascular systems in stem (e.g., polystelic condition in Selaginella).

The fusion of fertile trusses with their terminal sporangia resulted in the formation of synangia of Psilotum. The closed or reticulate venation pattern of some ferns, gymnosperm and many flowering plants are the result of syngenesis of the dichotomising veins of the primitive leaf.

(e) Curvation:

This evolutionary process is caused due to the unequal growth of the tissues on two opposite flanks of the telome.

It has two sub-processes:

(i) Recurvation:

In this sub-process the telome bends inward toward an axis (Fig. 7.138A, B). The inward-projecting sporangia on a sporangiophore of Equisetum (Sphenopsida) is the result of this sub-process.

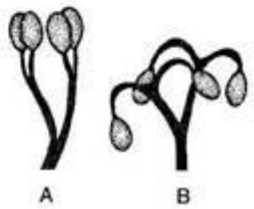


Fig. 7.138 : Telome concept : A–B. Evolutionary process of recurvation

(ii) Incurvation:

In this sub-process, the fertile telome bends downward resulting in the downward shifting of the sporangia from terminal to the ventral surface of the leaf. This sub-process is responsible for the formation of ventral position of the sporangia in fern (Pteropsida) leaf

Concept of Telome Theory:

The telome concept has been used in understanding the origin and evolution of the following major groups of plants:

1. Psilopsida:

The telome theory can be applied to interpret the evolution of a synangium of Psilotum. The overtopping, reduction and syngenesis have combined to produce a synangium of Psilotum (Fig. 7.139A-D).

Initially, the overtopping occurred in the aerial branch of Rhynia- type plant to form a pseudomonopodial branching system with laterals having 3-dimensional dichotomously branched fertile and sterile telome trusses.

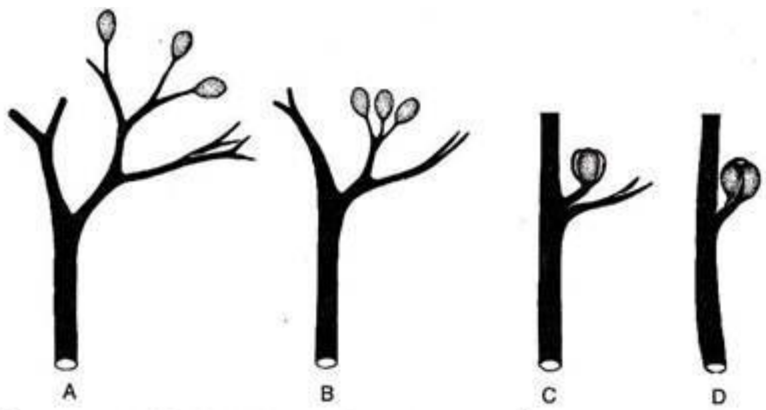


Fig. 7.139 : Telome concept : A–D. Evolutionary process of overtopping, reduction and syngenesis to depict the origin of synangium in *Psilotum*

Then, due to the continuous reduction in both the telome trusses, the sporangia were placed in a condensed cluster and became proximal to the main axis. Then the further reduction had occurred in the fertile telome which allowed sporangia to come in close contact with each other and, again, allowing syngenesis to occur resulting in the formation of a synangium.

The bifid appendage which subtends a synangium in Psilotum is a product of reduction of vegetative telome truss associated with fertile telomes.

2. Pteropsida:

A megaphyllous leaf of Pteropsida originates following the three steps overtopping, planation and webbing (Fig. 7.140A-D). By overtopping, the original dichotomous branching system changed to pseudomonopodial branch with a main stem and lateral branches.

Now, the lateral telomes and mesomes of the truss, which were originally 3-dimensional (cruciate) type, became planted (one-dimensional). The planted telomes which have come closer became a flattened leaf-like structure with a number of tree-ending veins by webbing through the infilling with photosynthetic and other tissues between the planted telomes and mesomes.

Further, a reticulate venation pattern was obtained in some Pteropsida due to the syngenesis of the dichotomising veins.

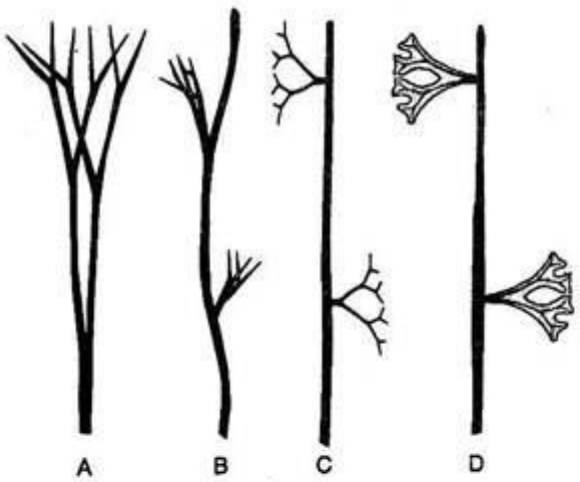


Fig. 7.140 : Telome concept : Stages in the evolution of the megaphyll of Pteropsida from primitive dichotomous axis (A) following overtopping (B), planation of axis (C) and syngenesis (D)

3. Sphenopsida:

The chief trends in the origin of sporangiophore in Sphenopsida were recurvation and syngenesis resulting in a pellate structure with reflexed sporangia (Fig. 7.141 A-C). Here the fertile telome truss followed recurvation which has been evidenced in many fossil members of Sphenopsida like Hyenia, Calamophyton, etc.

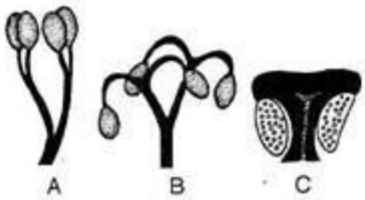


Fig. 7.141 : Telome concept : Stages in the evolution of the sporangiophore in Sphenopsida from primitive dichotomous fertile axis (A) following recurvation (B) and syngenesis (C)

Subsequently, a pellate sporangiospore with reflexed sporangia had evolved due to syngenesis. The nature of sporangiophore of Calamites and Equisetum provides examples of such process. However, the leaf of sphenopsida had evolved following planation and reduction.

4. Lycopsida:

The origin of microphyllous leaf of Lycopsida can also be demonstrated in the light of telome concept following overtopping and reduction (Fig. 7.142A-C). Here the lateral branch of pseudomonopodial branch system followed successive reduction to form a linear, unbranched microphyll.

Fig. 7.142 : Telome concept : Stages in the origin of microphyll following overtopping and reduction. A. Dichotomising lateral branch, B. Bifurcated microphyll of Protolepidodendrales, C. Microphyll of Lycopsids, D. *Asteroxylon* enation

Thus, the pentafid (Leclercquia), trifid (Colpodexylon) and bifid (Protolepidodendron) leaves and sporophylls are the intermediate forms. However, the stages of successive reduction of leaves do not coincide with the ages of the fossil plants.

Say for example, the microphylls of Upper Devonian lycopods are reported later in spite of their prim- itiveness than the much reduced enation (advanced) of Lower Devonian Zosterophyllopsida. Hence, the Telome theory is 'misfit' for interpreting the origin and evolution of microphylls in Lycopsida.

Enation Theory:

This theory was propounded by F. O. Bower (1935). The enation theory seems to be more convincing than the telome theory for explaining the origin of microphyllous leaves (Fig. 7.143A-D). According to Enation theory, the microphylls were initiated as nonvascularised spine-like outgrowths (enations) on the shoot of primitive vascular plants (e.g., Zosterophyllopsida).

These spine-like enations were not arranged in a definable pattern. Initially, tooth-like enations were arranged in vertical rows on opposite sides of the axes (e.g., Crenaticaulis,

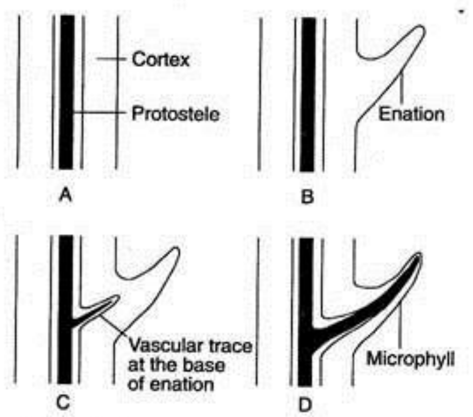


Fig. 7.143 : Enation theory : A–C. Stages in the origin of microphyll. A. Axis of Rhyniopsida, B. Axis of Zosterophyllopsida, C. Axis of *Asteroxylon*, D. Axis of Lycopsida showing a microphyll

Serrulacaulis).

However, in Sawdonia, irregularly disposed tapered and pointed spine-like enations are reported on the axes. In zosterophylls, enations are devoid of any vasculature (first step). However, in the next step (second step) as exemplified by Asteroxylon, a trace of vascular tissue arises directly from the protostele of the axis and enters the base of the enation. Here enations are spirally arranged on the axes.

In the final step, the enations become elongated, flattened and leaf-like and the vascular trace grew up to the tip of the leaf. In this way, a microphyllous leaf (a single unbranched leaf trace arises directly from the protostele) evolved in the Lower Devonian.

The further elaboration of the microphyll (with branched tips) in early herbaceous lycopods (Leclercquia, Protolepidodendron, Estinnophyton) can only be explained by telome theory.

Significance of Telome Theory:

(i) The telome theory portrays the origin and evolution of the sporophytes in the earliest known land plants.

(ii) The theory is based mostly on account of the comparative study of the fossil as well as living genera of the vascular plants. It actually explains the phylogenetic relationship between the fossil and the living plants.

(iii) The five elementary processes like overtopping, reduction, planation, recurvation and syngenesis give a unified concept of the manner in which evolution might have proceeded in the land plants. These processes explain in a simple and lucid way as to how the primitive land plants led to the evolution of both the simple and the complex land plants of today.

Moreover, these processes provide a basis of interpretation in solving the morphological controversies of different organs in the vascular plants such as:

(a) The nature of the aerial portion of the plant body of the Ophioglossaceae,

(b) Anatomy of some species of the Medullosaceae,

(c) Nature of the plant body un the Coenopterid forms,

(d) Evolution of the vegetative and reproductive structure of Cordaitales and early conifers,

(e) Phyllogeny and origin of stamens and carpels.

The theory explains in a satisfactory manner that the entire sporophyte is an axis that has an underground portion called the root and an aerial part called the shoot. The appendages of the shoot that is the sporophylls, sporangia and sterile leaves are nothing but modified parts of the shoot.

Development of Sporangium:

Eusporangiate Sporangium: A large sporangium developing from several initial cells producing many spores.

Leptosporangiate Sporangium: Small, specialized sporangia developing from a single initial cell producing a small, definite number (<128) of spores.
Apospory is the development of 2n gametophytes, without meiosis and spores, from vegetative, or nonreproductive, cells of the sporophyte.

In contrast, **apogamy** is the development of 1n sporophytes without gametes and syngamy from vegetative cells of the gametophyte.

Heterospory in Pteridophytes:

Most of the Pteridophytes produce one kind of similar spore. Such Peridophytes are known as homosporous and this phenomenon is known as homospory. However, there are some Pteridophytes which produce two different types of spores (differing in size, structure and function).

Such Pteridophytes are known as heterosporous and the phenomenon is known as heterospory. The two types of spores are microspores and megaspores. Microspores are smaller in size and develop into the male gametophyte while the megaspores are large and develop into female gametophyte.

Seed Habit in Pteridophytes:

The adoption of heterospory and the retention and germination of a single megaspore within megasporangium to form a female gametophyte, led to the phenomenon of “seed habit”, a characteristic feature of the spermatophytes. A seed is that ovule which contains an embryo developed as a result of fertilization.

The origin of seed habit is associated with the following:

(i) Production of two types of spores (heterospory).

(ii) Reduction in the number of megaspores finally to one per megasporangium.

(iii) Retention and germination of the megaspores and fertilization of the egg.

(iv) Continued development of the fertilized egg into the embryo while still in situ.

Seed Habit in Pteridophytes:

The adoption of heterospory and the retention and germination of a single megaspore within megasporangium to form a female gametophyte, led to the phenomenon of “seed habit”, a characteristic feature of the spermatophytes. A seed is that ovule which contains an embryo developed as a result of fertilization.

The origin of seed habit is associated with the following:

(i) Production of two types of spores (heterospory).

(ii) Reduction in the number of megaspores finally to one per megasporangium.

(iii) Retention and germination of the megaspores and fertilization of the egg.

(iv) Continued development of the fertilized egg into the embryo while still in situ.

UNIT II:

General Characters of Psilophytopsida

Psilophytopsida is a now obsolete class containing one order, Psilophytales, which was previously used to classify a number of extinct plants which are now placed elsewhere. The class was established in 1917, under the name Psilophyta, with only three genera (Rhynia, Horneophyton and Psilophyton) for a group of fossil plants from the Upper Silurian and Devonian periods which lack true roots and leaves, but have a vascular system within a branching cylindrical stem. The living Psilotaceae, the whisk-ferns, were sometimes added to the class, which was then usually called Psilopsida. This classification is no longer in use.

The class should not be confused with the current use of the name Psilotopsida, which refers to a class of living ferns, containing only Psilotaceae (whisk-ferns) and Ophioglossaceae (moon-worts and adder's-tongue ferns).

Description

The class was created in 1917 by Kidston and Lang for fossils found in the Rhynie Chert Bed.Three genera were initially included, Rhynia, Horneophyton and Psilophyton. All lacked leaves and true roots, consisting only of branched stems; however they were considered to contain vascular tissue.

Additional fossil genera were added later. As described by Sporne in 1966, Psilophytopsida consisted of four families:

Rhyniaceae
Rhynia – now placed in the class Rhyniopsida
Horneophyton – now placed in the class Horneophytopsida
Cooksonia – now considered to be paraphyletic basal trachaeophytes
Yarravia – uncertain position
Zosterophyllaceae – now placed in the class Zosterophyllopsida
Zosterophyllum
Psilophytaceae
Psilophyton – now considered to be a basal euphyllophyte
Asteroxylaceae – now placed in the order Drepanophycales.
Asteroxylon

By 1975, it had become clear that the class had become increasingly unnatural, containing unrelated early vascular plants. It was split up by Banks into three subdivisions: Rhyniophytina, Zosterophyllophytina, and Trimerophytina. Later cladistic analyses of early land plants suggested that at least the rhyniophytes and the trimerophytes were not monophyletic. Separating out 'basal groups', such as the earliest land plants, is intrinsically difficult, since at this stage they contain many shared characters (plesiomorphies) which are not sufficient to distinguish them.

The current classification of former members of the class is largely due to Kenrick and Crane in 1997.

LYCOPSIDA

Lycopodiopsida is a class of herbaceous vascular plants known as **lycopods**, **lycophytes** or other terms including the component **lyco-**. Members of the class are called **clubmosses**, **firmosses** and **quillworts**. They have dichotomously branching stems bearing simple leaves called microphylls and reproduce by means of spores borne in sporangia on the sides of the stems at the bases of the leaves. Although living species are small, during the Carboniferous, extinct tree-like forms formed huge forests that dominated the landscape and contributed to coal deposits.

The nomenclature and classification of plants with microphylls varies substantially among authors. A consensus classification for extant (living) species was produced in 2016 by the Pteridophyte Phylogeny Group (PPG I), which places them all in the class Lycopodiopsida, which includes the classes **Isoetopsida** and **Selaginellopsida** used in other systems. (See Table 2.) Alternative classification systems have used ranks from division (phylum) to subclass. In the PPG I system, the class is divided into three orders, Lycopodiales, Isoetales and Selaginellales.

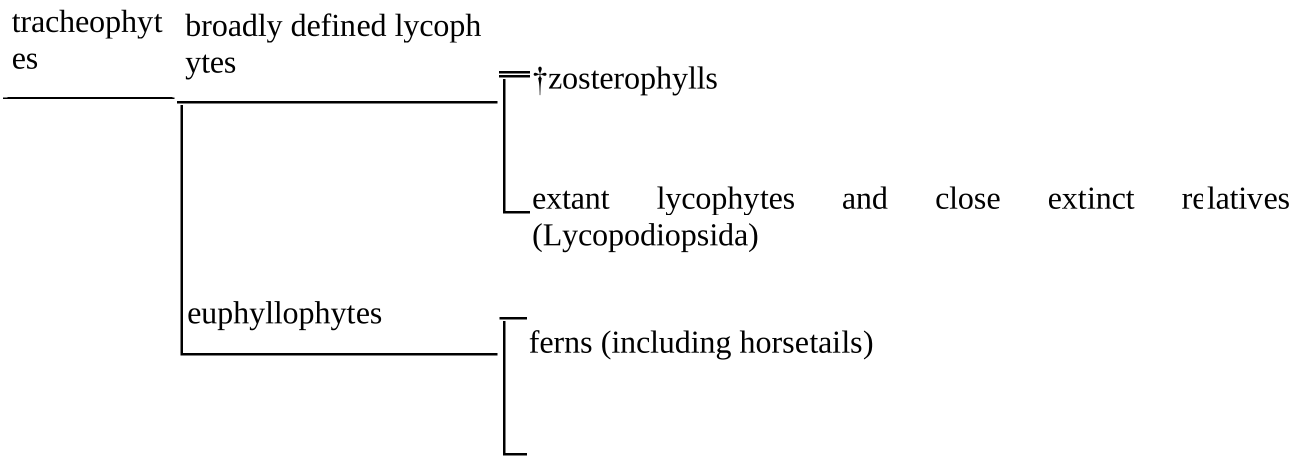
Characteristics:

Club-mosses (Lycopodiales) are homosporous, but the genera *Selaginella* and *Isoetes* are heterosporous, with female spores larger than the male, and gametophytes forming entirely within the spore walls. A few species of *Selaginella* such as *S. apoda* and *S. rupestris* are also viviparous; the gametophyte develops on the mother plant, and only when the sporophyte's primary shoot and root is developed enough for independence is the new plant dropped to the ground. Club-moss gametophytes are mycoheterotrophic and long-lived, residing underground for several years before emerging from the ground and progressing to the sporophyte stage.

Taxonomy

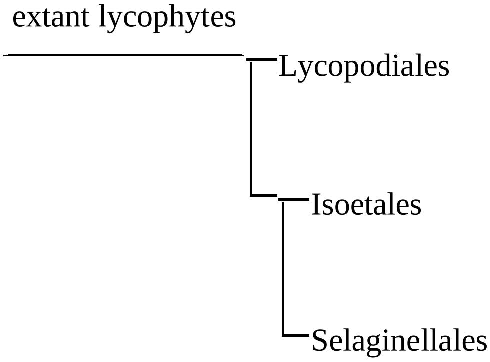
Phylogeny:

The extant lycophytes are vascular plants (tracheophytes) with microphyllous leaves, distinguishing them from the euphyllophytes (plants with megaphyllous leaves). The sister group of the extant lycophytes and their closest extinct relatives are generally believed to be the zosterophylls, a paraphyletic or plesion group. Ignoring some smaller extinct taxa, the evolutionary relationships are as shown below.



seed plants (spermatophytes)

As of 2019, there was broad agreement, supported by both molecular and morphological evidence, that the extant lycophytes fell into three groups, treated as orders in PPG I, and that these, both together and individually, are monophyletic, being related as shown in the cladogram below:



Classification

The rank and name used for the taxon holding the extant lycophytes (and their closest extinct relatives) varies widely. Table 1 below shows some of the highest ranks that have been used. Systems may use taxa at a rank lower than the highest given in the table with the same circumscription; for example, a system that uses Lycopodiophyta as the highest ranked taxon may place all of its members in a single subclass.

Table 1: Alternative highest ranks used which include only extant species and their closest relatives

Highest rank	**Name**	**Example sources**
Division (phylum)	Lycophyta	Taylor et al. (2009), Mauseth (2014)
Division (phylum)	Lycopodiophyta	Niklas (2016)
Subdivision (subphylum)	Lycopodiophytina	Ruggiero et al. (2015)
Class	Lycopsida	Kenrick & Crane (1997)
Class	**Lycopodiopsida**	PPG I (2016)
Subclass	Lycopodiidae	Chase & Reveal (2009)

Some systems use a higher rank for a more broadly defined taxon of lycophytes that includes some extinct groups more distantly related to extant lycophytes, such as the zosterophylls. For example, Kenrick & Crane (1997) use the subdivision Lycophytina for this purpose, with all extant lycophytes falling within the class Lycopsida. Other sources exclude the zosterophylls from any "lycophyte" taxon. In the Pteridophyte Phylogeny Group classification of 2016 (PPG I), the three orders are placed in a single class, Lycopodiopsida, holding all extant lycophyte species. Older systems have used either three classes, one for each order, or two classes, recognizing the closer relationship between Isoetales and Selaginellales. In these cases, a higher ranked taxon is needed to contain the classes (see Table 1). As Table 2 shows, the names "Lycopodiopsida" and "Isoetopsida" are both ambiguous.

Table 2: Alternative arrangements of the orders of extant lycophytes into classes

Order	3 classes e.g. *IUCN Red List*, 2004	2 classes e.g. Yatsentyuk et al. (2001)	1 class PPG I
Lycopodiales	Lycopodiopsida	Lycopodiopsida	Lycopodiopsida
Isoetales	Isoetopsida	Isoetopsida	
Selaginellales	Sellaginellopsida		

Subdivisions

The PPG I system divides up the extant lycophytes as shown below.

- Class Lycopodiopsida Bartl. (3 orders)
    - Order Lycopodiales DC. ex Bercht. & J.Presl (1 extant family)
    - Family Lycopodiaceae P.Beauv. (16 extant genera)
        - Order Isoetales Prantl (1 extant family)
    - Family Isoetaceae Dumort. (1 extant genus)
            - Order Selaginellales Prantl (1 extant family)
    - Family Selaginellaceae Willk (1 extant genus)

Some extinct groups, such as zosterophylls, fall outside the limits of the taxon as defined by the classifications in Table 1 above. However, other extinct groups fall within some circumscriptions of this taxon. Taylor et al. (2009) and Mauseth (2014) include a number of extinct orders in their division (phylum) Lycophyta, although they differ on the placement of some genera. The orders included by Taylor et al. are:

- Order †Drepanophycales (including *Baragwanathia*, *Drepanophycus* and *Asteroxylon*)
- Order †Protolepidodendrales
- Order †Lepidodendrales
- Order †Pleuromeiales

Mauseth uses the order †Asteroxylales, placing *Baragwanathia* in the Protolepidodendrales.

The relationship between some of these extinct groups and the extant ones was investigated by Kenrick and Crane in 1997. When the genera they used are assigned to orders, their suggested relationship is:

- †Drepanophycales (†*Asteroxylon*, †*Baragwanathia*, †*Drepanophycus*)
- Lycopodiales
  - †Protolepidodendrales (†*Leclercqia*, †*Minarodendron*)
    - Selaginellales (*Selaginella*, including subg. *Stachygynandrum* and subg. *Tetragonostachys*)
      - Isoetales (*Isoetes*)
      - †Lepidodendrales (†*Paralycopodites*)

Evolution

Axis (branch) from *Archaeosigillaria* or related lycopod from the Middle Devonian of Wisconsin

The Lycopodiopsida are distinguished from other vascular plants by the possession of microphylls and by their sporangia, which are lateral as opposed to terminal and which open (dehisce) transversely rather than longitudinally. In some groups, the sporangia are borne on sporophylls that are clustered into strobili. Phylogenetic analysis shows the group branching off at the base of the evolution of vascular plants and they have a long evolutionary history. Fossils are abundant worldwide, especially in coal deposits. Fossils that can be ascribed to the Lycopodiopsida first appear in the Silurian period, along with a number of other vascular plants. The Silurian *Baragwanathia longifolia* is one of the earliest identifiable species. *Lycopodolica* is another Silurian genus which appears to be an early member of this group. The group evolved roots independently from the rest of the vascular plants.

From the Devonian onwards, some species grew large and tree-like. Devonian fossil trees from Svalbard, growing in equatorial regions, raise the possibility that they drew down enough carbon dioxide to change the earth's climate significantly.[17] During the Carboniferous, tree-like forms (such as *Lepidodendron* and other "scale-trees" of the order Lepidodendrales) formed huge forests that dominated the landscape. Unlike modern trees, leaves grew out of the entire surface of the trunk and branches, but fell off as the plant grew, leaving only a small cluster of leaves at the top. The trees are marked with diamond-shaped scars where they once had leaves. Quillworts (order Isoetales) are considered their closest extant relatives and share some unusual features with these fossil trees, including the development of both bark, cambium and wood, a modified shoot system acting as roots, bipolar and secondary growth, and an upright stance.[1][18] The remains of scale-trees formed many fossil coal deposits. In Fossil Park, Glasgow, Scotland, fossilized lycophyte trees can be found in sandstone.

The Lycopodiopsida had their maximum diversity in the Pennsylvanian (Upper Carboniferous), particularly tree-like *Lepidodendron* and *Sigillaria* that dominated tropical wetlands. The complex ecology of these tropical rainforests collapsed during the Middle Pennsylvanian due to a change in climate. In Euramerica, tree-like species apparently became extinct in the Late Pennsylvanian, as a result of a transition to a much drier climate, giving way to conifers, ferns and horsetails. In Cathaysia (now South China), tree-like species survived into the Permian. Nevertheless, lycopodiopsids are rare in the Lopingian (latest Permian), but regained dominance in the Induan (earliest Triassic), particularly *Pleuromeia*. After the worldwide Permian–Triassic extinction event, members of this group pioneered the repopulation of habitats as opportunistic plants. The heterogeneity of the terrestrial plant communities increased markedly during the Middle Triassic when plant groups like horsetails, ferns, pteridosperms, cycads, ginkgos and conifers resurfaced and diversified quickly.

Microbial association:

Lycophytes form associations with microbes such as fungi and bacteria, including arbuscular mycorrhizal and endophytic associations.

Arbuscular mycorrhizal associations have been characterized in all stages of the lycophyte lifecycle: mycoheterotrophic gametophyte, photosynthetic surface-dwelling gametophyte, young sporophyte, and mature sporophyte. Arbuscular mycorrhizae have been found in *Selaginella spp.* roots and vesicles. During the mycoheterotrophic gametophyte lifecycle stage, lycophytes gain all of their carbon from subterranean glomalean fungi. In other plant taxa, glomalean networks transfer carbon from neighboring plants to mycoheterotrophic gametophytes. Something similar could be occurring in *Huperzia hypogeae* gametophytes which associate with the same glomalean phenotypes as nearby *Huperzia hypogeae* sporophytes.

Fungal endophytes have been found in many species of lycophyte, however the function of these endophytes in host plant biology is not known. Endophytes of other plant taxa perform roles such as improving plant competitive fitness, conferring biotic and abiotic stress tolerance, promoting plant growth through phytohormone production or production of limiting nutrients. However, some endophytic fungi in lycophytes do produce medically relevant compounds. *Shiraia* sp Slf14 is an endophytic fungus present in *Huperzia serrata* that produces Huperzine A, a biomedical compound which has been approved as a drug in China and a dietary supplement in the U.S. to treat Alzheimer's Disease.[23] This fungal endophyte can be cultivated much more easily and on a much larger scale than *H. serrata* itself which could increase the availability of Huperzine A as a medicine.

Uses:

The spores of lycopods are highly flammable and so have been used in fireworks. Lycopodium powder, the dried spores of the common clubmoss, was used in Victorian theater to produce flame-effects. A blown cloud of spores burned rapidly and brightly, but with little heat. (It was considered safe by the standards of the time.)

UNIT III

General characters - classification of Gymnosperms (,Sporne, 1965), origin andPhylogeney of Gymnosperms, Gymnosperms compared with Pteridophytes and angiosperms – Economic importance of Gymnosperms**.**

General Characteristics of Gymnosperms

1. They do not produce flowers.
2. Seeds are not formed inside a fruit. They are naked.
3. They are found in colder regions where snowfall occurs.
4. They develop needle-like leaves.
5. They are perennial or woody, forming trees or bushes.
6. They are not differentiated into ovary, style and stigma.
7. Since stigma is absent, they are pollinated directly by the wind.
8. The male gametophytes produce two gametes, but only one of them is functional.
9. They form cones with reproductive structures.
10. The seeds contain endosperm that stores food for the growth and development of the plant.
11. These plants have vascular tissues which help in the transportation of nutrients and water.
12. Xylem does not have vessels, and the phloem has no companion cells and sieve tubes.

Classification of Gymnosperms

Gymnosperms are classified into four types as given below –

Cycadophyta

Cycads are dioecious (meaning: individual plants are either all male or female). Cycads are seed-bearing plants where the majority of the members are now extinct. They had flourished during the Jurassic and late Triassic era. Nowadays, the plants are considered as relics from the past.

These plants usually have large compound leaves, thick trunks and small leaflets which are attached to a single central stem. They range in height anywhere between a few centimetres to several meters.

Cycads are usually found in the tropics and subtropics. Some members have adapted to dry arid conditions, and some also have adapted to oxygen-poor swampy environments.

- Order **Cycadales**
- Family **Cycadaceae**: *Cycas*
- Family **Zamiaceae**: *Dioon*, *Bowenia*, *Macrozamia*, *Lepidozamia*, *Encephalartos*, *Stangeria*, *Ceratozamia*, *Microcycas*, *Zamia*.

Coniferophyta

These are the most commonly known species among the gymnosperm family. They are evergreen; hence they do not shed their leaves in the winter. These are mainly characterised by male and female cones which form needle-like structures.

Coniferous trees are usually found in temperate zones where the average temperature is 10 °C. Giant sequoia, pines, cedar and redwood are one of the many examples of Conifers.

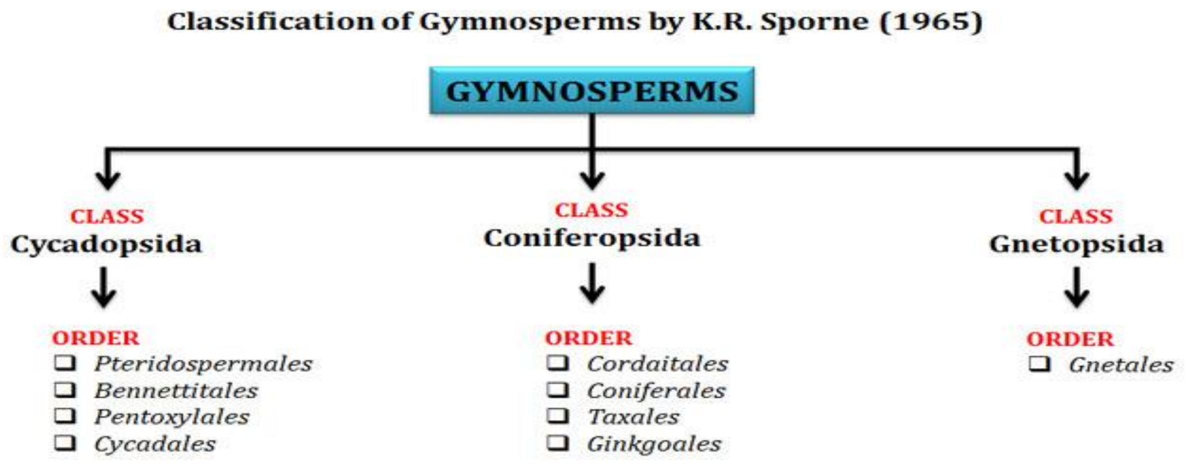
Gnetophyta

Just like any other member of gymnosperms, Gnetophytes are also relics from the past. Today, only three members of this genus exist.

Gnetophytes usually consist of tropical plants, trees, and shrubs. They are characterised by flowery leaves that have a soft coating. This coating reveals an ancestral connection with the angiosperms.

Gnetophytes differ from other members of this class as they possess vessel elements in their xylem.

- Order **Gnetales**
- Family **Gnetaceae**: *Gnetum*



Origin and phylogeny of Gymnosperms

There are over 1000 living species of gymnosperm. It is widely accepted that the gymnosperms originated in the late Carboniferous period, replacing the lycopsid rainforests of the tropical region.This appears to have been the result of a whole genome duplication event around 319 million years ago.Early characteristics of seed plants were evident in fossil progymnosperms of the late Devonian period around 383 million years ago.

It has been suggested that during the mid-Mesozoic era, pollination of some extinct groups of gymnosperms was by extinct species of scorpionflies that had specialized proboscis for feeding on pollination drops. The scorpionflies likely engaged in pollination mutualisms with gymnosperms, long before the similar and independent coevolution of nectar-feeding insects on angiosperms.Evidence has also been found that mid-Mesozoic gymnosperms were pollinated by Kalligrammatid lacewings, a now-extinct family with members which (in an example of convergent evolution) resembled the modern butterflies that arose far later.

Conifers are by far the most abundant extant group of gymnosperms with six to eight families, with a total of 65–70 genera and 600–630 species (696 accepted names). Conifers are woody plants and most are evergreens. The leaves of many conifers are long, thin and needle-like, other species, including most Cupressaceae and some Podocarpaceae, have flat, triangular scale-like leaves. *Agathis* in Araucariaceae and *Nageia* in Podocarpaceae have broad, flat strap-shaped leaves.

Cycads are the next most abundant group of gymnosperms, with two or three families, 11 genera, and approximately 338 species. A majority of cycads are native to tropical climates and are most abundantly found in regions near the equator. The other extant groups are the 95–100 species of Gnetales and one species of Ginkgo.

Pteridophytes and Gymnosperms: Comparison | Plants

Similarities between Pteridophytes and Gymnosperms:

1. There is a regular heteromorphic alternation of generations.
2. Sporophyte is the predominant plant body and is differentiated into root, stem and leaves.
3. Some pteridophytes and some gymnosperms exhibit air cinate vernation in young leaves.
4. There are no vessels anatomically in both pteridophytes (except Selaginella, Marsilea) and gymnosperms (except Gnetales).
5. Phloem does not have companion cells.
6. Spores are always haploid as they are always a product of meiosis.
7. Some pteridophytes and all gymnosperms are heterosporous.
8. Gametophyte is comparatively a reduced structure in both.
9. In heterosporous pteridophytes and all gymnosperms mega spore is always retained within the mega-sporangium.
10. Sex organs of the gametophytes are always antheridia and archegonia.
11. Spores are produced in strobili or cones (with some exceptions).
12. Root hairs are absent in both.

Differences between Pteridophytes and Gymnosperms:

1. The sporophytic plant body is by and large arborescent in gymnosperms while it is not so in pteridophytes.
2. Roots are adventitious in pteridophytes while they arise from the radicle (tap root) in gymnosperms.
3. Pteridophytes may be homosporous or heterospoers, while all gymnosperms are heterosporous.
4. Most of the pteridophytes have a preference for cool, moist areas, while gymnosperms generally exhibit xeric characters.
5. Branching of the stem is dichotomous in pteridophytes while it is lateral in gymnosperms.
6. Heterospory has never resulted in dioeciousness in the sporophyte in pteridophytes, while it is so in many gymnosperms.
7. Generally secondary growth is absent in pteridophytes, while it is present in gymnosperms.
8. In pteridophytes both microspores and megaspores are released from their respective sporangia, whereas in gymnosperms, megaspore is permanently retained.
9. There is pollination in gymnosperms, while it is absent in pteridophytes.
10. Siphonogamous fertilization (pollen tube development) is seen in only gymnosperm.
11. Male gametes are ciliate in pteridophytes, while they are not in gymnosperms (except for few like cycas).
12. Gymnosperms are seed plants (spermatophytes), while there is no seed in pteridophytes.

Economic importance of Gymnosperms

Gymnosperms are the small group of plants, which constitutes a sub division of spermatophyta or phanerogams. There are about 73 genera and 7000 species in subdivision gymnospermae.

1. As food

- Seeds of some species are edible: *Cycas, Ginko, Pinus, Gnetum*
- Stem of *Cycas revoluta* is a good source of Sago starch
- *Zamia* is a rich source of starch.
- Seeds and stem of *Cycas revoluta* used for making wine.

2. As medicine

- Leaves of *Cycas circinalis, Taxus* are used as medicines.
- Pollen grains of some *Cycas* have narcotic effect
- Oil of *Juniperus* is important.
- Ephedrine derived from *Ephedra* used in treatment of cold, cough.
- Anti-cancerous drug called taxol, is obtained from the bark of *Taxus*

3. As ornaments

- Species of *Cycas* are used for decoration purposes
- *Ginkgo bioloba,* possess beautiful ornamental leaves
- *Thuja, Pinus, Taxus* etc are grown in parks.

4. In industry

- Spruce or *Picea* is an important source of pulp wood.
- Wood of *Juniperus* is used in making pencils, scales and holders.
- Bark of *Larix* yields a tannin.
- Terpentine is obtained from *Abies balsemea*.
- Wood of red spruce is especially important for music industry.

UNIT IV:

General Characters of Pteridospermales:

1. Extinct Palaeozoic and Mesozoic plants found from Devonian to Jurassic periods.

2. Plants possessed slender stems with large frond-like leaves as in Alethopteris, Sphenopteris, etc.

3. Primary xylem was mesarch, represented by solid or medullated protostele. Rarely, the primary xylem was exarch. Polystelic condition was also observed in some members.

4. The secondary wood was manoxylic (loose and soft) and limited in amount.

5. The radial walls of tracheids had multiseriate pits.

6. The cortex was well-developed and had longitudinally aligned fibre strand.

7. Leaves were usually fern-like, relatively large, pinnately compound, and often pinnate several times.

8. The leaves were covered by a resistant cuticle.

9. Ovules borne separately along margins of, or on surface of pinnately compound megasporophylls.

10. Ovule-bearing frond or megasporophyll was not part of a cone.

11. Megasporophylls were not arranged in strobili.

12. Megasporophylls were like foliage leaves, or specialized structures, sometimes peltate.

13. Microsporophyll's pinnately compound and not in strobili.

14. The microsporangia had no annulus and were sometimes grouped into synangia.

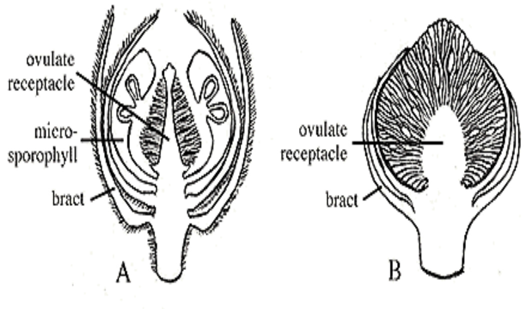
15. A well-developed vascular supply was present in the seed.

16. The seeds were also provided with a definite pollen chamber, e.g. Lagenostoma lomaxi.

Bennettitales

1. These extinct Mesozoic plants were present were present on the earth from Triassic to Cretaceous. • 2. Bennettitales were so abundant during Mesozoic era that this period is known as 'Age of Cycads'. • 3. The members of this group are found either as compressions or petrifactions. • 4. The stems were stout or slender and had a wide pith. • 5. The stem grew very slowly and had manoxylic wood. • 6. Resembling living Cycads, the Bennettitalean leaves were mostly pinnately compound, and only occasionally simple. • 7. Venation was open, and only rarely closed. • 8. Syndetocheilic type of stomata were present. • 9. The wall of the epidermal cells was sinuous. • 10. The reproductive organs were organised in the form of hermaphrodite (e.g. Cycadeoidea) or unisexual (e.g. Wielandiella) "flowers", which in turn were protected by many bracts. • 11. The 'flowers' developed in the axil of leaves. • 12. Male reproductive organs were borne in a whorl. They were free or fused, entire or pinnately compound. • 13. Microsporangia were present abaxially in the form of synangia. • 14. Microsporophyll's sometimes surrounded megasporophylls forming hermaphrodite "flowers". • 15. Ovules were

numerous and stalked and borne on a conical, cylindrical or dome-shaped receptacle. • 16. Many inter-seminal bracts were present on the ovule containing receptacle. • 17. The scales or bracts were united at end to form shield through which micropyle protrudes. • 18. Seeds were dicotyledonous.



Pentoxylales:

1. Extinct Mesozoic plants found in Jurassic period.

2. Although the exact habit of these plants is not clearly established, these were probably shrubs or very small trees.

Long and short shoots were present on these plants.

4. Short shoots had spirally arranged leaves and terminally located reproductive organs.

5. Leaves were thick, simple, lanceolate, and had diploxylic leaf trace.

6. Stomata were formerly thought to be syndetocheilic, but now they are considered to be haplocheilic.

7. Leaves possessed open venation.

8. Stems were polystelic. Basinger et al. (1974) opined that “it may be more appropriate to call each stele as vascular segment or sympodium”.

9. Wood of Pentoxylon was pycnoxylic and resembled Araucaria.

10. Ovules were sessile.

11. Female reproductive organs were like stalked mulberry, consisting of about 20 sessile seeds attached to central receptacle and surrounded by stony layer and then fleshy outer layer of integument uniting them.

12. Male reproductive organs or microsporophyll’s form whorl of branched micro-sporangiophores.

13. The micro-sporangiophores were fused basally into a disc-like structure.

Cycadales:

1. The plant body is sporophytic, and the sporophyte is differentiated into well-developed roots, columnar and generally un-branched stem and pinnately compound leaves.

2. Members exhibit xerophytic characters. The growth of cycads under xerophytic conditions is extremely slow. It has been estimated that a plant of Dioon grows only 2 to 2.5 metre in one thousand years under natural conditions.

3. Young leaves show circinate vernation.The wood is manoxylic.

5. Mucilage canals are present in the pith as well as cortex.

6. The leaf trace is diploxylic

7. Plants are dioecious without exception, and the reproductive organs are generally in the form of cones.

8. The cones are generally terminal or lateral in position.

9. In male cones the microsporophyll's are arranged on cone axis, and form a compact structure.

10. Microsporangia are arranged on the abaxial side of the microsporophyll's.

11 The flagella on the sperms are arranged in spiral bands. The male gametes are very large. These measure 80 µm in length in Microcycas, 180-210 µm in Cycas revoluta and as much a 400 µm (largest) in Chigua.

12. Megasporophylls are foliage leaf-like structures, the tip portion of which is sterile. Several ovules (2-8) are arranged in the middle region of the megasporophylls.

13. The ovules are orthotropous.

14. The apical meristem in all Cycads is extremely massive.

Vegetative reproduction

Vegetative reproduction is by the formation of adventitious buds or bulbils . The bulbils develop from the basal part of stem especially from cortical cells. They are found between the persistent leaf bases. They are more or less oval shaped. Several scale leaves are arranged spirally and compactly over a dormant stem in a bulbil. Upon detachment from the stem, a bulbil germinates to produce a new plant. A bulbil from male plant produces a new male plant while a bulbil from female plant produces a new female plant.

***Sexual Reproduction* : Cycas** is strictly dioecious ie., male and female plants are *distinctly different from each other. .*

The male plant of Cycas produces male strobilus (cone) at the apex of the stem in between the crown of foliage leaves. Each male cone is a shortly stalked compact, oval or conical woody structure. It is 40-80 cm in length, perhaps the largest among plants. Each male cone consists of several microsporophylls which are arranged spirally around a central axis. Each microsporophyll is a woody, brown coloured and more or less horizontally flattened structure with a narrow base and an expanded upper portion. The upper part is expanded and becomes pointed at its tip. The narrow of cells. Pollen grains or microspores are produced at the end of meiotic division of microspore mother cells found in the microsporangium.

Each microspore on pollen develops into male gametophyte partly even before the release of pollens from microsporangium. The transfer of pollens from male plant to the female plant is called pollination. At this stage, the male gametophyte has a prothallial cell, a generative cell and a tube cell. Dispersal of pollens is effected by wind (anemophyllous). Further development of male gametophyte starts only after the pollen reaches nucellar surface of the ovule where the pollen germinates to produce pollen tube. The pollen tube carries two top-shaped sperms. Each sperm contains thousands of cilia . By means cilia, the sperms move freely in the pollen tube.

The pollen tube. The pollen tube penetrates the nucellar region of the ovule and subsequently delivers the male gametes into the archegonial chamber.

The female plant produces megasporophylls that are not organised into cones and instead they occur in close spirals in acropetal succession around the stem apex (fig). New megasporophylls are produced in large numbers every year. The megasporophylls of a year occupy the region between the successive whorls of leaves. The growth of the female plant is monopodial; the axis contines to grow as it produces foliage leaves and megasporophylls.

Each ovule consists of a large nucellus surrounded by a single integument. The integument remains fused with the body of the ovule except at the apex of the nucellus where it forms a nucellar beak and an opening called micropyle. The opposite end of the microphyle is called chalaza. The integument is very thick and is differentiated into three layers - the outer and inner fleshy layers and a hard and stony middle layer. Some cells in the nucellar beak dissolve to form a pollen chamber. The young ovule is green and hairy whereas the mature one is red or orange without hairs.

One of the deeply situated cells in the nucellus differentiates into megaspore mother cell and divides meiotically to produce 4 linearly arranged haploid megaspores. Of the four megaspores, the upper three cells degenerate while the lowermost acts as functional megaspore.

Female gametophyte : The functional megaspore develops into a large, haploid multicellular tissue called female prothallus or endosperm. The nucellus is used up as the female gametophyte develops. At this stage, some superficial cells of the female gametophyte at the micropylar end enlarge and develop into 2-8 archegonia. Each archegonium has a large egg nucleus and venter canal nucleus. The arehegonial chamber is found above the archegonia.

The megasporophylls are considered to be modified leaves. They are flat, dorsiventral and measuring 15-30 cm in length A megasporophyll is differentiated into a basal stalk and an upper pinnate lamina. Ovules are formed on the lateral sids of the stalk. The number of ovules per megasporophyll varies from 2-10 depending upon the species.

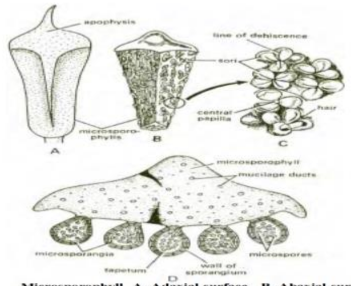


Fig.. Microsporophyll A. Adaxial surface, B. Abaxial surface C. Sori, D. Microsprophyll TS

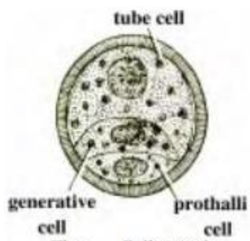


Fig. Pollen grain

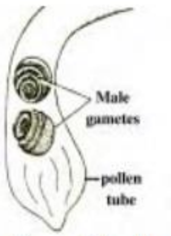


Fig. Pollen tube with male gametes

Ovule : *The ovule of cycas is orthotropous and unitegmic. It is sessile or shortly stalked and perhaps Fig.1.70. Structure of ovule LS the largest ovule (about 6 cm length and 4 cm width) in the plant kingdom.*

Fertilization : The fusion of male and female gametes is called fertilization. The pollen tube of the pollen releases sperms or male gametes into the archegonial chamber. Normally, only one male gamete enters each archegonium and fuses with the egg thus resulting in the formation of zygote. Only one egg, in any one of the archegonia, is fertilized. The diploid zygote develops into embryo. The embryo takes about one year for its complete development. The ovule ultimately gets transformed into seed.

Cordaitales:

1. This group of fossil plants had tall trees with slender trunks and a crown of several well-developed branches.

Plants were present from Devonian to Permian periods of Palaeozoic era (Fig. 1.1)

3. The leaves were simple, spirally arranged and strap-shaped, grass-like or paddel-like.

4. The leaves attained a length up to 1 metre or even more, and had parallel venation.

5. A scanty primary wood was present.

6. In mature stems, the secondary wood was mostly pycnoxylic.

7. Compound unisexual cones were present.

8. Each compound cone had a main axis with bracts subtending secondary fertile shoots possessing fertile and sterile appendages.

9. Mega-strobili had sterile appendages below and ovule-bearing fertile appendages above.

10. One to four ovules were present on each female fertile appendage.

11.Micro-strobili had sterile appendages below and pollen-sac containing fertile appendages above.

12. Four to six terminal pollen sacs were present on each male fertile appendage.

13. Sperms have not been reported, but presence of pollen chambers suggests that motile sperms might have been formed.

External Morphology:

Cordaitaceae grew luxunently and formed large forests of tall trees during Upper Carboniferous period. Plants attained a height of more than 30 metres. They had terminal and spirally arranged well-spread branches bearing tufts of leaves .

The leaves were large, leathery, grass-like or paddle-shaped, and attained a length of about 1 metre and a breadth of about 15 cm (Fig. 9.2). They were, however, smaller than that of Cycads. Some members also had small needlelike leaves. The leaves had a dichotomous venation.

Fig. 9.1. *Eu-Cordaites* Reconstruction of a plant (after Grand's Eury)

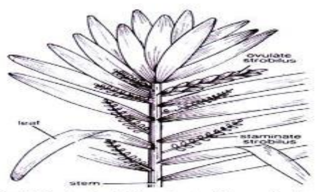


Fig. 9.2. *Eu-Cordaites laevis*. Reconstruction of a branch

The leaves of several members of Cordaitaceae were highly variable in shape and were put under a form-genus Cordaites. The same name is now given to the stem as well as to the entire plant.

Some other stem-genera of Cordaitaceae include Mesoxylon, Metacordaites, Parapitys, Caenoxylon, Mesopitys, Cordaicladus and Artisia. Amyelon is a root-genus while Cordaianthus is a name give to the cones or inflorescence. Seeds have been described under the form-genera Cardiocarpus, Mitrospermum and Kamaraspermum.

Cridland (1964) studied and reconstructed a cordaitean plant. According to him the plants attained a height of nearly 5 metre with stilt roots similar to mangrove plants. These studies suggest the habitat of Cordaites in the swamps along the seashores.

Anatomy of Cordaitaceae:

1. Stem:

The stem resembled closely with Conifers. Both Cordaites and Mesoxylon possessed a large central pith and cortex. The wood was scanty in some species while in others it developed a large vascular cylinder, and in still other cases distinct growth rings were present. The primary wood was endarch but in Mesoxylon it was mesarch. The secondary wood consisted of pitted tracheids having multiseriate pittings.

The tracheids were long and slender. Bordered pits were present, and they were confined mainly on the radial walls. In older tracheids, however, the pits were also present on the tangential walls. Medullary rays were one or two cells wide. The bordered tracheids were hexagonal in outline (Fig. 9.4) and the large pith was characteristically discoid .

Mesoxylon differed from Cordaites in the structure of the leaf trace. A network of sclerenchyma, present in the outer cortex of Mesoxylon, was absent in Cordaites. Since, technically speaking, the genus Cordaites refers to the leaves of Cordaitaceae, an alternative name Cordaioxylon was proposed by Arnold (1967).

Coniferales:

1. Plant body is sporophytic and the sporophytes are richly branched trees or shrubs. One species (Juniperus horizontals is prostrate. They are generally evergreen and xerophytic but genera such as Larix, Metasequoia and Taxodium are deciduous.

They are found from Carboniferous to the present times

3. Their growth habit varies from extremely tall trees as in Sequoia (Taxodiaceae) to miniature forms of Dacrydium (Podocarpaceae) which are only some centimeters high.

4. Branches may be of one kind or they may be dimorphic as in Pinus.

5. Stems contain a small pith and the secondary wood is pycnoxylic.

6. The secondary wood consists of tracheids with large uniseriate or rarely multiseriate pits on their radial walls.

7. Vessels are absent.

8. Resin canals are distributed in pith and cortex and sometimes also in wood.

9. Leaves are of two types, i.e. foliage leaves and scaly leaves. They are generally arranged spirally and only in opposite or whorled manner. Foliage leaves are filiform, needle-like and called needles. Occasionally the leaves are broad.

Plants are either monoecious or dioecious.

11. Reproductive organs are unisexual cones.

12. The sporophylls are generally arranged in the form of cones, and, therefore, the common name Conifers is given to them.

13. The micro-strobili or male cones are simple and contain many scale like microsporophyll's.

Pollen grains may be winged (Pinus) or un-winged (Taxodium). They are wind-dispersed.

15. The male gametes are non-motile.

16. The female cone or mega-strobili consist of many sterile bract scales and fertile ovuliferous scales.

17. On the upper surface or in the axil of ovuliferous scales are present one to many ovules.

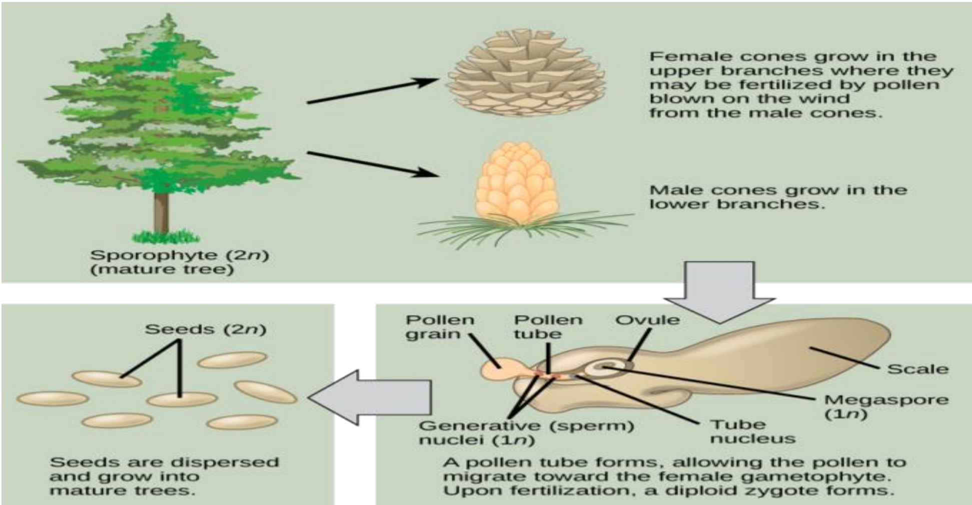
. Pollination is anemophyllous.

19. Female gametophyte is completely dependent on the sporophyte.

20. Oospore has the ability to produce more than one potential embryos, and thus conifers show the phenomenon of polyembryony.

21. Seeds are endospermic and winged with hard testa.

22. Two to many cotyledons are present in the embryo.



Gingoales

Completion of the entire reproductive cycle, from the advent of pollination to the production of seeds with well-developed embryos, takes about 14 months. Pollination and the development of the sexual, or gametophytic, phase of the life cycle occur in the first year (April to September), but embryo development is not completed until the spring of the following year.

Ginkgo is dioecious, which means that pollen-producing structures and ovules are produced on separate trees. The reproductive structures are restricted to the spur branches, where they are evident in the spring in the axils of bud scales and foliage leaves.

The pollen-producing strobilus is a loose, pendulous, catkinlike structure consisting of a main axis to which are attached numerous appendages, each of which usually bears two microsporangia at its tip. Meiosis occurs in cells of the microsporangia, giving rise to numerous haploid microspores. Cell divisions take place within the microspores, resulting in the formation of five-celled pollen grains (male gametophytes).

Ovuliferous structures also arise in the axils of bud scales and the foliage leaves of spur branches. Each consists of a stalk that bears two or sometimes three or more erect ovules. An ovule is composed of an integument (the future seed coat) surrounding a tissue called the nucellus. It is in the nucellus that meiosis occurs, resulting in the formation of four haploid megaspore cells. It is at about this time that pollen grains are released from the microsporangia of male trees. The pollen (male gametophyte) is carried by wind currents and adheres to a pollination droplet, which exudes from the micropyle at the tip of the integument. Retraction of the droplet brings the pollen grains into a pollen chamber in the nucellus, where they develop into multibranched pollen tubes (male gametophytes).

One of the megaspores in the ovule that results from meiosis enlarges and undergoes a succession of free nuclear divisions (without wall formation). After about 8,000 haploid nuclei are produced, cell walls begin to form. After the female gametophyte becomes cellular, archegonia (normally two) are initiated at the surface toward the micropylar end of the ovule. An archegonium consists of neck cells and a large egg cell.

The basal end of the filament-like male gametophyte becomes suspended in a cavity above the female gametophyte (called the fertilization chamber). The spermatogenous cell of a male gametophyte divides, resulting in the production of two multiflagellated sperm. The sperm and the contents of the pollen tube are released into the fertilization chamber. The sperm swim in the liquid for a brief period of time. Approximately 1,000 flagella are attached to a spiral band at the anterior end. A sperm enters an archegonium and fuses with the egg nucleus. *Ginkgo* and the cycads are the only seed-producing plants that have motile sperm.

The growth of the embryo (embryogenesis) may begin shortly after fertilization but continues after the developing seeds fall to the ground. The embryo grows into the nutritive tissue of the female gametophyte. A seed at maturity consists of a dicotyledonous embryo, nutritive tissue of the female gametophyte, and the seed coat, which is made up of a hard inner layer and a fleshy, orange-coloured outer layer.

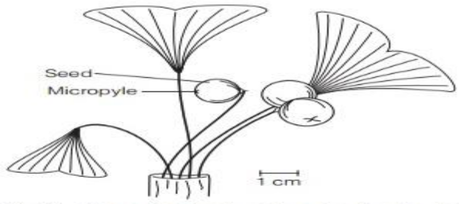


Fig. 2. Shoot of a female ginkgo, showing developing seeds.

Gnetum

1 The genus Gnetum consists of thirty species, widely distributed in the tropical and sub- Most species is tropical humid zones of the world. Of these 7 occur in tropical America, 2 in western Africa rain fonst below 1500 m altitude. Root The plant has a tap root system with well developed lateral roots.

2. Leaves are simple elliptical or strap-shaped or sometimes reduced to minute scales. They are generally opposite or whorled.

3. Vessels are present in the secondary wood.

4. ‘Flowers’ are unisexual, usually dioecious and only rarely monoecious as in some species of
Gnetum.

5. **‘Flowers’** are arranged in compound strobili or ‘inflorescences’.

6. The male flowers are surrounded by a perianth. Each male flower contains an antherophore with one to eight synangia.

7. A single erect orthotropous ovule is present in each female flower.

8. Nucellus of the ovule remains surrounded by two or three envelopes.

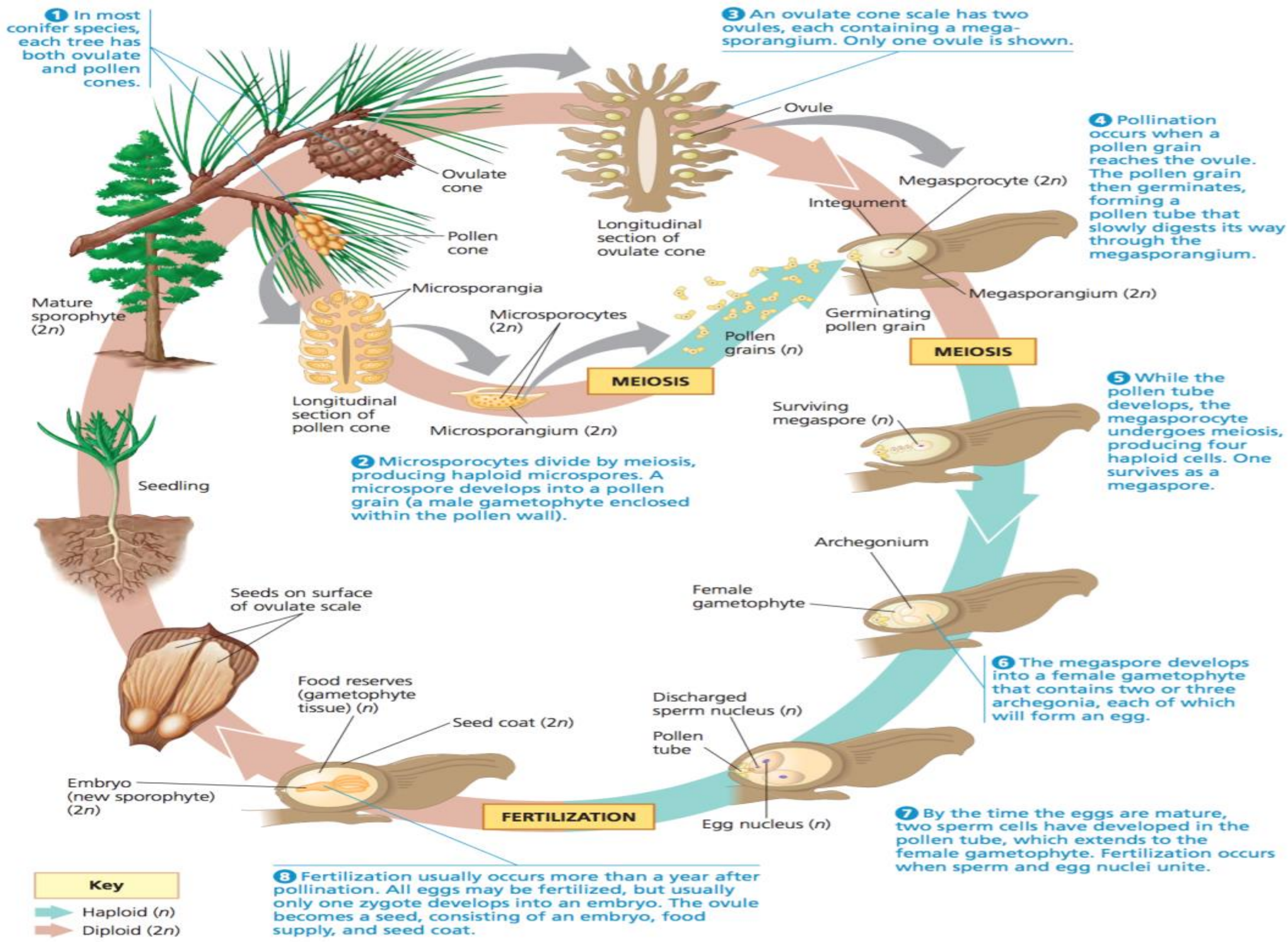
8. Nucellus of the ovule remains surrounded by two or three envelopes.

9. The micropyle of each ovule remains projected in the form of a long bristle-like tube.

10. At the time of fertilization the pollen tube contains two male nuclei.

11. A unicellular primary suspensor is present in the embryo.

12. Two cotyledons are present in the embryo.



UNIT V:

UNIT-V: PALEOBOTANY

Concept of Paloebotany

- Palaeobotany or the study of fossil plants, i.e., the plants existed in the past and now are entirely extinct. This is the difficult branch of Botany in respect that the fossil plants are difficult to obtain and they are rather scarce. Whenever the fossil plants are found, they are in parts which are to be coordinated.This is a tough process of the study. The fossils are cut in sections with a great difficulty and thereafter the preparations are made which require great labour, time and technique.
- The study of fossils is useful academically as well as economically. The academic interest lies in that their study clears up to a great extent the inter-relationships and evolution of the ancient groups of the plants. The economic interest lies in that some fossils are confined to definite strata of earth crust and they are associated with petroleum, coal and similar other things of economic value.
- Actually some coal fields were discovered only on account of the presence of certain fossils just above the coal mines. Another point of view of academic interest is that the fossils help in the determination of the climate of ancient time in different regions.
- During Carboniferous period the earth was covered by very luxuriant forests and it is assumed that climate in those days was very uniform because the plants flourished in those times (i.e., Carboniferous period) were greatly the same on the whole surface of the earth.
- According to one school of thought, the outer part of earth crust is solid and comparatively thinner than interior of earth which is supposed to be in molten condition. Some workers are of opposite view. They believe that the interior portion of the earth is firmer and more solid while the outer crust of the earth is of light matter.
- They also presume that the interior crust of the earth consists of many heavy metals like iron and lead. Whatsoever might have been the position but it is very clear that the first crust which formed the first surface much have been very uniform.
- Later on the water and air appeared and with the appearance of these two destructive factors the surface of the earth began to change. Rain and air affected the surface of the earth to great extent and at certain places the surface rose up in high mountains by bursting of interior of matter and at other places it sank down and formed seas and oceans.
- The rocks withered off, the volcanic eruptions and other changes took place and the general topography of the earth was completely changed.
- Rivers coming down from mountains bring down pieces of rocks and large quantity of sand when they flow in the plains. This sand settles down at the bottom of the water. Along with this sand the parts of the plants and animals which get into that sand would have a chance of being preserved. This preservation takes place in different forms.
- The fossils are mainly found in the sand which has been brought down by the rivers from the mountains. This sand has become compressed and sedimentary rocks have been formed in the bottom of water. They contain the pieces of plants or entire bodies or bodies of animals which have been surrounded by mud and salt and they got the chance of being preserved.

Technique of Palaobotany:

The different methods of the study of fossil plants are as follows:

It is a laborious process and requires sufficiently great time. Usually the petrified specimens are cut in serial sections which give an idea of the actual structure of the fossil plant. These petrified pieces are cut into very fine slices by different methods. In one method each such piece is attached to glass plate and grounded to sufficient thinness and thereafter studied under the microscope.

Another improved method of the study of these petrified specimens is to prepare the films of the material by special techniques. The method of preparing thin films is as follows: First of all the surface of the section of the petrified material is made smooth. If the material consists of calcium carbonate, then on the smooth surface of the slice a film of 5 per cent hydrochloric acid is allowed to act for five minutes.

If the slice of the petrified material is silica then the film of 10 per cent hydrofluoric acid (HF) is allowed to act on the smooth surface for ten minutes so that the silica is dissolved.

The surface of the petrified section by the action of these acids becomes rough on account of the dissolution of the mineral matter. If any organic matter remains on this surface, now put hot gelatin on the surface. As soon as the things dry up, they are removed and studied under the microscope. This process may be successful only in the case when organic matter is left in petrified specimens. In cases where organic matters are already decayed, such preparations are never good.

The fossils naturally would be pieces of plants. It is very rare that entire plant could have preserved. This way, only pieces can be studied. In such type of study the individual pieces are given botanical names, just as in living plants. The botanical names of the fossil plants are not so significant as those of living ones.

As they are represented by the pieces of the plants and, therefore, their generic names would be according to stem, leaf and root or any reproductive structure. The stems are usually given the generic names which end with ‘dendron’ (tree) or ‘xylon’ such as, Lygenodendron or Cladoxylon. The leaves end with ‘pteris’ or ‘phyllum’ and reproductive parts end with strobilus. This way, the paleobotany is the study of the parts of fossil plants and in certain cases marvellous results have been obtained.

In the case of Lygenopteris, one of the Cycadofilicales of Carboniferous period which was found in pieces and later on the palaebotanists supported that all the pieces belonged to one particular plant. Later on after few years the complete intact plant was found.

Important Strata of Paleobotany:

The Palaeozoic and Mesozoic strata are very important from the study point of view of the fossil plants. It is in the upper middle Palaeozoic, i.e., the Devonian strata, we come across with the first land plants such as lycopods belonging to Lycopodiales, Equisetales, the seeded ferns, the primitive gymnosperms, the pteridophytes, etc. In the late Palaeozoic, i.e., both in the upper and lower. Carboniferous strata the earth was covered up by the very luxuriant forests. These forests were formed by lycopods, horsetails, seeded ferns and later on with primitive gymnosperms.

The Carboniferous strata is most important. The coal mines are situated in this strata. The coal mines are the result of dense forests having got submerged in those times. The Mesozoic is also very important from the point of view that the first angiosperms made their appearance; otherwise the higher gymnosperms formed luxuriant forests in those times. In the later Mesozoic some of the gymnosperms disappeared. Majority of the Cycads disappeared and only a few forms have been left up to the present day. In India the most important strata is described technically the ‘Gondwana system’ named after Gondwana Kingdom. For the first time the rocks of this period were discovered near Narmada river.

Work on Paleobotany in India:

The first most work on Indian fossils was done by Fiestmental, the Director of Geological Survey of India. He published a monograph of Indian fossil forms. Thereafter Seward and Bencroft made a number of additions. From 1895 to 1909 most of the work on Indian fossils was carried on in Europe. It had been since 1919 till the death of Dr. Birbal Sahni, i.e. 1949, that work of Indian fossils had been added to a great of deal.

He first revised the known Indian fossils and then published a number of monographs describing numerous fossil forms. The most important Indian fossil of Cycads is Williamsonia sewardiana. In India it is only in few places that there is a good collection of fossil plants, e.g. Museum of Calcutta, the Lucknow University Museum; Presidency College, Madras, Prince of Wales College, Jammu. The collections are made from Raniganj coal field, in Bengal, places near about Nagpur, Reeva state, Kotah state, in some parts of Kashmir near about the Sutlej river, salt range in Punjab (now in Pakistan), and Rajmahal hills, Bihar.

GEOLOGICAL PERIODS

GEOLOGICAL PERIODS IN THE NORTHERN HEMISPHERE

Era	Period	Age in million years	Types of vegetation
CENOZOIC	Quaternary	1	Modern
	Upper Tertiary, Pliocene Miocene	10 20	Modern
MESOZOIC	Lower Tertiary, Oligocene Eocene Upper Cretaceous Lower Cretaceous Upper Jurassic Lower Jurassic (Liassic) Upper Triassic (Rhaetic)	35 50 75 100 130 140 160	Modern, with tropical plants in Europe Gymnosperms dominant (Conifers and Bennettitales) Luxuriant forests of Gymnosperms and Ferns
	Lower Triassic (Bunter) Upper Permian	180 190	Sparse desert flora with Gymnosperms (Conifers and Bennettitales)
PALAEOZOIC	Lower Permian Upper Carboniferous (Coal Measures)	200	Tall swamp forests with early Gymnosperms, Tree Lycopods *Calamites* and Ferns.
	Lower Carboniferous Upper Devonian	250 260	Early Gymnosperms, large tree Lycopods and Ferns
	Middle Devonian	275	*Rhynia* vegetation in marshy localities.
	Lower Devonian Upper Silurain	300	Herbaceous marsh plants (*Psilophyton* and *Zosterophyllum*) and some small shrubs.
	Silurian	350	Marine algae
	Ordovician	425	Marine algae
	Cambrian	500	Marine algae, but some evidence of land plants too.
PRECAMBRIAN		4500 ?	Fungi and bacteria reported to have occurred 2,000 million years ago.

MAIN EVENTS OF EARTH'S HISTORY

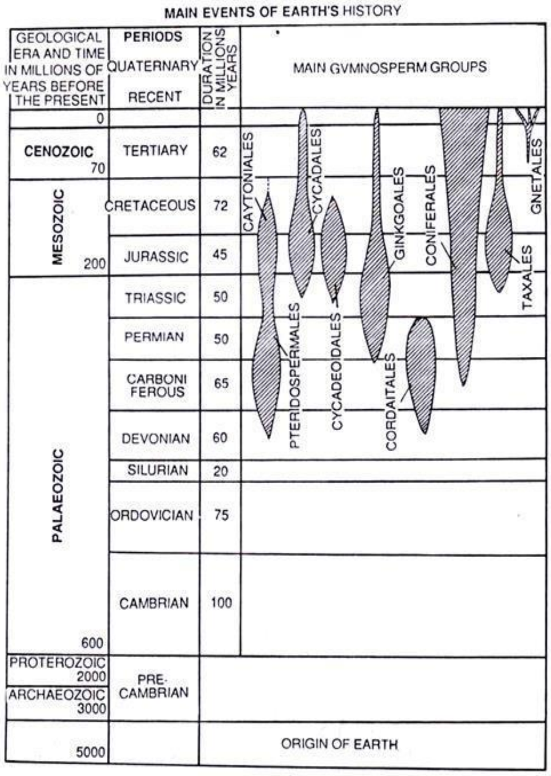


Fig. 2.1. Geological history of the Gymnosperms.

Fossills and Fossilization

Meaning of Fossils:

Remains or vestiges or traces of plants and animals of the past are called fossils. These remains of organisms from past geological ages remain preserved in sedimentary rocks either as actual structures or as impressions, casts or molds. The word ‘fossil’ is derived from the Latin word **“fossilis”** which means **“to dig up”.** In the earlier studies, therefore, a large number of things dug out of earth’s crust were called fossils. These things also included minerals and rocks besides remains of plants and animals. Later on, however, study of fossils was made restricted to only animals and plants.

Study of fossils is of great importance because:

(i) They furnish evidence of the prehistoric life, and
(ii) They also provide missing links in the evolutionary chain.

Plant fossils are rarely as well preserved as animal fossils because their tissues normally do not contain calcified structures. They are usually, therefore, completely decomposed before the process of fossilization. The fossils or remains of large or macroscopic structures, such as leaves, branches, fruits and seeds, are called mega fossils while those of very small or microscopic structures (e.g. spores, pollen grains, etc.) are termed as microfossils.

The species of plants or animals which no longer exists is called extinct. On the other hand the species which exists at present is called extant. If a fossil cannot be assigned to any genera containing extant species then its genus is termed as an organ genus. Similarly, if it cannot be assigned to a family, it is placed in a form genus. Study of fossils is now an established science. It has helped in the construction of phylogenetic classification schemes. It has also thrown light on how some of the complex structures of extant plants and animals have evolved. A full-fledged research institute, devoted fully to the study of fossil plants, now exists in our country. It’s name is Birbal Sahni Institute of Palaeobotany, Lucknow.2. Formation of Fossils:

In the basic process of fossilization, the physical part of any plant or animal must be buried within a well-protective matrix in the crust of the earth. This matrix in the earth’s crust is usually sedimentary. The sedimentary environment of this kind can be of several types such as lake, stream, inland sea or

estuarine, etc. In several cases it has also been observed that diatom frustules also get incorporated in deposits of deep sea basins. In rare cases, the sedimentary environment is in the form of volcanic deposits or other subaqueous conditions. The portions of the organisms (plant or animal) preserved in sediment become stony or lithified during course of time.

Accumulation of rock particles results in the formation of sedimentary rocks. Weathering and mechanical abrasion of existing rocks take place and give rise to the rock particles. Chemical weathering and flooding also help in the formation of these particles. These rock particles or sediments accumulate and water is squeezed out of them. During course of time, this makes them much more compact or rocky structure. Such a rocky structure is called sedimentary rock.

Some other conditions which favour fossilization include:

(i) Anaerobic conditions, (ii) Low pH, (iii) Forest fires in the form of fossil charcoal, and (iv) Presence of sedimentary materials such as carbonates, silicates, salts of iron, etc.

Types of fossils: 1. Compressions: Of all the types of fossils these are the most common ones found in the rocks. As the very name suggests the plant gets flattened due to the pressure of the sediments. As a result a thin carbonaceous film is retained outlining the surface features of the plant parts. Generally little or no internal structure is retained. Rarely, however, the cell pattern of cutinized epidermis is retained.

Sediments of various types are involved as matrices for compressing the plant parts. These are shale, sand stone, volcanic ash, diatomaceous earth etc. Compressions help us to understand the external features of plants of the past. They provide reliable clues in establishing the affinities.

2. Molds, Incrustations and Casts: After the plant part is entombed in the sediment if there is no compression the surrounding sedimentary material hardens to form a three dimensional structure called the mold. Incrustations may be defined may be defined as external molds of a plant usually in some incompressible materials like sandstone, ironstone or tufa. After the formation of mold, sometimes the plant part may decay. This space later is filled by crystalline substances such as iron pyrites, sphalarites, chalerite, opal, agate etc. Such hardened structures are called casts. Casts exhibit the same external configurations as the original plant fragment. No organic material is seen in a cast. Hence there is no question of cellular details.

3. Petrifactions: Of all the types of fossils, petrifactions are the best, but rarest. In these fossils external form, internal structure and sometimes the substances of original plants are preserved. Cellular details are preserved due to infilteration of some minerals into the plant tissues.

During petrifaction, the entombed plant is impregnated with about twenty minerals such as carbonates, sulphates, silicates, phosphates, iron pyrites etc. Solidi-faction of plant tissues takes place ultimately. Petrifactions are of great importance because they can be cut into sections for anatomical studies.

4. Coal Balls: Petrifactions of spherical specimens are generally termed coal balls. During the formation of coal balls the plant material in swamps gets infiltrated with carbonates of calcium or magnesium, so that the debris of plants will not get converted into coal. Coal ball plants are of great value in palaeobotanical studies.

5. Compactations or Mummified Plants: Plant fragments compressed by vertical pressure are called compactations. Aggregations of plant material found in peat, lignite etc., represent large scale mummifications.

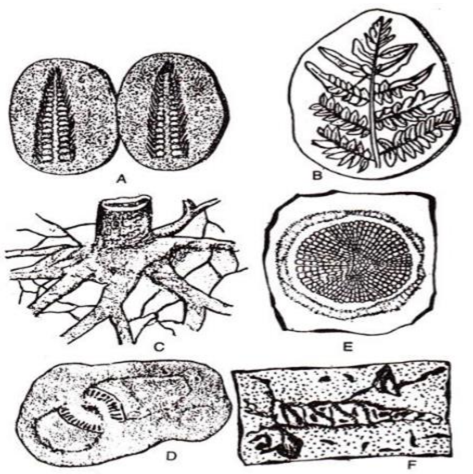


Fig. 10. Types of Fossils
A. Compression (Cone of Lepidodendron),
B. Impression (Leaf of *Neuropteris*), C. Cast (Stump of *Stigmaria*),
D. Section of a coal ball showing transverse section of a petrified stem (*Sphenophyllum*).
E. Sections of stems within coal balls. F. Compression (spike of *Zosterophyllum*)

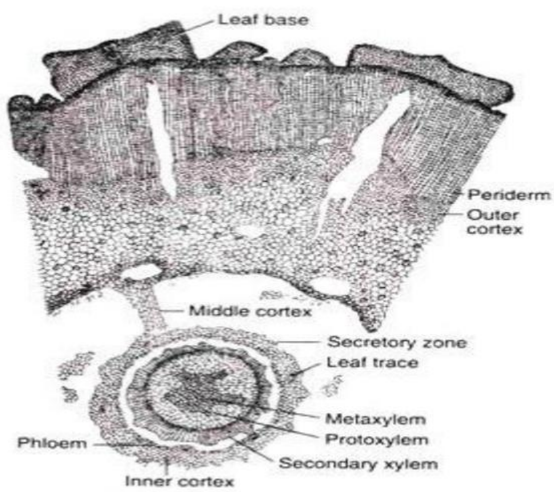


Fig. 7.40 : T.S. of *Lepidodendron* stem

LEPIDODENDRON

Division - Lepidophyta

Class - Lycopsida

Order - Lepidodendraceae

Genus – *Lepidodendron*

(i) More than one hundred species under the genus Lepidodentron have been described.
(ii) It appeared during upper devonian, flourished in carboniferous and disappeared in pennian.

(iii) It is tree and reaches up to a height of 40 meters and the diameter of the trunk was approximately 50 centimeters.
(iv) The trunk was straight and columnar, unbranched upto certain distance above the ground.
(v) Dichotomous branched were clothed with spiral or whorls of leaves.
(vi) Leaves (lepidophyllum) were deciduous, simple ligulate, linear to acicular in shape and 2 to 18 cm in length.
(vii) Leaves were shed by abscission leaving base attached to the branches called leaf cushion which appeared as projecting truncated cone or pyramid iike.
(viii) The trunk at the base was attached to stigmarian root system which appeared as dichotomously forked th ick and spreaded.

ANATOMY OF THE TRUNK: The trunk was differentiated into central stele surrounded by cortex. The cortical zone was very thick and can be differentiated into. (a) Inner cortex, (b) Secretary zone, (c) Middle cortex and (d) Outer cortex. (i) The inner cortex was made up of parenchyma cells. (ii) The secretary zone was composed of large and small cells. Some of them were filled with dark coloured substance. (iii) The middle cortex was similar to inner cortex in structure and appearance and the outer cortex was composed of alternating patches of thin and thick walled tissue. (iv) The outer cortex was encircled by hard periderm layer formed by phellogen. (v) The stele was either siphonostelic or protostelic. (vi) The protoxylem was exarch and showed_polyarch condition. (vii) The meta xylem of tracheids was with scalariform thickening and the protoxylem was with spiral thickenings. (vii) The secondary wood has scalariform tracheids and small wood rays.

ANATOMY OF LEAVES (i) Leaf is known as Lepidophyllum. (ii) They were borne spirally on the stem and were triangular in shape. (iii) Stomata were present on the abaxial side in two longitudinal grooves. (iv) The leaf base was seen with a small single vascular strand. (v) The vascular strand was flanked by two triangular or rounded areas or scars - one on each side. (vi) These scares were termed as. perichnos. The perichnos represented secretory or aerating parenchyma cells extending from stem cortex into the leaf. (vii) A ligular scar or pit was present in the centre of the cushion above the perichnos. (viii) The ligule was shunken and small. (ix) The mesophylls were present in the central region of the leaf.

REPRODUCTIVE ORGAN strobili of Lepidodendraceae were discovered from carboniferous rocks and were named as form genus Lepidostrobus. (i) These strobili (lepidostrobus) were ellipticle, born terminally on the lateral branches of the crown. (ii) They were 2.5 to 30 cm long and l to 7.5 cm in diameter. (iii) The strobili were heterosporous having microsporophylls and megasporophylls, arranged spirally or venically on the axis of the strobilus . (iv) The sporophylls were ligulate. (v) The sporangia were sessile, elongated and of same size born on adaxial surface near the base of the respective sporophylls. (vi) The sporangia may be septate or aseptate. (vii) The wall of the sporangia were made up of one layer of prism shaped cells. (viii) The microsporangium had many small microspores and the megasporangium had 5-16 megaspores. (ix) The size of the microspores ranged from 0.02 to 0.03 mm in diameter and that of megaspores ranged from 0.5 to 2.0 mm in diameter.

STRUCTURE OF GAMETOPHYTE (i) The male gametophyte has not yet been reported. (ii) Female gametophyte with archegonia has been reported. (iii) The megaspore developed into female gametophyte while still within the megasporangium.

CALAMITES

Order – Calamitales

Family – Calamitaceae

Genus – *Calamites*

The name *Calamites* was originally used for the pith cast of stem Suckow (1784) but successfully the entire plant was referred as *Calamites*.

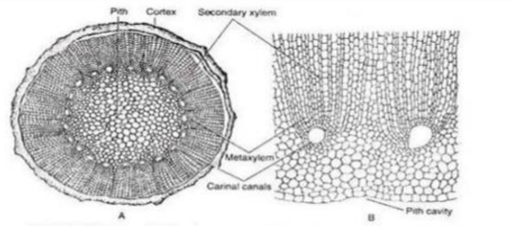


Fig. 7.76 : *Calamites* : A. T.S. of young stem, B. A portion of T.S. of mature stem

External Structure - The saprophytic plant/known mainly from casts were mostly trees height of 20 to 30 meters although some of them might have been similar shrubs. The plant had a stout rhizome like stem well differentiated into nodes and internodes. Adventitious roots were present in whorls at the nodes. *The aerial shoots arose from a strong horizontally* growing rhizome as in case of Equisetum. The rhizome was differentiated into nodes and internodes with a whorl of adventitious roots at each aerial shoots were branched and bore whorled leaves. On the basis of mode of branching pattern the genus Calamites has been divided into following three sub-genera.

(a) Eucalamites - It was most dominant sub-genera in which branches were present on every node. These branches again branched repeatedly giving rise to a bushy structure. The leaf verticils were on final branchlets. **(b) Calamitina -** The whorls of branches were present on certain nodes. The internodes were short but the branch bearing nodes surmount internodes much shorter than others. Leaf verticils were on secondary branches. **(c) Stylocalamites -** The branches were few and irregularily scattered. The leaf verticils were at the top. The leaves of Calamites were found mostly on the smallest branches although they often remained attached after the stem had attained considerable size. They were often present at the same nodes that support larger branches. Leaves of Calamites were placed in two form genera i.e.*Annularia and Asterophyllites.* **Annularia -** This leaf exhibits a great diversity in forms. They were arranged in whorls around the stem. The number of leaves in whorls varies but usually there were from 8 to 13. The leaves Annularia were linear, lanceolate or spatulate with a single vein and ranges in length from 5mm. to few centimeters.

Asterophyllites - These leaves were slender, and needle like and form a whorl around the shoot. The number of leaves per whorl varies but usually there were from 15 to 30. The Roots of Calamites were produced adventitiously at the nodes of the stem. Nodes and internodes were completely absent in these adventitious roots. The roots of calamites are placed in the form genus Asteromyelon (when the specimen was petrified) and the Pinnularia (when the specimen was compressed).

Internal Structure - Anatomically the stems closely resembled those of Equisetum. Pith casts of calamites showed ridges and furrows, corresponding in number with protoxylem strands. A central pith cavity was present at nodes. (The pith was solid and delicate. The pith was surrounded by an endarch siphonostele) The protoxylem strands disintegrated forming carinal canals which was surrounded by Metaxylem. The metaxylem was centrifugal and consisted of scalariformed and pitted tracheids. The secondary xylem was composed of radial rows of tracheids with scalariform pittings or multiseriate

circular bordered pits on the radial, walls. Interfascicular rays traversed the secondary xylem. The annual rings were absent.

A young stem shows a ring of primary collateral vascular bundles. The cortex was divided into a thick walled outer zone and thin walled inner zone. A thick and smooth periderm was formed in the cortex during secondary growth. (A number of leaf traces were departed from the main vascular cylinder. The leaf traces were simple bundle. Leaf gaps were not formed. The leaf Asterophyllites has been found in petrified condition so that the anatomy of these leaves are well known. The cross section of leaf was semicircular or triangular in shape. A small vascular strands in the centre was surrounded by starch bearing bundle sheath. The bundle sheath was encircled by long radiating palisade cells. There was a single layered epidermis all round, which contain stomata.

In the T.S. of Roots the primary xylem was exarch and the carinal carlals were absent. It was diarch or polyarch. Masses of phloem were present alternating to the patches of protoxylem. Endodermis was double layer. The pith was small and not hollow, hence casts were not formed. Large air spaces were present in the cortical region-as in aquatic plants.

Fructifications - At least five types of strobili of Calamites have been described. Two of them, i.e. Palaeostachya and Calamostachys have been found as Petrifactions and are best known forms. The strobili were borne on fertile shoots at the nodes in the virticils of two or more in the axil of bracts. (Each strobilus possess a central axis bearing whorls of sporangiophores. The sporangiophores bore sporangia commonly 4 in number. The strobili in Calamites were homosporous as well as heterosporous.

(a) Palaeostachya In Palaeostachya a sporangiophore whorl alternates with a sterile bract whorl. The former whorl was axillary to the latter. The sporangiophores were not appendages to the bracts as they have independent vascular supplies coming from the axis. The sporangiophores were peltate. Each sporangiophore bore four re-curved sporangia.

(b) Calamostachys fit was the most common petrified genera. It was widely distributed organ genera that ranged from Lower Coal Measures to the lower Permian. In this strobili the whorl of sporangiophore alternating with sterile whorls of bracts. Both of the whorls arose directly from the stem at right angles to it, so that they look quite independent. The sporangiophores were peltate. And each sporangiophore bore 4 sporangia directed towards the cone axis.

LYGINODENDRON

Division - Cycadophyta
Sub-division - Pteridospermae **Order -** Cycadofilicales **Family -** Lyginopteridaceae

Form genus - *Lyginopteris* (Lyginodendron) **HABIT AND HABITAT**

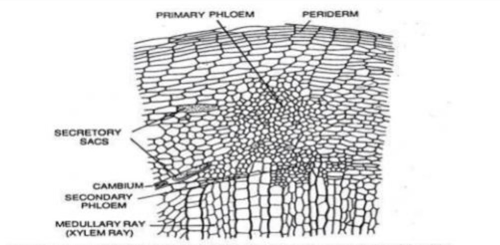


Fig. 2.6. *Lyginopteris oldhamia.* A part of T.S. stem showing the outer portion of the stele.

The plant was first described by Binney (1866) under the name of "Dadoxylon Oldhamium" Williamson (1873, 95) gave its name "Lyginodendron oldhamium" and· gave thorough knowledge of its vegetative structure.

ANATOMY OF ROOT It has a distinct name **-** Kaloxylon Hookeri : Diameter is about 5 mm T.S. of root shows the following characters. (i) Secondary tissues at all stages of development. (ii) Triarch diarch vascular bundles. (iii) 4-8 xylem groups-alternating with .Phloem. (iv) Pericycle one ot more layer surrounds the vascular tissue. (v) Endodermis beyond the pericycle. (vi) Inner cortex of lax parenchyma.

(vii) Double peripheral layers of exodermis. (viii) Sec9ndary growth like gymmosperms and dicotylendons. (ix) No distinct formation of periderm.

ANATOMY OF STEM

T.S. of stem shows the following features : (i) Monostelic structure (ii) Middle of the stele occupied by a large parenchymatous pith, containing irregular groups of dark sclerotic tissue.

(iii) Primary xylem of collateral vascular bundles (V.B.) which are 5-9 in number and surround the pith.

(iv) Around the primary xylem secondary xylem with pitted tracheids and medullary rays are found. (v) Opposite the primary xylem, group of primary phloem is recognized. (vi) Bast formed cambium is

present. (vii) Beyond the phloem zone, pericycle is present. (viii) Collateral leaf trace bundle, embedded in pericycle are found. (ix) Few layers of periderm are found outside the pericycle. (x) Beyond the periderm, thin walled inner cortex and outer cortex of sclerenchyma is present which appear as dark radial bands. (xi) First cases of branching were discovered by Mr. James Lomax in 1902.

ANATOMY OF LEAVES

(i) The main petioles of the leaves associated with stem reaches a centimeter in diameter. (ii) The petioles were named Rachiopteris aspera. (iii) Phloem completely surrounds the xylem. (iv) Inner cortex contains bands of sclerotic cells. (v) Leaflet has epidermis, hypodermis and palisade parenchyma towards upper surface. (vi) Towards the lower surface, mesophyll is the spongy parenchyma. (vii) Traces of stomata on lower surface. (viii) V.B. enclosed in sheath. (ix) V.B. collateral.

(x) It is compound and like fem leaflets with xerophytic structures. (xi) Sphenopteris is the name of leaflet.

THE SEED

F. W. Oliver (1903) identified the seeds of Lyginodendron (Lyginopteris) by presence of glands on its enveloping husk. Williamson named the seeds as "Lagenostoma lomaxi ". It possess the following features : (i) Seed is barrel shaped 5.5 mm in length 4.25 mm in diameter. (ii) Enclosed in an outer husk or cupule. (iii) Attached with pedicel, Pedicel and cupule studded with capitate glands. (iv) Cavity of the head is empty. (v) Cupule is ribbed in lower parts and divided into lobes above. (vi) Peidcel traversed by a single concentric and mesarch vascular bundle which gave rise 9 to IO bundles into the cupule. (vii) Cupular bundles are branched and collateral and mesarch. (viii) Pedicel and cupule were of foliar nature. (ix) It is orthotropous and cycadean type with radial symmetry. (x) Integument is single, adherent to the nucellus except in apical region. (xi) Central strand of pedicel, after giving of cupular bundles passes straight up and becomes the chalazal strand which is surrounded by mass of thick walled strengthening tissue. (xii) The integument expands towards the micropyle which forms 9 chambered canopy. In each locule one of the _nine V.B. entered. (xiii) Canopy may represent water storage for pollination by drop mechanism. (xiv) Outer layer of integument has columnar structure. (xv) Free apex of the nucellus forms the pollen - chamber. (xvi) Pollen grains are multicellular. (xvii) Outline of megaspore or embryo sac can be traced. (xiii) Absence of trace of embryo.

CORDAITES

Division - Coniferopsida **Order** - Cordiatales **Family** - Cordiataceae **Form genus -** *Cordaites*

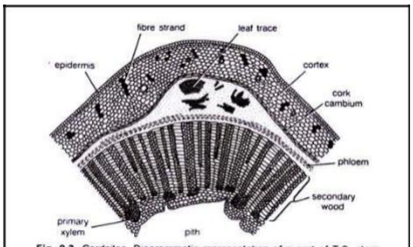


Fig. 9.3. *Cordaites*. Diagrammatic representation of a part of T.S. stem.

The genus *Cordiates* is known from the assemblage of dismembered parts which are known under various names. Stem and wood – *Cordiates, Dadpxylon,Mesoxylon, Parapitys* etc.

Leaves - Cordaites **-** Defoliated branches **-** Cordaicladu. **Roots** -Amyelon. Strobilus **-** Cordainthus. **Seeds -** Cordiaicarpus. (Cordiocarpus). The plant body of Cordaites was a tall tree reaching a height of 30 metres and grew in dense forests. The stems were slender and attained a diameter of 65-70 cms. The branching was lateral and arose only at the top part of the plant. Leaves (compressions) were found on the branches and were spiral in arrangement. They were petiolate, subulate or spatulate or grass like and had an entire margin. Venation in the leaf was parallel. Based on the nature of the leaves the genus is divided into three subgenera viz., Eucordaites (Leaves broad with a blunt apex Dorycordaites (leaves with acute apex) and Poacordaites (Leaves were grass like and small). The plant was anchored to the soil with the help of repeatedly branche root system.

INTERNAL STRUCTURE :

Stem-As has alteady been said, Cordaitalean stems are known under various names, In Cordaites the stem has an extensive cortex which had parenchyma with interspersed scelernchyma. Secretory sacs were also present in the pith. Pith had large air chambers separated by diaphragms. Pith casts cortex The vasculature in its primary structure consisted of a large number of endarch or mesarch protoxylem elements. Secondary growth in the stem resulted in the formation of compact (pyconoxylic) wood. The tracheids in the secondary wood were long and narrow and had uniseriate bordered pits. Interspersed with the wood elements, were the parenchymatous rays which were simple and one cell wide. Some of the cells of the ray had resinous material. However there were two resin canals as in Pinus. The leaf traces resembled those of cycads in the pseudomesarch and diploxylic nature. Each leaf was provided with a pair of traces. **Leaf-** 1. Anatomically the leaves exhibited differentiated mesophyll in most cases. 2. The epidermis had stomata distributed in longitudinal bands. Guard cells were surrounded by 4 6 subsidiary ceils. Root 1. Internally the root showed a diarch to tetrach xylem. 2. Stele was protostelic. **REPRODUCTION** 1. Cordaitean plants were dioecious. 2. The strobili, called Cordaianthus were unisexual and 1 cm long. 3. The male strobili had a central axis which had a few microsporophylls and numerous sterile br.cts Each microsprophyll bore 1-6 pollen sacs. 4. The female strobili like the male ones had a stout central axis on which were borne spirally arrangd bracts. 5. The length of the strobili varied from 25-30 cms. 6. In the axis of the bracts arose short, fertile, secondary shoots which had spirally arranged fertile and sterile bracteoles (megasporophylls). 7. Each megasporophyll had 2 or more ovules at its apex.

PALEOPALYNOLOGY

The science concerning the study of pollen and spores is called "palynology" and the term was given by Hyde and Williams in 1945 Pollen grains or microspores are the male reproductive bodies of the flowering plants while the spores are very loosely applied to several types of reproductive bodies in algae (e.g. Zoospores. endospores, akinetes, ex-ospores etc.) fungi (e.g. Uredospores. basidiospores. chlamydospores, conidiospores, ascospores etc.) and ptertdophytes. Pollen grains develop in the sporogenous tissue of anthers or micro sporangia in angiosperms. The outer walls of pollen and spores are made up of a pectinous substance known as "pollenin". The chemical formula of pollenine is C00 H129 (OH)5• The protoplasm of pollen grains contains proteins, lipids, carbohydrate, vitamins, hormones and enzyme. It also contains traces of some inorganic substances such as Mg, Cl. K. 'Ca. Cu, Si, Fe & S. Comparatively a new branch of science, Paleopalynoloyg is an offshoot of Palynology. It is concerned with the study of methods of reconstructing floras of the past based on observations on pollen grains and other spores preserved in ancient peat and sedimentary deposits. The resistance to decay of the outer coats of pollen grains with their distinctive sculpturing makes possible both qualitative and quantitative estimates of species occur in the past. Thus it has been helpful in taxonomic consideration of extinct fossil genera, evolution, and affinities age determination of continental and marine sediments, paleoecology, paleogeography and paleocltmate. The utilization of paleopalynology as a tool in solving problems of coal and · oil exploration have attached paramount significance to this new branch of science.

TECHNIQUES TO STUDY PALEOPALYNOLOGY

The pollen or spore materlal is acetolysed with acetic anhydrlde and H2 SO4 and mounted In glycerlne Jelly and sealed with a cover glass with the help of paraffin wax. The pollen/spores are observed mlscroscopically using apuchromatlc and fluorite lenses and Immersion objectives.

FOSSIL FUELS The dominating fossil fuels In world economy are two; coal and oil. Apart from the fact that they are organic substances and they are burnt to provide energy, there Is very little in common between two. They are quite different In form, occur in widely varying environments and are the products of entirely different processes. Details of coal and oil are discussed separately in the present text.

COAL AND COALIFICATION Coal Is one of the dominant fossil fuels of the world. It is derived from vegetable matter, when trees and other Vegetation fall into the swamps, and are covered over soil, they undergo partial decomposition and become peat. In peat, the original woody material is generally visible. As more and more peat accumulates, bacteria break up the organic compounds present in it. liberate gases and convert It In the lignite (brown coal). As more and more gaseous constituents are eliminated, by pressure of sediments deposited on coal bed. or by pressure from earth movement. the lignite is converted into various grades of Coal. High grades of coal have a heating value of some 7000 K cal. per pound. Lower grades have only half or one-third as much heating value.

COAL EXCAVATION AND PALEOPALYNOLOGY –

Excavation of coal to find out location. number and thickness of coal layer in a coal seam ts usually made by boring through basin. Exact estimation of lateral extent of each coal layer poses a major problem. because of disturbed structure of coal basin. However. correlative studies on rocks and their distribution coupled with determination of coal properties from varied parts and depth in coal basin has paid heavy dividends in solving problems of coal excavation. Paleopalynological studies in coal may be a tool to ascertain age of coal layer and the quantities of coal deposits. Adjacent to coal layers pollen grains and spores are frequently preserved in their form. They bear variety of shape, size, organisation and ornamentation. The qualitative and quantitative representation of such structure and their variation are very much helpful in demarcating coal layers and seams in coal field. · Except the paleopalynological studies the megafossils of the plants also plays an important role in coal excavation. Plant parts like stem, leaves, fruits and seeds are frequently preserved adjacent to coal layer. These megafossils can be studied with naked eye. As types of plants occurring in various geological times are known, they may help in establishing age of coal deposits and their position in succession of rocks.

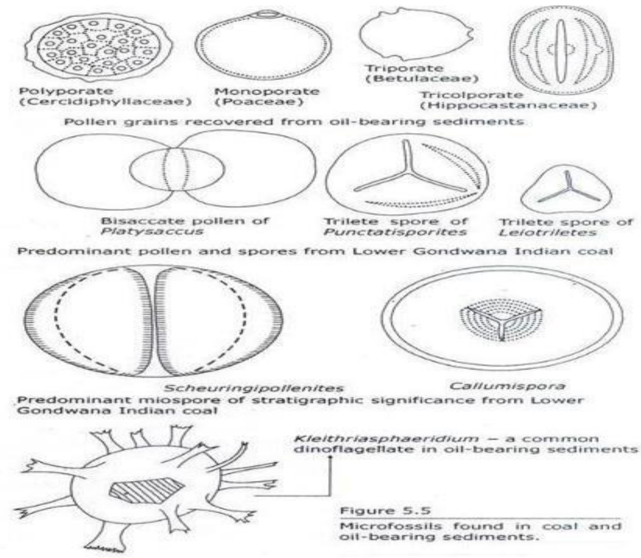


Figure 5.5
Microfossils found in coal and oil-bearing sediments.

OIL EXPLORATION - Paleoecological and paleogeographical information obtained from study of microfossil helps in search for source of an oil reservoir. It is well known that sediments parallel to sea shores are rich in oil. Research has shown that frequency of spores and pollen decreases from continents towards shores. Microfossil counts help to trace pathway of ancient shores and prospective exploration of oil.