

GYMNOSPERMS, TAXONOMY OF ANGIOSPERMS AND ANATOMY (BOT 503)

BLOCK-I-GYMNASPERMS

**Unit-2: Morphology and Anatomy of Cycadales,
Ginkgoales, Coniferales, Taxales and Gnetales**

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CYCADALES

Order Cycadales includes living as well as extinct forms which originated in upper Triassic period of early Mesozoic era. The group flourished through Jurassic and Cretaceous period after which their decline began. In the present scenario about 10 genera with around 110-117 species are known to be distributed in regions of Australia, Central America, South Africa and Eastern Asia including India. Extinct forms have been reported from mid Jurassic Cayton Bay beds on Yorkshire coast.

Seward (1933) has mentioned that **“The cycads of today may rightly be called “living fossils” because they come down from the remote past with so little change that if a man from Cretaceous is brought today, he would very easily recognize the modern living forms of it.**

Cycadales have been classified by different workers differently.

- Pilger and Melchior included all living genera into five subfamilies.
a. *Cycadoideae* (b) *Stangerioideae* (c) *Bowenioideae* (d) *Dioonoideae* (e) *Zamioideae*.

- Sporne classified the order Cycadales into two families.

- a. *Nilssoniaceae* – All living forms were included into this family.
 - b. *Cycadaceae* – This family included one fossil genus, *Palaeocycas* and ten living genera.
- Cycadales were classified into three families by Bierhorst
 - a. *Cycadaceae* – This family includes *Cycas*.
 - b. *Stangeriaceae* – This family includes *Stangeria*.
 - c. *Zamiaceae* – This family is represented by eight different genera; *Zamia*, *Lepidozamia*, *Macrozamia*, *Encephalartos*, *Dioon*, *Microcycas*, *Bowenia*, and *Ceratozamia*.

Distribution of Cycadaceae

Cycadaceae were almost worldwide in distribution in the past ages, and the members of this family have been in existence for at least past 200 million years. The members are, however, now restricted to four main regions in the world, namely Central America, South Africa, Eastern Asia and Australia.

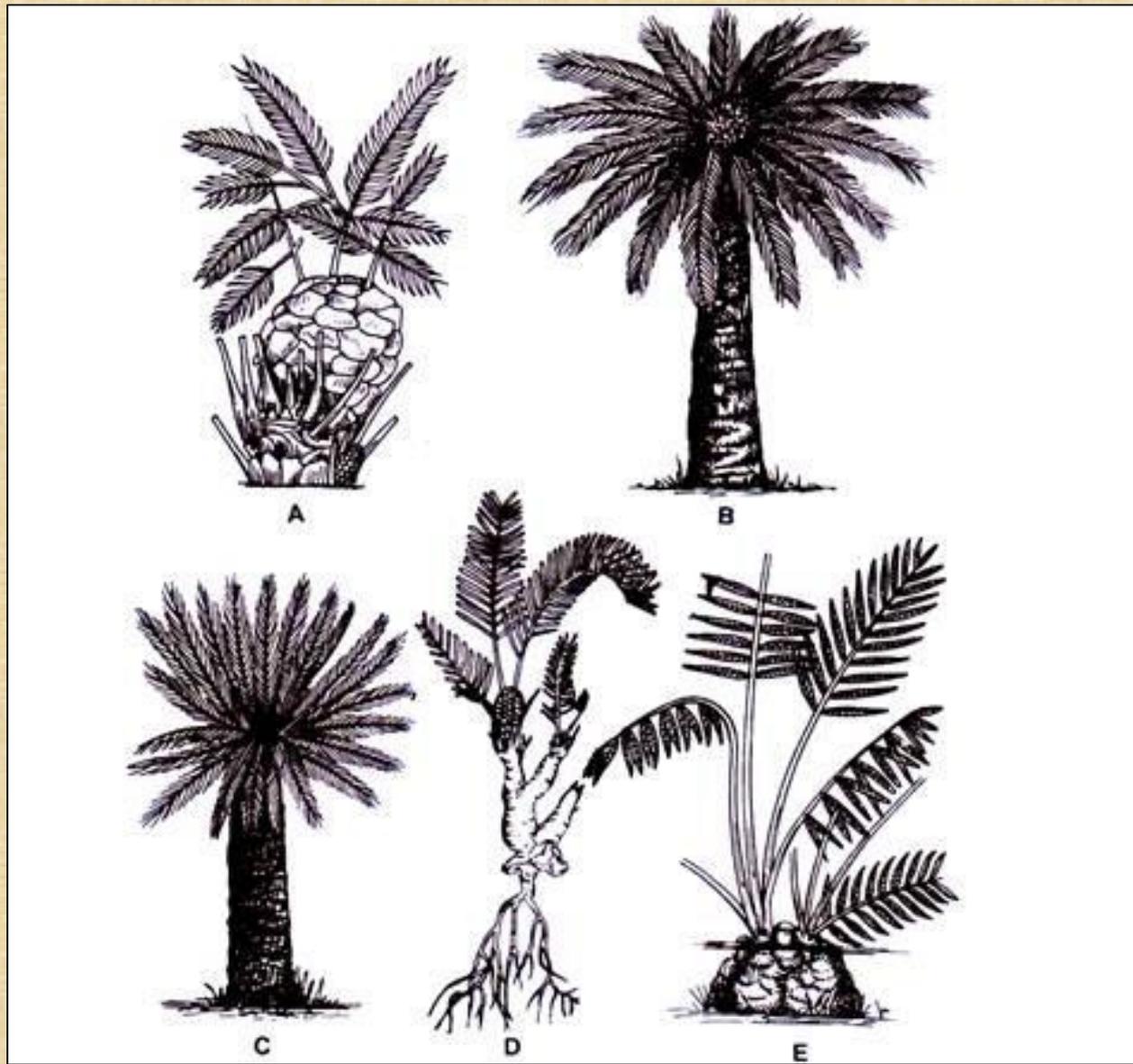
Geographic distribution of members of Cycadaceae

Geographical region	Member of Cycadaceae
South Africa	Encephalartos and Stangeria
Australia	Bowenia, Lepidozamia and Macrozamia
Indian sub-continent, China, Japan, Australia, Madagascar	Cycas
Mexico	Ceratozamia and Dioon
Cuba	Microcycas
Mexico, West-Indies, North-western South America and Florida	Zamia
Columbia	Zamia

External Features of Cycadaceae

- Plants of the family have been reported to exhibit slow-growth and have a general appearance similar to that of a palm with thick, stout, cylindrical and generally unbranched stem.

- The height of stem in species such as *Macrozamia* and *Dioon* reaches upto 10-15 meters.
- The stem is either spherical or tuberous in *Bowenia* and *Zamia*. Large stem apices are found in cycads and tunica is absent in Cycads.
- A crown of pinnate leaves is present at the apex. The leaves are large, pinnate or bi-pinnate and have spiral arrangement.
- Some of the genera possess incurved rachis and leaflets are enrolled in the bud condition showing circinate vernation as in *Cycas*.
- The rachis of the young fronds show sub-circinate vernation in *Stangeria*, *Bowenia* and *Ceratozamia*.
- Midrib is absent in several genera however a distinct midrib is reported to be present in leaflets of *Stangeria* and *Cycas*.
- Genera which do not contain midrib have open dichotomous venation.
- The leaves are long-lived and persist on the stem for several years. When the leaves are shed a scar is left on stem.



Some Cycadales. A. *Bowenia spectabilis*, B. *Cycas revoluta*, C. *Dioon spinulosum*, D. *Zamia floridiana*, E. *Stangena paradoxa*

ANATOMY

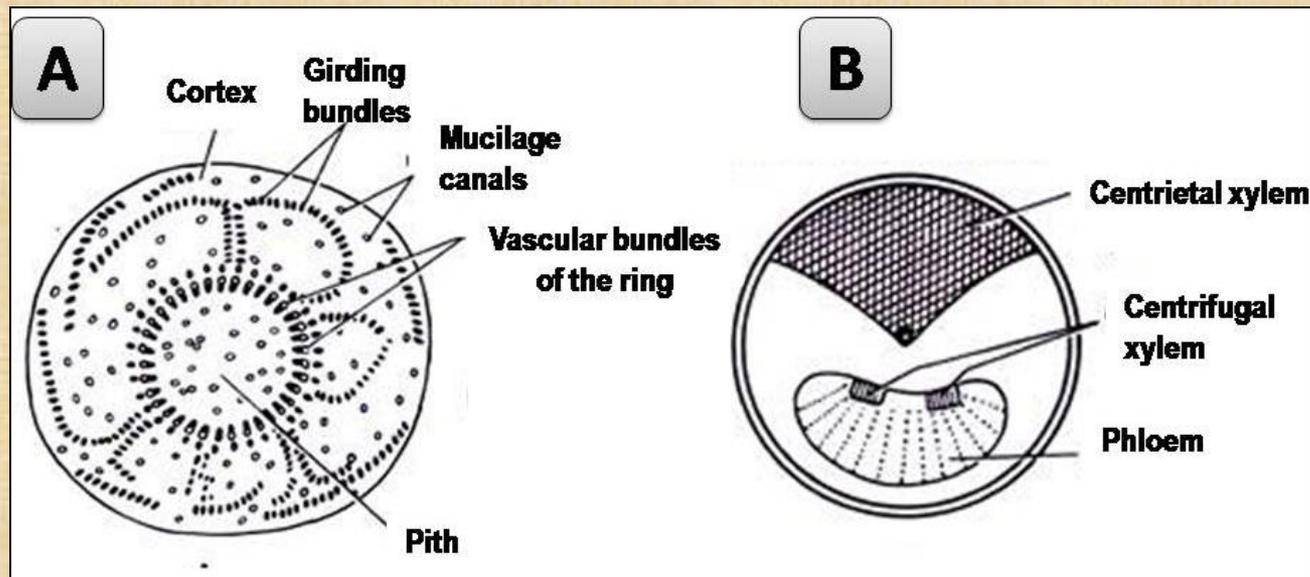
Stem

Owing to the presence of persistent leaf bases, the cycadaceous stems are roughly circular in outline. Both centrally located pith and the peripheral cortex are large and well developed and contain mucilage canals. The endodermis and pericycle are not clearly demarcated. The primary vascular bundles are conjoint, collateral, open and endarch.

The leaf traces are cauline i.e. develop singly from the vascular cylinder of the stem. They completely girdle the stem cortex. Presence of such girdling bundles is a characteristic feature of the family. In many cycads leaf traces after entering the petiole, form either an omega-shape or horse-shoe-shaped pattern. Both centripetal and centrifugal xylem are present in the leaf trace bundles, i.e. they are diploxylic.

Well developed, strong, stout and large trunk has been found in many members of Cycadaceae however secondary wood is surprisingly small. Persistent leaf bases provide mechanical strength to such strong trunk.

Cycadaceae generally possess single persistent cambium, but in many species of *Cycas* and some species of *Encephalartos*, *Macrozamia* presence of successive cambial layers have been reported. Such cambial layers form co-axial cylinders of secondary xylem and phloem. Presence of scalariform tracheids in the secondary wood, a primitive characteristic feature, is present in the stems of *Stangeria* and *Zamia*. The wood in Cycadaceae is diffused and contains 1-7 cells wide medullary rays.

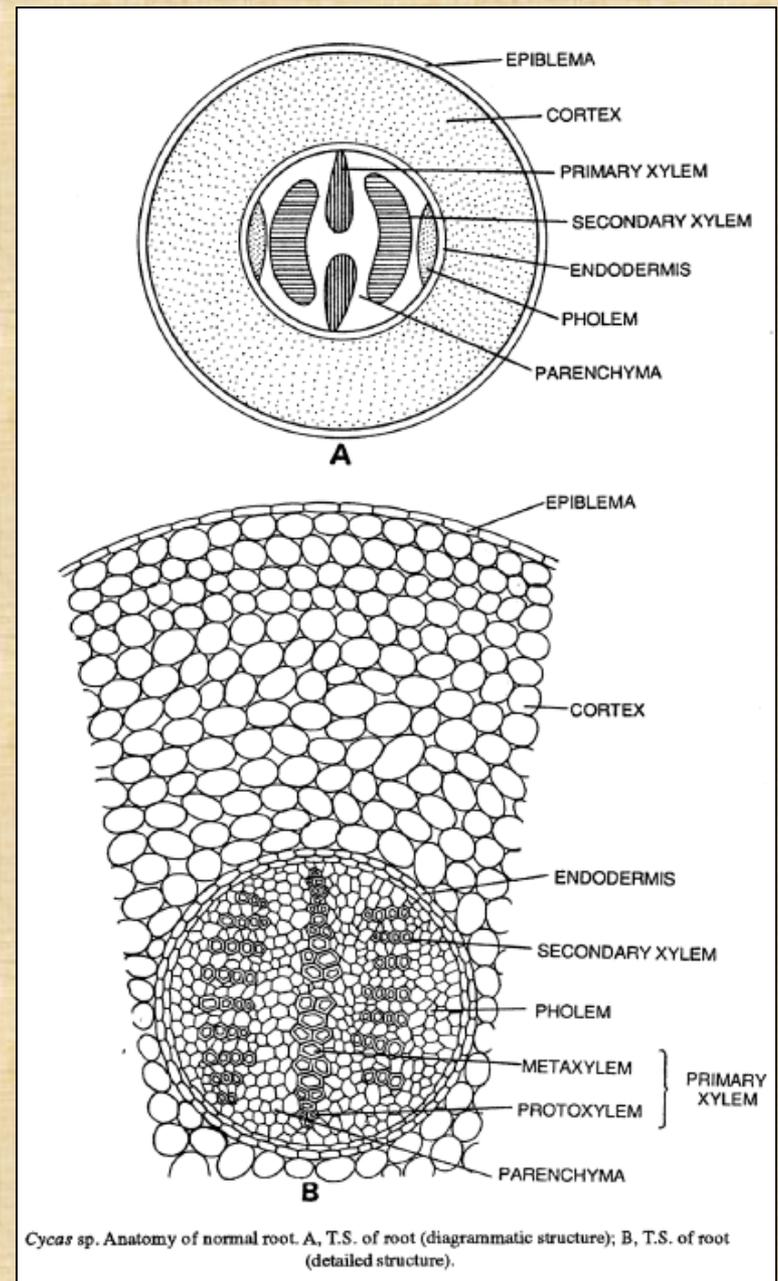


A- T. S. of stem of Zamia floridana, B- Leaf trace bundle of Cycas revoluta (showing diploxylic condition)

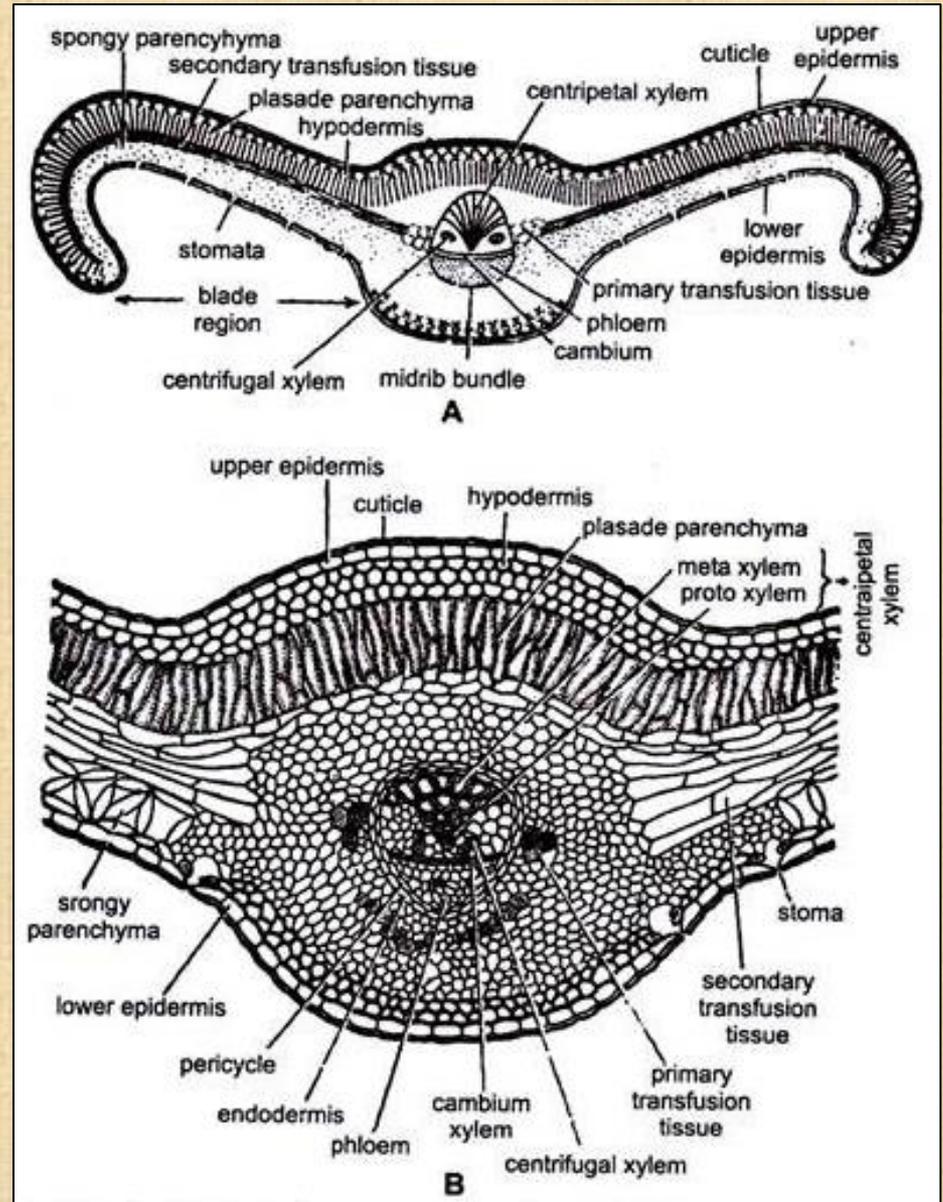
Leaf and Root

The leaves of cycads are covered with a thick cuticle. Leaves contain haplocheilic type of sunken stomata. The vascular bundles are diploxylic, i.e. two types of xylem (centripetal and centrifugal). Usually at the centripetal xylem is triangular with a single protoxylem group. Two types of xylem are separated by parenchymatous region.

Roots of cycads are usually polyarch. Xylem bundles are known to alternate with the equal number of phloem bundles. The number of bundles gradually decreases towards the apex which results into a diarch condition at the tip of the root.



Concentric cylinders of secondary wood are produced by the accessory cambial rings in the older roots. The primary xylem is exarch.



Cycas Leaflet A. TS ground plan. B. TS of a portion through midrib

GINKGOALES

At present order Ginkgoales is represented by only one living member, i.e. *Ginkgo biloba*. Ginkgoales were abundantly present during the Triassic period of Mesozoic age and were represented by many species of about 16 genera. All other genera, except *Ginkgo biloba*, are now extinct. Dallimore and Jackson (1948) reported *G. biloba* to be represented by five different varieties which are *Ginkgo biloba* var. *aurea* (Nelson) Beisson, *G. biloba* var. *fastigata* Henry, *G. biloba* var. *paciniata* Carriere, *G. biloba* var. *pendula* Carriere and *G. biloba* var. *variegata* Carriere.

Kaempfer (European botanist) first of all introduced the name "Ginkgo" in 1690. The same name was adopted by Linnaeus (1771). Due to the presence of several primitive characters, and also because of its long geological records, Ginkgo is regarded as a living fossil. The name Ginkgo was first proposed in 1690 by, and the same name was adopted by Linnaeus (1771). Linnaeus proposed the species *biloba* owing to presence of notch in leaves of the plant. Details of the geological history of Ginkgoales indicate that its members started appearing on the earth during Permian, achieved worldwide distribution during Triassic and Jurassic periods of Mesozoic age, started

declining during Cretaceous and now is represented only in some parts of Southern and Eastern China by only one living member i.e. *Ginkgo biloba*. Ramanujam (1976) have reported some records of this order from Late Palaeozoic of India. These orders include Ginkgophyton, Psymnophyllum and Rhipidopsis. Seward (1938) has considered Ginkgo to be one of the wonders of the world as the plant has survived and persisted with little change until the present through a long succession of ages.

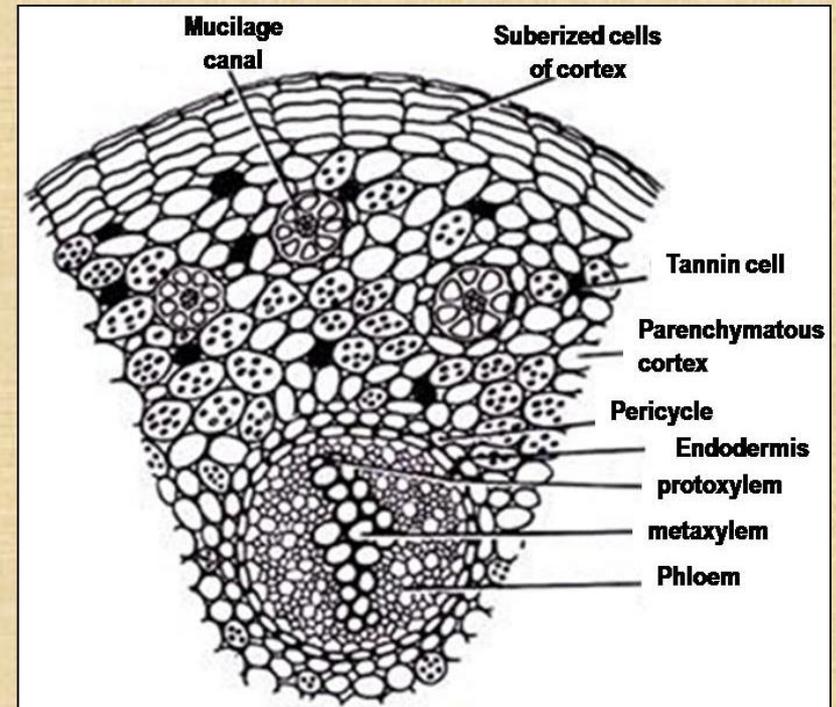
Characteristic features of *Ginkgo biloba*

- Tall trees with excurrent habit
- Deep penetration roots with tap root system.
- Deciduous nature of leaves.
- Leaves are fan shaped and possess open dichotomous venation.
- Leaves arise singly along terminal branches.
- Buds present in axil of leaves give rise to dwarf shoots. These shoots also bear cluster of leaves at their apex.
- Growth of plant is comparatively slow.
- Plants are dioecious in nature.

- Wood is pycnoxylic .
- Inflorescence is catkin like, contains microsporangioophores having 2-12 microsporangia that arise in axil of leaves on dwarf shoots.
- Ovules arise in groups from apices axillary branching.
- Presence of endosperms tent pole is a characteristic feature.
- Seeds are large and fleshy and produce in large number.
- Integument comprises of outer fleshy orange coloured portion and hard inner stony layer, fleshy coat is rich in butyric acid and produces an unpleasant smell on crushing- seeds hang out for a period of 1-2 months after leaves are shed. This gives a beautiful look to female tree. *Ginkgo biloba* is also known as maidenhair tree.
- Spermatozoids are motile.

Root

Transverse section of roots shows them to be circular in outline. Mature roots are surrounded by phellogen or suberized cells of cortex. Young roots possess extensive cortex which is made up thin walled cells which contains tannin filled cells, mucilage cavities and crystals of calcium oxalate. Young roots clearly depict presence of a layer of endodermis and pericycle. Such distinction is not visible in mature roots. Diarch or triarch condition is found in young roots, it means that two or three xylem strands alternate with same number of phloem strands. Xylem is exarch. Indistinct annual rings develop due to secondary growth.



G. biloba: TS of young root

Stem

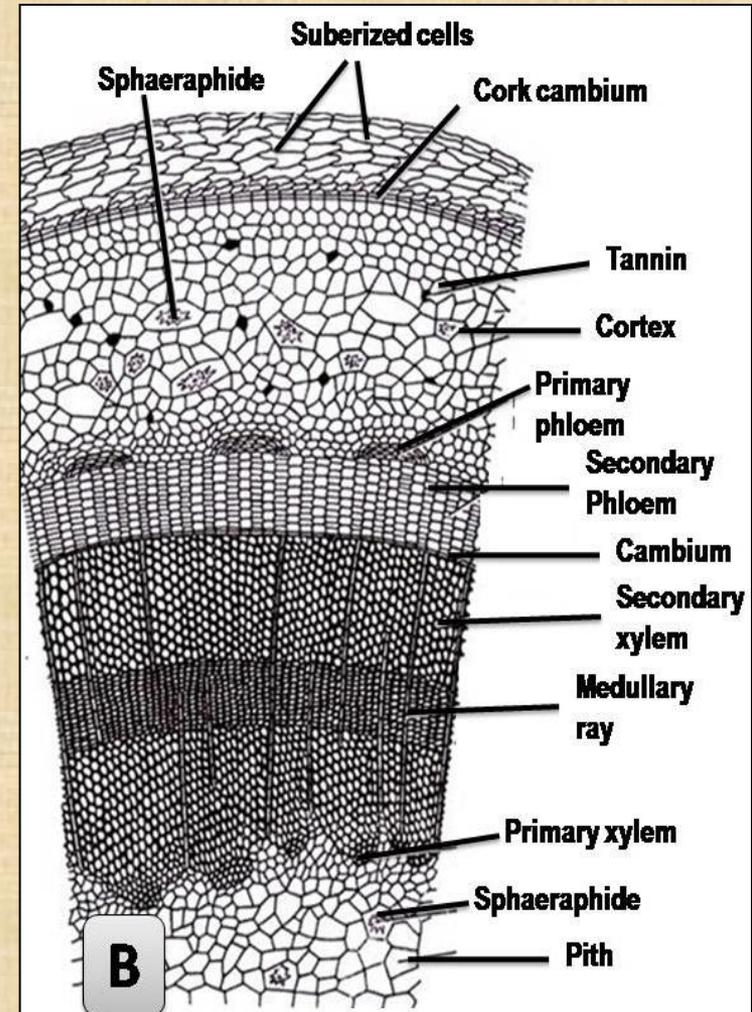
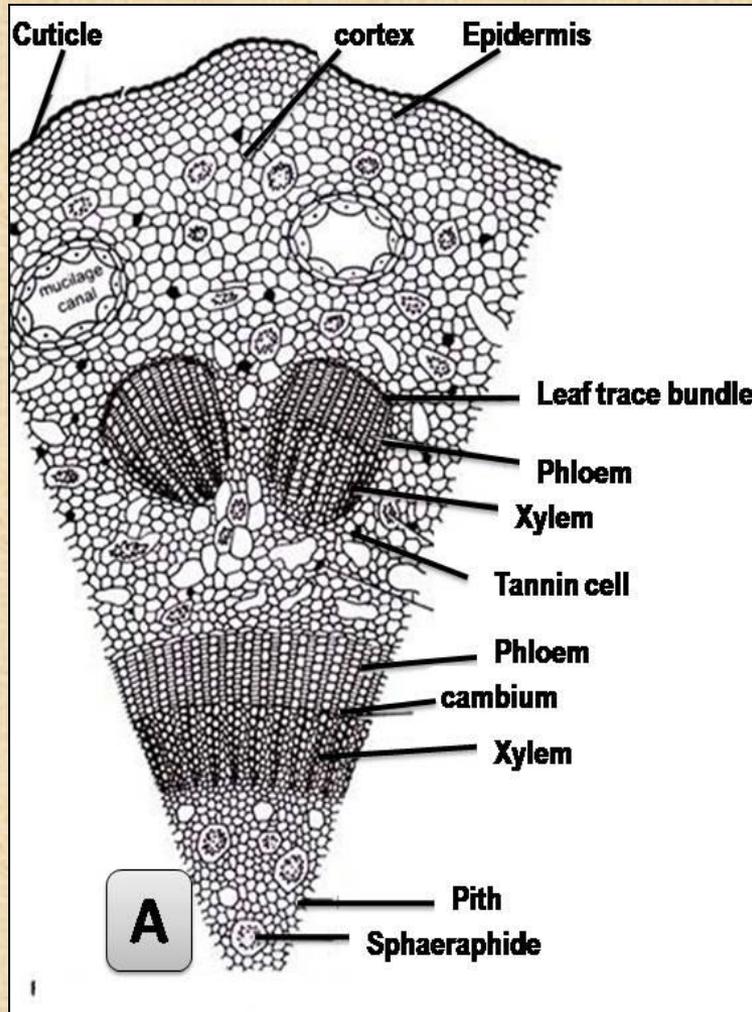
The young stems are more or less circular in outline. The outermost layer is the epidermis. In young stems it is single-layered, made of brick-shaped cells and covered by a thick cuticle. In older stems the epidermis is replaced by the periderm, which originates from the cortex. After the epidermis, the next region is the cortex. It is extensive in dwarf shoots and comparatively narrow in long shoots. It contains mucilaginous canals, sphaeraphides and many tannin-filled cells. No distinct endodermis and pericycle are present. The stem of a young stem contains several vascular bundles arranged in a ring. These are conjoint, collateral, open and endarch. These vascular bundles run longitudinally through the stem and also branch to give rise to leaf traces. Once secondary growth starts, the vascular cylinder of the stem becomes an endarch siphonostele with no parenchyma in the wood except that of uniseriate medullary rays. Uniseriate medullary rays are present, which are 1-5 cells high in dwarf shoots and 1-15 cells high in long shoots. The stellar system in Ginkgo is of the eustele type. Protoxylem possesses spiral thickenings while bordered pits are present on the radial walls of the metaxylem tracheids. The phloem consists of sieve tubes and phloem parenchyma. The centrally located

pith is extensive and large in dwarf shoots and narrow in long shoots. Pith contains mucilage canals and calcium oxalate crystals.

Secondary Growth in Stem

Secondary growth takes place through activity of single ring of cambium which remains active throughout the plant life. The wood is characterised to be pycnoxylic as well as monoxylic cambium after developing a complete ring cuts off secondary phloem elements towards outside and secondary xylem towards pith. It is made up of fusiform initials (which give rise to vascular elements) and ray initials (which give rise to uniseriate rays). Uniseriate rays are 1-5 cell high in long shoots and 1-15 cell high in dwarf shoots secondary phloem is made up of sieve elements and parenchyma phloem fibres and companion cells are however absent. Secondary xylem is made up of tracheids and possess weakly developed annual rings. Tracheids have moderately thick wall and most of tracheids end at same level. This makes the wood brittle having no economic value, tracheids contain circular bordered pits which may be present alternately or opposite . cork cambium is present in outer cortex and forms peridium which

replaces epidermis. Cambium also forms secondary cortex towards innerside.



G. biloba: TS of young (A) and mature stem (B)

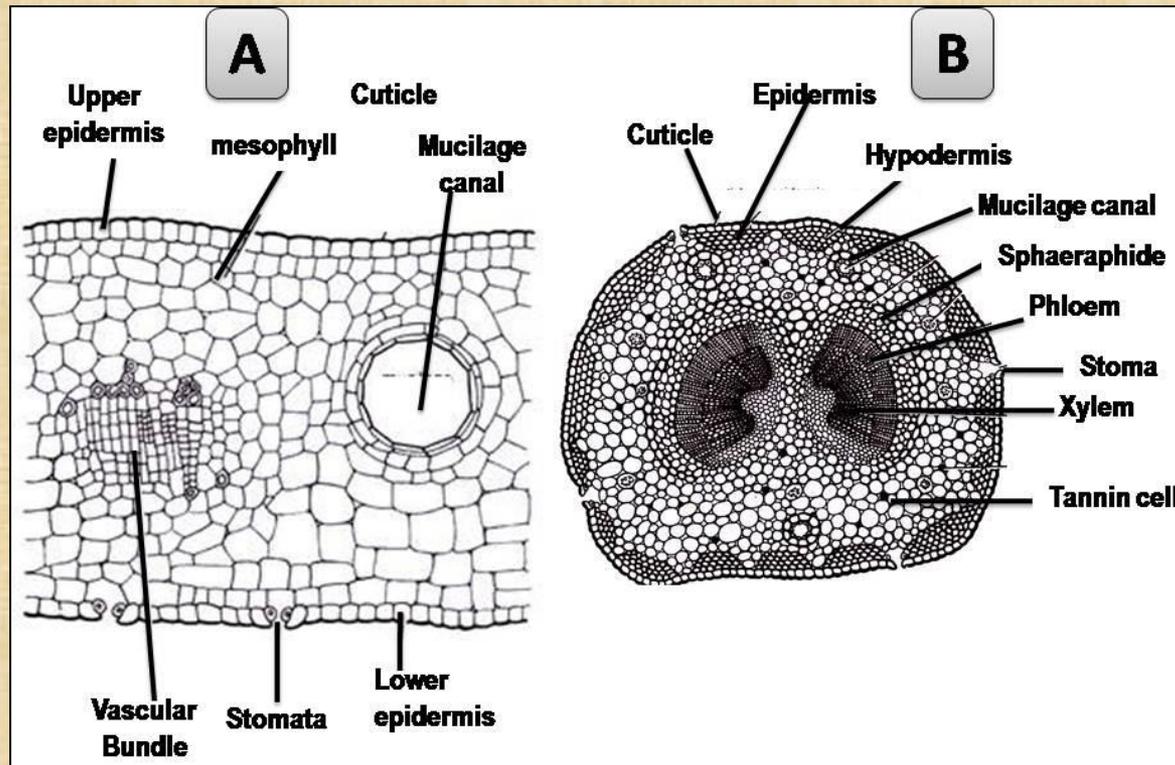
Leaf

Upper as well as lower surface of leaf are lined by layer of epidermis covered by cuticle. Epidermal cells are polygonal between the veins and rectangular over the vein. Stomata are haplocheilic type and present only on lower epidermis. Kanis and Karstens (1963), have however, reported some stomata to be present on the upper epidermis of the leaves on long shoots of male plants. Guard cells of stomata are surrounded by accessory cells which may be 4-6 or 7 in number. Mesophyll present between two epidermal layers is not well-differentiated into palisade and spongy parenchyma except in the old and mature leaves of long shoot. Many mucilage canals or secretory canals and a few tannin-filled cells are also present in the mesophyll region. Large number of loosely arranged chloroplasts are present. Loose arrangement of chloroplast allows air spaces to be enclosed between them.

Petiole

Petioles are covered with thickly cuticularized epidermis, whose continuity 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 has a pair of endarch vascular bundles which are surrounded by a sclerenchymatous bundle sheath. Protoxylem contains spiral thickenings. Xylem is traversed by uniseriate rays. Medullary rays of xylem are continuous with those of phloem. Sphaeraphides are irregularly distributed in the cortex. The petiole has a pair of endarch vascular bundles. Protoxylem contains spiral thickenings.



A- TS of leaf of G. biloba, B- Ts of petiole of G. biloba.

CONIFERALES

Conifers are tall trees with foliage and branches which have a cone like appearance. Coniferales are known as dominant forest-makers of the world. They comprise of about 54 living genera having more than 570 species. They are widely distributed in areas of Northern and Southern hemispheres.

In India conifers are represented by genera including *Pinus*, *Abies*, *Picea*, *Cedrus*, *Tsuga*, *Cupressus*, *Juniperus*, *Araucaria* and *Podocarpus*. They are found from Carboniferous to the present times. Conifers have been classified into different families.

Family	Brief overview
Lebachiacea	Earliest conifers, Based on the genus <i>Lebachia</i> and formed by Florin out of Upper Carboniferous and Permian fossils. <i>Lebachia</i> was a tree with pinnately arranged branch-lets on which very small needle-like leaves were borne spirally in an imbricate manner. There were separate male and female cones. <i>Lebachiaceae</i> is the best known of the earliest conifers

Voltziaceae	The Voltziaceae (after taking out the Lebachiaceae) shows a group of fossils from the Permian to the Jurassic.
Palissyaceae	Represented by two genera Palissya and Stachyotaxus. Palissya is well represented in the Indian Upper Gondwana by Palissya conferta, P. indica and P. jabalpurpsis from the Rajmahal, Kota and Jabalpur Stages
Cheirolepidaceae	Is a family of Triassic-Jurassic fossils which is very close to the Podocarpaceae and also related to the Araucariaceae. Only the female cones are known.
Protopinaceae	Protopinaceae represents an assorted group of coniferous wood fossils from the Jurassic and the Cretaceous which shows affinities with Pinaceae, Taxodiaceae, Cupressaceae and Podocarpaceae.
Taxodiaceae	Includes 10 genera and 18 species. Is a family of monoecious trees with vary in size from small to huge size, small needle-like to falcate or scaly leaves borne spirally (rarely opposite). Cones are small with spiral members. Bracts and ovuliferous scales are almost completely fused. There may be 2 to 9 ovules on an ovuliferous scale. Pollens are wingless.

Cupressaceae	Largest family with 20 genera and 148 species. Leaves are persistent, small, scale-like, opposite or in whorls. No shoot dimorphism, Male strobili are small, female cones arise on short branches. Number of ovules varies from 3-30 (rarely 1-2), wingless pollen,
Araucariaceae	Is a family of beautiful trees with branches in whorls. Leaves linear or broad and spirally arranged, Male cones large, catkin-like. Female cones woody, large, with spiral scales. There are two genera Agathis (monoceious) and Araucaria (Dioceious) with about 35 species.
Podocarpaceae	Family includes 7 genera and 150 species, shrubs or trees with linear or lanceolate leaves. Male strobilus of microsporophylls each with two microsporangia. Pollens are winged. Definite female cones in some species, in others it is very much reduced. This is an ancient family with fossils clearly known up to Upper Triassic.
Cephalotaxaceae	Represented by six species of genus Cephalotaxus, found in subtropical forest of Japan, China and Eastern Himalayas. Shrubs or small trees, dioceious, spirally arranged leaves, male cones arise in clusters.

General Characters of Coniferales

- Plant body is sporophytic and the sporophytes are richly branched trees or shrubs
- Their growth habit varies from extremely tall trees to miniature forms.
- Branches may be of one kind or they may be dimorphic as in *Pinus*.
- Stems contain a small pith and the secondary wood is pycnoxylic and consists of tracheids with large uniseriate or rarely multiseriate pits on their radial walls.
- Resin canals are distributed in pith, cortex and sometimes also in wood.
- Leaves are of two types, i.e. foliage leaves and scaly leaves.
- Plants are either monoecious or dioecious.
- The sporophylls are generally arranged in the form of cones.
- The micro-strobili or male cones are simple and contain many scale like microsporophyll's.
- The female cone or mega strobili consist of many sterile bract scales and fertile ovuliferous scales.

- Female gametophyte is completely dependent on the sporophyte.
- Oospore has the ability to produce more than one embryos, hence conifers show polyembryony.
- Seeds are endospermic and winged with hard testa.
- Members of conifers have economic value as they are source of timber, pulp, wood, oils, resins, turpentine, etc.

Structure and anatomy of leaves of conifers

Leaves of Conifers are either scale like or they possess well developed laminae. Leaves are simple and a prominent midrib present in most of Conifers.

General shape of leaves in conifers

FAMILY	SHAPE OF LEAF
Pinaceae	Needle like, linear
Taxodiaceae	Linear, scale like
Araucariaceae	broad

Cephalotaxceae	linear
Cuprasaceae	Scale like
Podocarpaceae	Linear, scale like

In general leaves are linear and needle like. Most of the Conifers are evergreen. In *Araucaria* the foliage (leaves) remain green for about 10-15 years. However genera such as *Taxodium*, *Metasequoia*, *Larix* etc are deciduous and in these leaf fall occurs in every autumn. Considering the small size and single vein leaves of conifers are regarded to be microphyllous but in other view if it is believed that leaf traces leave leaf gap in stem stele then the leaves of Conifers are megaphyllous. Phyllotaxy (arrangement of leaves) in most of Conifers is alternate or spiral. Family Cupressaceae however possesses whorl and opposite phyllotaxy. In Pines needle like green leaves are borne on spur shoots. Spur shoots arise from axillary bud of a scale leaf. Needles fall alongwith the spur and hence are deciduous. Leaf is characterized by thickly cuticularized well defined epidermis cells have a thin cell wall. Stomata are sunken, haplocheilic and are generally present in parallel rows forming vertical band on each side of midrib.

There is no regular arrangement of stomata in *Cedrus*, *Cupressis* and *Cryptomeria*. Pinaceae is characterized by needle like leaves and stomata are present on all sides of leaves (amphistomatic distribution). The arrangement of stomata in *Tsuga*, *Podocarpus*, *Abis* is hypostomatic stomata are found only on abaxial surface. Contrary to this arrangement of stomata in *Thiia*, *Junipersus* and *Cupressus* stomata are present only on adaxial surface and hence are hyperstomatic.

Leaves of *Cephalotaxus* and *Tsuga* specifically lack hypodermis. Whereas hypodermis is present in distinct patches in *P. roxburglis* and *P. merkusii*. Sclerenchyma is uniformly present in *Abis*, *Cedrus*, *Cryptomeria*, *Agathis* etc. Well developed palisade tissue and spongy parenchyma is found in *Agarthis* and *Podocarpus*. Such distinction is not seen in other members. Cells of mesophyll tissue in Pines contains foldings and mesophyll tissue of *Cryptomeria* is characterized by presence of well developed air spaces. Distribution of resin canal varies from genera to genera and species to species. In *Cryptomeria* a big resin canal is present above vascular bundle. Leaf traces is double in living Pinaceae and single in Cupressaceae.

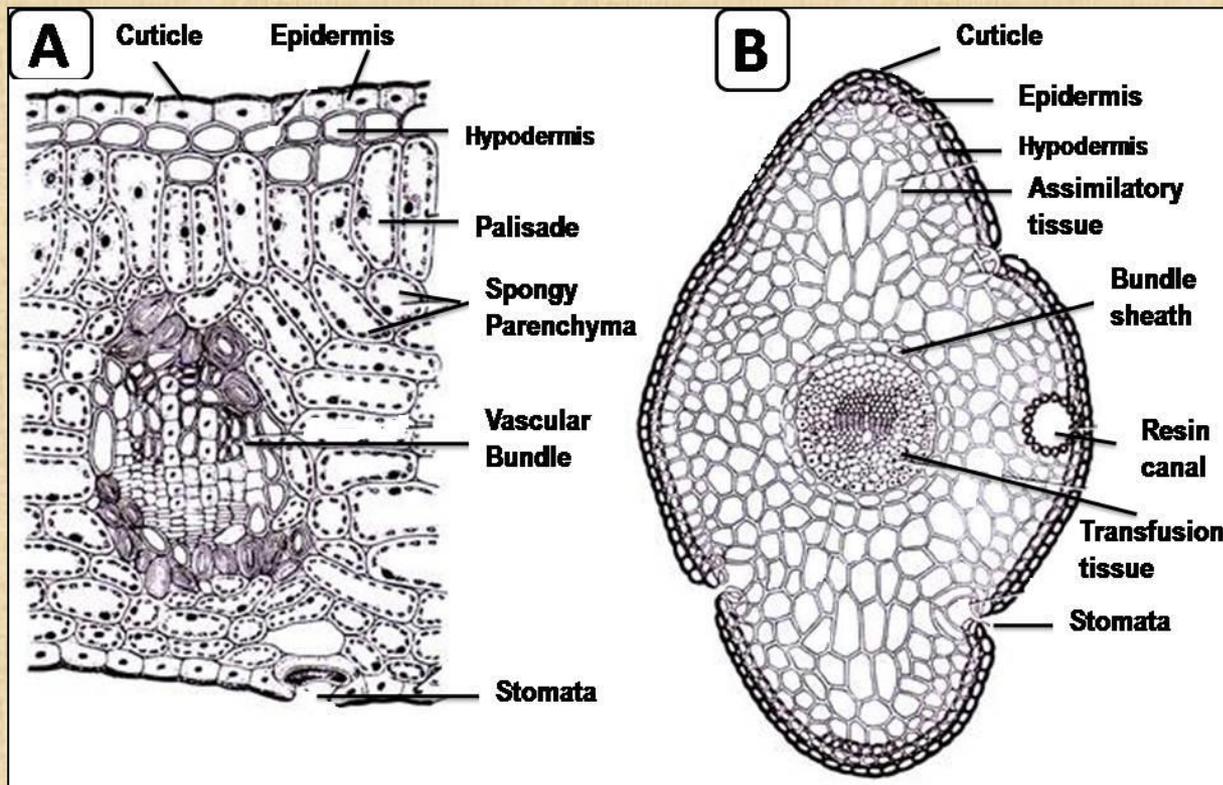
A characteristic feature of leaves of Conifers is presence of transfusion tissue. In Pines transfusion tissue consist of two types of cells:

- Transfusion tracheids which are dead cells having thick, lignified walls

and circular bordered pits.

b) Second type of cells are transfusion parenchyma cells which are living cells and contain tannin like contents.

Both cell types are present in vascular region enclosed by endodermis. They function to conduct water and food material between vascular bundle and mesophyll tissue.



A- TS of leaf of Agathis robusta, B- TS of Picea exceisa

ANATOMY OF CONIFERS

Stem

Shoot apices of conifers exhibit similar development as found in other gymnosperms. However variation occurs in seasonal distribution of growth. For example shoot apices of *Sequoia* exhibit slow but continuous growth over long periods. However in Conifers such as *Pinus*, *Pseudotsuga* and *Torreya* annual shoot development occurs during a specific seasonal phase. In the shoot apex there are different zones which differ from one another in mitotic activity, direction of growth and cellular constitution.

In Pinaceae the apical meristem shows nuclear distinction between tunica and corpus. An initial group of apical cells divide (anticlinically and paraclinically) to form lateral derivatives and central mother cell zone. In centre of this zone, cells having meristematic activity gradually differentiate to give rise to peripheral zone. From this peripheral zone arise leaf primordia (in part), cortex, procambium and epidermis. The central mother cell gives rise to rib meristem which eventually produces pith. Central mother cell are also found in *Sequoia*, *Araucaria* and *Pseudotsauga*, however central mother cell are absent in most of the conifers including *Pinus*. From peripheral zone arises provascular strands

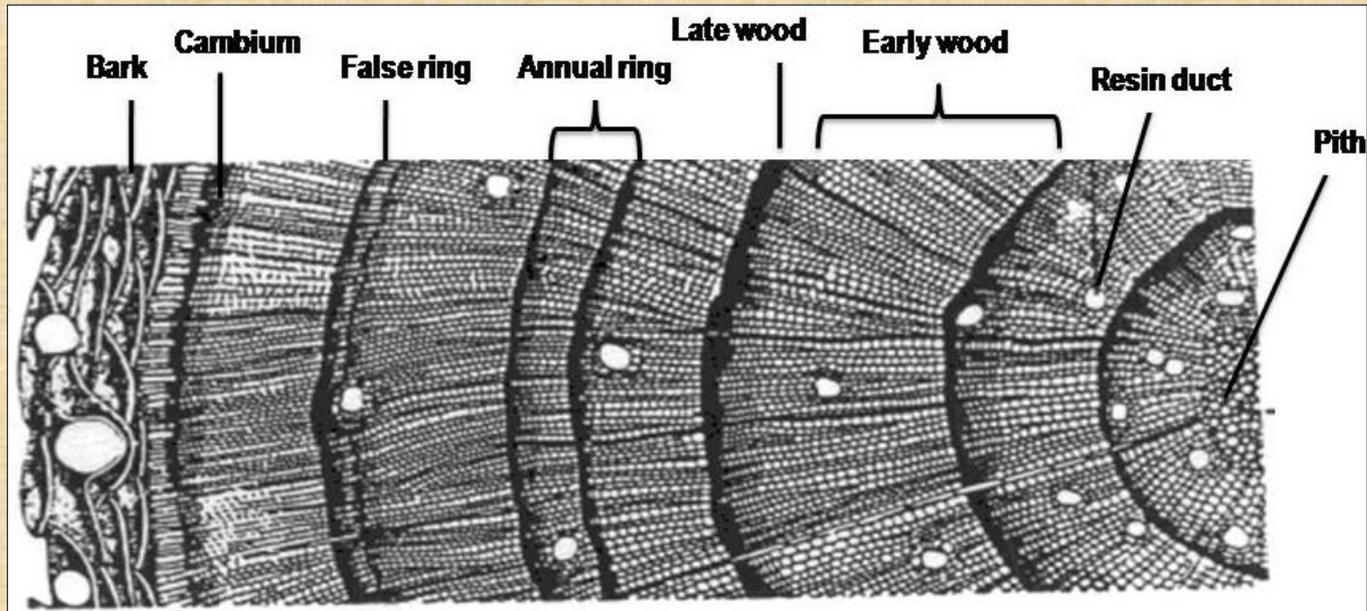
which differentiate into vascular bundles. Vascular bundles (strands) are conjoint collateral, open and endarch and form a ring around the central pith. Conifers contain large vascular cylinders and small area of pith cortex. Cortex as well as pith contains resin passage. Leaf traces may be single or double.

A characteristic feature of Conifers that in them cambial activity begins very early. All xylem elements are radially aligned from the pith outwardly. A few bundles of the ring arise at later stage. These are entirely derived from cambium and contain protoxylem elements. As the stem matures the cambium forms a complete ring and cambium cells tangentially divide to form secondary xylem and phloem.

There exists a remarkable similarity in structure of xylem and phloem in almost all families of conifers. Secondary wood in Conifers is pycnoxylic. Except for medullary rays which are heterogenous rest of wood has homogenous texture. Xylem contains tracheids which are long, narrow and contains circular bordered pits having distinct tori. Pits are generally present on radial walls and are uniseriate however biseriate pits are found in *Agathis*, *Araucaria*, *Microbiota*, *Cedrus* and *Keteleria*. Vessels are absent in xylem. Medullary rays are uniseriate and few cells high. Secondary phloem is made up of sieve elements or sieve

cells and undifferentiated parenchyma. Sieve cells have small, rounded and separated sieve areas confined to radial walls. Companion cells are absent. *Pinus* contains two types of phloem rays one which dies with rest of phloem and other which is starch filled remains alive even when the next of phloem is dead. Cambium remains active for hundreds of years. Annual rings are distinct however false rings may also arise because of abnormal cambial activity.

Outer cortex contains cork cambium, whose cells divide horizontally to cut off cork cells (or phloem cells) outwardly and secondary cortex (or pheloderm cells) within. As a result of regular increase in growth of secondary wood and phloem the outer cork layer are shedd (sloughed) off and new layers arise by activity of cork cambium. Hence in older stems bark of tree comprises of periderm. Made up of cork layer, cork cambium and secondary cortex and a nonfunctional secondary phloem. A specific term rhytidome is used to describe fissured or wrinkled and furrowed portion of bark. In *Sequoies* bark of trees can be as thick as 2 feet and it forms an effective insulating tissue which provides protection from heat of forest fires. This is considered to be most important reason for survival of conifers for thousands of years.

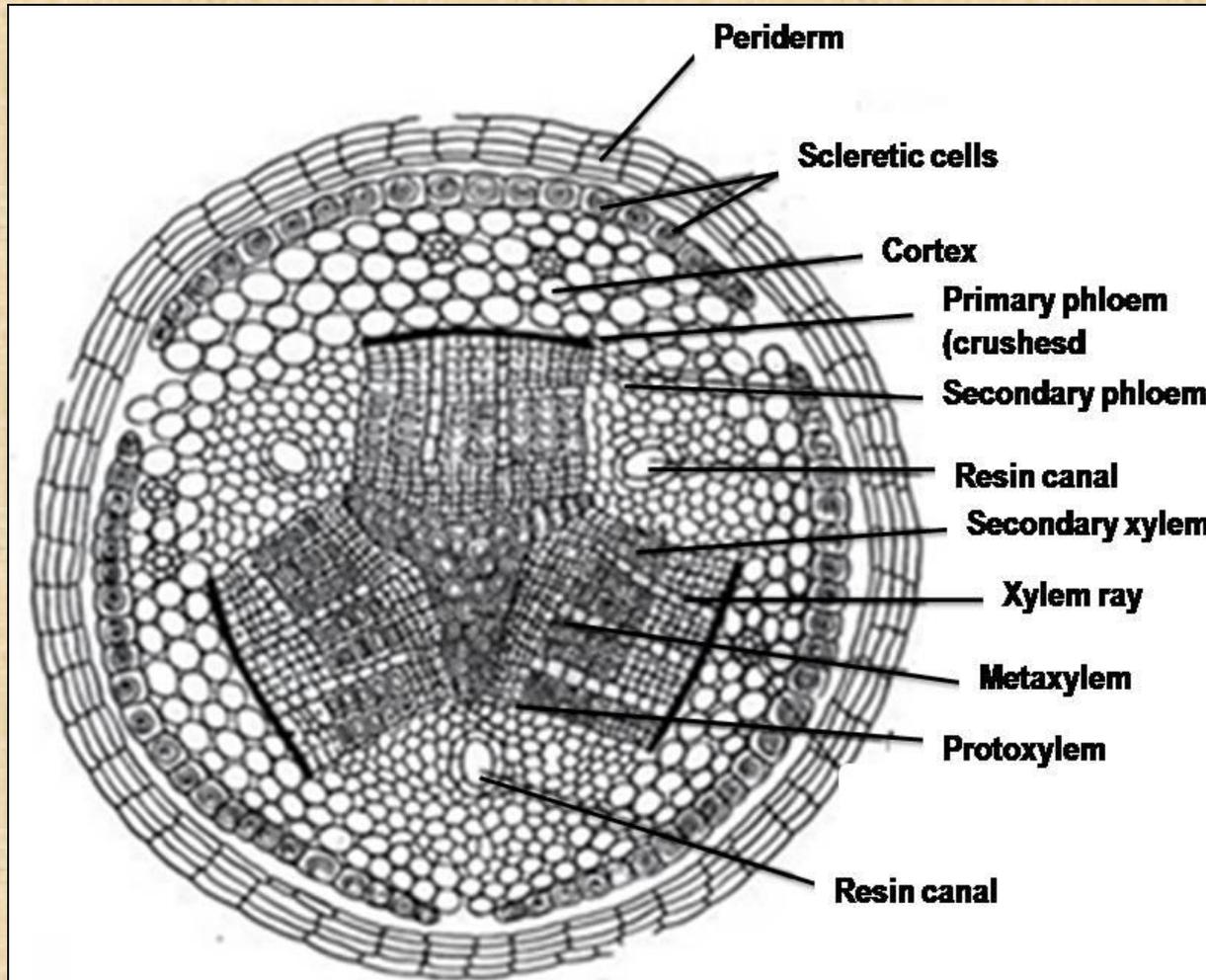


Cross section of young conifer stem

Roots

At the root apex are present apical initial cells which repeatedly divide to form cells which contribute to root cap zone and stelar mother cell zone. These initial cells divide to form several verticals rows of cell which form one core of root cap. Core cells divide to form cortex and lateral cells of root cap. From this it becomes clear that cortex and root cap have a common origin because of which there is no well defined dermatogen and periblem present at root tip.

Cells of stelar mother cell zone divide transversely to form pro cambial cells. These pro cambial cells elongate and divide longitudinally to form a distinct procambial zone. Generally a diarch stele is present in root but triarch and tetrach stele are also commonly found. *Taxodium imbricatum* specifically contains pentarch roots. Xylem is exarch and in *Pinus* protoxylem is Y shaped which contains a resin duct in arms of Y. Pericycle and endodermis are clearly visible. Primary cambium is very active and divides to form secondary vascular tissue. Due to secondary growth continuous layers of secondary xylem and phloem are formed. Endodermal cells are characterized by presence of casparian strips. Annual rings are not prominent. Internal organization of roots of old plants looks similar to that of stem.



TS of triarch root of Pinus

TAXALES

The order is represented by single family Taxaceae, which has been recovered from conifers and placed in separate order due to differences in reproductive organs. Engler and Prantl (1889) recognized only one species, *Taxus baccata*, under *Taxus*, while Dallimore and Jackson (1948) and Sporne (1965) included 9 species viz. *Taxus baccata*, *T. brevifolia*, *T. canadensis*, *T. chinensis*, *T. cuspidata*, *T. floridana*, *T. globosa*, and *T. media*. *Taxus* is widely represented in North and South America, Europe and Philippines, Algeria, Morocco and India extending even up to Malaysia. In India, *Taxus* occurs both in the eastern as well as western Himalayas in Khasi and Naga hills, Assam, Manipur, Simla and several other areas at an altitude of about 1800 metres or more above sea level. Raizada and Sahni (1960) recognized a tenth species of *Taxus* (*T. wallichiana*) growing in Himalayas.

The family is characterized by evergreen small trees or shrubs. They show extensive branching. Leaves are simple solitary and spirally arranged. Secondary wood is pycnoxylic. There is no distinction of shoot apex into tunica and corpus. Wood rays are homogenous and have thick walls. Trees are generally dioceious however monoceious tress are also known.

A terminally borne single ovule represents female strobili. Male strobilus consists of small central axis terminating a dwarf shoot. Seeds are endospermic.

Morphological Features of *Taxus baccata*

- *Taxus baccata* is an evergreen tree with a height of 9-20 metres. It is commonly known as 'Yew'.
- *T. baccata* possesses a huge trunk, stem is profusely branched and is covered with a thin brown-coloured bark.
- All branches exhibit unlimited growth and form a very dense canopy, which makes *T. baccata* a shade-providing tree. It differs from *Pinus* in not possessing dimorphic branches.
- Only the green leaves are present on vegetative branches. The upper surface is dark green while the lower surface is pale or rusty red in colour.
- Leaves are linear, small (2-3 cm long), spirally arranged and shortly stalked.
- Each leaf contains a single strong vein and recurved margins.

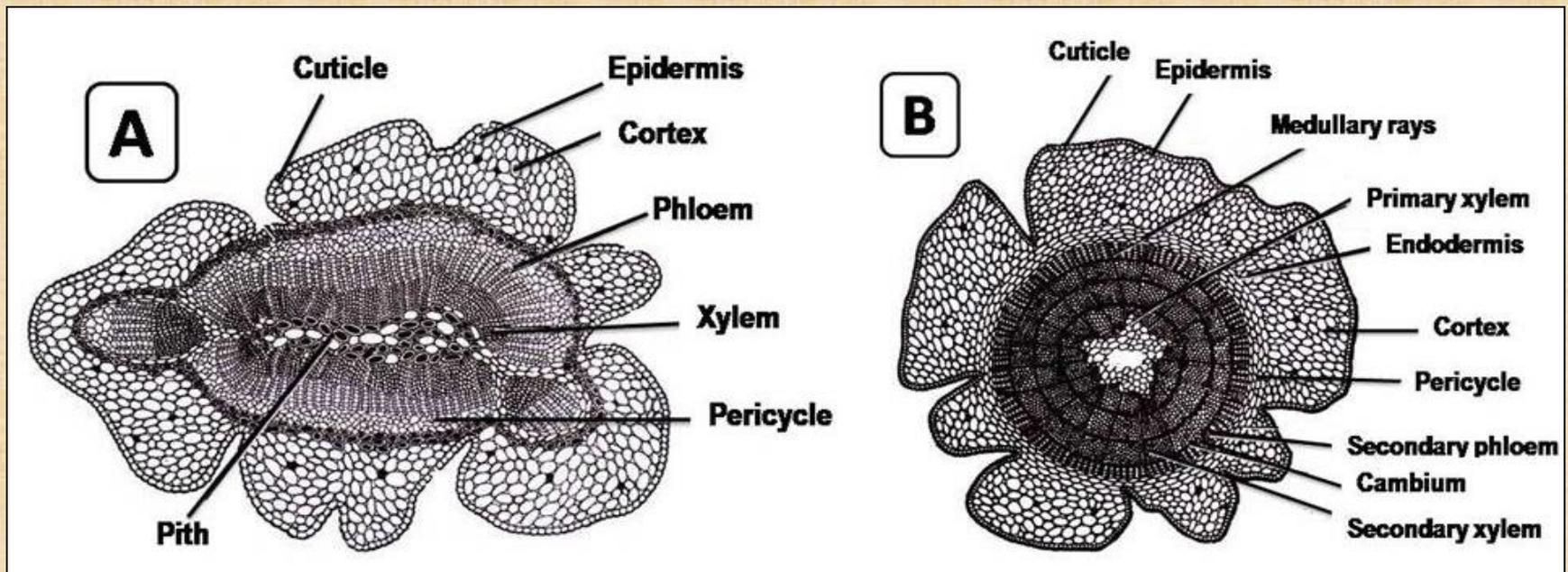
- The apex is sharply pointed mainly because of accumulation of silica.
- The scaly leaves present on the fertile shoot are opposite and decussate.
- Well- developed tap-root system is present. Roots are deep-feeders and highly branched.

ANATOMY

Stem

In transverse section the stem exhibits similarity with *Pinus* in structure. It is surrounded by a single-layered epidermis having a thick cuticle. Next to epidermis is present parenchymatous cortex which possesses tannin-filled cells. Inner to cortex region is present endodermis and sclerenchymatous pericycle. The young stem shows a ring of conjoint, collateral, open and endarch vascular bundles enclosing a distinct pith in the centre. The protoxylem consists of spiral tracheids, and the phloem contains sieve cells with sieve plates and phloem parenchyma. Companion cells are absent. The cambium is persistent and develops a thick vascular cylinder due to secondary growth. The cambium cuts secondary phloem towards outer side and secondary xylem towards

inner side. The secondary wood lacks resin canals and wood parenchyma. Uniseriate bordered pits are present only on their radial walls of tracheids. The tracheids possess spiral thickenings. The medullary rays are uniseriate and homogeneous however in *Taxus baccata* they have been reported to be bi-seriate. The wood is strong and dense. Due to the presence of tertiary spirals the wood is elastic in nature. Phellogen may develop in the older stems showing extrastelar secondary growth.



Stem of Taxus baccata, A- T S of young stem, B- T S of old stem

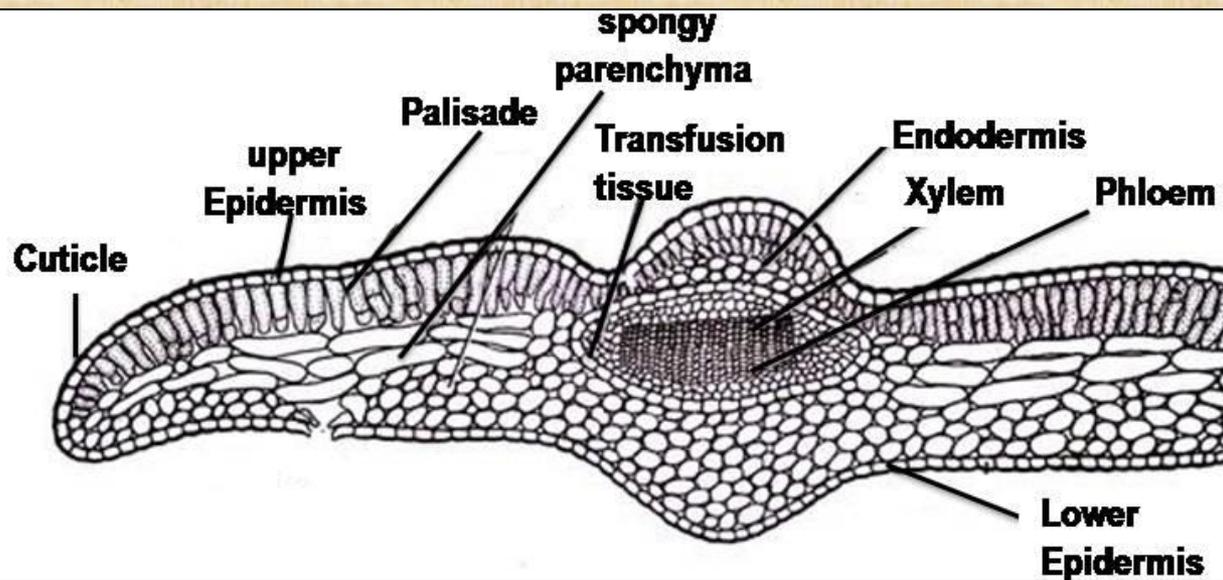
Root

Root has an outer layer called epiblema in younger regions where cells possess long and unicellular root hair. A thin cuticle is also present. Next to epidermis is present cortex which is several layers thick and made up of parenchymatous cells. These cells enclose intercellular spaces. A distinct endodermis is present. Pericycle contains resin canals and is multilayered except opposite protoxylem. Stele is diarch and exarch and protoxylem lacks resin passages. There is no pith present as it is occupied by plates of metaxylem tracheids. Secondary growth is similar to the one seen in *Pinus*.

Leaf

The leaf is dorsoventral and exhibits xerophytic characters. Cells of both upper and lower epidermis are rectangular in shape and thickly circularized. The cuticle is comparatively thin on the lower surface. Sunken stomata are present only to the lower epidermis. Stomata show haplocheilic development. The mesophyll is differentiated into palisade (two layered) and spongy-parenchyma. Single vascular bundle is present in the mid-rib region. Enclosed by a distinct endodermal layer or bundle sheath. The collateral vascular bundle contains phloem towards

the lower side and xylem towards the upper side. On both the sides of the vascular bundle is present transfusion tissue. Resin canals are generally absent. In the above mentioned description presence of thick cuticle, sunken stomata, transfusion tissue and differentiation of mesophyll into palisade and spongy parenchyma comprise xerophytic characters of leaves.



V S of leaf of Taxus baccata

GNETALES

Gnetum genus includes about 30 -35 species which comprises of woody trees, shrubs and climbers. *Gnetum* species are dioecious and mostly found in rain forests. In India five species are found which includes *G. costatum* which is a scandant shrub found in regions of Kerala and Madras; *G. gnemon* which is a tree and has six varieties out of which two are found in India; *G. montanum* which is a woody climber and is distributed in regions of Sikkim, Orissa, Assam, China and Siam; *G. latifolium* has five varieties all of which are woody climbers and *G. ula* is also woody climber found in various parts of India.



Gnetum costatum

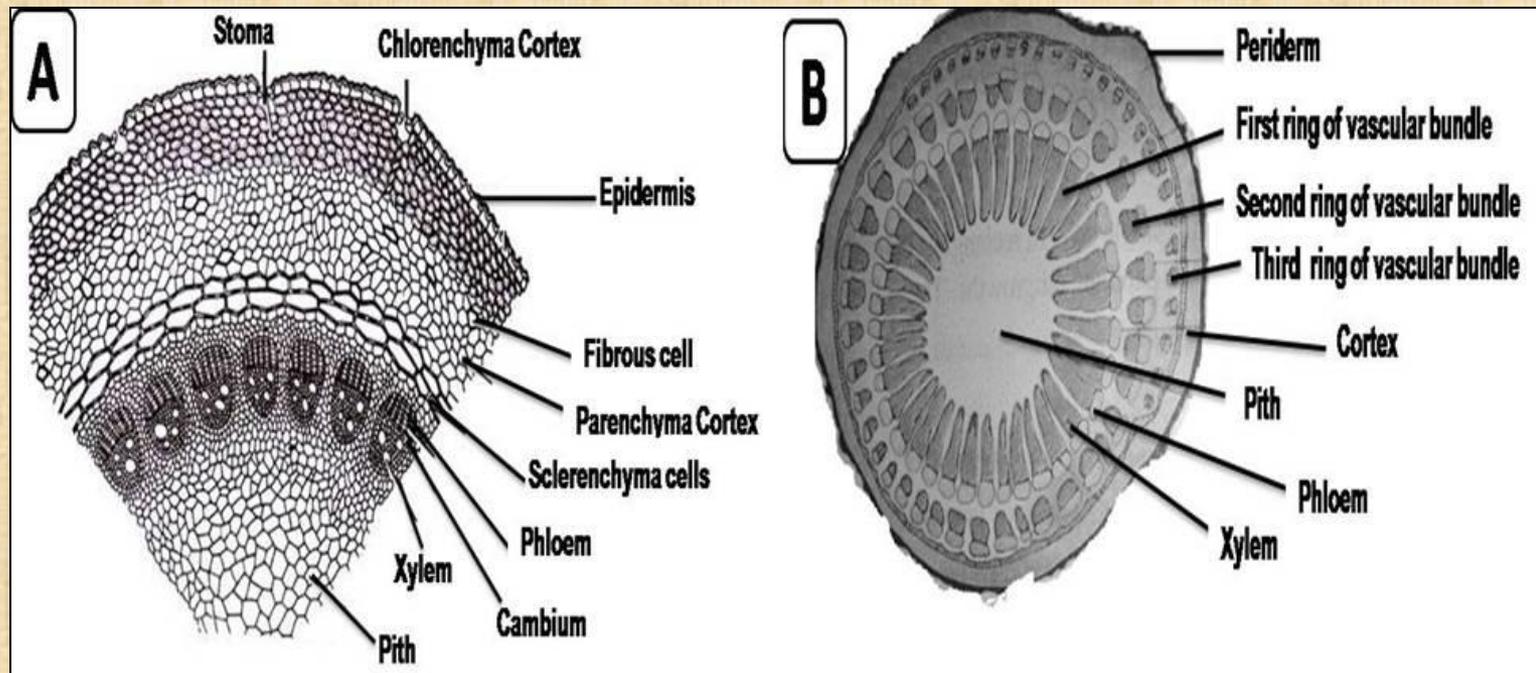
ANATOMY

Stem

In transverse section young stems appear to be roughly circular in outline and are quite similar to a typical dicotyledonous stem. A single-layered epidermis is present which consists of rectangular cells. Some cells of epidermis show papillate outgrowths. Stomata are sunken. Cortex consists of three regions; outer region is chlorenchymatous region which is 5-7 cells thick. Middle parenchymatous region is few cells thick and inner region is sclerenchymatous which is 2-4 cells thick. Endodermis and pericycle regions are not very clearly distinguishable. Young stem contains several vascular bundles which are arranged in a ring. These vascular bundles are conjoint, collateral, open and endarch. Xylem contains both tracheids and vessels. 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. Pith is extensive and consists of polygonal and parenchymatous cells.

Secondary growth is observed in old stems of *Gnetum*. The primary cambium is ephemeral i.e., short-lived. The secondary cambium in different parts of cortex develops in the form of successive rings. The first cambium cuts off secondary xylem towards inside and secondary phloem towards outside. This cambium ceases to function after some time. Another cambium gets differentiated along the outermost secondary phloem region, and the same process is repeated. During later stages, excess amount of secondary xylem is produced on one side and comparatively less on the other side due to which formation of eccentric rings of xylem and phloem occurs in the wood. (Such wood is the characteristic feature of angiospermic lianes). Periderm is thin contains lenticels and develops from the region of outer cortex. The cortex also contains chlorenchymatous and parenchymatous tissues and many sclereids. Secondary wood of older stems consists of tracheids and vessels. Tracheids contain bordered pits present on radial walls whereas vessels are characterized by presence of simple pits. Wood xylem and medullary rays can be clearly seen in tangential longitudinal section of stem. . Bordered pits are present on radial as well as tangential walls. Medullary rays consist of polygonal parenchymatous cells and can be either uniseriate or multiseriate.

Sieve cells of the phloem contain oblique and perforated sieve plates.

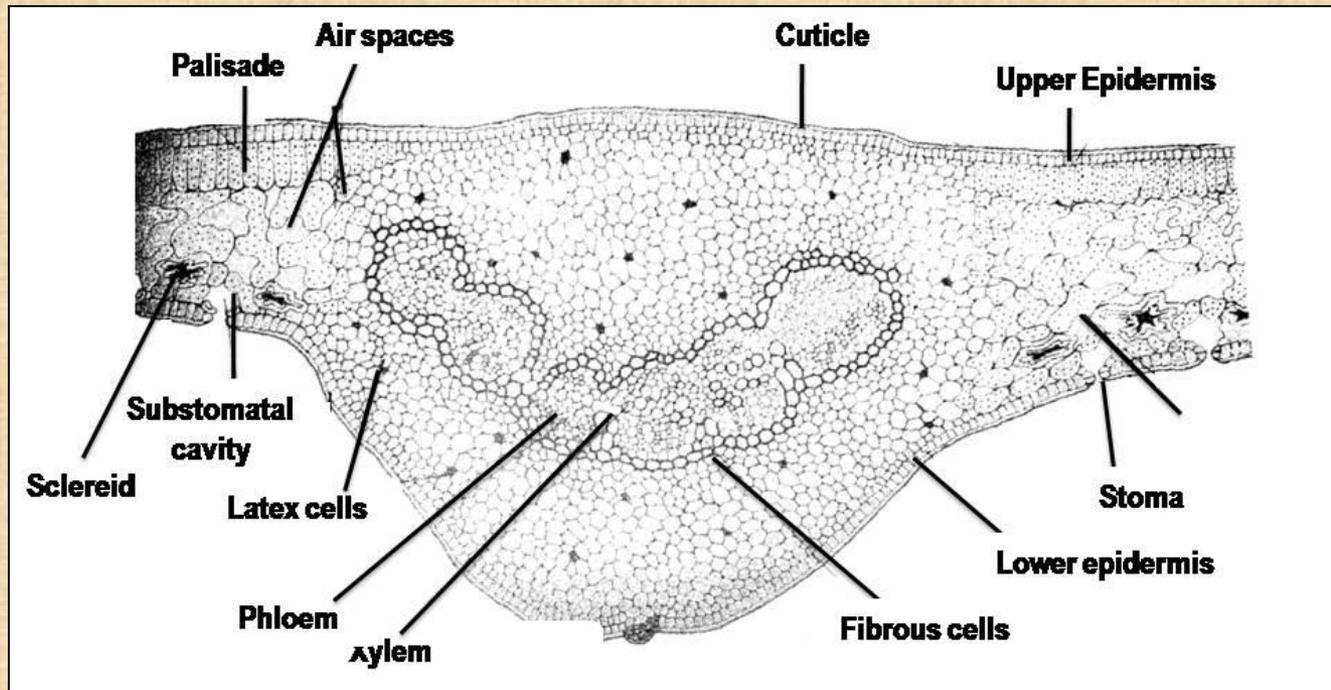


Gnetum, A- TS of young stem, B- TS of old stem

Leaf

Leaves of *Gnetum* are bifacial or dorsiventral and show resemblance with a dicot leaf. Upper and lower epidermis is covered with cuticle. Cuticle is thin on lower surface as compared to cuticle present on upper epidermis. Stomata are syndetocheilic and are distributed all over the lower epidermis except the region of midrib and veins. Maheshwari and Vasil reported stomata in *G. gnemon* and *G. ula* to be haplocheilic.

Mesophyll is differentiated into a single-layered palisade and spongy parenchyma. Palaside layer is full of chloroplast. Spongy parenchyma contains loosely-packed lobed cells which contain chloroplast, stellately branched sclereids which have thick and lignified walls, stone cells and latex tubes scattered in midrib region. In the midrib region are present several vascular bundles either in form of an arch or curve. Vascular bundles are conjoint and collateral. The xylem of each vascular bundle faces towards the upper surface and is made up of tracheids, vessels and xylem parenchyma. Phloem faces towards the lower surface and consists of sieve cells and phloem parenchyma.



T S of leaf of Gnetum

Root

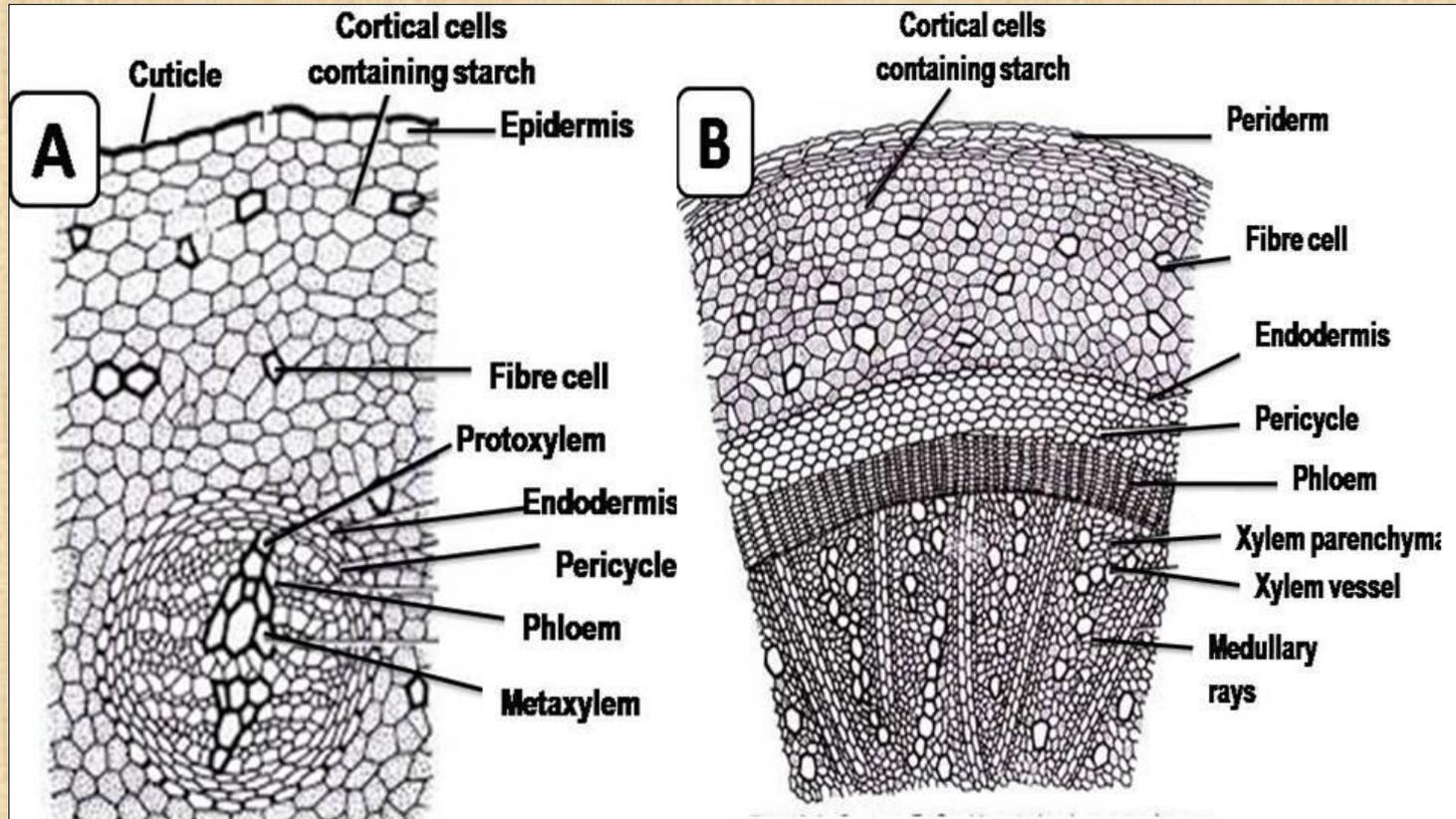
In young roots cortex is made up of several layers of parenchymatous cells. These cells are polygonal in outline and contain starch grains. Among the cortex cells are present groups of sclerenchymatous cells. A distinct endodermis and casparian strips are present. Cell of endodermis also contains starch grains. Pericycle consists of 4-6 layers of parenchymatous cells.

Vascular bundles are diarch and exarch. Primary xylem consists of fewer elements and its identity is lost after secondary growth. Roots exhibit normal secondary growth and a cambial arc is formed which is internal to phloem and external to xylem. Secondary xylem consists of tracheids, vessels and xylem parenchyma.

The tracheids are elongated cells having tapering ends and possess uniseriate bordered pits (present on radial and tangential walls) along with bars of Sanio. Vessels contain simple or small multiseriate bordered pits. Bars of Sanio are absent in vessels.

Phloem consists of sieve cells and phloem parenchyma. Parenchyma cells are living and have walls (thick or thin) with simple pits.

Parenchyma cells forms rows which alternate with those of sieve cells. Secondary medullary rays are multiseriate and made up of thin walled cells due to which wood of roots is soft.



Gnetum, A- T S of young root, B- T S of old root

Thank You