PLANT ANATOMY PRACTICAL Sem 2; CC3 BOTA (part 3)

1) Types of Stomata, Sclerides ,Raphides (Colocasia), Cystolith(Ficus) leaf, Starch grains, Aleurone grains, Laticiferous Ducts; Oil Glands…….. (Part 1). .
2) Study of anatomical details through permanent slides ;- Monocot & Dicot Roots; Monocot & Dicot Stem; Monocot & Dicot Leaf……..……..(Part 2).
3) Study of Anomalous Secondary Structures in Stem of Boerhaavia; Bignonia; Tecoma; Dracena; & Root of Tinospora……....(Part 3)
4) Study of Adaptive Anatomical features:- Hydrophytes (Nymphaea petiole); Xerophyte (Nerium leaf)..... .....(Part 3)

ANOMALOUS SECONDARY GROWTH

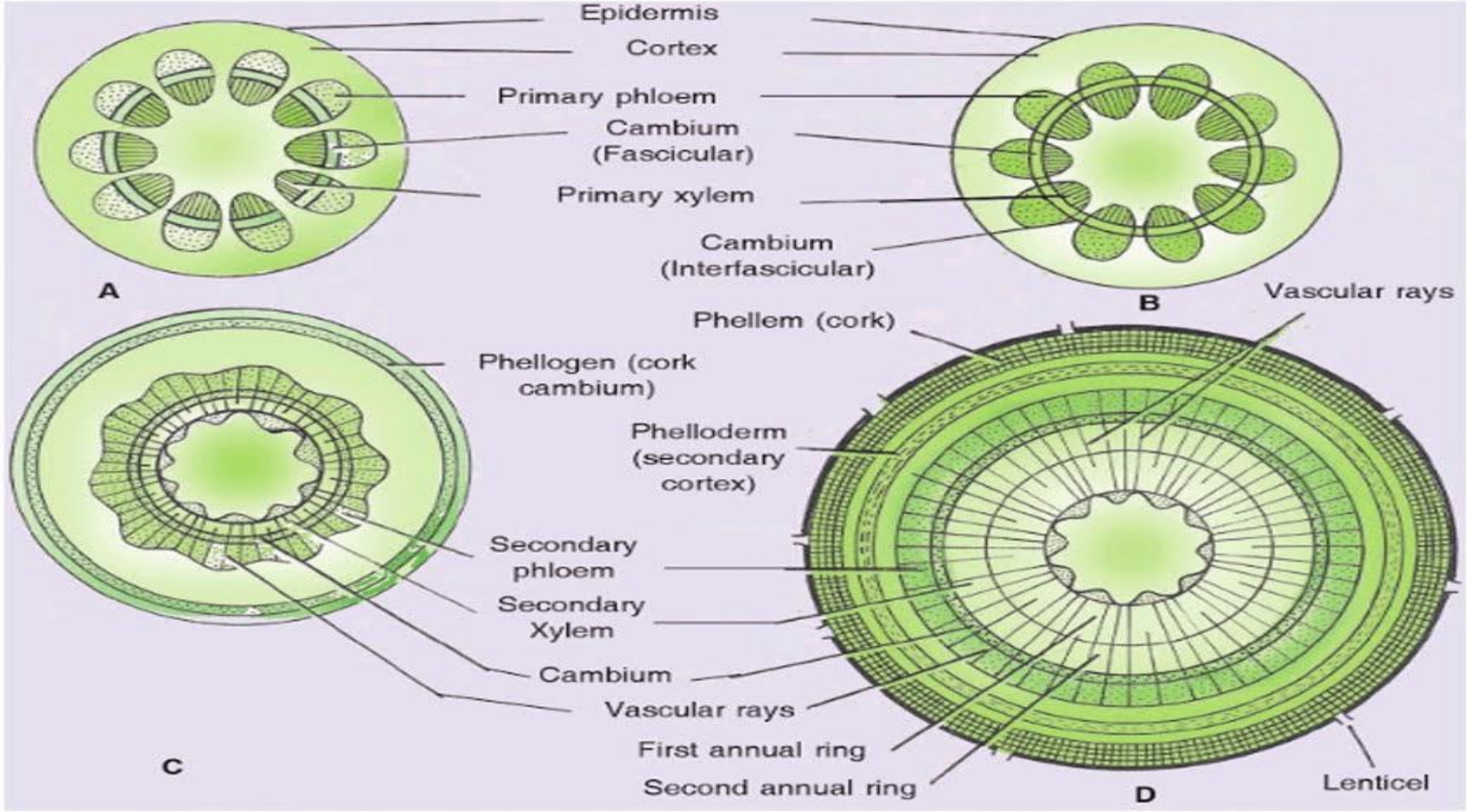
Shoot System: Secondary Growth in Stem, Activity of Vascular and Cork Cambium

Secondary Growth in Stem

Secondary growth occurs only in dicot stem a little away from the shoot apex and helps the plant to grow in girth (thickness) and makes it very strong to stand upright for many years. The growth in thickness becomes possible due to formation of some new tissues entirely by the activities of the lateral meristems. There are two types of lateral meristem: vascular cambium and cork cambium or Phellogen. These tissues are known as secondary tissues and the growth in girth or thickness thus accomplished is referred to as secondary growth.

Activity of Vascular Cambium

The secondary tissue produced by the vascular cambium is called the secondary xylem and secondary phloem. A few living parenchyma cells of the medullary rays, which retained the potentialities of cells division and new strips of meristems, are formed in a line with the fascicular cambium. They are known as interfascicular cambium. It is secondary in origin and joins up with the fascicular cambium and thus a distinct continuous cambium ring is formed. Cambium divides and adds cells on internal side (towards pith) which mature into secondary xylem and cells added towards external side (periphery) mature into secondary phloem. Amount of secondary xylem produced is more than secondary phloem.



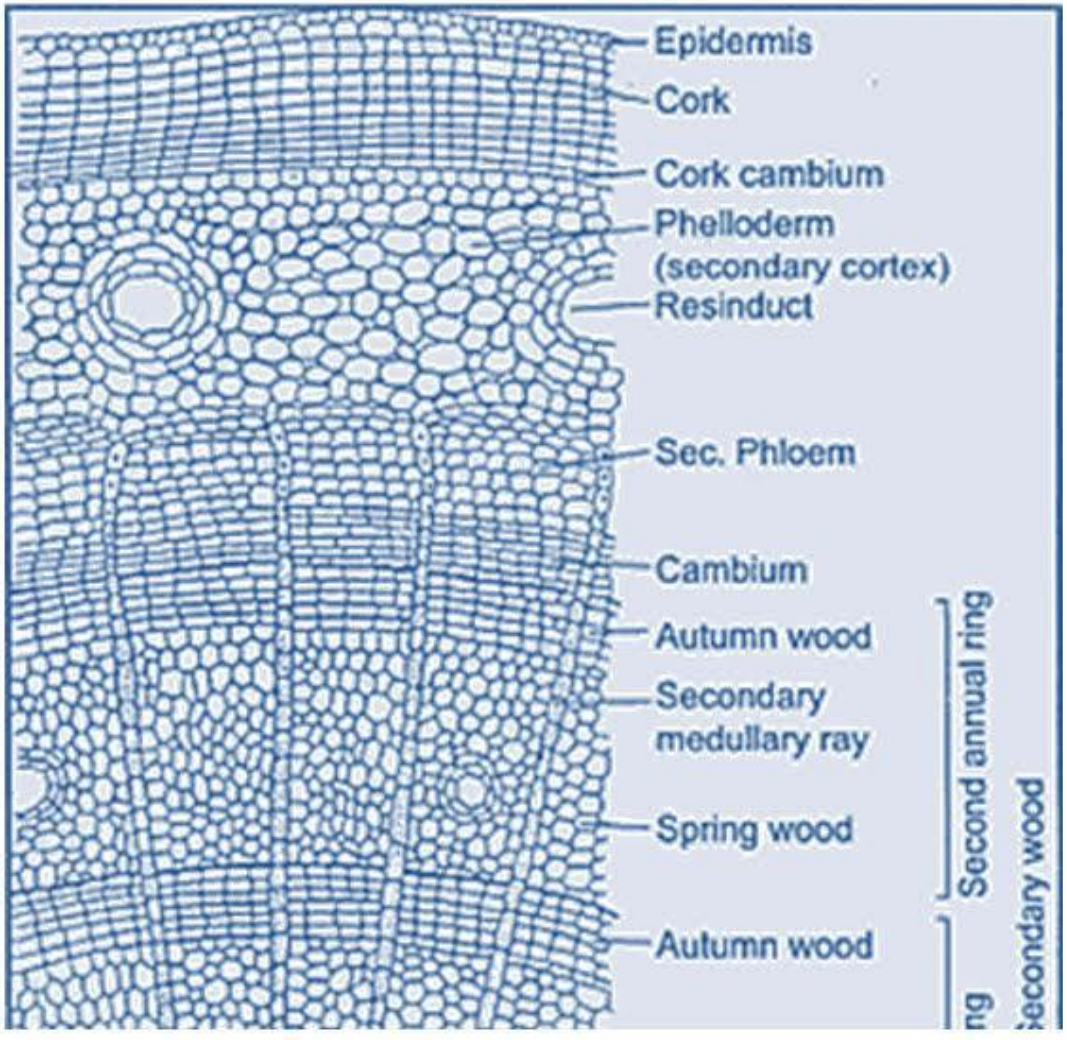
Activity of Cork Cambium

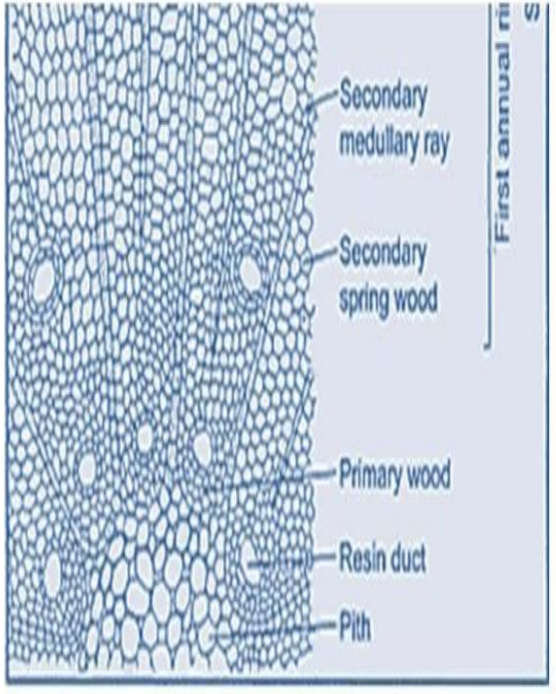
- The cork cambium (Phellogen) is the lateral meristem that produces cork or Phellem towards the outside and secondary cortex or Phelloderm towards the inner side. The cork cells or Phellem are waxy, impregnated with suberin, a lipid material that makes them waterproof but also causes them to die. Areas of loosely packed cells penetrate cork layers and enable gas exchange to occur. Phelloderm consists of living

1

parenchyma cells, which may be photosynthetic and store nutrients. Phellogen produces much more Phellem on the outerside than Phelloderm on the inner. The cells constituting Phellem or called cork cells.

- Phellogen, Phelloderm and Phellem together constitute the periderm. Due to internal increase in thickness, periderm replaces the epidermis, becomes protective in function. All the dead cells lying outside the active Phellogen constitute the bark.





In Betula bhojpatra bark peels off like sheets of paper. Ancient manuscripts are still preserved on them. Cork tissue becomes very thick in Cork tree (Quercus suber) and is used commercially as, bottle-stoppers, insulators, shoe soles etc.

Anonalous Secondary Growth

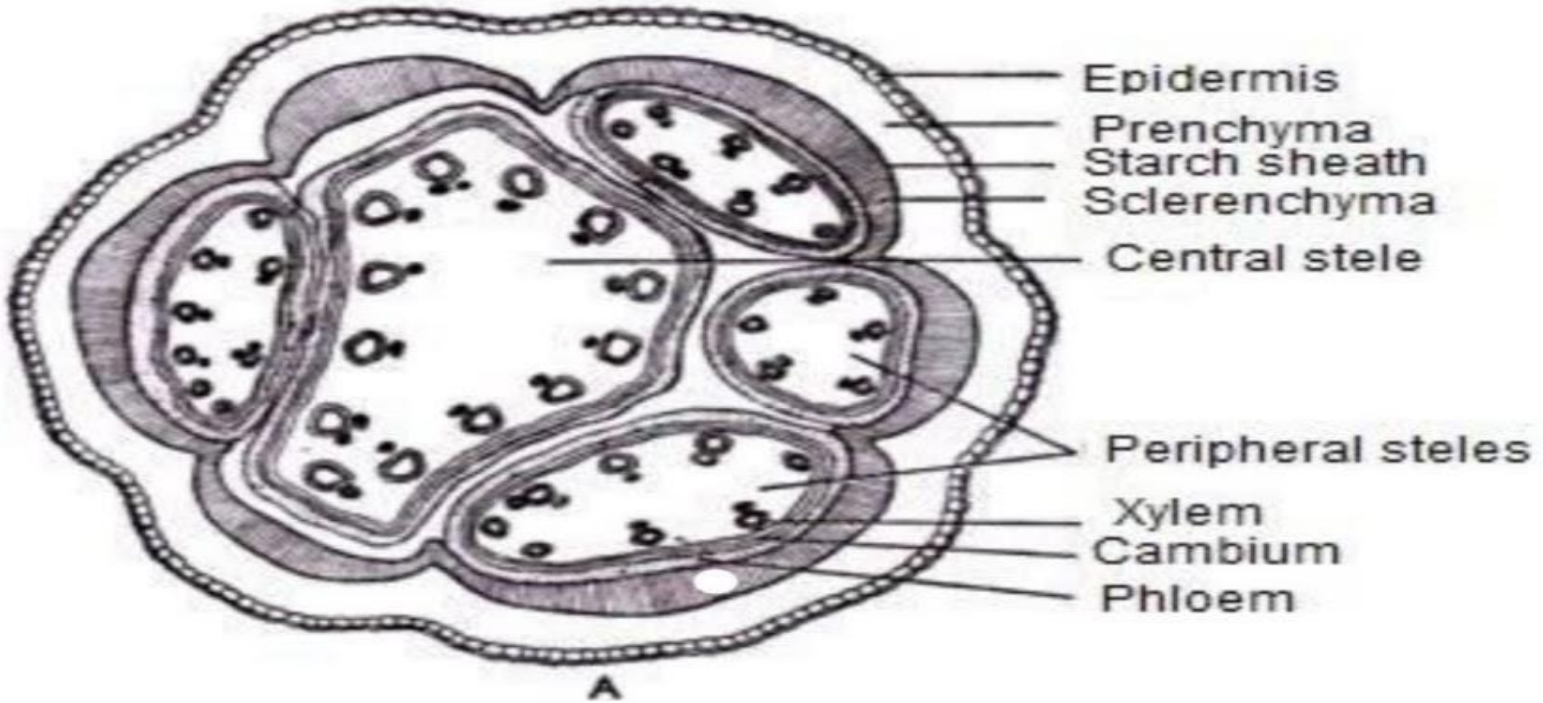
Several dicotyledons show secondary growth that is different from **normal** secondary growth. The deviating methods of secondary thickening are called **abnormal or anomalous** secondary growth. In **dicot** stem anomalous secondary growth occurs due to following reasons:

1. Anomalous position of **cambium**
2. **Accessory cambium** formation and its activities
3. Abnormal behavior of **normal cambium**
4. **Extrastelar cambium** formation
5. **Interxylary phloem** or **included phloem**

1. Anomalous position of cambium

In this case, the **position** of cambium is **anomalous** but the **activity** of cambium is **normal**. e.g. ***Serjania sp.*** Here secondary growth occurs due to the anomalous position of cambium. A very **peculiar** structure is noticed in ***Serjania***, a climber of family **Sapindaceae**, where the cambium from the very beginning occurs in separate strips, each strip having primary xylem towards the center and primary phloem towards the periphery. It thus appears like a **deeply-lobed** compound structure made of several stems fused together. With age and consequent development of periderm the compound structure becomes more marked. The development of interfascicular cambium and its union with fascicular ones result in the formation of **separate cambium rings**. In fact, there is a large central stele, surrounded by a few peripheral

ones.



T.S. of stem (Serjania sp.)

2. Accessory cambium formation and its activity

- In the stem of ***Baugainvillea*** and others member of the **Nyctaginaceae** (e.g., ***Boerhaavia,*** **Mirabilis** etc.) several cambia arise successively in a **centrifugal** direction. Each cambium produces xylem and **conjunctive** tissue to the inside and phloem and conjunctive tissue to the outside. The resulting tissue gives the appearance of **concentric ring** of vascular bundle embedded in conjunctive tissue.
- The TS of ***Boerhaavia diffusa*** show two medullary bundles, a middle ring of **6-10 vascular bundle** and another ring of **15-20** or more small bundle. The bundle of the middle ring increase in thickness to a limited extent by a fascicular cambium. The bundle of the outer ring are initially separate, quite small and each provided with its own **fascicular cambium**. The fascicular cambium of the bundle becomes interconnected by interfascicular cambium.

Anomalous secondary growth in *Boerhaavia* Stem

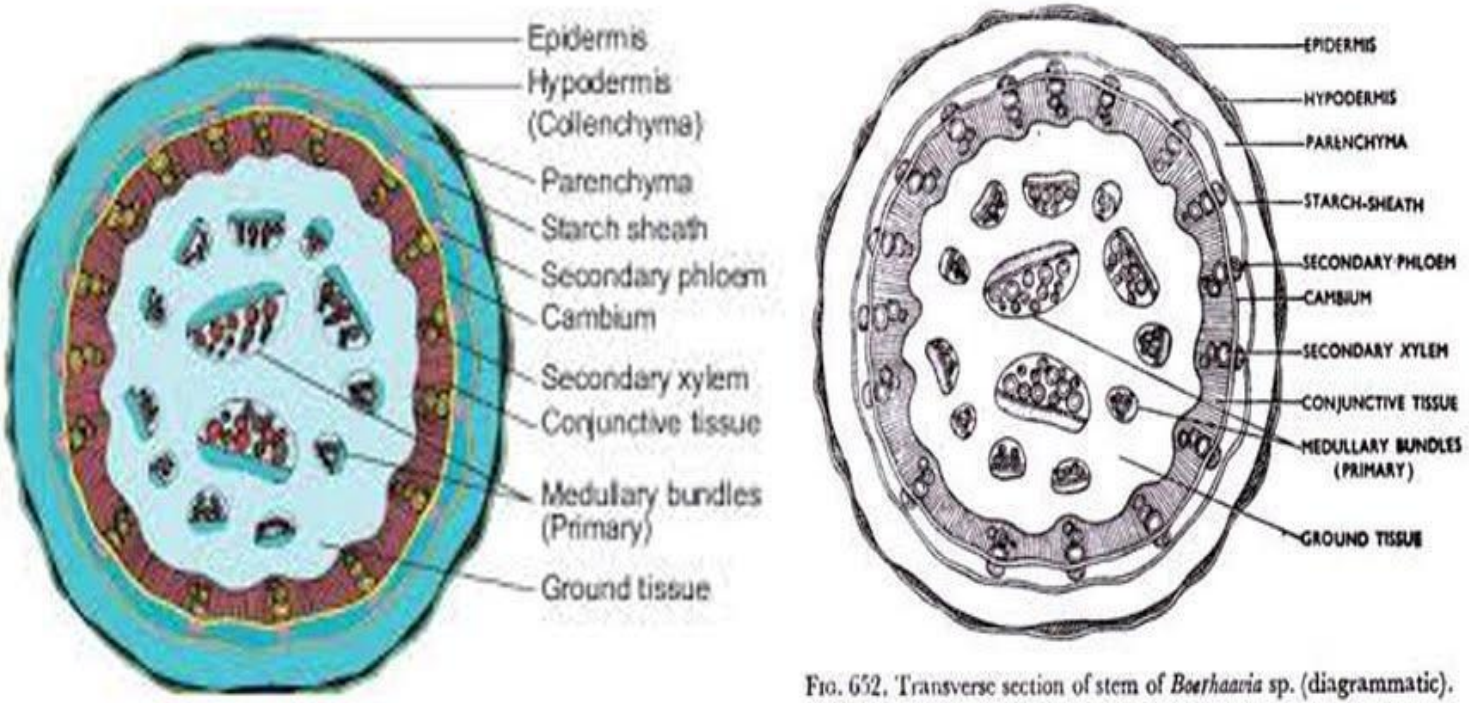


FIG. 652. Transverse section of stem of *Boerhaavia* sp. (diagrammatic).

Secondary growth in ***Boerhaavia*** **stem** is not typical of that found in **dicotyledonous** stem. In this plant the **cambium** is **accessory in position** but **normal in activity.**

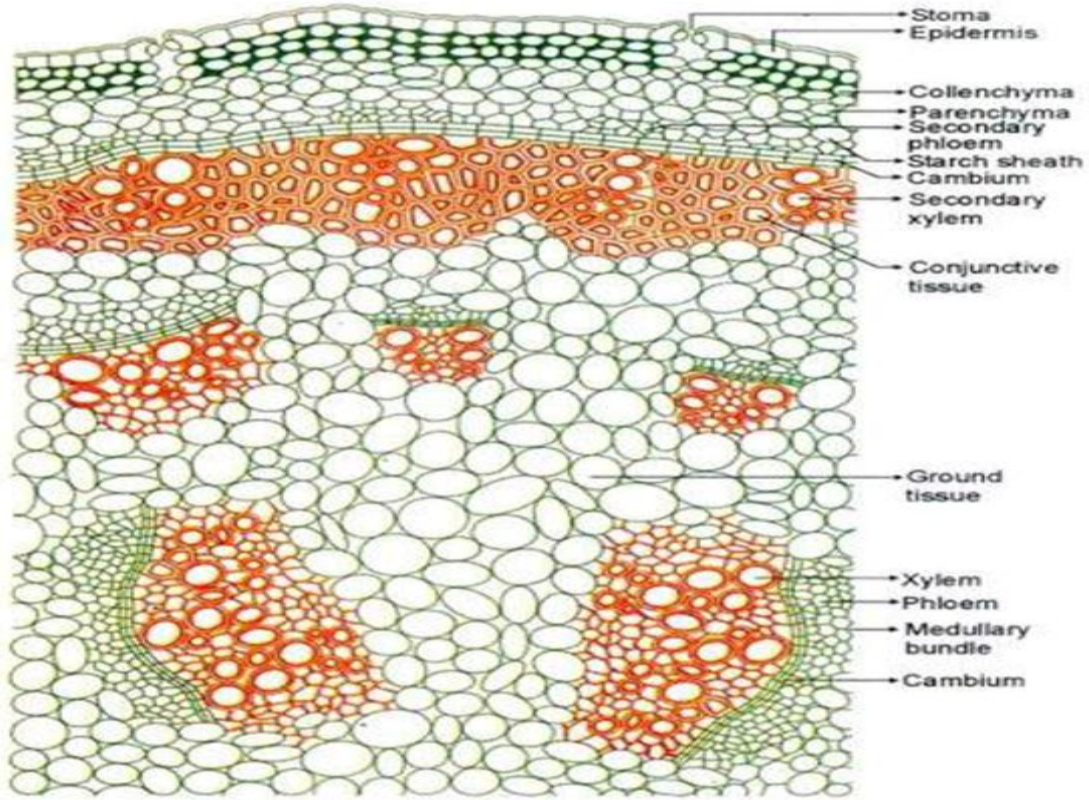
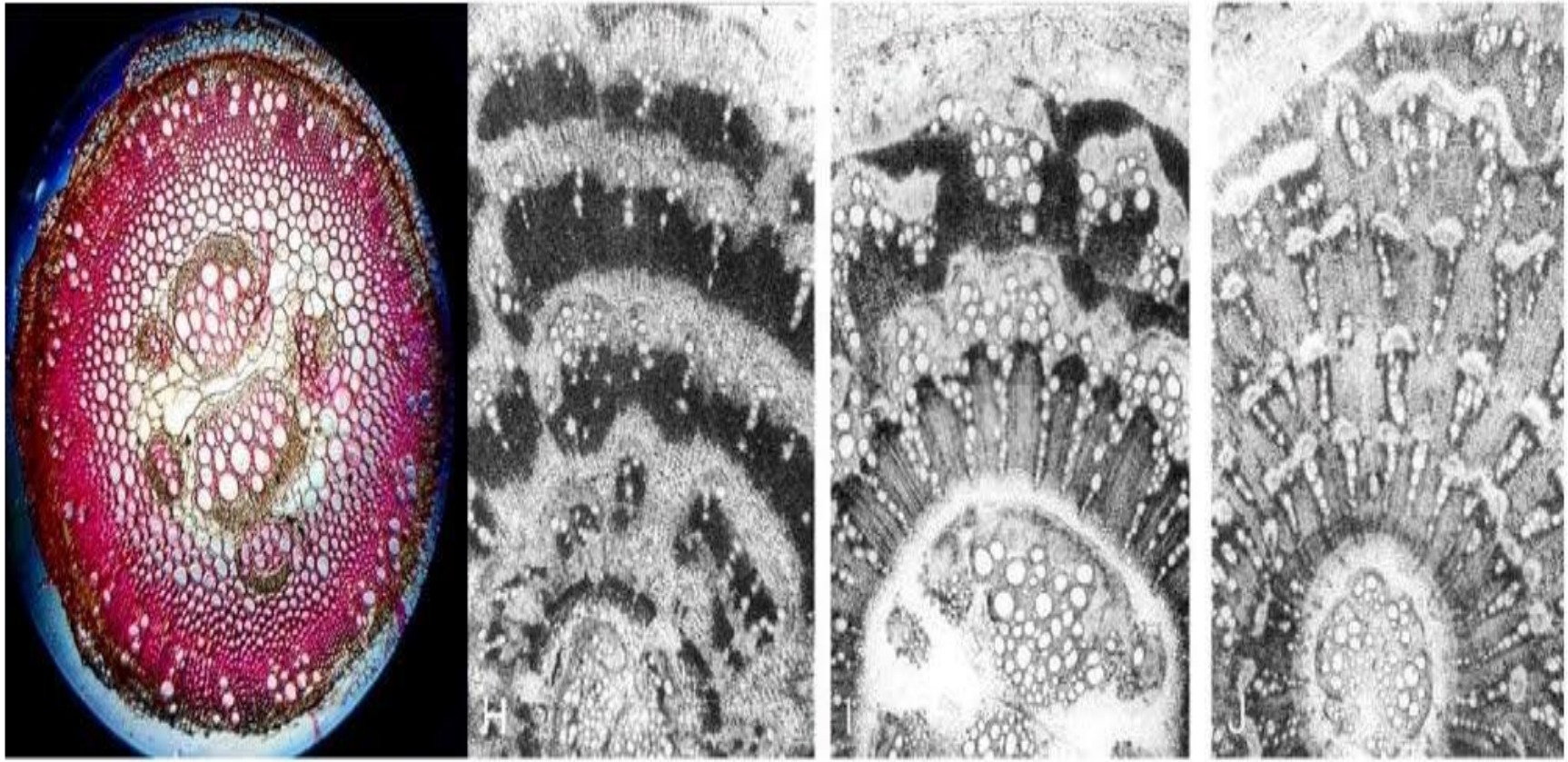


Figure 31.18
A portion of transverse section of *Boerhaavia* stem.

- Anomaly due to formation of **accessory cambium**
- Vascular Bundles (VB) arranged in ring normally or remain scattered irregularly in ground tissue forming **medullary bundles**.
- VB are **open collateral**
- Fascicular cambium- either inactive, or cease activity after sometime
- Later **secondary accessory cambium** arises in the pericycle region, just on outer side of bundles.
- This Secondary cambium cuts off **centripetally new VBs embedded in conjunctive tissue**, intra-fascicular tissue or intermediate tissue.
- **Conjunctive tissue** either thin walled **parenchyma** or thick walled **lignified cells without intercellular space**.
- No or very little parenchyma tissue added on outside by this accessory cambium
- Secondary VB may be arranged in concentric ring or scattered.

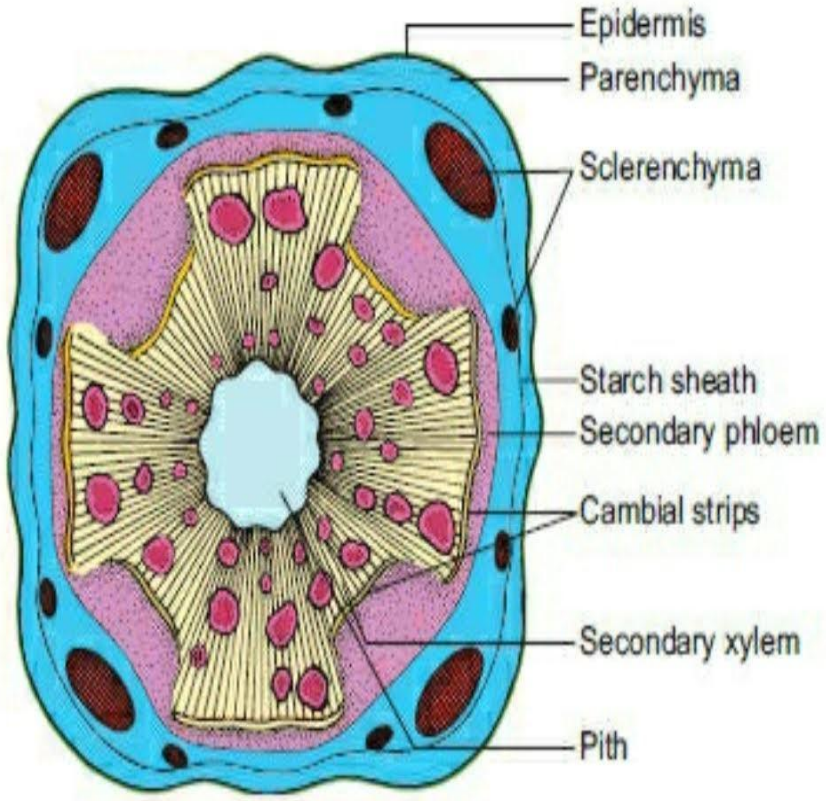
T.S. of *Boerhaavia* stem



- The stem shows anomalous secondary growth characterised by the development of successive rings of xylem and phloem.
- The cambium is exclusively composed of fusiform initials giving rise to rayless secondary vascular tissues.
- While undergoing periclinal divisions cambium appeared nonstoried but remained storied when the divisions ceased.
- Each successive ring of cambium was originated from the outermost phloem parenchyma cells.
- The cambial ring was functionally segmented into fascicular and interfascicular regions, the former mainly producing conducting elements of xylem and phloem and the latter giving rise to parenchyma cells.
- The parenchyma cells on the xylem side developed into conjunctive tissue following thickening and lignification of cell walls. However, in *B. verticillata* and *B. rependa* the parenchyma cells on the pholem side also became lignified. In *B. diffusa* parenchyma cells did not undergo lignification. As a result, alternate bands of lignified and parenchyma bands became distinct in the stem.
- Vessel elements were short with simple perforation plate on slightly oblique to transverse end wall.
- Sieve tube members were slightly shorter as compared to the fusiform cambial cells.

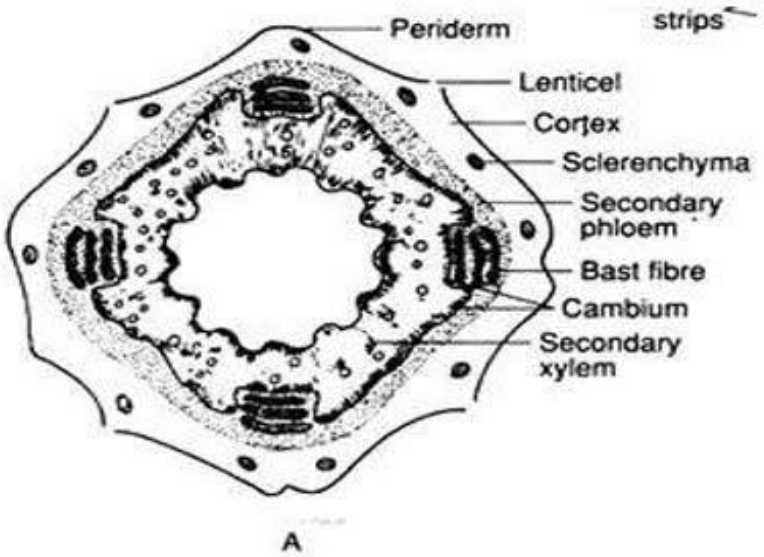
3. Abnormal behavior of normal cambium

Sometimes when the normal cambium starts to cutting cell at several places **irregularly** and forms at certain places much larger portion of xylem and a **ridge** and furrowed **xylem cylinder** produced. This may be of simple structure or very complex. e.g. ***Bignonia sp.***



T.S. of Bignonia sp. Showing anomalous growth. Details

Anomalous secondary growth in *Bignonia* Stem



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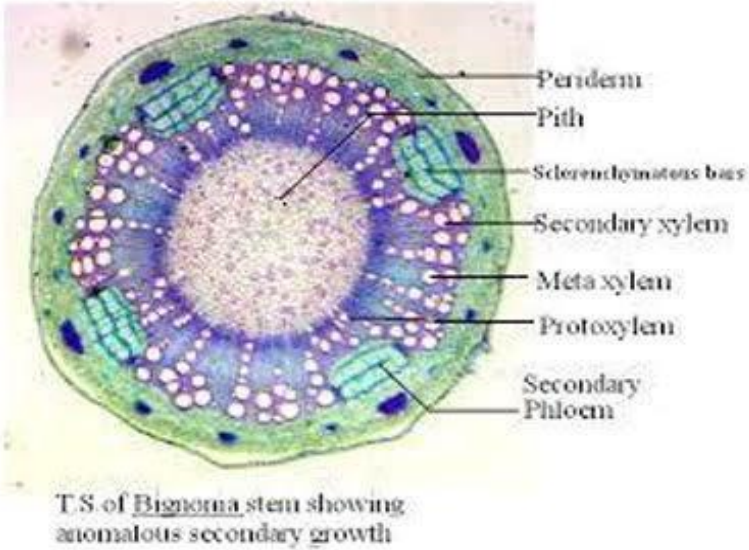
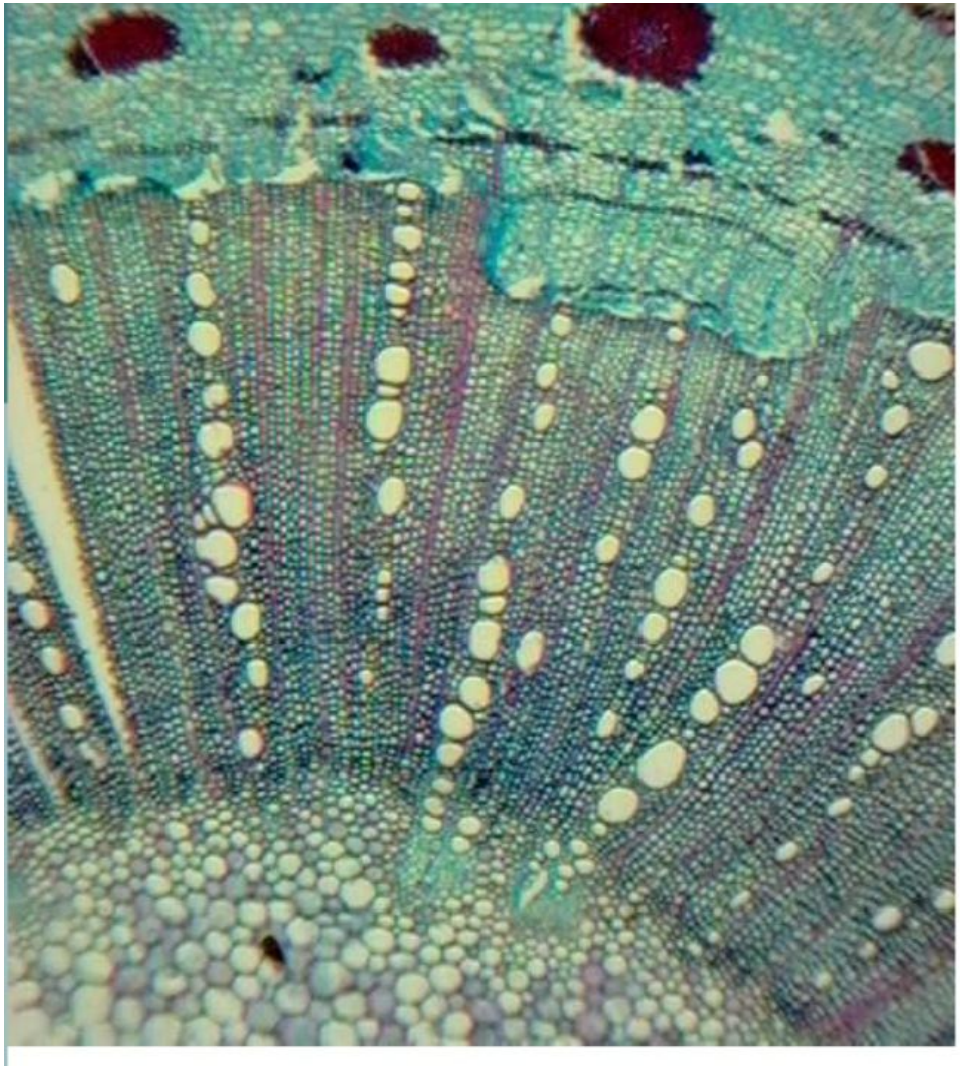


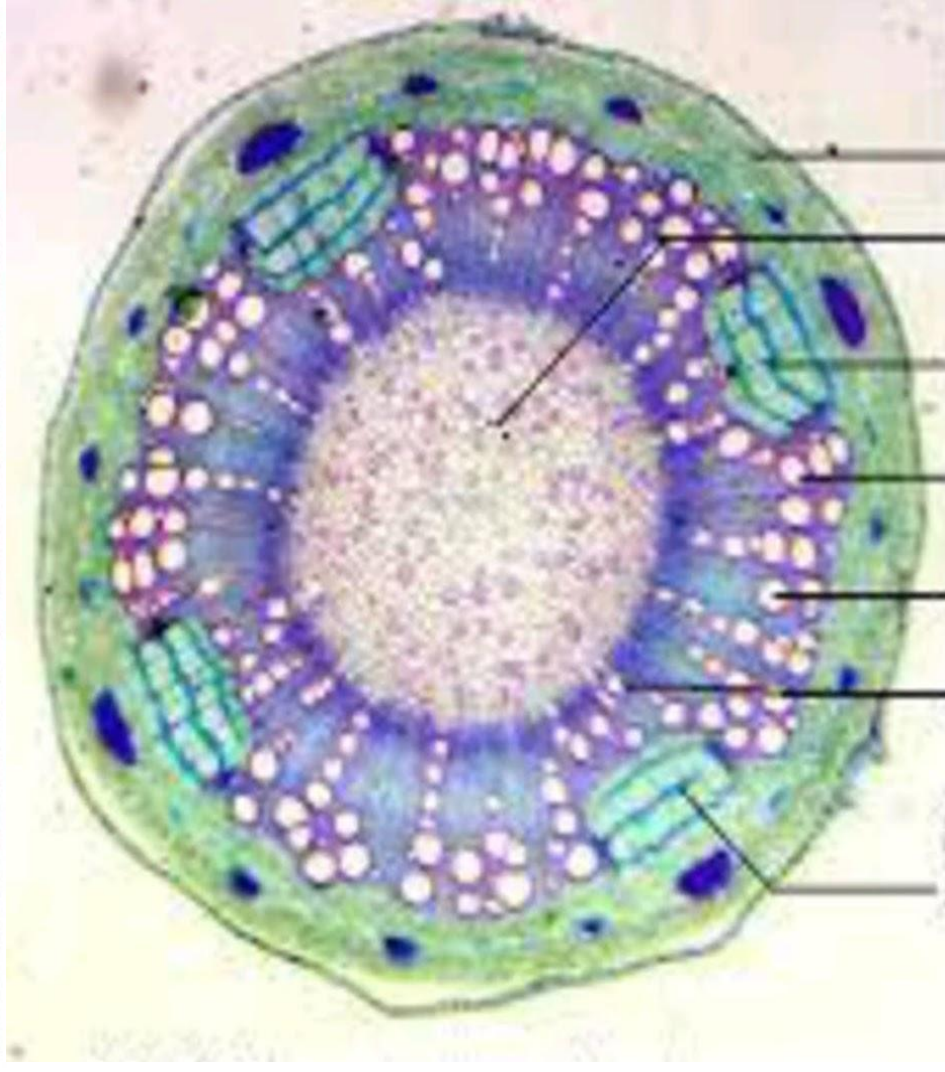
T.S of Bignonia stem showing anomalous secondary growth

- Secondary growth in ***Bignonia*** **stem** is not typical of that found in **dicotyledonous** stem. In this plant the **cambium** is **normal in position** but **abnormal in activity.**
- In some plants like *Bignonia* and other members of the family Bignoniaceae, the cambium is normal in position and activity for the first time, but immediately it cuts off different proportions of xylem and phloem at four alternative points in form of a cross.

- The cambium produces secondary xylem and secondary phloem in **variable quantities**; in some segments much greater amount of xylem than of phloem and in others more phloem than xylem.
- As a result, a characteristic structure is formed with ridged and furrowed xylem cylinder.
- The ridges are wider than the grooves.
- In the secondary phloem formed in the grooves, parallel strips of bast fibres are formed.
- The cambium breaks up into a number of strips, the wider ones remain on top of the ridges and narrower ones remain at the base of the grooves.
- The number of wedges formed is usually four in number, symmetrically arranged corresponding in position to the larger primary vascular bundle.

This is a kind of adaptive anomaly, as *Bignonia* is a woody climber.





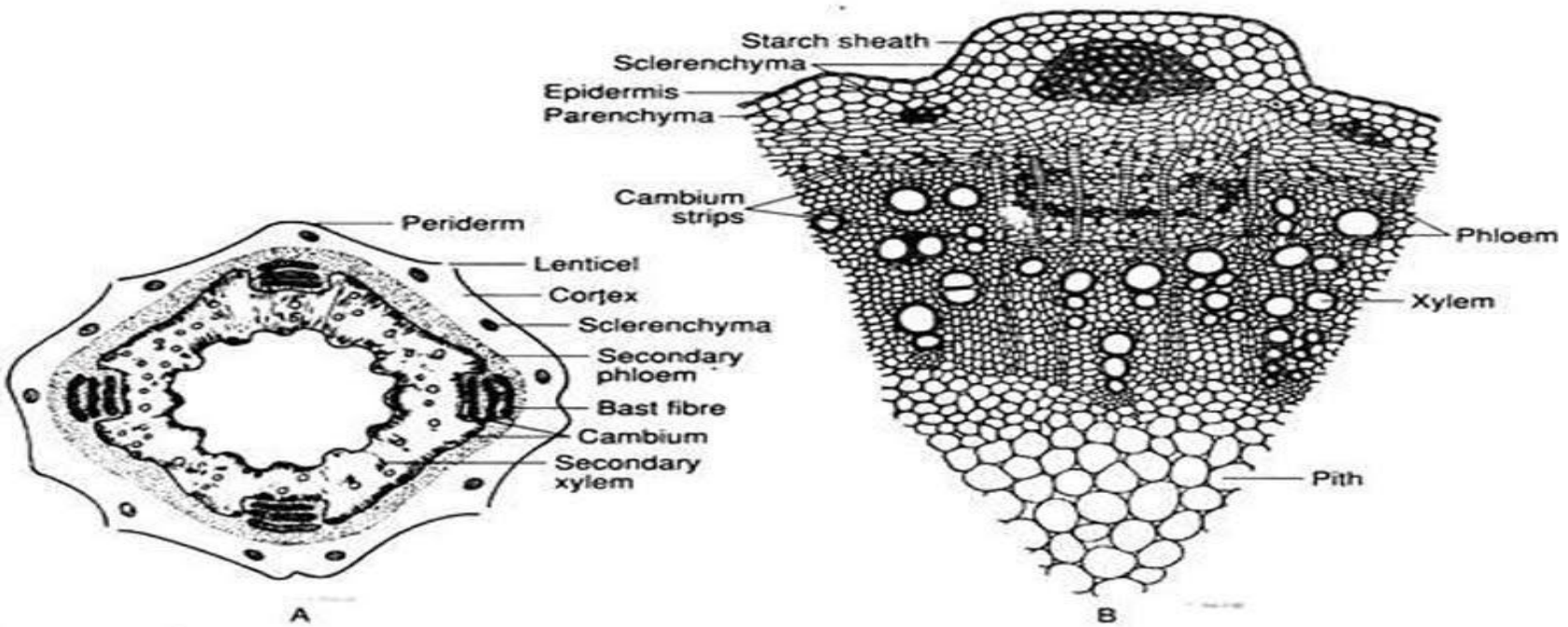


Fig. 5.147 : Transverse section of stem of *Bignonia* showing the anomalous secondary growth in thickness. A. Diagrammatic view of the whole transverse section of the same. B. Cellular drawing of a portion of the same

T. S. shows many ridges and furrows and reveals the following tissues from outside within:

Epidermis:

1. Single-layered epidermis consists of rectangular cells.
2. A thick cuticle is present.
3. A few multicellular hairs are also arising from some cells.

Cortex:

4. It is well-differentiated into collenchyma and parenchyma.
5. Collenchyma is present below the epidermis in the ridges in young stem but at maturity there develops sclerenchyma.
6. Parenchyma is present below the sclerenchyma or collenchyma in the ridges and directly below the epidermis in the grooves.
7. In old stem cortex consists of cork, cork cambium and cortex.
8. Endodermis is undistinguishable from cortical cells. The cells lack casparian strips.

Pericycle:

9. It is in sclerenchymatous patches.

Vascular system:

10. Phloem, secondary phloem, xylem and primary xylem constitute the vascular bundles along with the cambium.
11. Four longitudinal furrows of secondary phloem are present which are wedged in between the secondary xylem cylinder.
12. Vascular bundles are conjoint, collateral, open and endarch.

13. Primary phloem is crushed and present in small patches.
14. Secondary phloem is in the form of a ring which remains intruded into the secondary xylem at four places.
15. Intruded furrows (four) of secondary phloem are arranged in the form of a cross.
16. In *Bignonia*, bars of sclerenchyma are present in the furrows of secondary phloem.
17. Cambium is single layered, present in between xylem and phloem and bent towards inner side along the furrows of secondary phloem.
18. Secondary xylem consists of vessels, tracheids, fibres and xylem parenchyma.
19. Due to the intrusion of the phloem at four places, secondary xylem is ridged and furrowed at four places.
20. Primary xylem is present close to the pith facing its protoxylem towards the centre. It's location is just opposite to the patches of primary phloem.

Pith:

21. It is thin walled and parenchymatous.

Secondary Growth:

Formation of four furrows of secondary phloem in the secondary xylem is due to the abnormal functioning of cambium which was behaving normally sometimes earlier.

At four or more places cambium produces less amount of secondary xylem towards inter side and large amount of secondary phloem towards outer side. Thus four wedges of secondary phloem are formed. They intrude into the secondary xylem and so xylem cylinder appears ridged and furrowed.

Identification:

(a) Presence of vessels in the xylem.....Angiosperms

(b) Multicellular epidermal hairs

Conjoint, collateral, open and endarch vascular bundles..... Stem

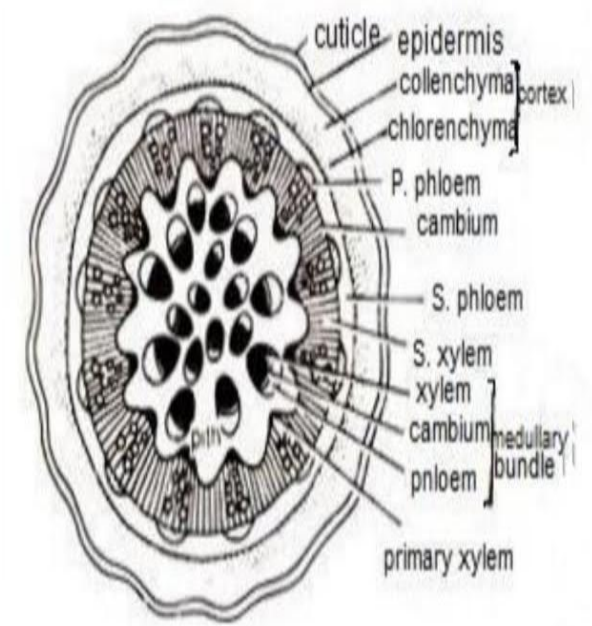
(c) Vascular bundles in a ring.

Presence of cambium..... Dicot Stem

Reference

4. Extra-stelar cambium formation

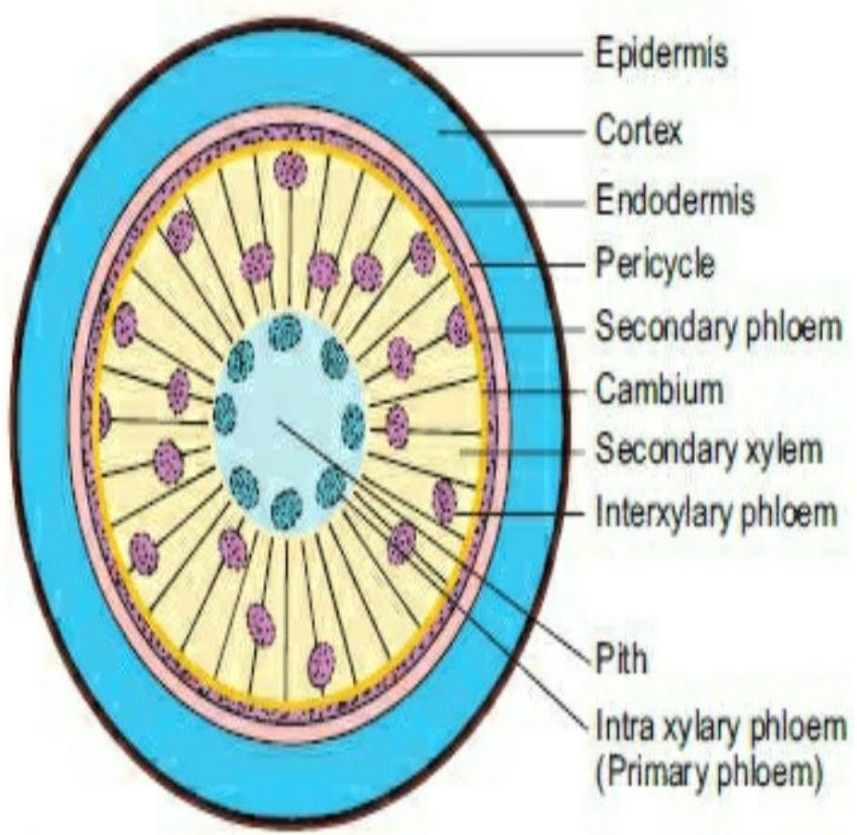
Medullary vascular bundle present. **Medullary** vascular bundle which are many and scattered in the pith. Bundles are open and collateral. **Cambial activity** is only found in individual bundle. The cambial activity ceases in this bundle. Anomalous secondary growth takes place due to the development of a new **extra-stelar** cambium formation outside the stele in the pericycle region. Cambium cuts off secondary **vascular** bundle and **interfascicular parenchymatous conjunctive tissue** on the inner side. e.g. ***Amaranthus sp.***



Anomalous secondary growth of ***Amaranthus sp.***

5. Interxylary phloem or included phloem

Interxylary phloem is defined as strands or **bands of phloem** embedded within the secondary xylem of a stem of a plant. Anomalous secondary growth occurs due to the anomalous activity of cambium. Some parts of cambium ring is identified as **cambial strip**. This cambial strip produce secondary phloem instead of secondary xylem on the inner side. Due to this anomalous activities of cambial strip secondary phloem embedded in the secondary xylem. Then cambium produce secondary xylem on the inner side. The presence of phloem strands embedded within the secondary xylem is called inter-xylary phloem or included phloem. e.g. ***Entada sp, Combretum sp, Strychnos sp.***

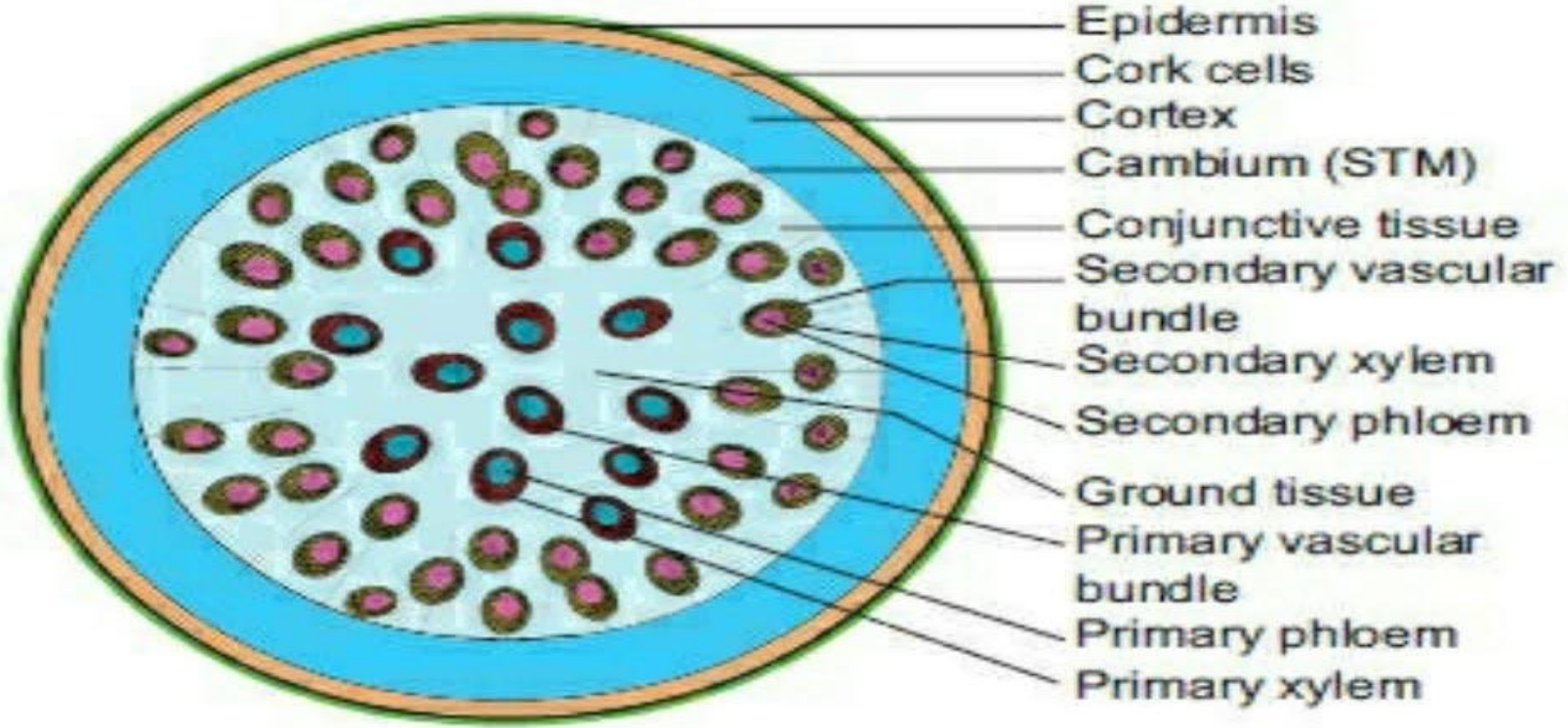


T.S. of Strychnos stem.

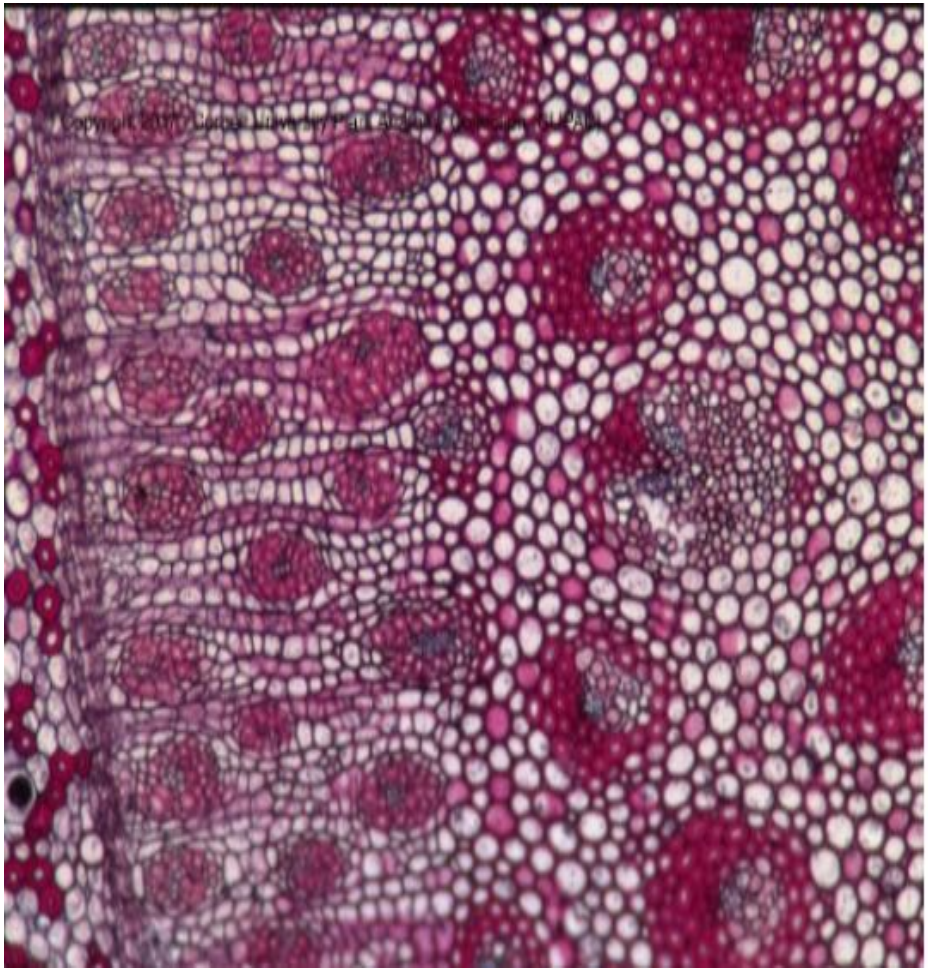
Anomalous Secondary growth in monocot stem

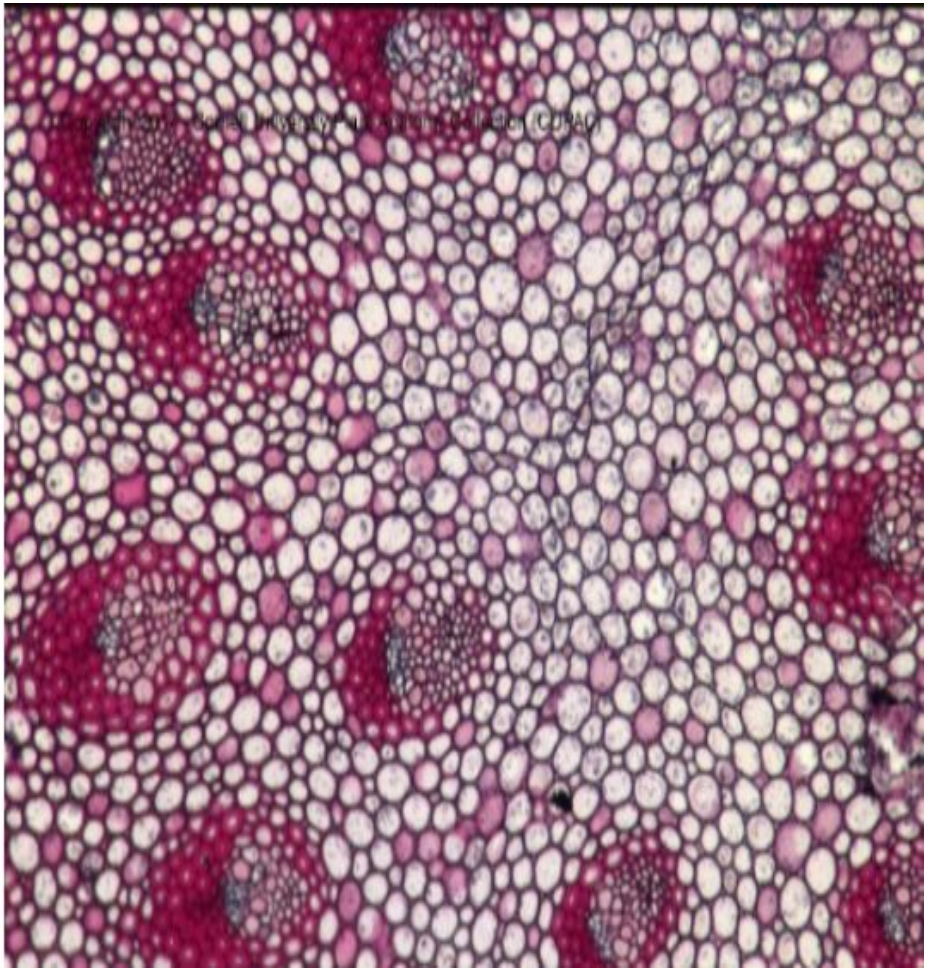
Secondary growth occurs in **herbaceous woody liliflorae (Aloe, Agave).** In ***Dracaena*** and other groups of **monocot** (**Cheadle 1937**), the meristem concerned with this growth is called **cambium**. The cambium originates in the parenchyma outside the vascular bundles. This part is identified as **cortex**.

Dracaena shows anomalous secondary growth where the cambium appears in the parenchyma cells outside the vascular bundle. This region in which cambium appears identify as cortex. These newly formed cambium cuts cells towards outside and inside both. The tissue develops in the inner side of the cambium is differentiated into secondary vascular bundle remain separated by each other by lignified cell.



T.S. of Dracaena sp. showing anomalous growth. Details



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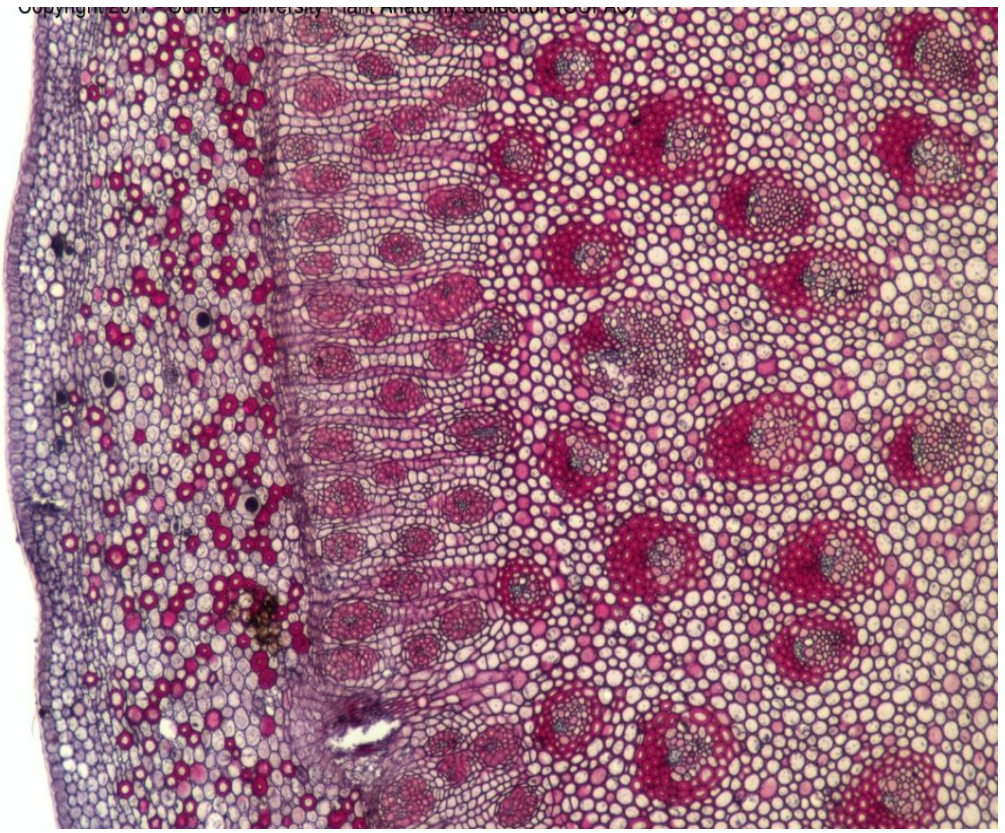
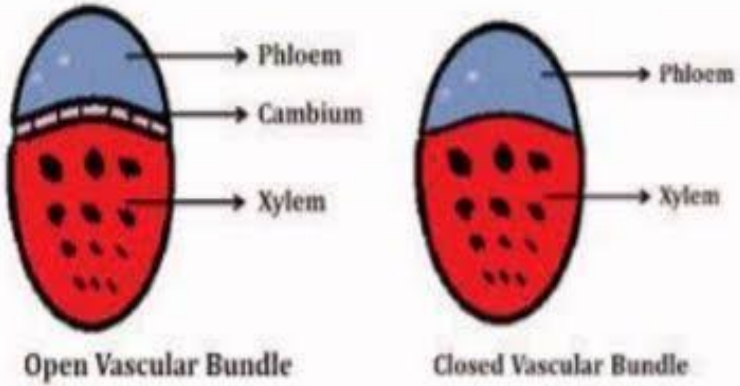


The monocotyledonous have **closed vascular bundles** as they lack intra-fascicular cambium (meristematic tissue between xylem and phloem).



Due to absence of the cambium monocots lack secondary growth and the vascular system is wholly composed of primary tissues also the bundles remain irregularly scattered in the ground tissues where the limits of cortex and other ground tissues can be hardly discerned.

Dracaena, a monocot that belong to the order Liliales, family Agavaceae, is arborescent. It exhibits a peculiar type of secondary increase in thickness. It is to note that in *Dracaena* anomalous secondary thickening is brought about by a special cambium—termed **secondary thickening meristem**. Due to the activity of this meristem conjunctive tissue and secondary vascular bundles originate. The continuous activity of the meristem results in the formation of indefinite amount of secondary tissues.

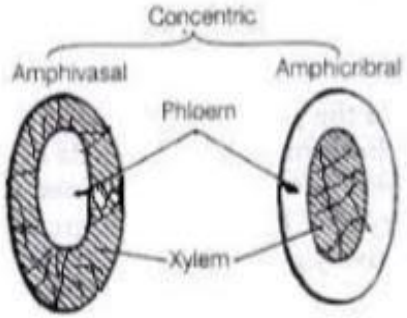
Young stem has:

Single layered paranchymatous epidermis.

Sclerenchymatous hypodermis present below the epidermis.

Ground tissue is paranchymatous and not differentiated.

Vascular bundle - Many irregularly arranged amphivasal closed vascular bundle distributed in ground tissue. These primary vascular bundles are not compactly arranged. Each vascular bundle is circular or oval in transverse section. The primary bundles are comparatively larger.

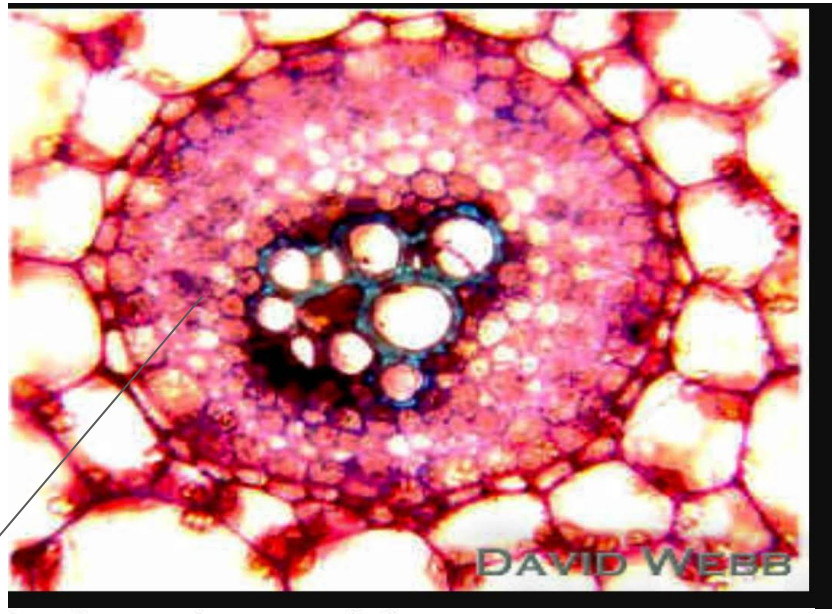


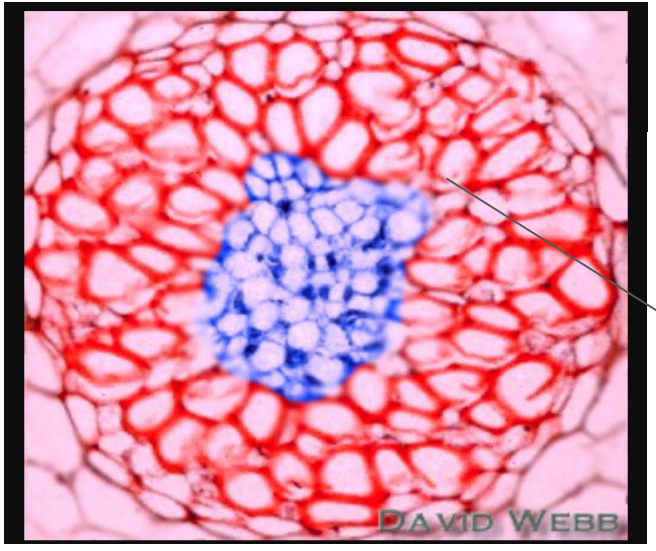
CONCENTRIC vascular bundle can be-

Amphivasal vascular bundle i.e. the xylem completely surrounds phloem and there exists no intra-fascicular cambium.

Amphicribal vascular bundle i.e. the phloem completely surrounds xylem and there exists no intra-fascicular cambium

3. Concentric bundle *- When either phloem surrounds the xylem or vica versa i.e., one type of vscular tissue completely encircles the other , it is termed to be as concentric bundle. It is of two types :-*





a) Amphicribal - When phloem tissue surrounds the central xylem tissue.(D)

b) Amphivasal - When xylem tissue surrounds the central phloem tissue.

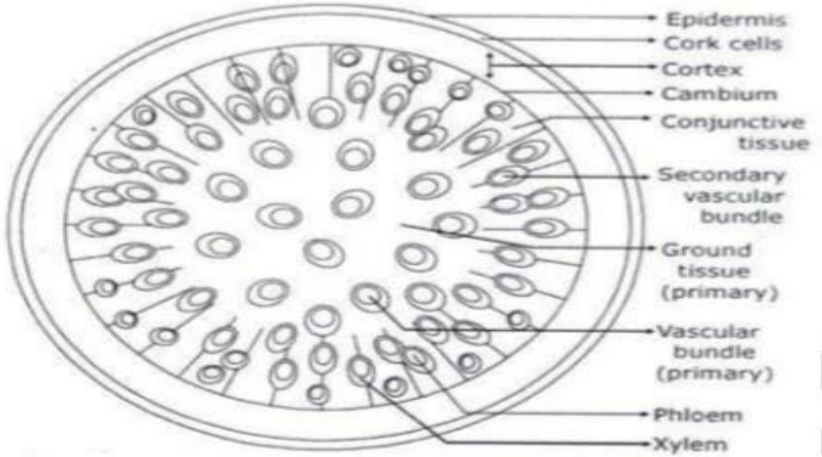
Anomalous Growth:

Showing secondary growth by monocot is itself an anomaly.

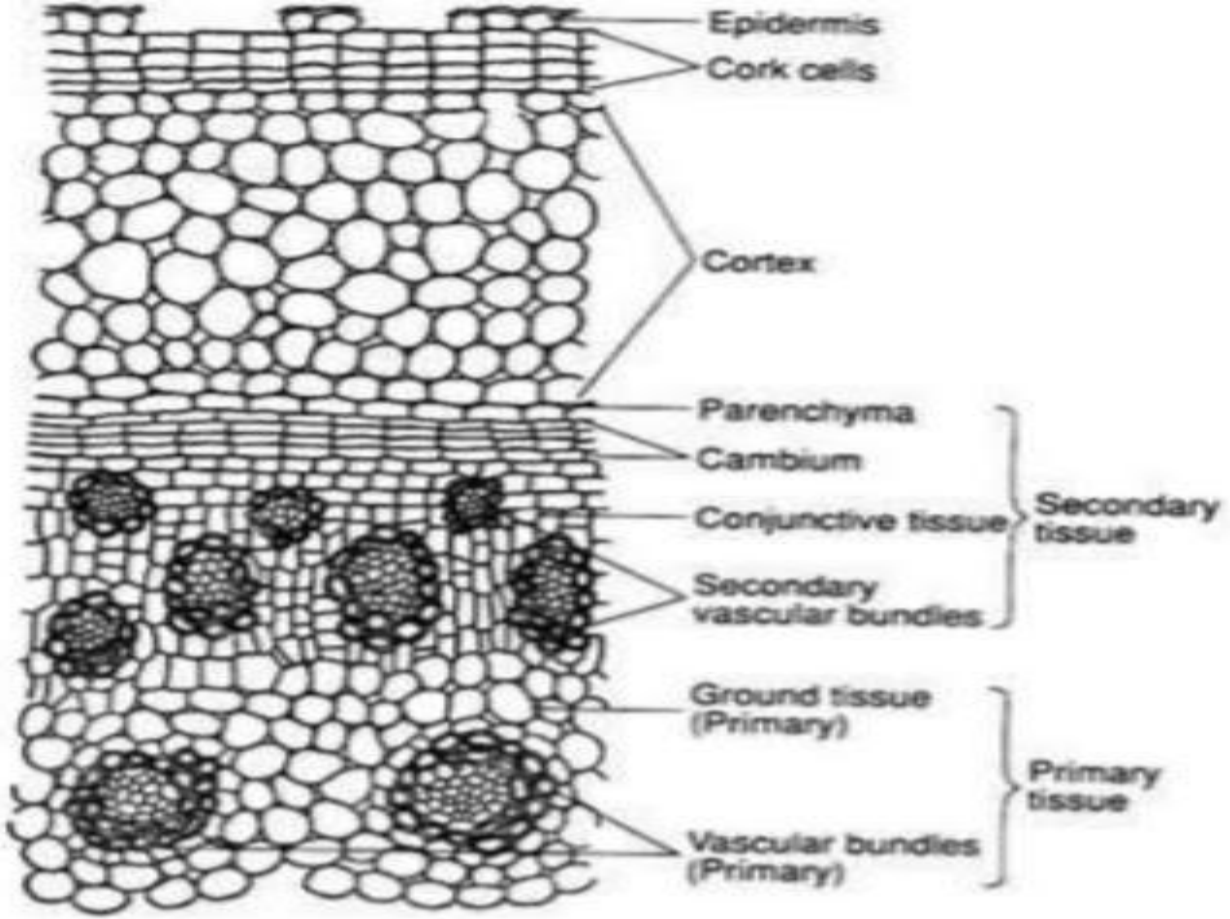
The cambium ring appears in the parenchyma outside the outermost vascular bundles (extrastelar). The region, in which the cambium ring appears, is sometimes identified as cortex, and sometimes pericyle.

Also, this cambial ring shows abnormal function-

Instead of forming phloem and xylem on the outer and inner sides, as in normal condition, the cambial cells go on dividing and producing secondary tissues on the inner side first, and later small amount of new tissues are cut off on the outer side as well. Those formed on the inner side differentiate into oval-shaped vascular bundles and radially arranged parenchyma cells. These parenchyma cells in which the vascular bundles remain embedded are said to constitute the *conjunctive tissue*. The radial arrangement of the parenchyma cells of conjunctive tissue is due to their origin by tangential divisions of the cambial cells. So they may be easily distinguished from the irregularly arranged parenchyma of the primary ground tissues. They may be thin-walled or thick- walled.



Transverse section of stem of *Dracaena* (Diagrammatic).



Cellular diagram of a portion of *Dracaena* stem in T.S. showing special type of secondary growth

Anomalous Secondary Growth In Tecoma

Tecoma is a genus of species of shrubs and small tree in the trumpet vine family **Bignoniaceae** having large showy flowers. Trumpet bush is the common name for plants in this genus.

Tecoma Stem :-

A transverse section through stem of ***Tecoma*** shows following tissue layer :-

Epidermis : -

* It is uniseriate, cuticularised and parenchymatous.

Cortex : -

* The cortex is narrow (5 to 6) layers in thickness, composed of parenchymatous cells.
* The inner layer is represented by the starch sheath layer.

Vascular Bundles :-

* Primary vascular bundles are arranged in a ring. They are co-joint, collateral and open type with endarch xylem.
* During secondary growth, cambial ring is formed due to appearance of intra-fascicular cambium. This ring functions normally producing secondary xylem inwardly and secondary phloem outwardly.
* After a period of secondary growth these bundles form a concentric ring around the parenchymatous pith.

Pericycle :-

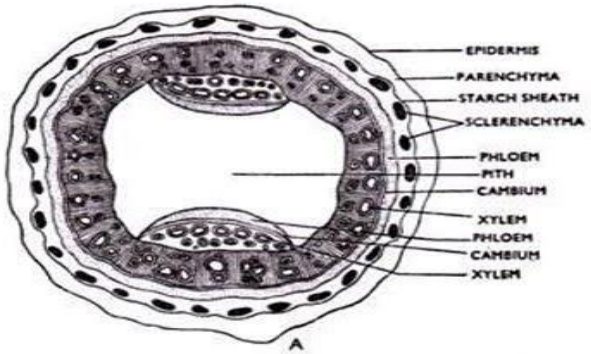
* There is a distinct pericycle region where the discontinuous patches of scattered sclerenchymatous cells (stone cells) are seen beneath the cortex form s sort of pericycle.

Secondary cambium develops in the inner part of stele, i.e. within the pith region instead of pericycle zone. This internal secondary cambium produces inverted bundles i.e. internal phloem and external xylem. This newly formed phloem is intraxylary phloem and secondary in origin.

Tecoma (Bignoniaceae)



Anomalous secondary growth in *Tecoma* Stem



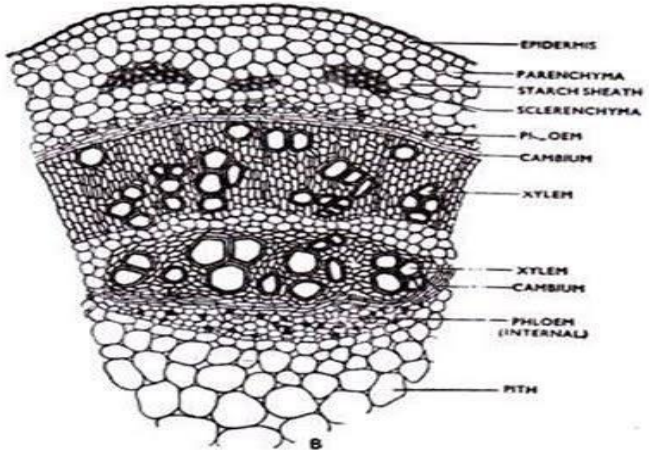
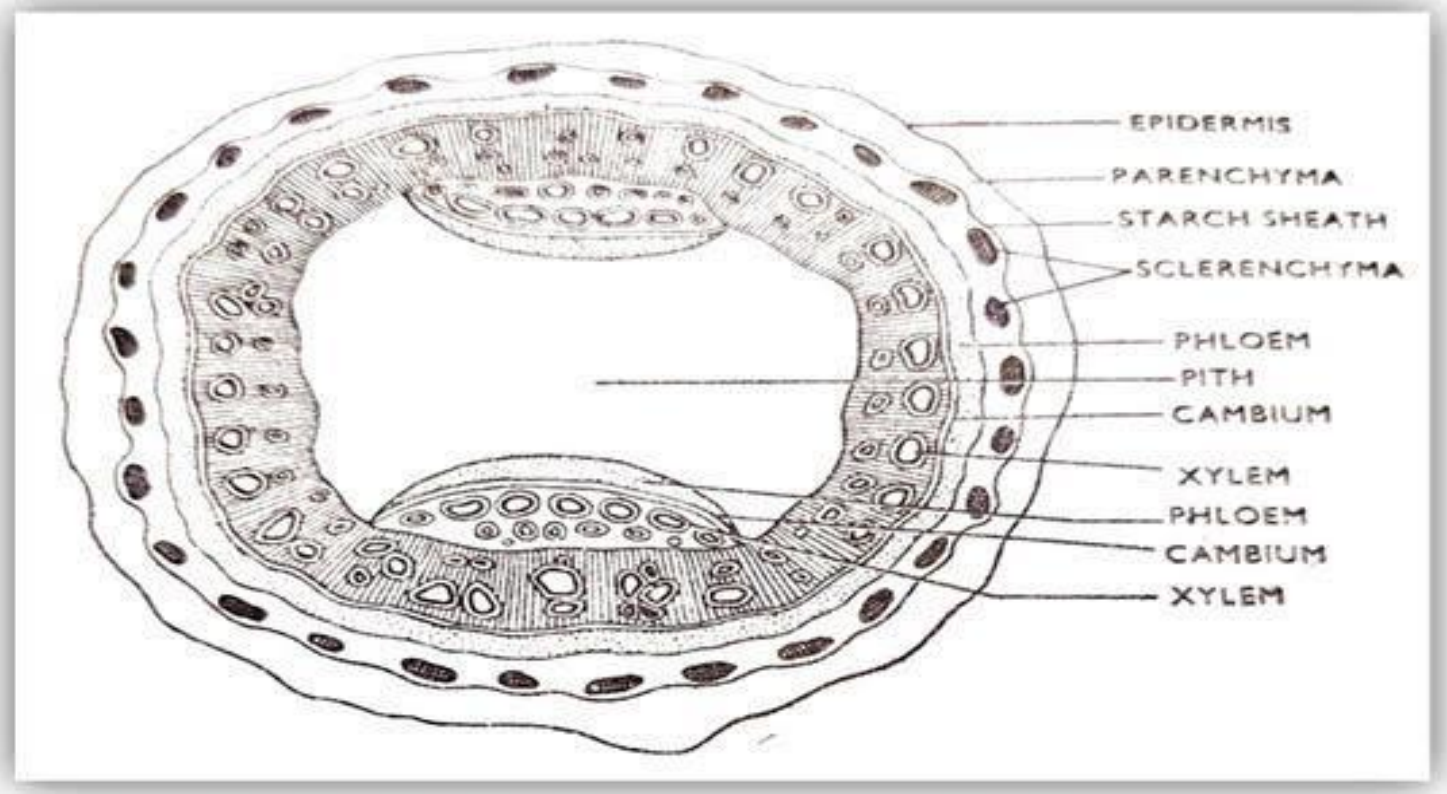


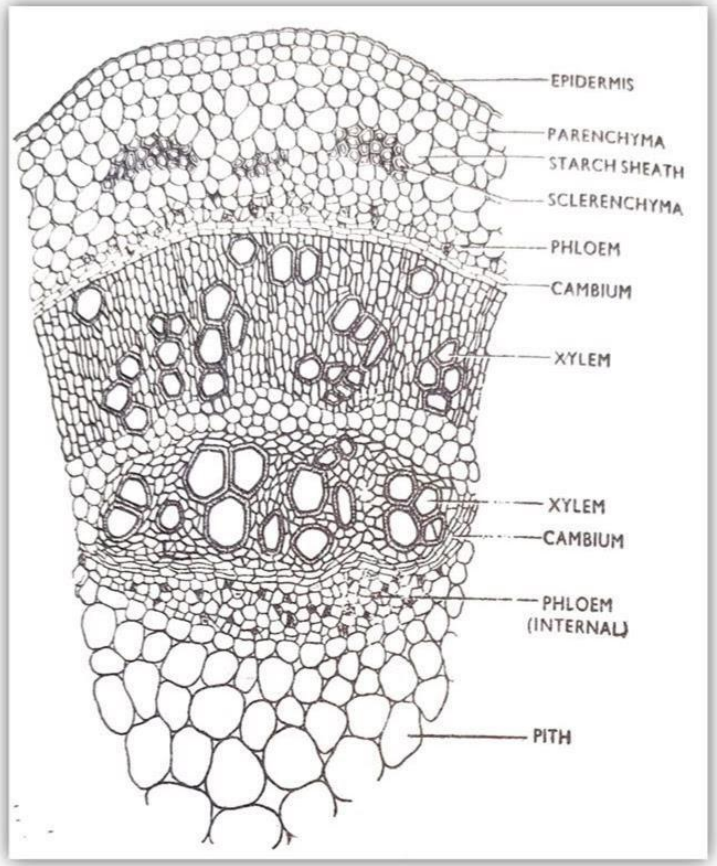
FIG. 651. Stem of *Tecoma* with anomalous structures. A. T.s. of stem (diagrammatic). B. Magnified view of a part showing tissues.

Tecoma is a dicotyledonous plant belonging to the family Bignoniaceae. In the stem of this plant anomaly is seen during secondary growth, due to the formation of **Accessory cambium with abnormal activity.**

1. In this genus, the **normal cambium ring** forms the **typical xylem and phloem** inside and outside respectively.
2. **Later accessory cambia formed n two arcs** at the outer margin of pith and on the **inner side** of the normal **vascular cylinder.**
3. These **accessory cambia** produces **secondary xylem and phloem in reverse order** i.e., Xylem outside and phloem inside.
4. As a result, **two arcs of vascular bundles** are formed at the margin of the pith, showing **inverse orientation of xylem and phloem** in contrast to normal vascular bundles.
5. The **two** patches of **internal phloem** thus formed gradually crush the pith.
6. So, these **phloem patches** are known as **intraxylary** and **secondary** in origin.



T.S. of *Tecoma* Stem Showing Anomalous Secondary Growth (Accessory Cambium and Internal Phloem), Diagrammatic



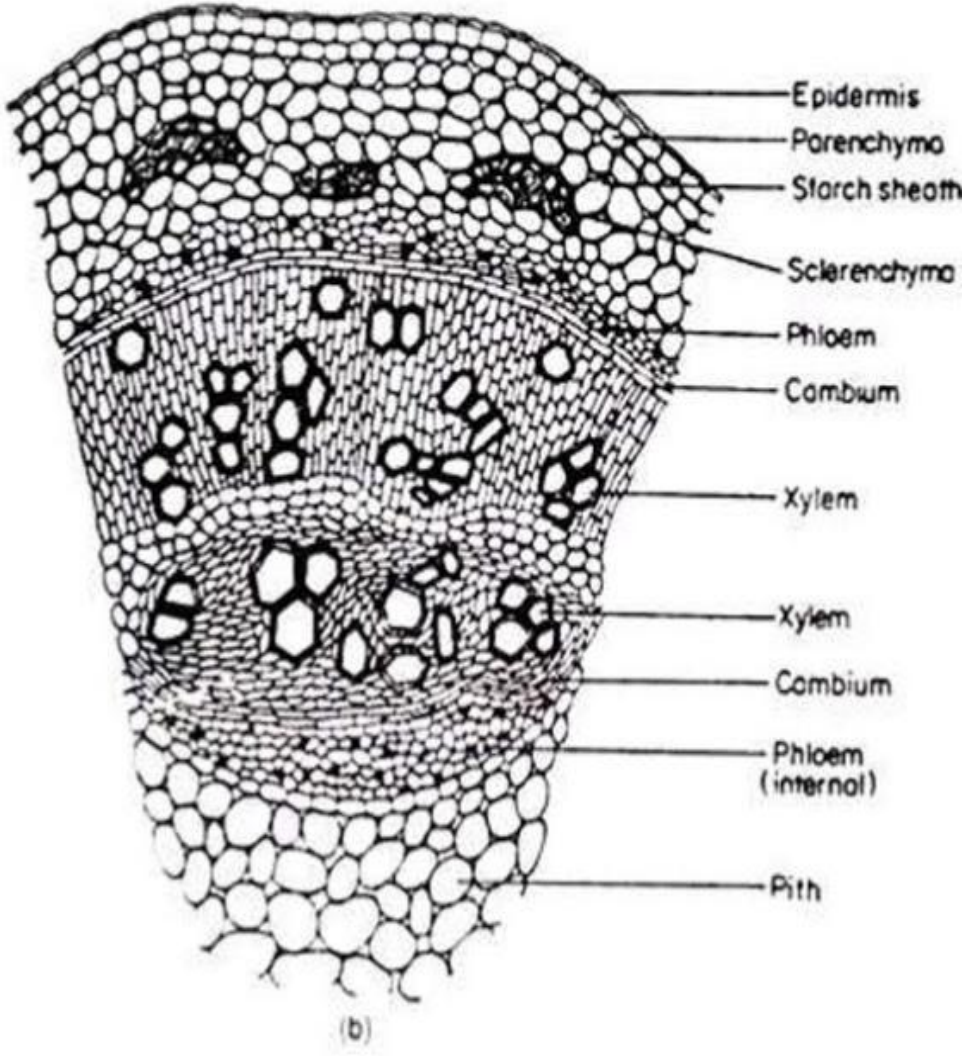


Fig :- The Stem Anomalous Structure - T.S. of stem of ***Tecoma*** showing anomaly internal inverted vascular bundles and intraxylary phloem (internal)

7. In the developing stem, some parenchyma cells are formed between the wood formed by the normal and accessory cambia.

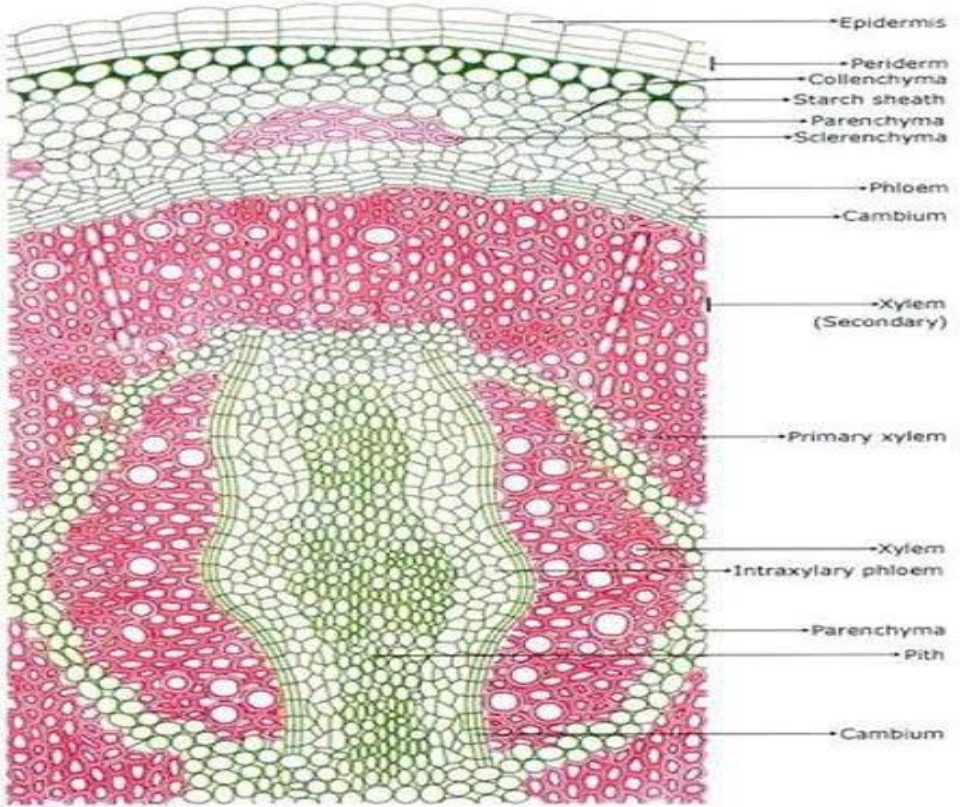


Figure 31.25A

Cellular drawing of a portion of *Tecoma* stem in cross-sectional view. Courtesy Dr. Nandini Chakrabarti.

Endodermis is not clearly discernible in the mature stem

Pith :- It is distinct and parenchymatous.

Anomalous Secondary Growth (Abnormality)

Tecoma is a dicotyledonous plant belonging to the family Bignoniaceae. In the stem of this plant anomaly is seen during the secondary growth, due to the formation of **internal accessory (secondary) cambium** in abnormal position (i.e. in the inner core of stem) with the abnormal activity.

* At the later stage an accessory (secondary) cambium arise in two arcs at the outer margin of the pith and on the inner side of the normal vascular cylinder.
* These secondary cambium produce secondary xylem and secondary phloem in a reverse order i.e. xylem towards the periphery (outside) and the phloem on the inside. As a result, two arcs of vascular bundles are formed at the margin of the pith showing **inverse orientation** of xylem and phloem.
* These newly formed phloem patches are known as **"Intraxylary phloem" (internal phloem)** and is **secondary in origin**. The two patches of internal phloem (Intraxylary) thus formed gradually crush the pith.
* The secondary xylem merges gradually with the previously formed secondary xylem. In the developing stem, some parenchyma cells are formed between the wood formed by the normal and accessory cambia.
* Secondary cambium development in abnormal position with abnormal activity resulting in the formation of internal secondary inverted vascular bundles (Intraxylary phloem) are very interesting anomaly features of this plant.

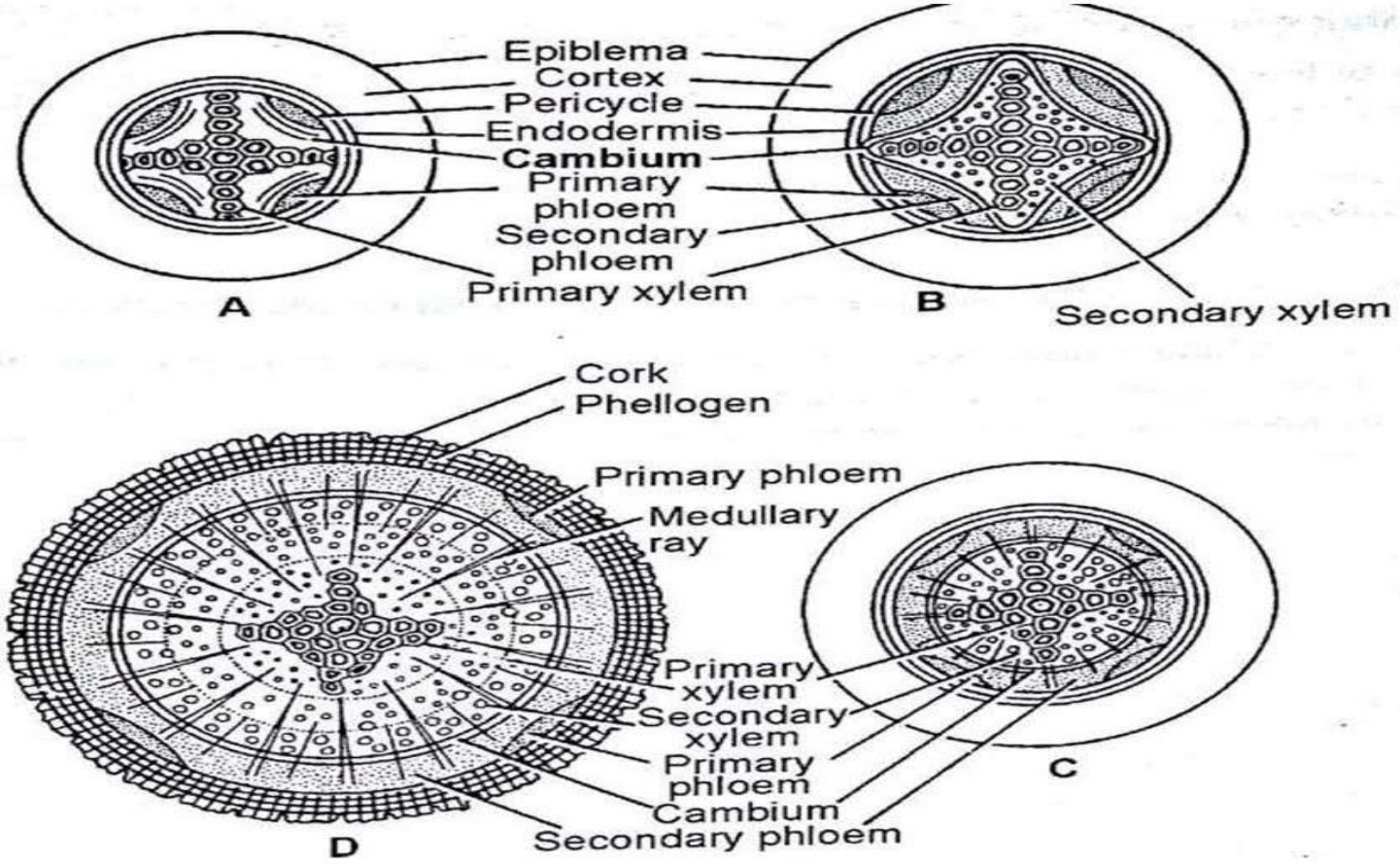
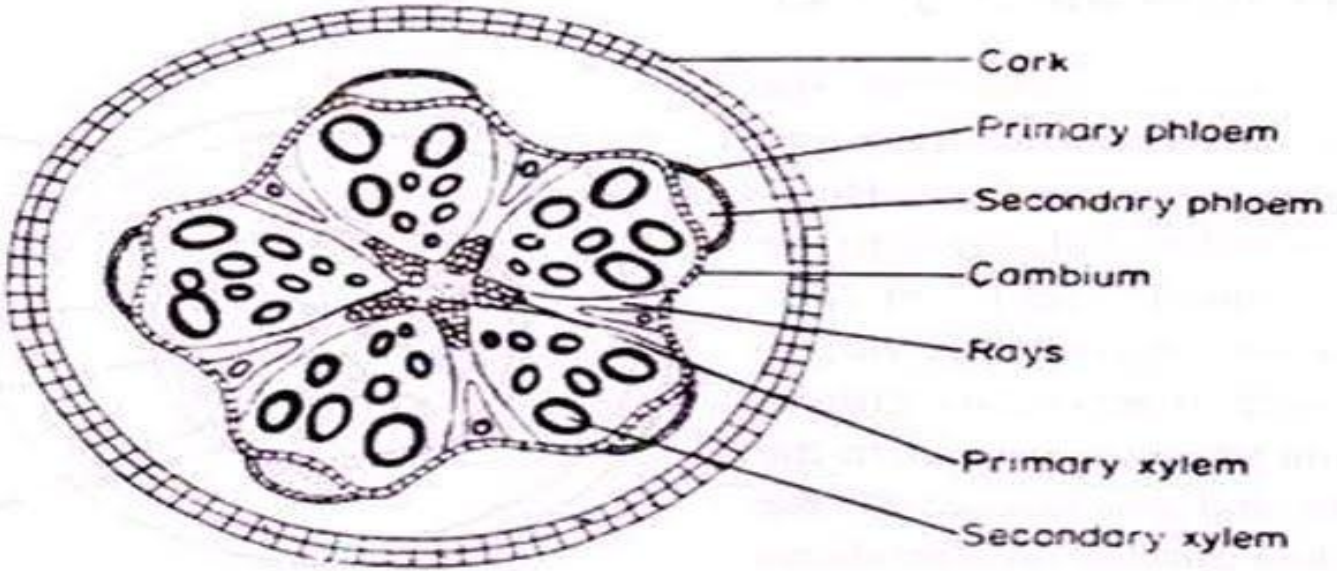


Fig. Stages of secondary Growth in dicot root.

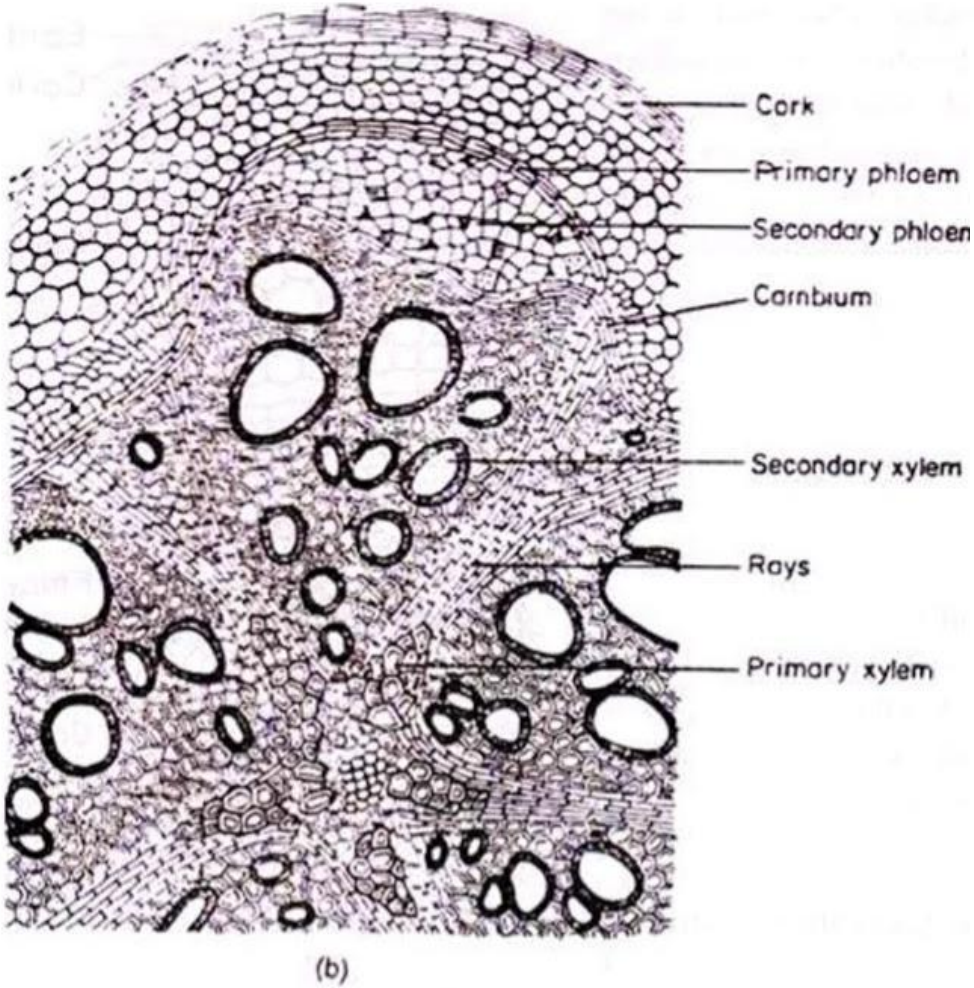
Anomalous secondary growth

Tinospora Root

Position of cambium: **Abnormal**
Activity of cambium: N**ormal**



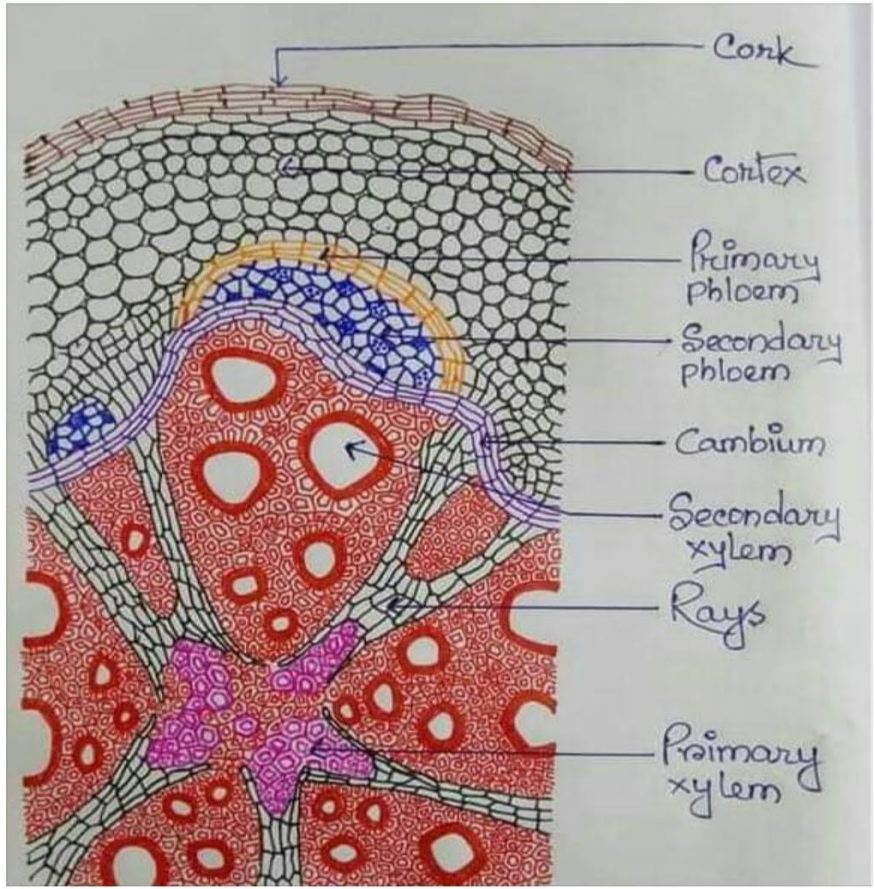
(a)

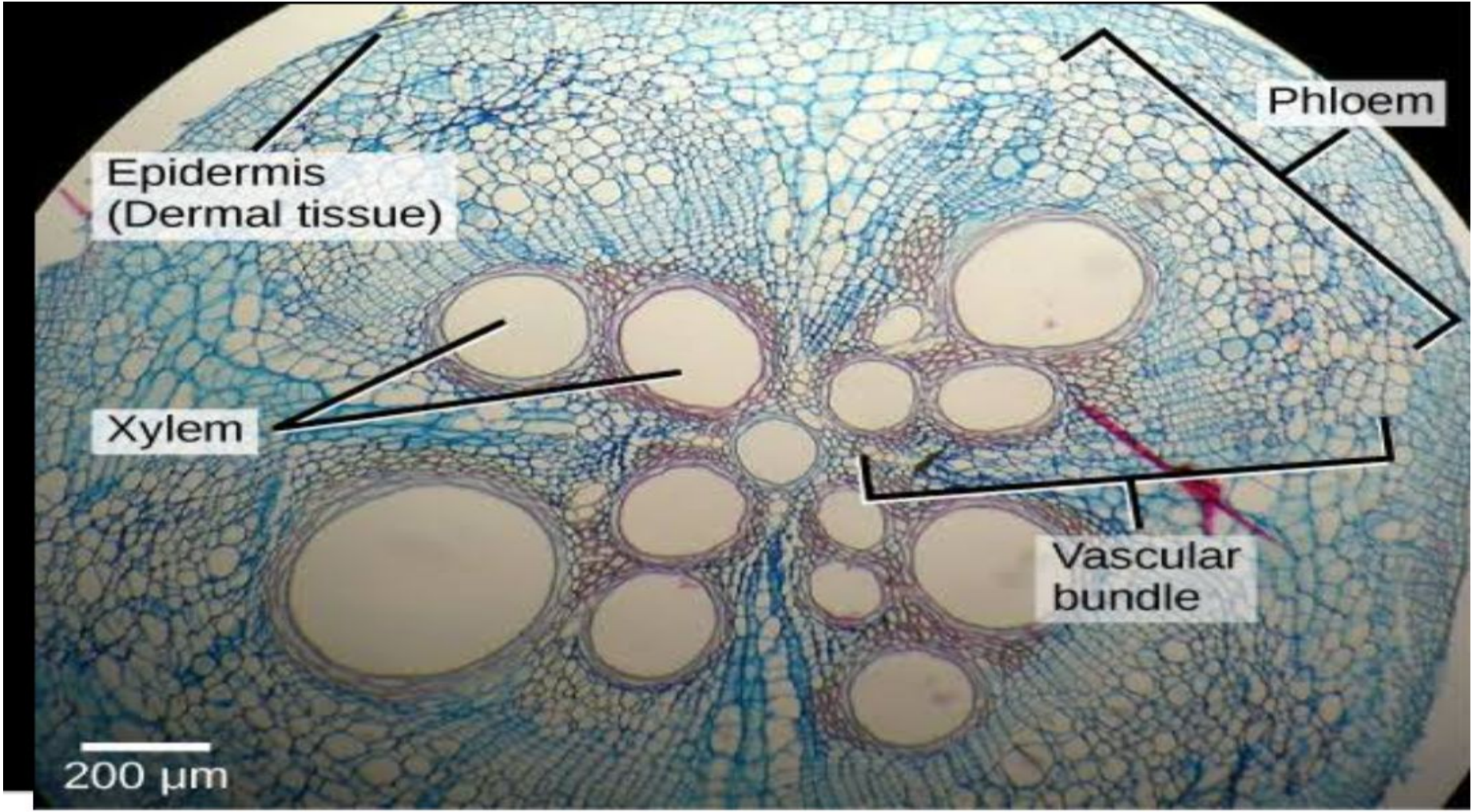


(b)

T.S. of root of *Tinospora* sp. : (a) Diagrammatic, (b) A magnified portion in

T.S. of Tinospora root showing secondary growth




Epidermis
(Dermal tissue)
Phloem
Xylem
Vascular
bundle
200 µm

- The cambium develops both within the stele as well as outside the stele, i.e., outside the pericycle layer.

- A few parenchyma cells beneath each phloem group become meristematic and thus form strips of cambium, the number of strips being equal to the number of phloem groups present.

- The cells of the uniseriate pericycle lying against the protoxylem groups now divide and form a few layers of cells.

- This tissue combines with cambium to form a **cambial ring**. This layer produces secondary vascular tissues as in stem.

- A continuous layer of secondary xylem and secondary phloem are formed inside and outside, respectively (with respect to cambial layer).

- The primary xylem is pushed towards the pith and primary phloem towards the circumference.

- Ray cells are formed frequently within the secondary xylem layer.
- Secondary phloem tissues are, however, formed in radial patches only.
- **The root nature is revealed by the presence of radial primary xylem at the centre**. (EXARCH)
- Periderm is formed from the outer cambial layer, which is developed just outside the pericycle.
- It is composed of outer cork cell layers (phellem), inner phelloderm layer and middle phellogen layer.
- The pressure developed due to the formation of secondary tissues inside ruptures the cortex with endodermis, which is ultimately sloughed- off.
- Lenticels may be formed.

Petiole of Nymphaea Stellata (Family Nymphaeaceae):

Transverse section of petiole is more or less round and reveals the following tissue organization from periphery towards the centre (Figs. 31.60).

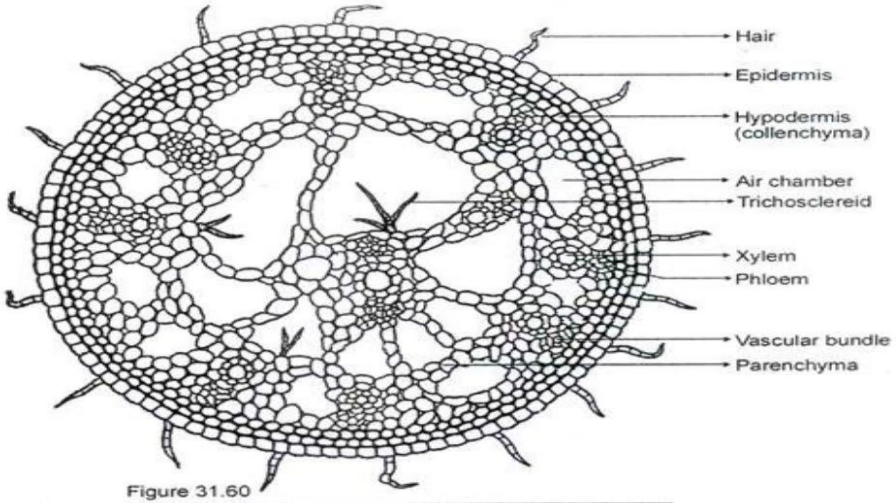
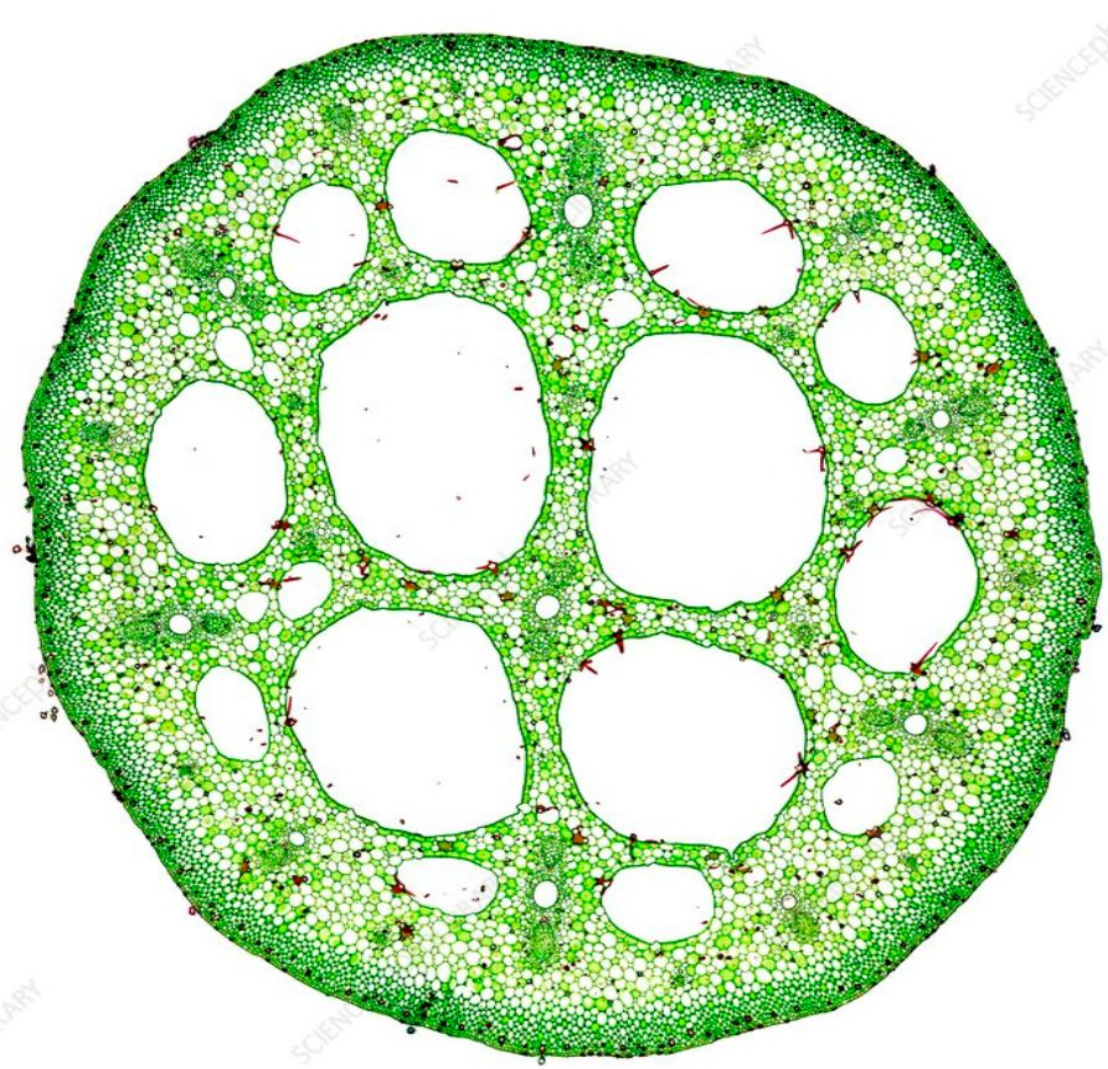


Figure 31.60
Cellular drawing of cross-section of petiole of *Nymphaea*.

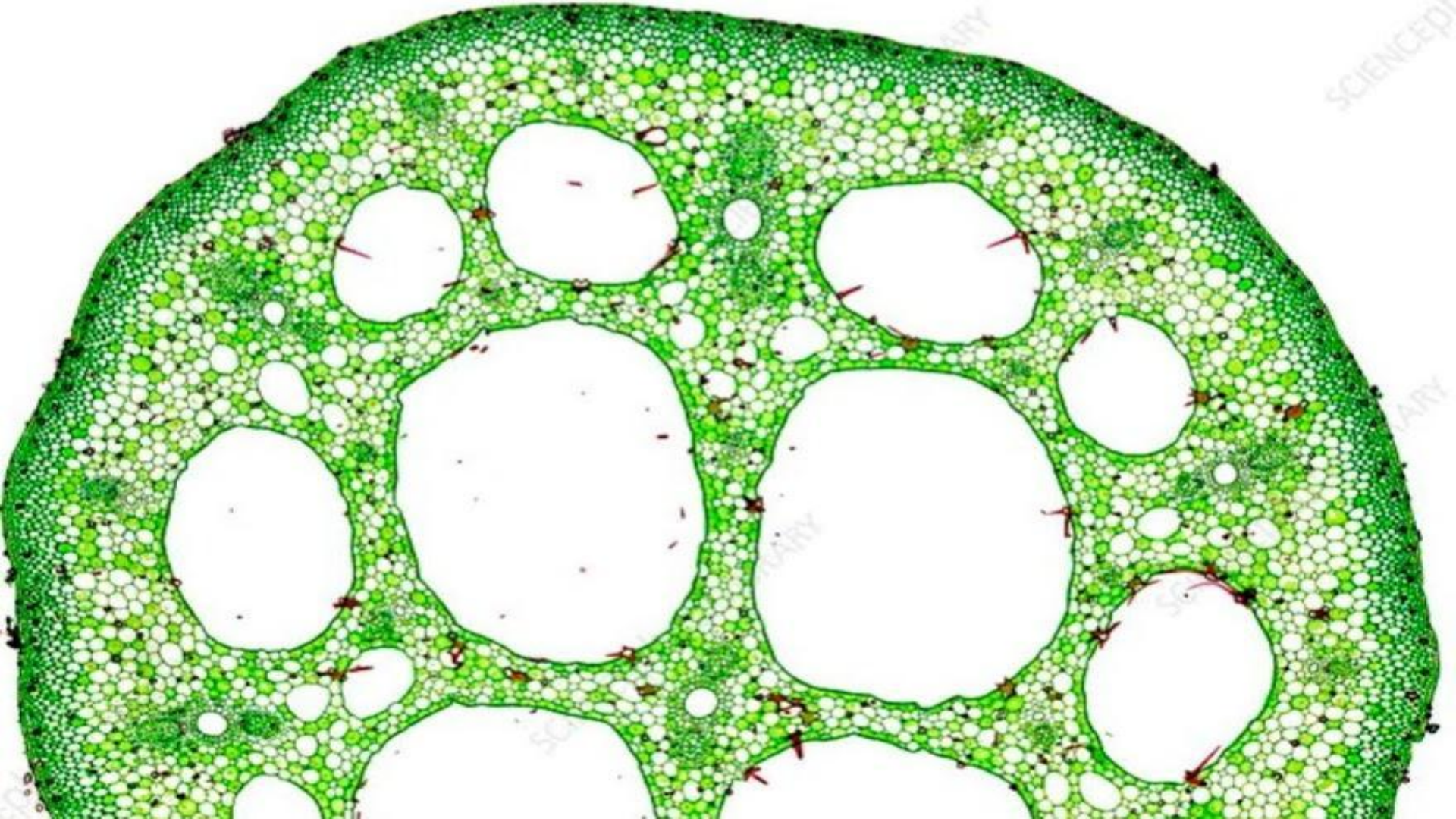
Epidermis:

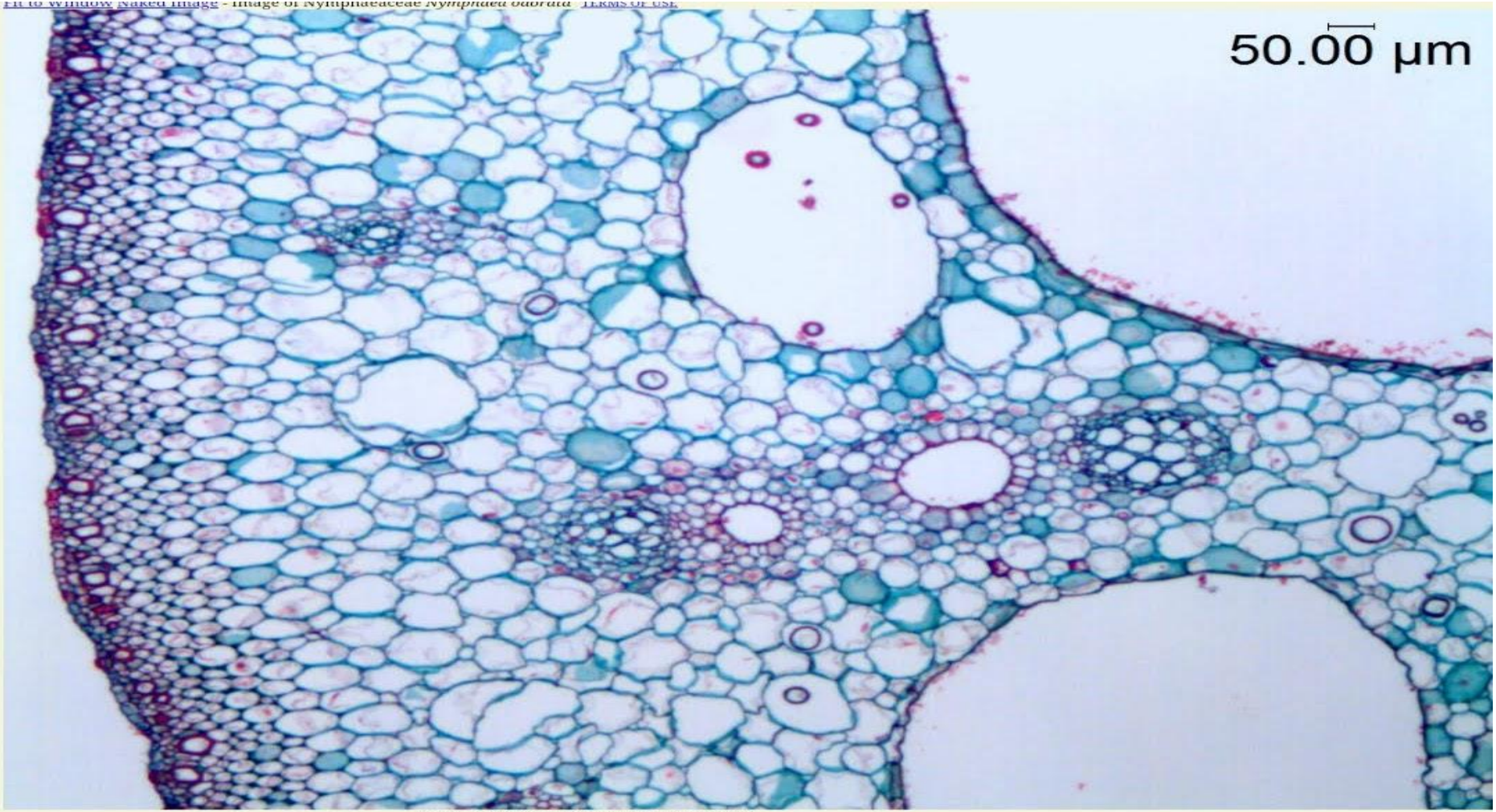
It is single layered. The cells are more or less round, thin walled, compactly arranged with thin cuticle on their outer walls. Chloroplastids occur in the epidermal cells. Unbranched multicellular hairs are present on epidermis here and there.



Ground tissue:

The peripheral layer of it forms hypodermis. It is two or more layered. It is composed of collenchyma cells that are thickened at the corners. The inner layers are composed of parenchyma cells. The cells are thin walled. Many large air spaces occur in this region. Numerous trichoblasts remain attached to the cells that border the air spaces. It is of different shapes and deposited with crystals of calcium oxalate.





Vascular bundle:

Large number of vascular bundles are present and they are scattered over the ground tissue. They remain on the partitions of air chambers. Each vascular bundle is collateral and closed. Xylem is poorly developed. The elements of xylem break down to form lacunae below the phloem.

The lacunae resemble air chambers. Phloem is well developed. The vascular bundles may be large or small. In the large bundles two patches of phloem occur on the peripheral side of xylem in contrast to small bundles that have a single patch of phloem.

Comment:

Petiole shows hydrophytic nature due to the presence of large air spaces in the ground tissue, poorly developed xylem and thin cuticle on the outer wall of epidermis.

Collenchyma at hypodermis is the only mechanical cell that provides strength to the petiole to hold the leaf in position. Anomaly in the petiole is due to the presence of scattered vascular bundles though it is a dicot. Presence of trichosclereids with calcium oxalate deposition is the characteristic of the petiole.

;;;;;;;END OF PART THREE;;;;;;;;;