COURSE: MSc Part -1

PAPER – 5

TOPIC- Gymnosperm (Different topics)

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Topic-1

Method of Fossilization

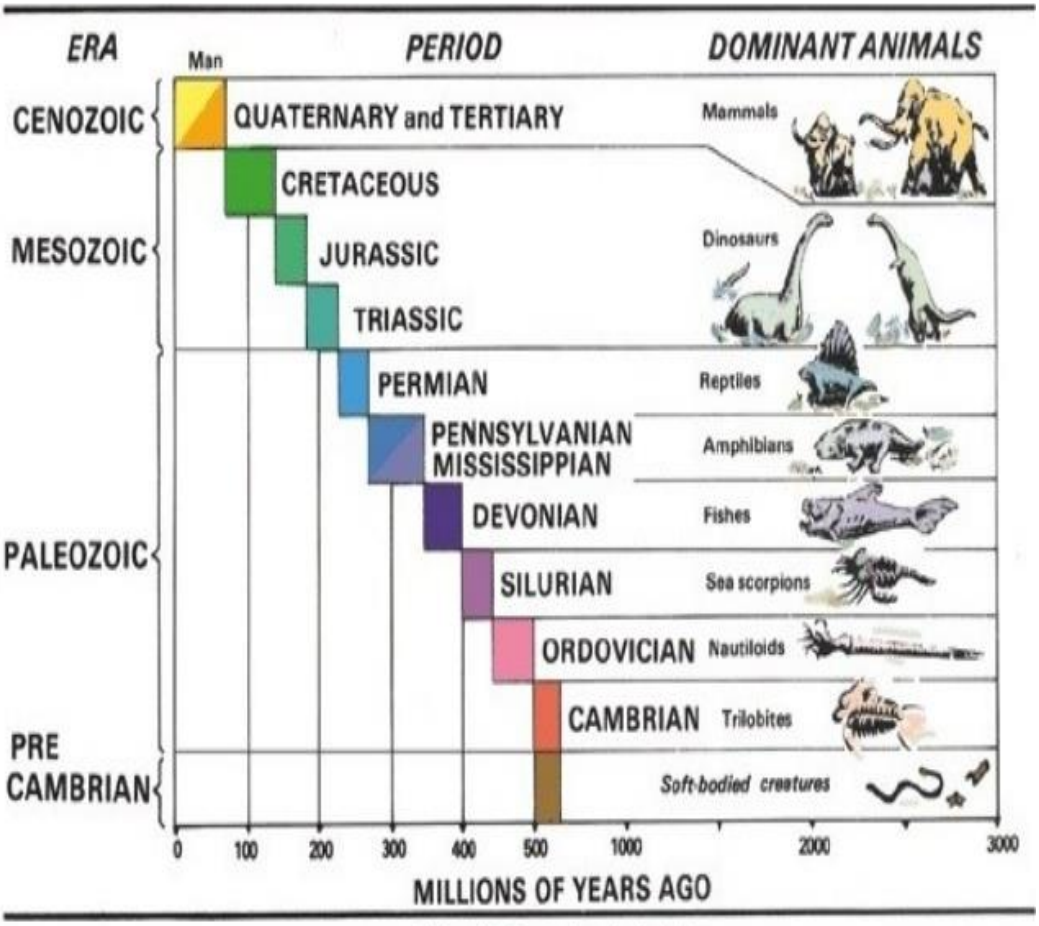
The term fossil refers to any trace of past life. A fossil may be an organisms remains, such as plant, shells, teeth or bones. A fossil record can also be of the activity of an organism. Fossils are formed in different ways, but most are formed when a plant or animal dies in a watery environment and is buried in mud and silt. Soft tissues quickly decompose leaving the hard bones or shells behind. Over time sediment builds over the top and hardens into rock. It is when the processes of erosion occur that these secrets in stone are revealed to us. Fossils, the preserved remains of animal and plant life, are mostly found embedded in sedimentary rocks. Of the sedimentary rocks, most fossils occur in shale, limestone and sandstone. Earth contains three types of rocks: metamorphic, igneous and sedimentary.

The history of earth can be described into different era which has been shown below:

EON	ERA	PERIOD	Millions of Years Ago
Phanerozoic	Cenozoic	Quaternary	1.6
		Tertiary	66
	Mesozoic	Cretaceous	138
		Jurassic	205
		Triassic	240
	Paleozoic	Permian	290
		Pennsylvanian	330
		Mississippian	360
		Devonian	410
		Silurian	435
		Ordovician	500
		Cambrian	570
Proterozoic	Late Proterozoic Middle Proterozoic Early Proterozoic		2500
Archean	Late Archean Middle Archean Early Archean		3800
Pre-Archean			

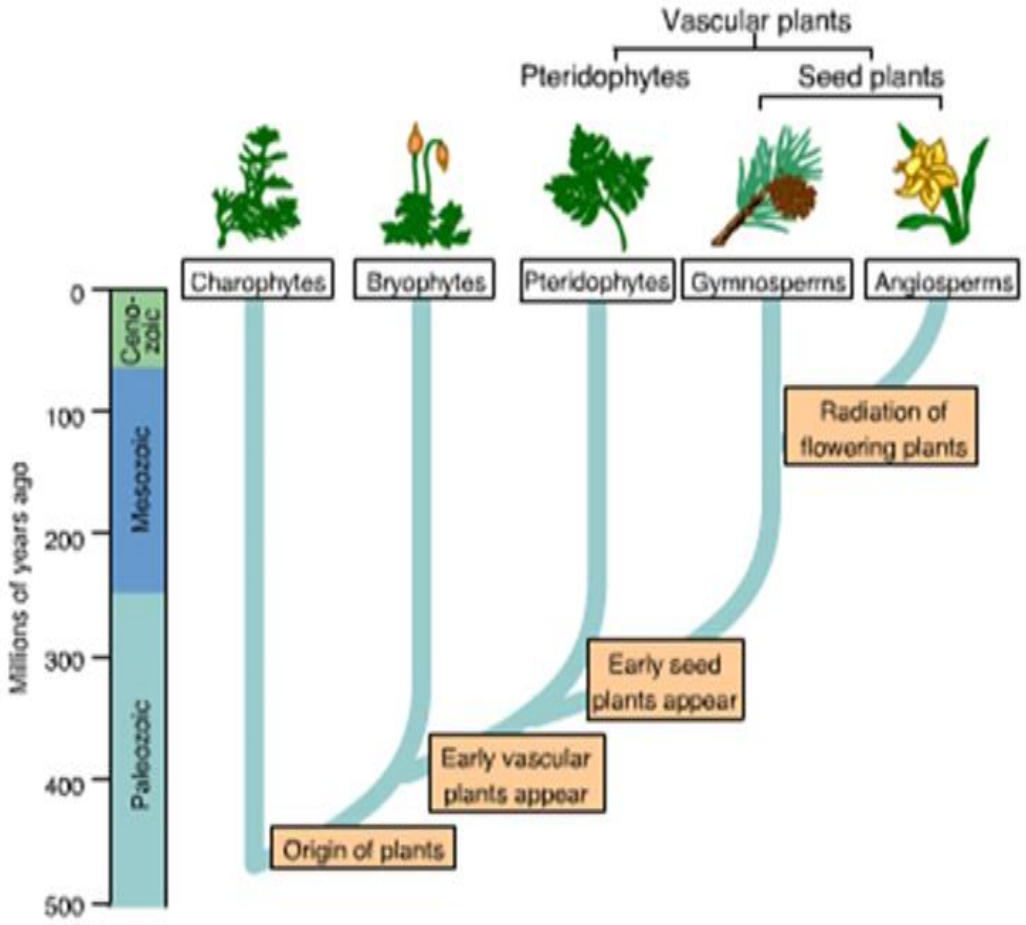
Geological time scale

Animals which survived as major Biodiversity during different era has been shown below:



Major divisions of geologic time.

Plants which survived as major Biodiversity during different era has been shown below:



A visit to different era of the earth suggests that different plants and animals appeared over this earth during different period of time. The remnant of which could be stored by this earth as fossil flora and fauna. The fossil record has helped us in tracing the origin and evolution of various plants and animals.

Process of Fossilization

The five most often cited types of fossils are mold, cast, imprint, permineralization and trace fossils.

1. Mold or Impression. A mold or impression fossil is formed when the plant or animal decays completely but leaves behind an impression of itself, like a hollow mold.

2.Cast. A fossil formed when an animal, plant, or other organism dies, its flesh decays and bones deteriorate due to chemical reactions; minerals gradually enter into the cavity, resulting in a cast. The mineralized impression of the organism left in the sediment is called a mold.

3. Imprint. Imprint fossils are formed from an organism moving in some way, leaving behind a trace or track. These tracks are preserved when the clay/silt dries slowly and is covered by other sediment. Plants can also leave imprint fossils when they are covered by sediment.

4. Permineneralization. One of the common types of fossils is permineralization. This occurs when the pores of the plant materials, bones, and shells are impregnated by mineral matter from the ground, lakes, or ocean. In some cases, the wood fibers and cellulose dissolve and some minerals replace them. Two common types of permineralization are silicification and pyritization.

Fossils are of various types some of which has been described below:

1. Petrified Fossils: There is molecule by molecule replacement of plant parts by minerals such as iron, pyrites, silicates, carbonates, sulphates etc. These minerals get deposited and impregnated inside the cells and the tissues of the plant. This type of fossil can be studied by preparing the sections and are most suitable for the study of structural details

2. Compression:

This type of fossil is common in the sedimentary deposits of rocks. It is a sort of impression where most of the organic remains of the plant remain in the fossil state. The plant or plant part gets buried and the sediments go on accumulating over the plant.

3. Impression:

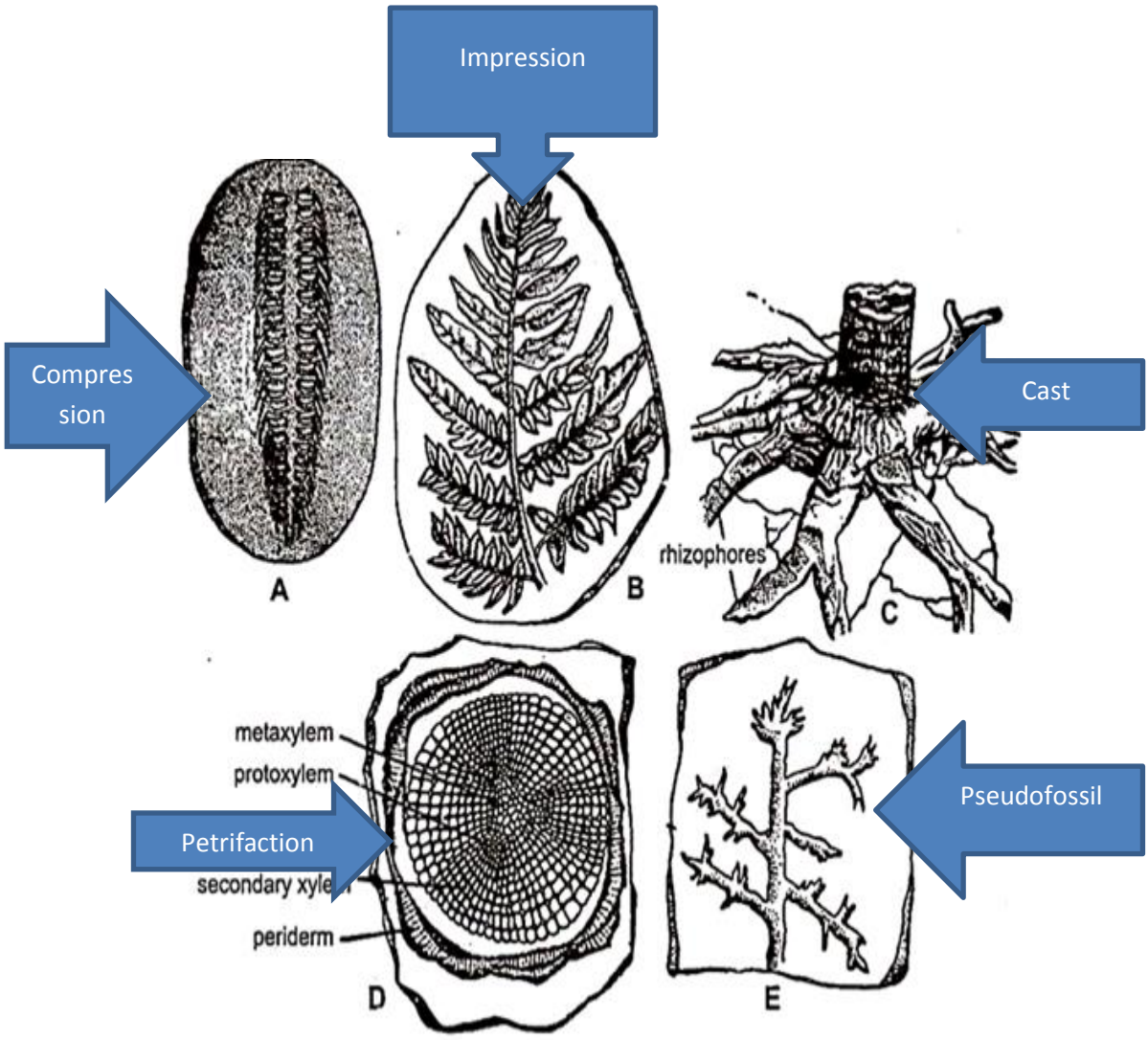
These fossils are just impression of plants or plant parts on sediments. These fossils are useful in studying the external features of various plant parts and venation pattern of leaves

4. Trace Fossils:

These fossils show the activities of the organisms. An animal makes a foot print when it steps in sand.

5. Preserved Remains or Amber:

Some organisms are preserved in or close to their original states. These fossils are called preserved remains e.g., an organism such as an insect is trapped in a tree's sticky resin and dies. More resin covers it sealing the insect inside. It hardens into amber



Topic-2

Codaitales

Distinguishing Features of Cordaitales:

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

2. Plants were present from Devonian to Permian periods of Palaeozoic era

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.

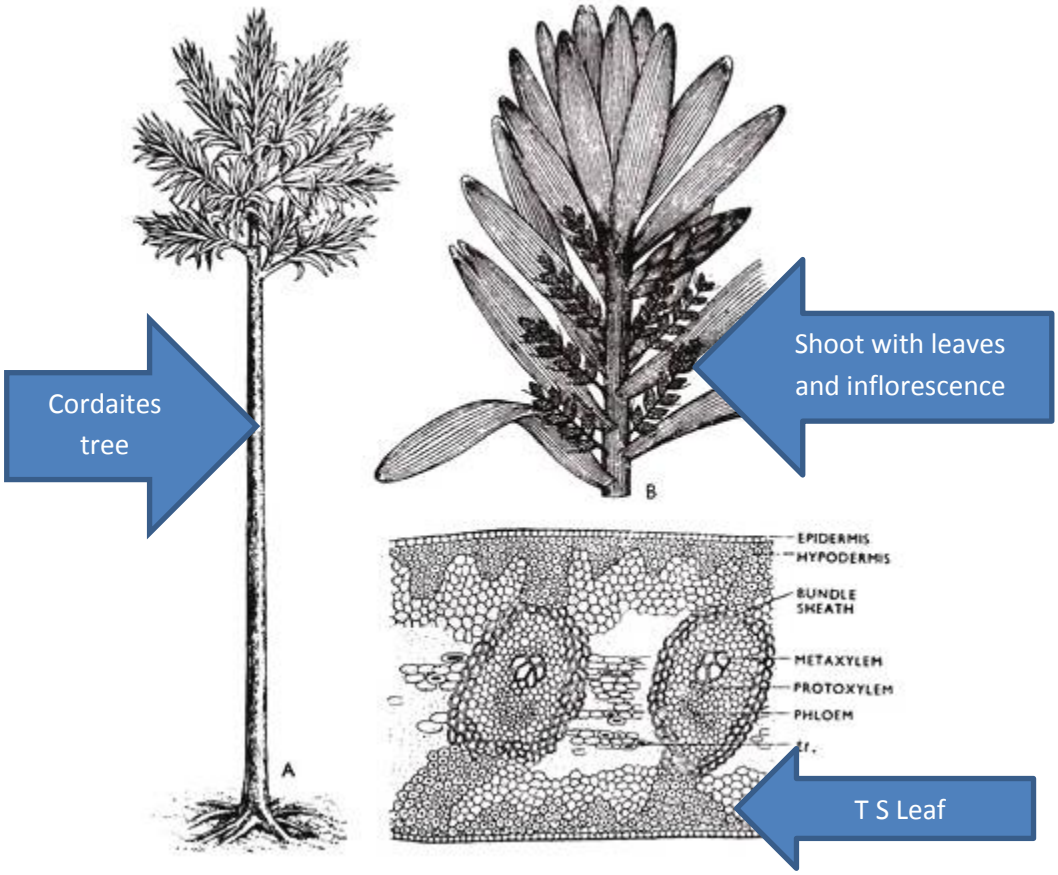
12. Four to six terminal pollen sacs were present on each male fertile appendage.

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

Features of Cordaitales of Cordaitales:

(A) Morphological Features:

The plant was tall and slender. It had a crown of branches near the top, leaves were large simple and pendulate and not found in any living gymnosperms.

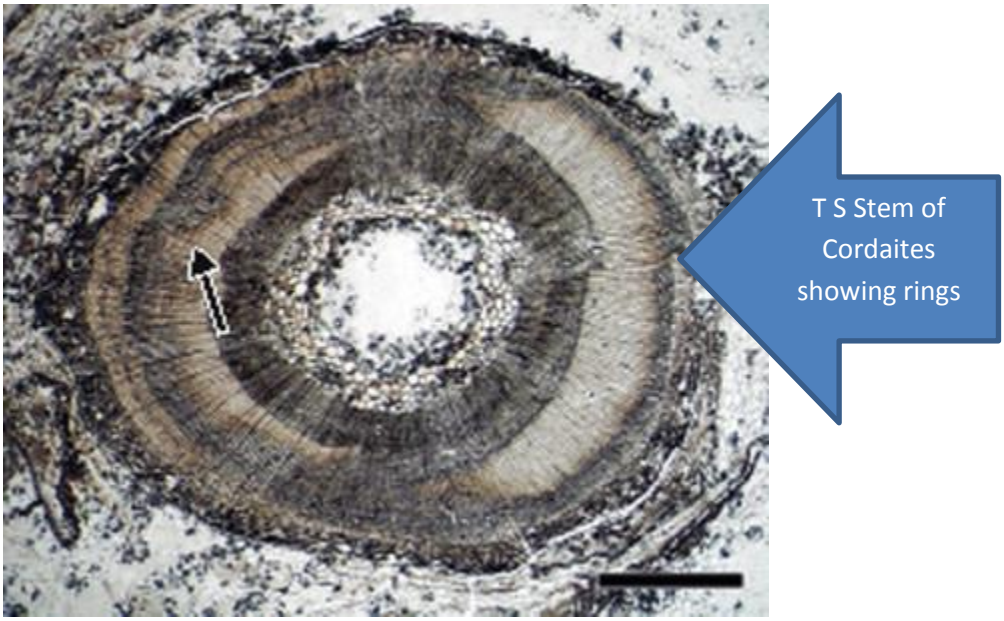


(B) Anatomical Features:

The internal structure of stem in Cordaites showed a combination of Cycas and conifers characters. Pith like cycads layer but discoid in form, i.e., it was in form of plates at intervals. The vascular cylinder was like those of conifers. It was made up of thick collateral endarch primary bundles which sometimes however, seem to have been mesarch as in Mesoxylon.

There was good deal of normal secondary growth. Secondary xylem was made up of living pitted tracheids with pits on radial walls. In fact it is clear that majority of plants found in Carboniferous period belonging to Cycadofllicales, Cordaitales and a number of fossil pteridophytes. The stems had good deal of secondary growth in them, but in these no annular rings.

The stem anatomy of Cordaitales shows variations from exarch to end-arch collateral primary vascular bundles with good deal of secondary growth in stem. So far anatomical structure is concerned the group is related to Cycadofilicales in having exarch and mesarch bundles and to gymnosperms especially to conifers in having developed endarch bundles.



Reproductive Structures of Cordaitales:

The plants were monoecious or dioecious but the strobili were always monosporous and never bisporangiate like Cycadeoideales (Bennettitales) or living Gnetales. Cordaitanthus was the reproductive shoot of Cordaites itself. It was not definitely organized to form a cone but it was more or less a strobilus.

The male and female strobili were borne separately in lateral sides of short simple axis. The strobili were enclosed when young by bracts so outwardly they could not be distinguished unless sections were cut and examined. Both were usually of small size.

Strobilus of Cordaitales:

Male Strobilus:

The male strobilus had a thick axis bearing spirally arranged bracts with stamens on them, the stamens themselves were either solitary or grouped near the apex and in between the stamens there were sterile bracts present. These bracts might have been sterile microsporophylls.

Each individual stamen was peculiar in form, in that it had a cluster of three to six terminal sporangia similar types of stamens have also sometimes described belonging to Cycadofilicales, but the important difference was that at the tips were borne synangia and separate or individual sporangia. The male strobilus of Cordaites resembled very much to the male bearing structure of Ginkgo except for the difference the sporangia of Cordaites was terminal whereas, it was pendant in Ginkgo and two in numbers.

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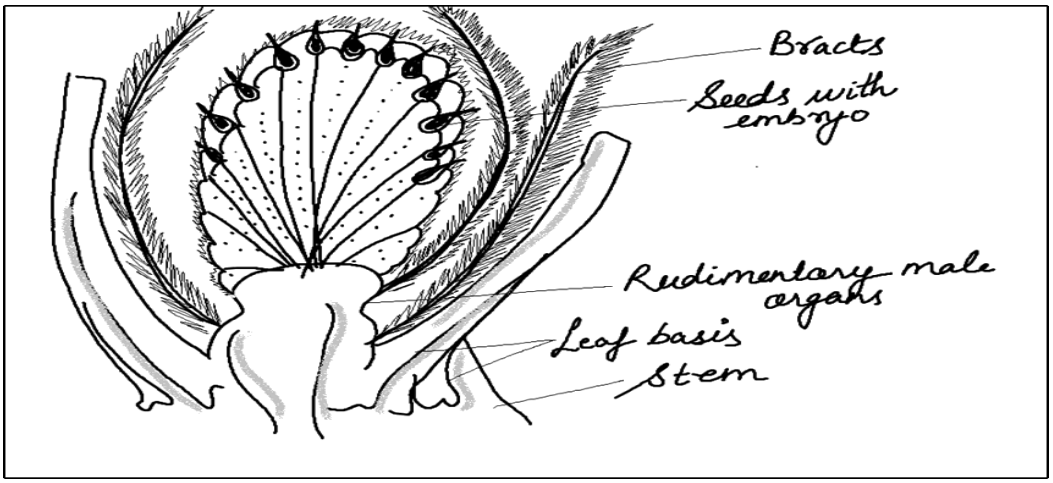
In fact the morphology of this male strobilus of Cordaites is not quite clear. Different interpretations are put on male catkin of Cordaites. Some think that whole of strobilus acting as single male flower in which there is large number of stamens, the stalk being the filamentous bearing a number of pollen sacs were simply sterile filaments.Other workers described this male catkin as inflorescence, each catkin bearing a flower itself, the filament is stalk of flower, the pollen sacs the stamens.

Female Strobilus:

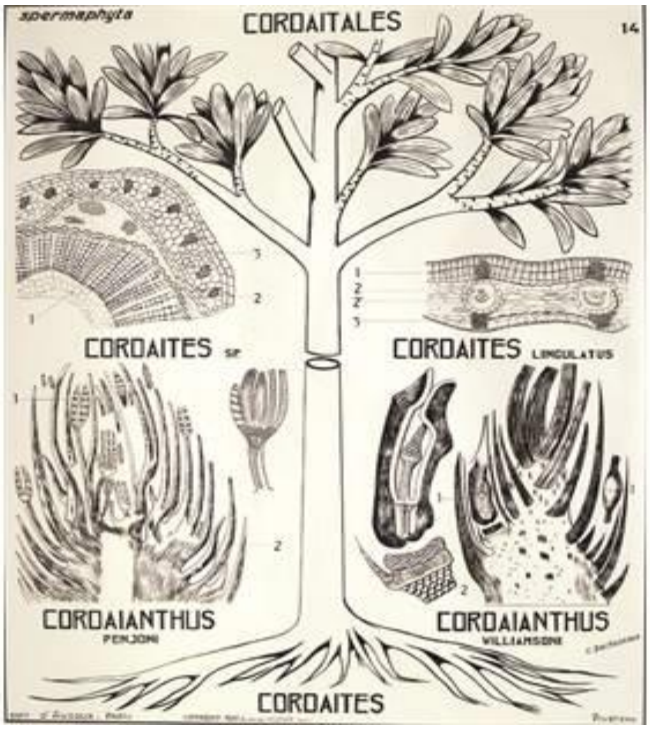
The female strobilus when young was enclosed by bracts. It had a thick conical axis bearing a number of spirally arranged bracts. In the axils of some of these bracts there were dwarf shoots present. These dwarf shoots in turn had minute bracts. On the tip of dwarf shoot there was a terminal ovule.



The Ovule of Cordaitales:

In the ovule the nucellus was completely separate from the integument. The integument formed a micropyle; at the base of micropyle the nucellus formed a prominent nucellar beak and a large pollen chamber. Round the ovules there were two coats outer thick and fleshy and the inner one delicate in young ovule but hard in older ovules.Both these coats were separate below but more or less united above. So these coats may be interpreted as two separate integuments which are formed at upper part or a case of single integument which differentiated into three coats one of which not preserved.

The female strobilus is distinctly compound in form as compared to male strobilus. The ovule bearing stalks were distinctly axillary in position just like those of present day conifers.



Affinities of Cordaitales:

Cordaitales and Cycadofilicales lived side by side in Palaeozoic time, both were very abundant in Carboniferous and disappeared just about Permian. Backwards both groups extend to Devonian, which of two is more ancient cannot be definitely stated.

Both seem to be related is clear from their habitat, the general form and structure of plants, the form of strobili especially male one, structure and form of ovule and finally of seed was very primitive in the two in the ovule of the two the presence of free nucellus.

The form of integument with two sets of vascular bundles in it, and the form of pollen chamber and lastly the absence of embryo are really primitive features which naturally present in the primitive groups. All these resemblances mean that either the Cycadofilicales give rise to Cordaitales or the Cordaitales to Cycadofilicales.

All combined features show that Cycadofilicales are more primitive while the Cordaitales show advanced features.

The other possibility is that both of them might have arisen from some common ancestral form as they lived side by side. So this second possibility is more accepted but what the ancestral form is not known.

Evidently it must be some heterosporous pteridophyte which lived near about the Devonian might have given rise to Cordaitales and Cycadofilicales which is clear from the stem anatomy of Cordaitales in which endarch siphonostele was more common.

The strobili of Cordaitales are better organized. The sporophylls here completely lost their leaf like appearance. The female strobilus was more complicated in that ovule bearing branch was always axillary in position. In Cycadofilicales the strobilus was simple and ovules were borne on leaves.

So these Cycadofilicales and Cordaitales can be said to represent two different lines of evolution; the Cycadofilicales was left behind with more primitive features in it and before it disappeared it gave rise to two branches of Cycadophyta line the fossil Cycadeoideales (Bennettitales) and living Cycadales.

The Cordaitales made some advance both in anatomy of stem organization and complexity of its reproductive parts. Being a primitive group naturally it had resemblances with Cycas which is seen in the presence of large pith, general leaf anatomy, general structure of seed and ovule and presence of sperms. Chamberlain is of opinion that Cordaitales represents one line of Gymnosperms, the Coniferophyte line characterized by the presence of large sized plant with pro-fused branched stem and simple leaf, small pith, abundant wood and narrow cortex. The reproductive structure organized to form more or less cones.

The Cordaitales seems to have given rise to Ginkgoales and conifers before it disappeared in or about in Permian times. In Ginkgoales there is good deal of resemblances. Both the plants are lofty and branched. The stem anatomy, the structure of ovule, and in presence of sperms two groups seem to be more or less closely related.

Topic-3

Ginkogales-A living fossil

Salient features of Ginkgo:

The plant body of *Ginkgo biloba* is sporophytic, and the sporophyte resembles several conifers in general habit. The branches are dimorphic i.e. bear long shoots which are of unlimited growth with scattered leaves and dwarf shoots which are short branches of limited growth.

The foliage leaves, present on the long shoots, are deeply lobed while those on the dwarf shoots are not so deeply lobed and sometimes more or less entire

Life cycle of Ginkgo biloba(Diagrammatic)

. In general, the leaves are bilobed, and hence the name ‘biloba’ was suggested to the species by Linnaeus (1771)..The leaves of the long shoot and seedlings are deeply bilobed while that of the dwarf shoot are not so deeply lobed and may be sinuate or even entire. They may be pale yellow, golden yellow or dark green in colour. A typical dichotomous type of venation is present in the leaves.

. Anatomy of Ginkgo:

(i) Root:

In transverse section the roots are somewhat circular in outline. Mature roots are surrounded by phellogen or suberized cells of cortex. A large portion of the young root is occupied by multilayered, thin-walled cortex which contains several tannin- filled cells and calcium oxalate crystals. Mucilage canals are also prominently visible.In young roots, a layer of endodermis and uni-layered pericycle are clear. Mature roots however, lack such a distinction. Diarch condition is clearly visible in the young roots. Xylem is exarch. It remains separated by the phloem strands. Sometimes the roots also show triarch condition.

(ii) Stem:

The young stem (long shoot) is more or less circular in outline and remains surrounded by a single-layered, thickly circularized epidermis made of brick-shaped cells. Epidermis is replaced by periderm in the older stems.

Inner to the epidermal layer is present a well-marked region of parenchymatous cortex. It contains mucilaginous canals, sphaeraphides and many tannin-filled cells. Cortex is comparatively less extensive in long shoots than dwarf shoots. Endodermis and pericycle are not well-marked in long shoot.

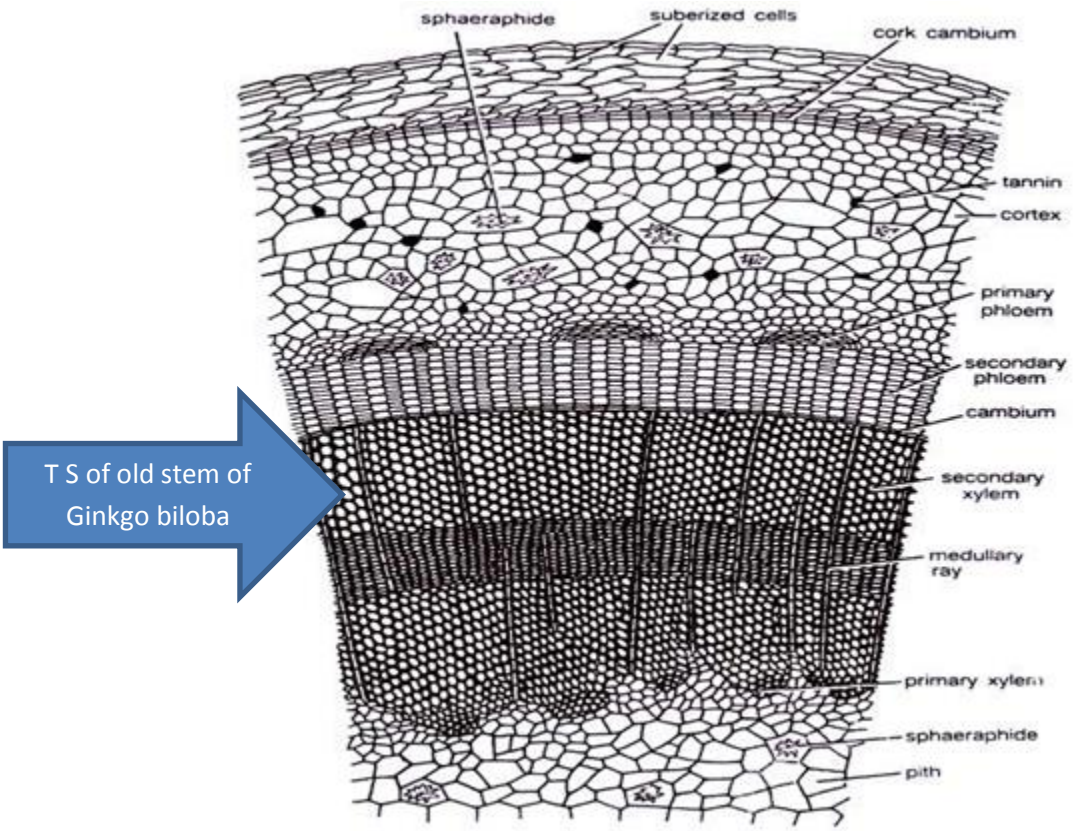
Several conjoint, collateral, open and endarch vascular bundles are arranged in a ring in very young stem. After the onset of the secondary growth, the vascular cylinder of the stem becomes an endarch siphonostele with no parenchyma in the wood except that of uniseriate medullary rays.

Protoxylem has spiral thickenings while bordered pits are present on the radial walls of the metaxylem tracheids. Sieve tubes and phloem parenchyma constitute the phloem. A narrow pith, containing mucilage canals and sphaeraphides, is present in the center of long shoot, while in dwarf shoot the pith is comparatively more extensive.

Secondary Growth in Stem: Cork cambium cuts periderm towards outer side and secondary cortex towards inner side Periderm replaces the epidermis. Mucilage canals are absent.

A single ring of cambium remains active throughout and cuts secondary phloem towards outer side and secondary xylem towards inner side.

One or two rows of bordered pits are present on the radial walls of the tracheids . Pits are circular in outline and have a clear torus. Bars of Sanio are also present. Bars of Sanio do not occur in primary wood. Trabeculae of Sanio, which cross the lumen of the tracheids, are also present.



(iii) Leaf:

A layer of epidermis is present on upper as well as lower sides of leaf. The epidermis is thickly cuticularised and consists of rectangular to polygonal cells. Haplocheilic type of stomata, restricted only to the lower epidermis, are present. Mesophyll is present in between the two epidermal layers. It is not well-differentiated into palisade and spongy parenchyma . The leaves

of long shoot, however, show a distinct palisade region. Many mucilage canals or secretory canals and a few tannin-filled cells are also present in the mesophyll region.

(iv) Petiole:

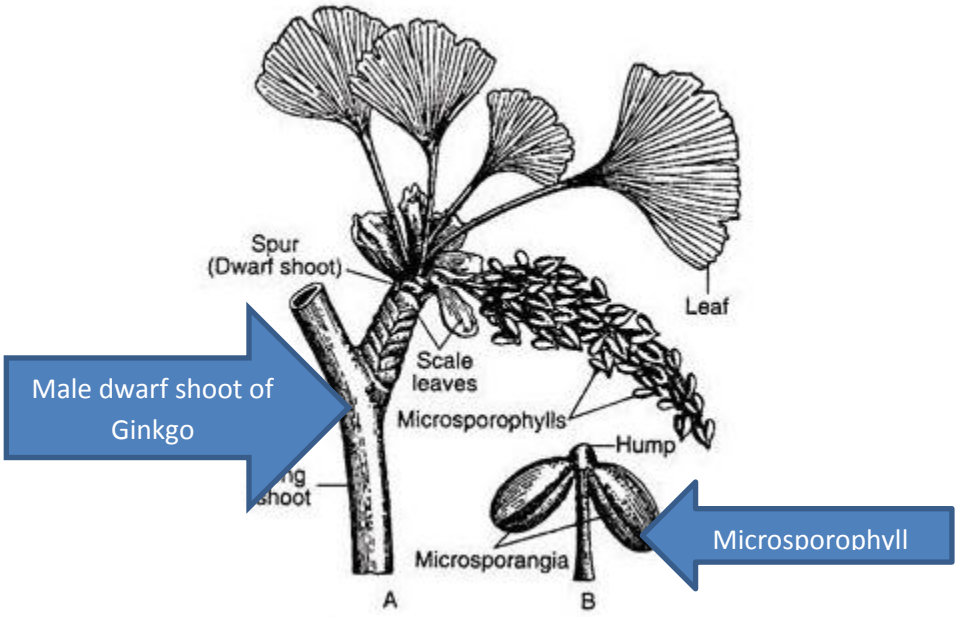
The petiole remains covered by a layer of thickly cuticulanzed epidermis, the continuity of which is broken by stomata. Inner to the epidermis are present a few hypodermal layers. Few mucilage canals, tannin-filled cells and sphaeraphides are irregularly distributed in the cortex. The petiole is supplied by a pair of endarch vascular bundles . It remains surrounded by a sclerenchymatous bundle sheath. Protoxylem has spiral thickenings. Cambium is clearly visible uniseriate rays are present in the xylem. These are continuous with those of the phloem.

. **Reproductive Structures of Ginkgo**:

Ginkgo biloba is dioecious. Male and female plants are,however, difficult to be differentiated, when young. Reproductive bodies of Ginkgo are most primitive among living seed plants except some Cycadales.

(i) Male Strobilus:

Male or microsporangiate fructifications develop in catkin-like clusters on the dwarf shoots of male frees. Each male strobilus contains several microsporophyll's arranged loosely on a central axis .It contains two pendant microsporangia. Rarely more than two sporangia are present in a microsporophyll.. Each sporangium is a tubular structure surrounded by many layers . The outermost layer of sporangial tissue differentiates into a tapetum. The sporogenous cells of the sporangium undergo reduction division and form many haploid microspores

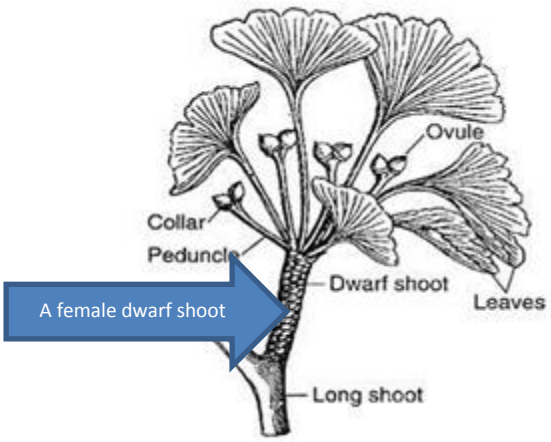


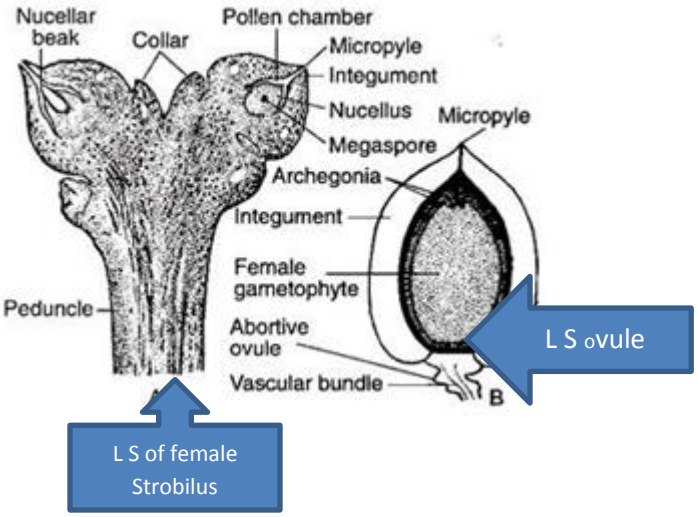
(ii) Development of Microsporangium:

It is of eusporangiate type, i.e., single archesporial cell divides by a periclinal wall forming primary wall cell and primary' sporogenous cell . The former develops into wall of microsporangium while the latter develops into sporogenous tissue. Sporangium dehisces by means of a longitudinal slit.

(iii) Female Strobilus:

The female strobili develop in groups in the axil of leaves or scaly leaves present on the dwarf shoots . These are much reduced structures, each having a long stalk or peduncle, which bifurcates apically. Each bifurcation usually bears a single ovule. Out of the two sessile ovules one generally aborts earlier.. At the base of each ovule is present a fleshy cup-like structure called ring or collar. The leaves surrounding the ovules do not show their bilobed character.





The development of ovule, mega-sporogenesis and structure of the mature ovule is similar to that of Cycas. There is a thick integument consisting of three layers, i.e., outer fleshy, middle stony and inner fleshy layers . A major difference between Ginkgo and Cycas is that the integuments of Ginkgo do not have any noticeable vascular supply.

Each ovule has a large and prominent nucellus. Free apex of the nucellus breaks down into a pollen chamber forming the nucellar beak. Quite deep in the nucellus tissue, a functional spore mother cell becomes prominent. The spore mother cell develops into a tetrad, of which only the innermost megaspore remains functional and develops into female gametophyte.

The vascular supply of the ovule is ill-developed. Two vascular strands enter the inner fleshy layer and reach up to the free part of the nucellus without branching. Outer fleshy layer lacks any prominent vascular supply.

. Gametophytes in Ginkgo:

(i) Male Gametophyte:

Major aspects of the development of male gametophyte of Ginkgo biloba are similar to that of Pinus. Male gametophyte starts developing in situ, i.e. within the sporangium.Pollen germination starts with a diffuse swelling of tube cell. Tube cell becomes very elaborate with a proximal un-branched tube and a much branched haustorial system.Microspore is the first cell of the male gametophyte. Each microspore is a rounded structure having thin intine and thick exine layers. A centrally located nucleus contains one or two nucleoli and remains surrounded by dense cytoplasm. An un-thickened portion, called pore, is also present in each microspore. It is a region where exine is not covering the intine.Two unequal cells are formed by the first mitotic division in the microspore. These are called 1st prothallial cell and inner cell . The 1st prothallial cell is smaller than that of inner cell. The inner cell again divides forming a 2nd prothallial cell and an antheridial initial.By this time the 1st prothallial cell starts to degenerate. The antheridial initial

then divides forming a generative cell near the 2nd prothallial cell and a tube cell . The tube cell does not divide any further. This is the 4-celled stage of the male gametophyte and the microspores are dispersed by wind at this stage.

. Structure and Development of Male Gametophyte

Pollination in Ginkgo biloba takes place sometime in April. At the time of pollination the ovule secretes a mucilaginous substance. Further development of the male gametophyte takes place in the pollen chamber. In pollen chamber the generative cell of the 4-celled young male gametophyte divides into a stalk cell, which is close to the 2nd prothallial cell, and a body cell.

Now the intine protrudes out near the pore and functions as a pollen tube . The pollen rube swells up and advances towards the archegonia by protruding into the nucellus. Just before fertilization the body cells divides into two, and the wall formation is at right angle to the base of pollen grains.

The blepharoplasts appear on the body of these so-formed two cells which function as sperms or male gametes. The antherozoids are represented by multi-flagellated sperms,

(ii) Female Gametophyte:

Out of the four megaspores formed from the megaspore mother cell, only the lowermost remains functional and the remaining three degenerate The nucleus of the functional megaspore migrates towards the micropylar end and divides into two followed by a number of free-nuclear divisions forming hundreds of free nuclei.A large vacuole is present in the megaspore at this stage . Now the wall formation starts and progresses from the periphery towards the centre. During wall formation first the anticlinal walls are formed followed by the vertical walls.

Each cell generally contains one nucleus but in some cells 2-3 nuclei are also seen. Due to more rapid cell divisions on the micropylar end a pole-like structure develops. This is called tent-pole . The female gametophyte possesses abundant chlorophyll.

Development of Female Gametophyte

The development of archegonium starts from the cells towards the micropylar end of the female gametophyte.Each archegonium possesses a short neck made up of only four cells and a small venter having a central cell. The central cell later on forms a ventral canal cell and an egg cell. According to Bierhorst (1971) only two cells are present in the archegonial neck.

. **Embryogeny in Ginkgo**:

The zygote becomes enlarged and starts dividing by many free-nuclear divisions just after fertilization. The nuclei are distributed irregularly . The cell wall formation starts just after a few

divisions of the nucleus and soon a pro-embryo is differentiated . Three types of cells are clearly differentiated in the pro-embryo

The cells towards the chalazal end are smaller in size with dense cytoplasm, followed by another zone of comparatively larger cells, which do not possess such a dense cytoplasm. Elongated cells are present in the uppermost zone. There is no differentiation of suspensor in the embryo.

The development of the cotyledon starts from the lowermost zone soon after the differentiation of these zones . Roots, stem and cotyledons are soon differentiated. Generally, five leaves are present in the mature embryo. Out of these five leaves the first two are decussate with cotyledons while the remaining leaves are irregular in arrangement in embryo and seedling.

Germination of Seed

The germination of the seed is of hypogeal type and quite similar to that of Cycas. A strong tap root develops soon and the seedling bears many bilobed leaves, which is characteristic feature of *Ginkgo biloba*. Soon, a mature plant, with many more leaves, develops.

Topic-4

Male and Female gametophyte of Pinus

Male gametophyte of Pinus

Microsporophyll is the microspore containing structure. The microsporangium is sessile and surrounded by a single layer of cells.

Each microsporangium produces several microspores. Each microspore is covered by inner intine and outer exine. Microspore is winged.

Microspore is the first cell of male gametophyte.

Microspore begins to germinate within the microsporangium.

The microspore nucleus divides to form a very small first Prothallial and a large cell.

The large cuts off a second Prothallial cell and the antheridial cell

At this stage Microspore is shed and falls in close vicinity to the female gametophyte. Further development of male gametophyte is inside the female gamertophyte..

The two Prothallial cell degenerate and the antheridial cell divide to form a small generative cell and a large tube cell(tube nucleus)..

The tube nucleus regulates the growth of the pollen tube in close proximity to the nucellus of Female gametophyte.

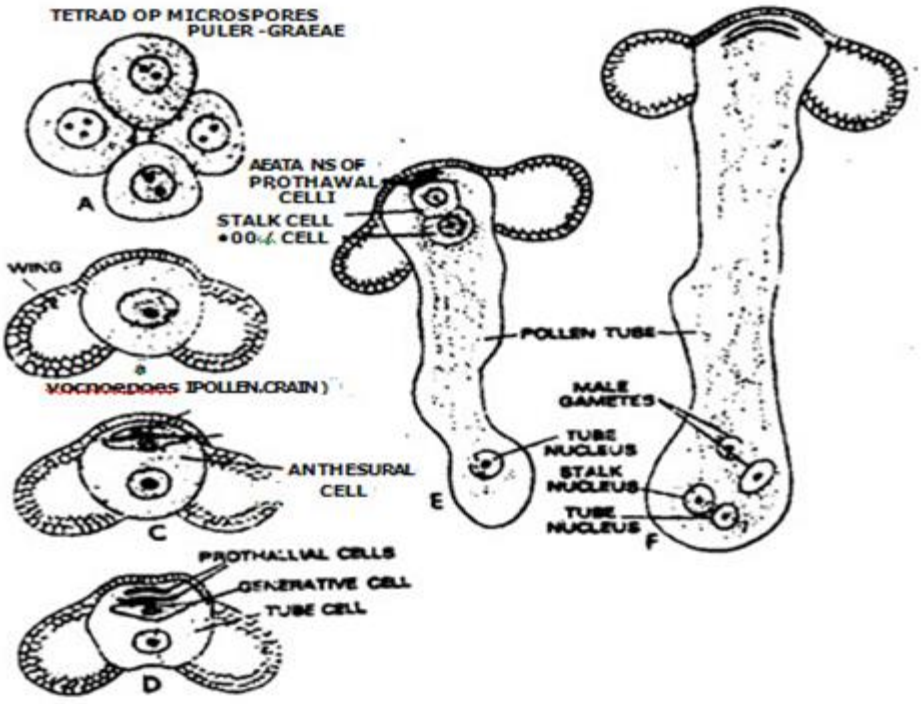
A mature ovule (megasporangium) secretes a mucilaginous substance from the micropyle. A large number of Pollen grains gets attached to the mucilaginous substance.

A few of them are drawn inside when the mucilage dries up and reaches close to the apex of the nucellus.

The tube cell grows and protrudes to form Pollen tube. The pollen tube is the proliferation of the intine of the microspore. The pollen tube penetrates the nucellus.

The generative cell then divides to form a sterile stalk cell and a fertile body cell.

The body cell then divides to form two non-motile unequal sized male gametes(Sperms).This marks the end of the development of male gametophyte of Pinus.



Germination of pollen grain

Female gametophyte of Pinus

The megasporophyll of the female cone is composed of large ovuliferous scale and smaller bract scale both are free from each other

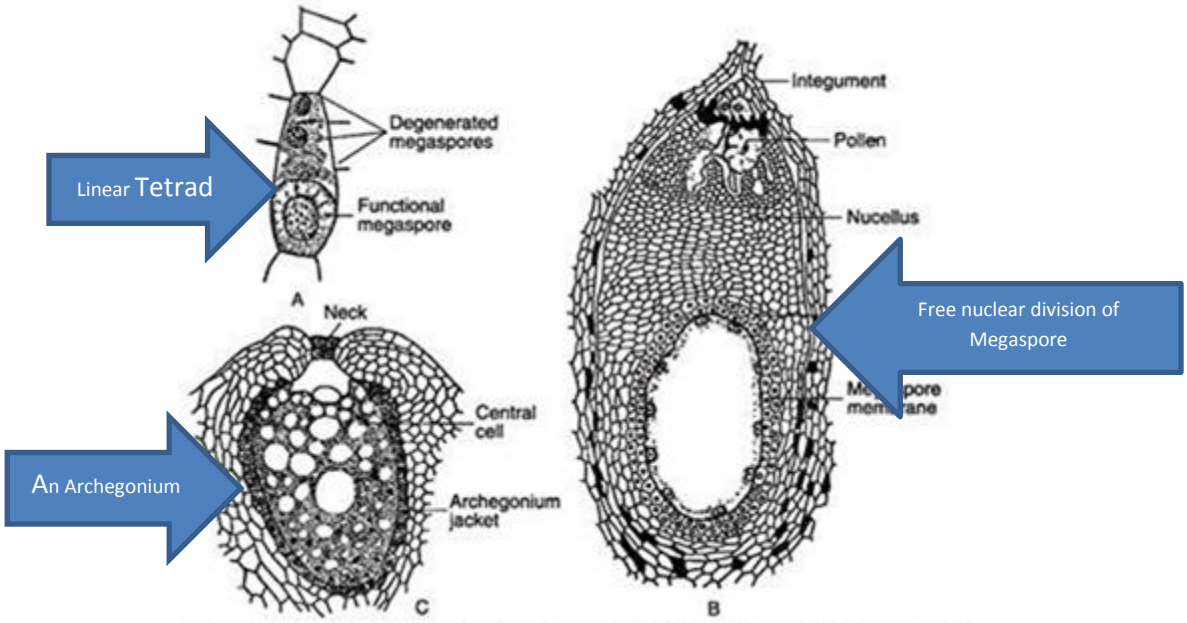
Each ovuliferous scale bears two anatropous ovules or megasporangia.The ovuliferous scale bears two inverted megasporangium on its upper surface towards the base.

Each megasporangium consists of a massive tissue called as Nucellus and a covering called as integument.At the basal portion the integument is fused with the nucellus and open at the top forming a micropyle.

A single megaspore mother cell is differentiated within the nucellus. This divides meiotically to form a row of four megaspore.

Out of the four megaspores only the lowermost remains frunctional while others degenerate.

The only functional megaspore increase in size and gets involved in the development of female gametophyte(Archegonia).


Linear Tetrad
Degenerated megaspores
Functional megaspore
A
Neck
Central cell
An Archegonium
Archegonium jacket
C
Integument
Pollen
Nucellus
Free nuclear division of Megaspore
B

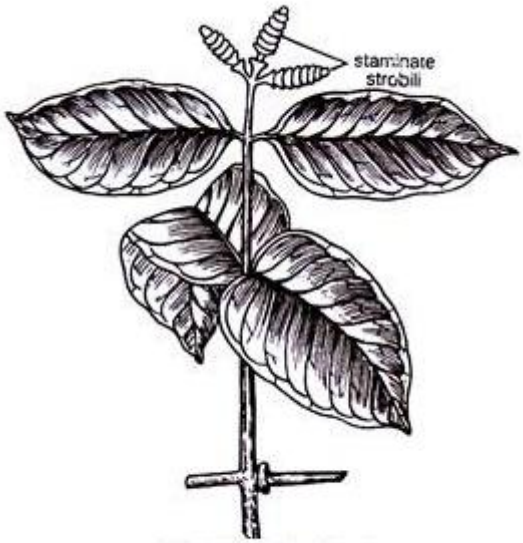
Topic- 5

Life cycle of Gnetum and its angiospermic feature

Gnetum (35 species) inhabits a variety of humid, tropical lowland, riparian, and swamp rainforests of South East Asia, Papua New Guinea, Fiji, the Americas, and Africa . Gnetum bears remarkably angiosperm-like leaves, consisting of a broad, entire-margined lamina with pinnate-reticulate venation and multiple vein orders The majority of Gnetum species are large woody climbers, producing xylem from multiple cambia. Some Gnetum vines ascend high into the canopies of dense riparian vegetation and lowland forest trees; other species occur as low scramblers in open, fire-burnt pastures and disturbed forest edges. Two Gnetum taxa (i.e., G. *gnemon*, widespread in the Indo-Pacific; *G. costatum*, from eastern Papua New Guinea and the Solomon Islands), that form sun-exposed medium-sized subcanopy trees in lowland rainforest and riverine gallery forests (typically 7 to 15 m, as high as 20 m) possess some peculiar liana-like features. In addition to the occasional production of scandent branches, older trees of G. gnemon develop additional anomalous cambia in the bark that are akin to multiple cambia of lianoid Gnetum species . Interestingly, molecular phylogenetic analyses indicate that tree-forming Gnetum species are well nested among Gnetum climbers, suggesting that arborescence is secondarily derived.

1.Habit of Gnetum:

Majority of the Gnetum species are climbers except a few shrubs and trees.The branch is of limited growth ,unbranched and bears decussate foliage leaves.The leaves are oval in shape having entire margin showing reticulate venation.



A branch of *Gnetum*.

Anatomy of Gnetum:

(i) Root:

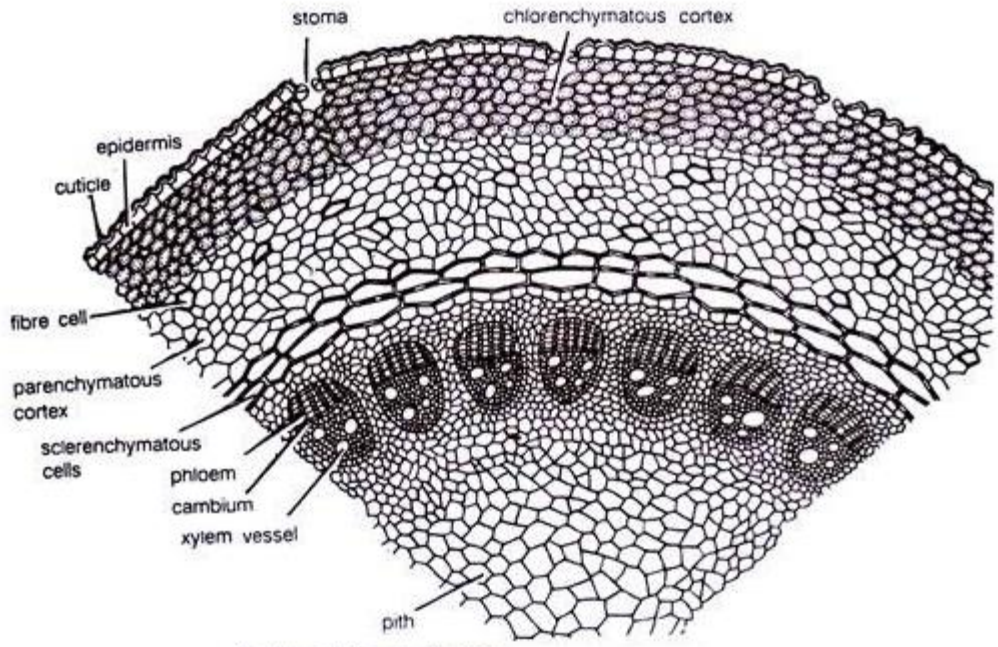
Young root has several layers of starch-filled parenchymatous cortex, the cells of which are large and polygonal in outline. An endodermal layer is distinguishable. Casparian strips are seen in the cells of the endodermis. The endodermis follows 4-6 layered pericycle. Roots are diarch and exarch. Small amount of primary xylem, visible in young roots, becomes indistinguishable after secondary growth.The secondary growth is of normal type. . It consists of tracheids, vessels and xylem parenchyma. The tracheids have uniseriate bordered pits along with bars of Sanio. Vessels have simple or small multiseriate bordered pits.

(ii) Young Stem:

The young stem in transverse section is roughly circular in outline, and resembles with a typical dicotyledonous stem. It remains surrounded by a single-layered epidermis, which is thickly circularized and consists of rectangular cells.The cortex consists of outer 5-7 cells thick chlorenchymatous region, middle few-cells thick parenchymatous region and inner 2-4 cells thick sclerenchymatous region. Several conjoint, collateral, open and endarch vascular bundles are arranged in a ring in the young stem. Xylem consists of tracheids and vessels. Presence of vessels is an angiospermic character. Protoxylem elements are spiral or annular while the metaxylem shows bordered pits which are circular in outline. The phloem consists of sieve cells and phloem parenchyma.

Old stems in Gnetum show secondary growth. In *G. gnemon* the secondary growth is normal, as seen also in the dicotyledons. But in majority of the species (e.g., *G. ula, G. africanum*, etc.) the anamolous secondary growth is present.

The primary cambium is short lived this cambium ceases to function after some time ,the secondary cambium in different parts of cortex develops in the form of successive rings, one after the other . The first cambium cuts off secondary xylem towards inside and secondary phloem towards outside. Another cambium gets differentiated along the outermost secondary phloem region, and the same process is repeated. In the later stages, more secondary xylem is produced on one side and less on the other side, and thus the eccentric rings of xylem and phloem are formed in the wood.Thus an abnormal type of growth is noticed.In old stems the secondary wood consists of tracheids and vessels. Tracheids contain bordered pits on their radial walls while vessels contain simple pits..



Gnetum. T. S. young stem.

Reproduction of Gnetum:

Gnetum is dioecious. The reproductive organs are organised into well-developed cones or strobili. These cones are organised into inflorescences, generally of panicle type. Sometimes the cones are terminal in position.

Male Cone and Male Flower:

The male flowers are arranged in definite rings above each collar on the nodes of the axis of male cone. The number of rings varies between 3-6. The male flowers in the rings are arranged alternately. There is a ring of abortive ovules or imperfect female flowers above the rings of male flowers.

Each male flower contains two coherent bracts which form the perianth. Two unilocular anthers remain attached on a short stalk enclosed within the perianth from which it comes out during maturity to dehisce.

Development of Male Flower :

In very young cones, certain cells below each collar become meristematic. They divide repeatedly and form a small hump-like outgrowth. Certain cells on the upper side of this annular outgrowth start to differentiate into the initials of the ovules. They develop into abortive ovules which form the uppermost ring. The cells of the lower side of this annular outgrowth form the primordium of male flower.

A central cushion of cells develops by the repeated divisions in the male flower primordium. This cushion gets surrounded by a circular sheath called perianth. The sheath-like perianth encloses the central cushion-like mass only partially. With the development of a depression or notch in the central mass two lobes differentiate and later on develop into two anther lobes.

With the help of many divisions the basal portion of this central mass of cells starts to differentiate into a stalk. This stalk elongates and pushes the anther lobes towards the outer side. Each anther lobe remains surrounded by an epidermal layer and a few wall layers which enclose a microsporangium.The innermost wall layer enclosing the sporogenous tissue is known as tapetum.

The sporogenous cells become loose, contract round up and change into the spore mother cells. In the process of microspore formation the tapetum and two wall layers are used for the developing microspores. The spore mother cells undergo meiosis and ultimately the spore tetrads are formed.

Female Cone:

The female cones resemble with the male cones except in some definite aspects. A single ring of 4-10 female flowers or ovules is present just above each collar . Only a few of the ovules develop into mature seeds In the young condition, there is hardly any external difference between female and male cones. All the ovules are of the same size when young but later on a few of them enlarge and develop into mature seeds. All the ovules never mature into seeds.Each ovule consists of a nucellus surrounded of three envelopes. The nucellus consists of central mass of cells. The inner envelope elongates beyond the middle envelope to form the micropylar tube or style. The nucellus contains the female gametophyte. There is no nucellar beak in the ovule of Gnetum.

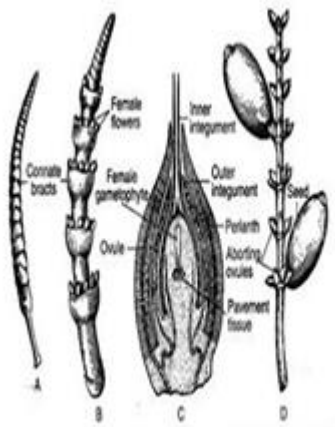
Fertilization in Gnetum

After the entry of pollen tube into the female gametophyte, whose lower end has become partly cellular, one or more nuclei (3-8) at its upper end also become delimited by cell-walls. These groups of cells are usually present in the neighbourhood of the pollen tube. Out of each such group, one or rarely two cells behave as egg cells, which often become surrounded by one or two layers of minute and degenerated cells.

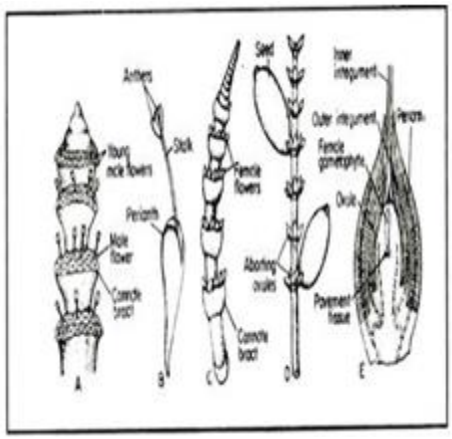
In all probability these inconspicuous cells provide nourishment to the egg and become used up at the time of fertilization. Only a male nucleus enters the egg, while its sheath is left outside. In cases where two eggs are present in the vicinity of the pollen-tube, double fertilization may result.

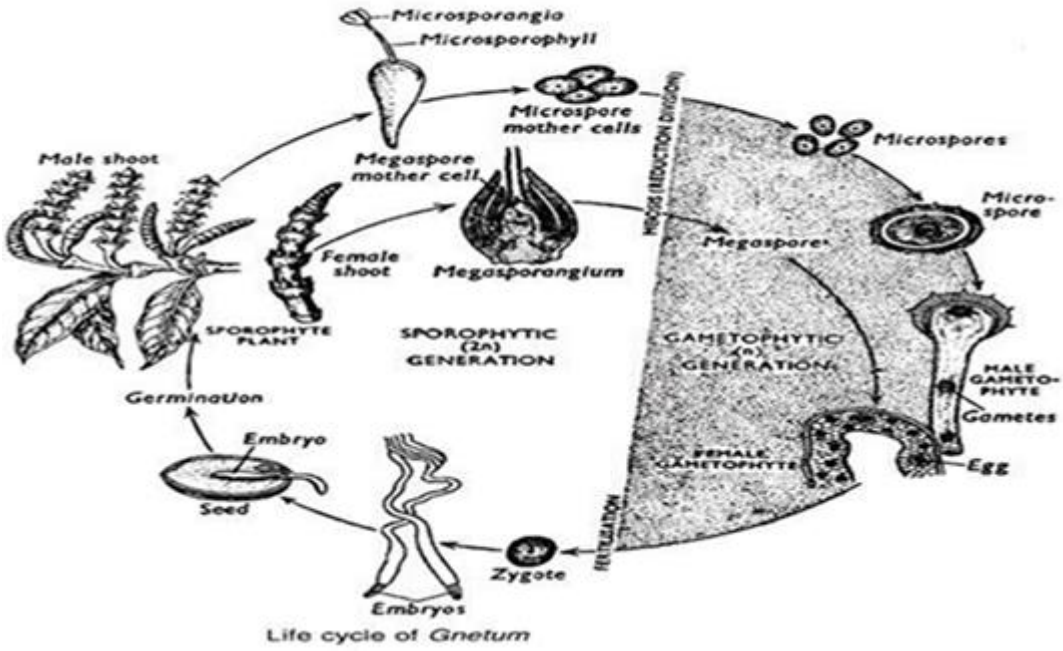
Gnetum is remarkable among gymnosperms in the fact that a typical gymnospermic endosperm, which is formed prior to fertiliza-tion, is lacking here. Madhulata (1960) reports in G. gnemon that while eggs are being differentiated, the female gametophyte re-mains in a free nuclear condition, and only when zygotes are produced in the micropylar region of the ovule, the first walls are laid down in the chalazal region producing in an upward direction.

Very rarely the cell-wall formation may take place simultaneously throughout the gametophyte. Sometimes walls may be laid down even when eggs are not differentiated within the gametophyte.



Gnetum ula : A. An young female inflorescence, B. A mature female inflorescence, C. Median L.S. of a female flower, D. A female inflorescence bearing two mature seeds





Diagrammatic life cycle of Gnetum

Angiospermic feature of Gnetum

A key position to Gnetum has been assigned by scientists while discussing the origin of angiosperms. Both Gnetales and angiosperms originated from a common stalk called "Hemi-angiosperm"

In a beautiful monograph on Gnetum, Maheshwari and Vasil (1961) are of the view that Gnetum possesses some strong angiospermic features" and hence they are close to angiosperms.

Some of the resemblances between Gnetum and angiosperms are mentioned below:

1. The general habit of the sporophyte of many species of Gnetum resembles with angiosperms.

2. Reticulate venation in the leaves of Gnetum is an angiospermic character.

3.Presence of Endarch vascular bundle shows closeness to dicot angiosperms

4.Presence of vessels in xylem is again an angiospermic character.

5. Clear tunica and corpus configuration of shoot apices is a character of both Gnetum and angiosperms.

6. Strobili of Gnetum resemble much more with angiosperms than any of the gymnosperms

7. Micropylar tube of Gnetales can be compared with the style of the angiosperms because both perform more or less similar functions.

8. Tetrasporic development of the female gametophyte is again a character which brings Gnetum close to angiosperms.

9. Absence of archegonia again brings Gnetum and angiosperms much closer.

10. Dicotyledonous nature of the embryo of Gnetum brings it quite close to the dicotyledons.

11.The presence of companion cells in the angiosperms is one of the constant anatomical features which …

12. Double fertilization

13 Some members of Gnetopsida produce nectars which is also found in Angiosperms.

Thompson (1916) opined that the ancestors of both Gnetum and angiosperms were close relatives. Hagerup (1934) has shown a close relationship between Gnetales and Piperaceae.

Topic – 6

Bennettitales

Nomenclature, History and Distribution of Bennettitales

The name "Bennettitales" has been given to honour J.J. Bennett,an English botanist. The fossilized trunk of genus Bucklandia was the first specimen of Bennettitales, collected from Great Britain in1825. A silicified trunk of Cycadeoidea etrusca was discovered in 1867 in an Etruscan tomb.

Williamson (1870) coined the name Williamsonia for a combination of foliage and reproductive organs of Williamsonia gigas. Professor Birbal Sahni (1932) discovered Williamsonia sewardiana from the Upper Gondwana beds of India.

A rich fossil flora of Bennettitales has been reported from Rajmahal Hills of Bihar (India). Some of the reported members include Bucklandia sahnii, B. indica, Dictyzamites, Otozamites benghalensis, Cycadinocarpusrajmahalensis, Sahnioxylon rajmahalensis, Williamsonia indica, W. sahnii and W. sewardiana. Classified Arnold (1948) classified Bennettitales into two families viz. Williamsoniaceae and Cycadeoideaceae while Sporne (1965) divided it into following three families

1. Williamsoniaceae, e.g. Williamsonia,Pterophyllum.

2. Wielandiellaceae, e.g. Wielandiella,Williamsoniella.

3. Cycadeoideaceae, e.g. Cycadeoidea(=Bennettites)

Distinguishing Features of Bennettitales

1. These extinct Mesozoic plants 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 (It is the non-compact wood with large amount of parenchyma, large pith and cortex mixed with less amount of xylem tracheids or wood. -Parenchyma cells are filled with starch grains) wood. This wood is not durable.

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(In some gymnosperms, applied to a type of stoma in which the 2 guard cells and the subsidiary cells are all derived from a single mother cell) type of stomata were present.

9. The wall of the epidermal cells was sinuous (many curves and turns).

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.

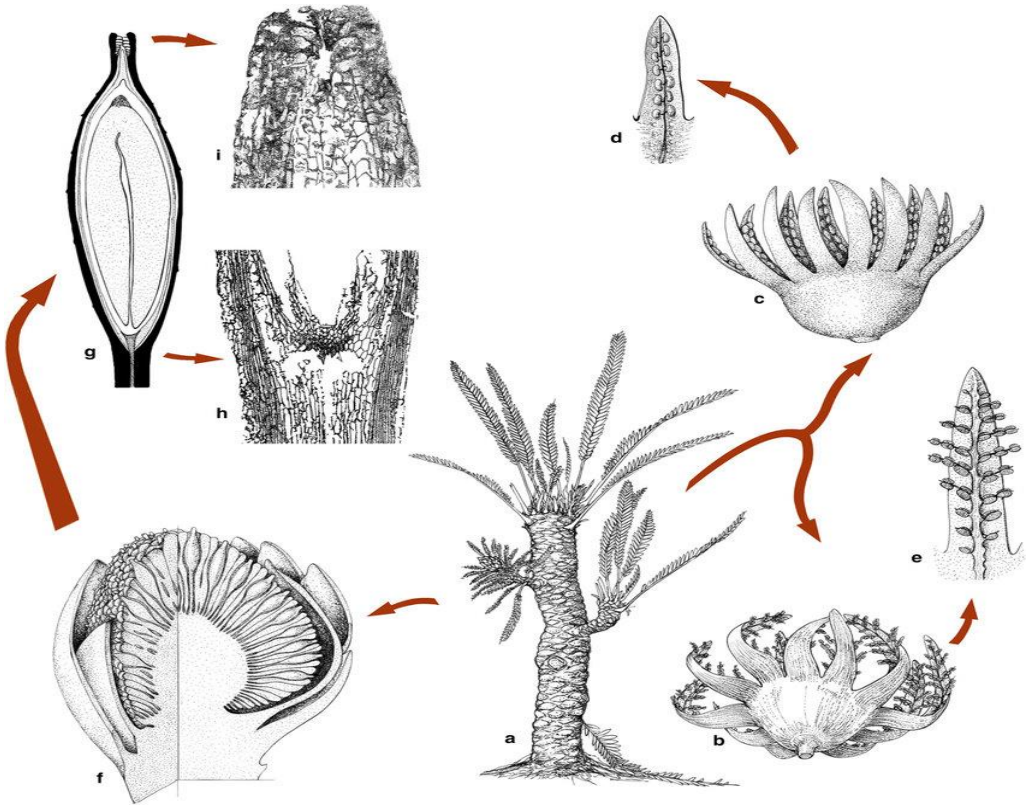
14. Microsporophyll's sometimes surrounded megasporophylls forming hermaphrodite "flowers".

15. Ovules were numerous and stalked and borne on a conical, cylindrical or dome-shaped receptacle.

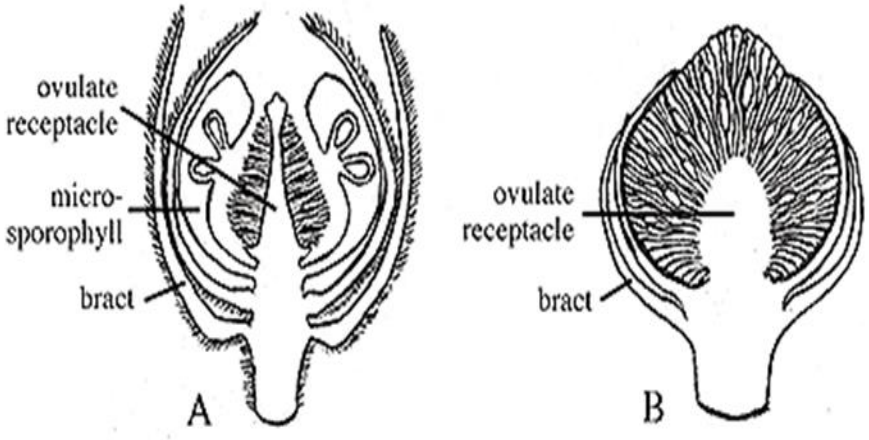
16. Many inter-seminal bracts were present on the ovule containing receptacle.

17. The scales or bracts were united at end to form shield through which micropyle protrudes.

18. Seeds were dicotyledonous.



Diagrammatic life cycle of Williamsonia



Reconstructed female cone of Williamsonia

Affinities of Bennettitales:

Resemblances of Bennettitales with Ferns:

Bennettitalean plants had multicellular ramenta on their entire body, a characteristic also seen in ferns.

Some other features suggesting the filicean affinity of Bennettitales include the presence of:

(i) Direct leaf traces,

(ii) Scalariform tracheids, and

(iii) Large pith.

Resemblances of Bennettitales and Cycads:

Bennettitales resemble cycads in the:

(i) structure of their fronds,

(ii) presence of short stems covered with an armour of persistent leaf bases,

(iii) presence of barrel-shaped trunk,

(iv) presence of very thick cortex, relatively thin wood and large pith in the stem,

(v) manoxylic wood,

(vi) monocolpate pollen grains (Colpus is a long furrow like aperture and pollen grains having such apertures are called colpate . Seeds having one aperture is called as monocopalate) ,

(vii) orthotropous ovules, and

(viii) dicotyledonous embryo.

On the basis of several such affinities, Chamberlain (1935) opined that both Bennettitales and Cycadales arose by parallel evolution from some common ancestor. The ancestral type must have had a foliar megasporophyll having the ovules at the apex as well as on both the sides.

During course of evolution, the lateral ovules must have suppressed and the megasporophyll must have reduced to a stalk-like structure,and thus the Bennettitales must have come into existence. On the other hand there exist several fundamental differences between Bennettitales and Cycadales, already listed in Table 6.1.

Due to so many dissimilarities it will not be possible to visualize any phylogenetic connection between two groups. Andrews (1961) concluded on the basis of such differences that both the groups have evolved along with two different and independent lines.

Topic-7

Pentoxylon

Habit : small trees or shrubs that possessed long and short shoots.Stem : called Pentoxylon because it frequently showed five segments of triangular vascular tissue arranged in a ring around a central ground tissue. The primary xylem is mesarch and secondary xylem is pycnoxylic ring around a central ground tissue. The primary xylem is mesarch and secondary xylem is pycnoxylic (resembling the wood of conifers). The short and long shoot are covered by an armour of spirally arranged leaf bases. The short shoots often terminated in a crown of spirally arranged Nipaniophyllum-type of leaves. Besides foliage leaves some short shoots were terminated by clusters of ovulate cones or pollen organs.

. **Discovery of Pentoxylales**:

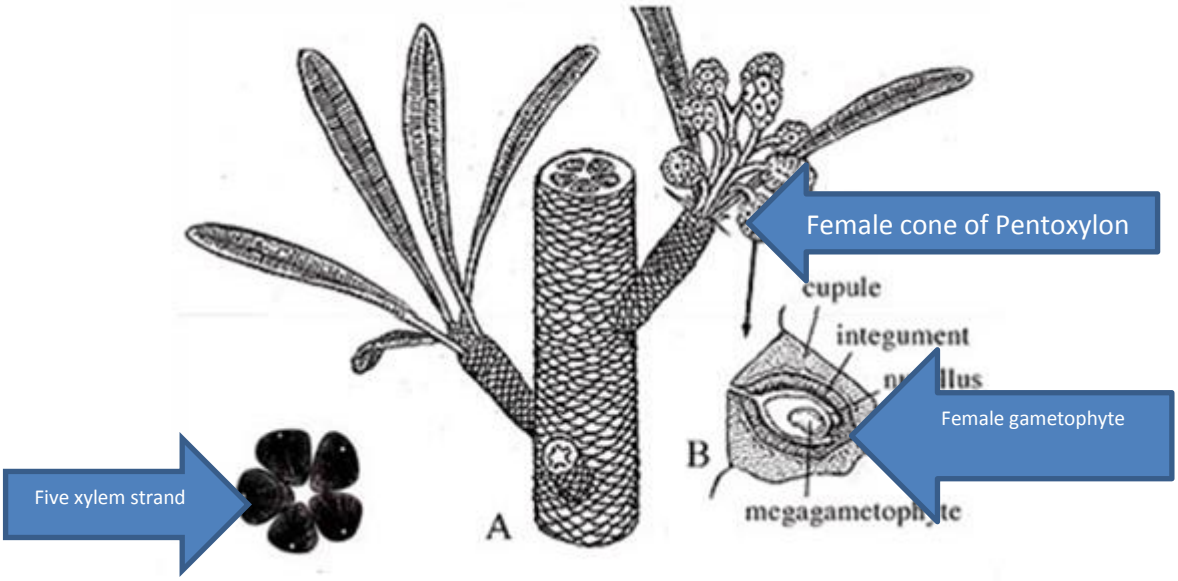
This group has been discovered and named as "Pentoxyleae" by well-known Indian Palaeobotanist Professor Birbal Sahni (1948). This is a group of some fossil plants described from Rajmahal Hills in Amrapara District (Santhal Parganas) of Eastern Bihar (India) revealing their existence inEastern Bihar (India) revealing their existence in Jurassic Period.

General characters

Pentoxylon (stem),exhibited Short- & long-shoot morphology (like Ginkgo), 3mm to 2 cm diameter. Each stele had its own cambium. The cambium was uniformly active in the young stems, but at maturity more secondary tissue developed towards the centre, and thus the secondary wood appeared eccentric. The primary xylem is mesarch and secondary xylem is pycnoxylic (resembling the wood of conifers) in five or six wedges around mesarch primary xylem strand (Pentoxylon) The short and long shoot are covered by an armour of spirally arranged leaf bases. The short shoots often terminated in a crown of spirally arranged Nipaniophyllum-type of leaves. Besides foliage leaves some short shoots were terminated by clusters of leaves.Apart from the occurrence of periderm, coniferous type secondary xylem and dwarf shoots bearing cone are some of the indirect indication of its tree nature. In the reconstruction presented here, the stem of Pentoxylon-plant is hypothetically drawn and its height has been assessed to be of 2-6 metres supposedly robust and crinkled. The branches presumably have been portrayed arising and dichotomizing at the extremity of stem in the form of long shoots which ultimately ramifies into dwarf (short) shoots bearing terminally or laterally borne foliage or male and female cones. The long shoots (Pentoxylon sahnii SRIVASTAVA 1946) bearing short shoots in the axil of sparsely placed leaf-cushions on maturity depict dwindling of leaf scars and shoot scars due to periderm formation. In the transverse section of

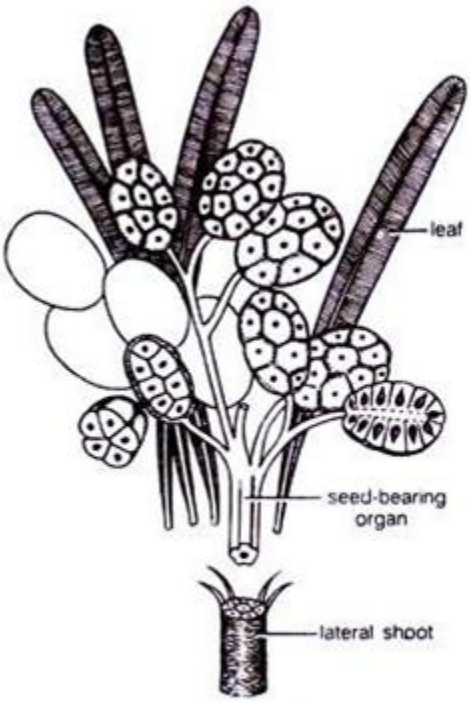
long shoots, generally five bundles are present associated with epidermis, compact outer cortex, parenchymatous inner cortex with nests of sclerotic and stone cells. Presence of cortical bundles has been marked with little variations: one with centrifugal secondary xylem associated with a few centripetal tracheids where as the other only with the centripetal secondary xylem. However, main bundles usually consists of less centrifugal but strong centripetal secondary xylem. Unusually centripetal and centrifugal xylem are of equal development in first season growth. Afterwards the growth is more towards centripetal side than centrifugal side. Secondary phloem is preserved outside the xylem of main bundles.

Nipaniophyllum (leaf)- Leaves : are petiolate strap-shaped with prominent midrib closely resembling form-genus Taeniopteris in general features.However, structurally preserved leaves have been called Nipaniophyllum Foliage arises from short shoots, where leaf scars are commonly visible Leaves long, narrow (Taeniopteris) bearing Syndetocheilic stomata. Prominent mid-rib and secondary veins arising at right angles and unbranched to the leaf margin has also been noticed.. Anatomically vascular bundles are arranged in row, each surrounded by sclerenchymatous bundle sheath showing diploxylic condition that is a central protoxylem, a larger centripetal primary metaxylem mass and a small arc of centrifugal mass. The stiff coriaceous leaves are borne in the form of bunch in the apical portion of slender shoots which usually emerge in the leaf axils of long shoots, th e plants were deciduous dropping off leaves in their entirety



Sahnia (male flower Sahnia nipaniensis) VlSHNU-MlTTRE (1953) Pollen organs were born in clusters on short shoots. They were present terminally on the shoot, and fused basally in a shallow disc .Vishnu-Mittre (1953) reported as many as 24 such pollen-bearing organs It consisted of a receptacle from whose rim like collar arose numerous microsporophylls or microsporangiophores. The stalks gave rise to secondary laterals that terminated in several stalked pollen sacs. Each microsporophyll possessed many pear-shaped, unilocular sporangia.The terminal position of the sporophyll was also occupied by a sporangium. Many details of male bearing structure is still not known.

Carnoconites (female cone) (SRIVASTAVA 1944) *C. compactum and C.laxum* Ovules aggregated into strobili,They were mulberry-like, and attained a length of about 1.8 cm in *Carnoconites compactum* and 3 cm in *C. laxum*.They were, however, narrower in *C. laxum*. Attached to short shoots Unisexual (maybe too specialized to be ancestor to angiosperms) About 20 sessile ovules were seen attached on the receptacle, and there were no inter-seminal scales. Any sporophyll-like structure was also not reported. In-spite of these facts Sahni (1948) used the word 'cone' for these structures.The ovules were covered by a single integument.The nucellus was free from the integumentOvules almost completely surrounded by cupule Integument has inner sclerenchymized layer and fleshy outer layer



Carnoconites compactum. Female cones. (after Sahni).

Affinities of Pentoxylales:

Some of their possible affinities are discussed below:

Affinities with Cycadales:

The two groups (Pentoxyleae and Cycadophytes) resemble each other in:

(i) possession of direct leaf trace in Pentoxyleae and seedlings of some cycads,

(ii) leaf traces anatomy in showing diploxylic nature of their vascular bundles,

(iii) haplocheilic stomata in the leaf,

(iv) nature of wood and pittings,.

Affinities with Conifers:

Some of the characteristics, in which Pentoxylales resemble with conifers, include the presence of:

(i) Pycnoxylic wood,

(ii) Tracheids with circular bordered pits arranged in uniseriate or bi-senate manner

(iii) Uniseriate wood rays, and

Affinities with Medullosaceae:

Pentoxylales also resemble with members of family Medullosaceae of Palaeozoic Pteridospermales (e.g. Medullosa) in possessing a polystelic primary vasculature in their stems. The secondary wood of Pentoxylon was pycnoxylic, character also encountered in some species of Medullosa.The two groups also resemble each other in their mode of branching as well as nature of their steles. Coniferous type of pittings were present in the stems of Pentoxylon and some species of Medullosa.

Affinities with Bennettitales:

Under mentioned are some of the resemblances between Pentoxylales and Bennettitales:

1. Presence of syndetocheilic stomata, in addition to haplocheihc ones.

2. Diploxylic nature of the vascular bundles.

3. Whorled micro-sporangiophores.

4. Superficial resemblances between male flowers of both the groups.

5. The manner in which the ovules were borne in Pentoxylales was similar to that of Bennettitales. However, the inter-seminal scales, found in members of Bennettitales, were absent in Pentoxylales.

6. Stachysporous nature of their male and female organs, i.e. instead of leaves, these organs were borne on the stems.

7. Both the groups share several common characters in their dwarf shoots.

8. Presence of direct leaf trace also brings the two groups quite close to each other.

Thus on the facts described above Pentoxylon appears to be a synthetic group showing features of diverse nature.

Phylogenetic Interpretations

Pentoxylon-plant belongs to a unique group of gymnosperm because:

1. Secondary wood of Pentoxylon stem having been of coniferous type but without

xylem parenchyma.

2. Bearing single-type of tracheidal pitting and different ray pit field.

3. Leaf exhibit anomocytic-type of stomata having vascular traces with diploxylic

condition identical to cycads but in its direct leaf traces, the leaf differs from cycads

having girdle leaf traces.

4. Microsporophylls are borne on cylindrical receptacle showing branching, at times

unbranched sac-like microsporangia quite distinct from bennettitalean synangia.

5. The ovules are bome directly on the cone axis without having any bract, ovuliferous scales or interseminal scales of perianth, an unique nature among the gymnosperm group as regards the mode of attachment of ovules.