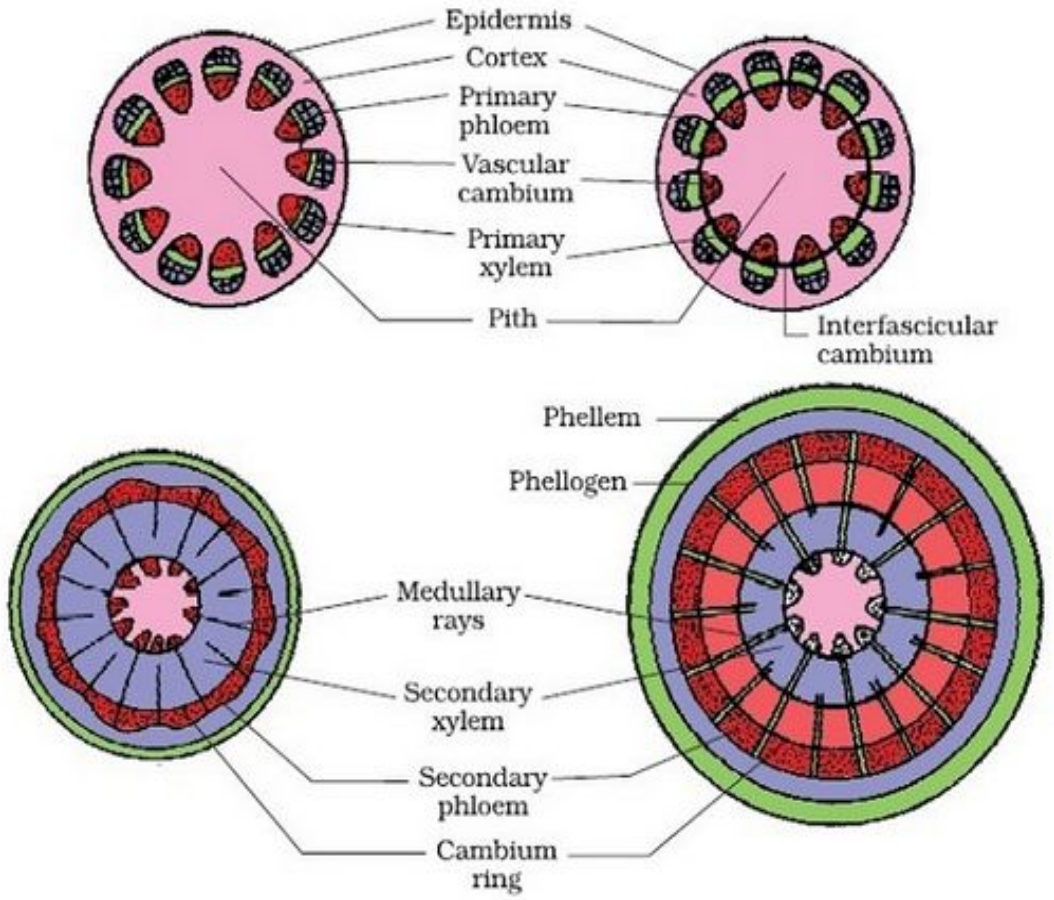
SECONDARY GROWTH

Normal Secondary Growth

- Fundamental parts of plant body are produced from apical meristem
- Further growth achieved in the distant regions is called as secondary growth in thickness
- Secondary growth in dicotyledonous stem is basically of two types- intrastelar and exrastelar
- Normally secondary growth in dicot stem is achieved by vascular cambium, also known as fascicular cambium, as their vascular bundle is conjoint and collateral
- Gradually cambium is extended in the interfascicular region from parenchyma and medullary rays and forms a complete cambial ring
- This cambial ring forms a continuous cylinder of secondary vascular tissue, phloem on the outer side and xylem on the inner side of the cylinder



Cambium:

- Cambium is a lateral meristem where the cells lie in a layer at stellar or extrastelar region with primarily periclinal mode of cell division
- Cambium is formed from the procambium strand of the primary tissue
- The fascicular cambium consists of fusiform initials and ray initials
- Fusiform initials form the vertical or longitudinal system of the phloem and xylem
- Ray initials form the transverse or horizontal system of the same
- In tangential views the cambium cells appear in two types-

a) **Storied** or **Stratified cambium-**where the fusiform initials appear in horizontal tiers of equal lengths and their ends lie more or less at the same level without overlapping

b) **Non-storied** or **Non-stratified cambium-** where the fusiform initials are comparatively longer and do not appear in horizontal tiers but overlap at their ends

- Each cambial initial divides into two cells, one of which becomes either a xylem mother cell or a phloem mother cell depending on its position, while the other one remains meristematic
- Usually the cambium produces more xylem than phloem thus pushing the tissues external to cambium more towards periphery

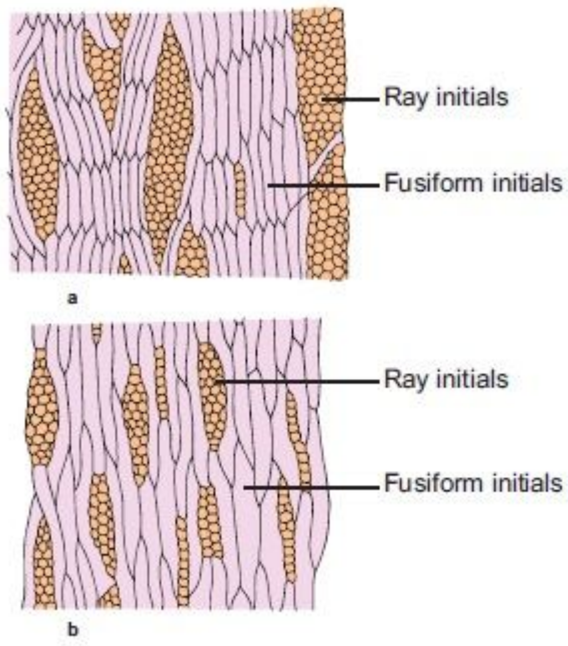


Figure 10.2: Tangential longitudinal section (TLS) of cambium (a) Storied cambium (b) Non-storied cambium

Secondary Xylem :

- Secondary xylem constitutes the major portion of the secondary vascular tissue in woody plants performing a number of important functions like conduction, mechanical support, storage of food etc
- The vertical system consists of the tracheary elements (tracheae and tracheid), xylem parenchyma and fibres.
- The horizontal system consists of xylem rays arranged at right angles to the long axis
- Xylem parenchyma when occur in association with vessels are called paratracheal parenchyma and when occur independently are called apotracheal
- Two main types of fibres are fibre tracheids-with poorly developed bordered pits, and libriform fibres-with simple pits
- The xylem rays are either vascular rays or parenchymatous rays
- Vascular rays are formed by the cambium and perform the function of storage along with conduction of water from xylem to phloem and food from phloem to xylem
- Parenchymatous rays are uniseriate or multiseriate and upright (vertical) or procumbent (horizontal)
- Secondary xylem containing both upright and procumbent rays are called heterogeneous and only one type is called homogeneous

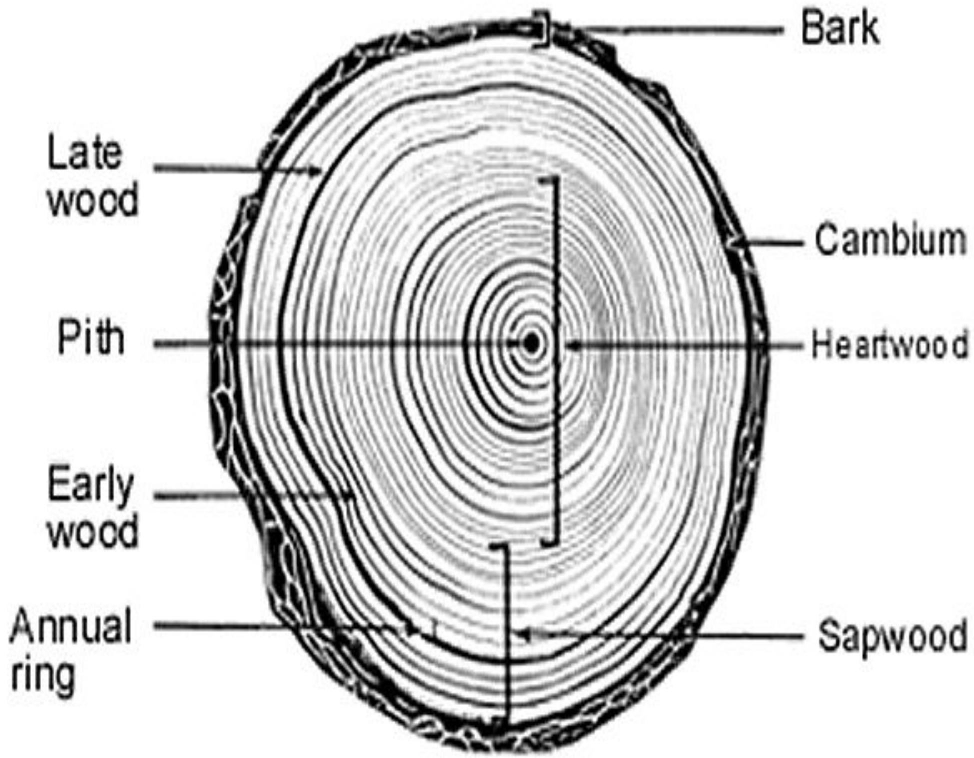
Primary Xylem vs Secondary Xylem

More Information Online WWW.DIFFERENCEBETWEEN.COM

	Primary Xylem	Secondary Xylem
DEFINITION	Primary xylem is the xylem formed during the primary growth by the procambium	Secondary xylem is the xylem formed during the secondary growth by the vascular cambium
OCCURRENCE	Present in both monocots and dicots	Seen only in dicots
TYPE OF GROWTH	Primary growth	Secondary growth
MERISTEM TYPE	Apical meristem	Lateral meristem
PIT FORMATION	Not observed	Observed
VESSEL	Long and thin	Short and wide
TYLOSES	Absent	Present
NUMBER OF XYLEM FIBRES	Less	High

Annual Ring:

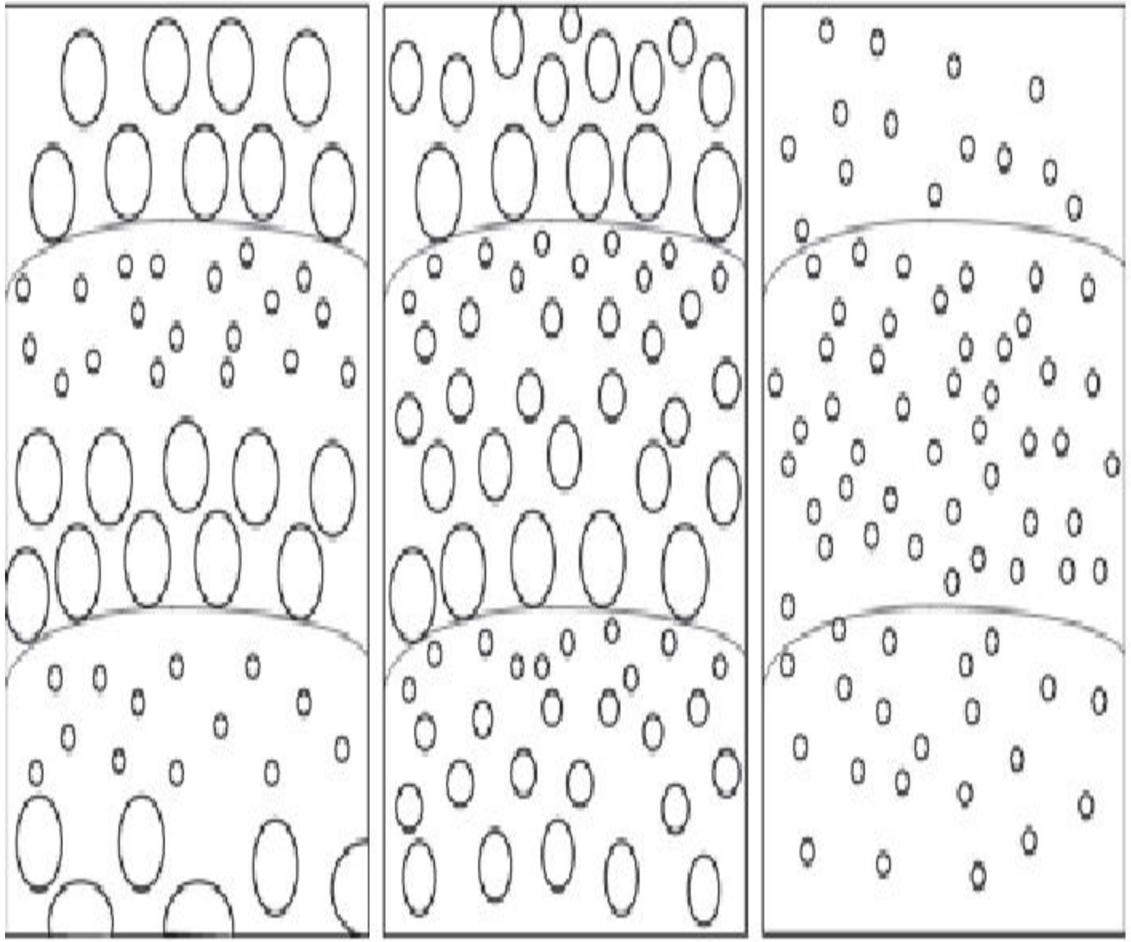
- Due to periodical activity of cambium distinct growth layers are formed appearing as rings in transverse view and thus termed as growth rings
- Mostly such activity shows seasonal periodicity (forming different types of wood in different seasons) and thus also called as annual ring
- Due to rapid rate of photosynthesis during spring season the wood formed is less dense, made of vessels with wider diameter for transport of photosynthate and called early wood or spring wood
- Due to high temperature and scarecity of water the rate of photosynthesis decreases in summer and hence secondary wood formed in this season is dense, made up of narrow, compact and lignified vessels and called as late wood or summer wood
- Adverse conditions like drought, defoliation and disease stops wood development temporarily in the same season and leads to formation of false annual rings or multiple annual rings when numerous in number
- The vessels in early wood are of unequal diameter and the largest ones show ring like arrangements and thus are called ring porous wood
- When the vessels have differences in size and are distributed from smaller to larger ones throughout the wood it is called diffuse porous wood



Differences between Spring Wood and Autumn Wood

Spring Wood	Autumn Wood
It is also called early wood.	It is also called late wood.
It is formed during spring season.	It is formed during winter season.
It constitutes the major part of the annual ring.	It constitutes as a narrow strip in the annual ring.
Spring wood is present in the beginning of an annual ring.	Autumn wood is present at the end of an annual ring.
Forms plenty of xylem vessels with wider-cavities.	The cavities of xylem vessels are narrower.
Xylem fibres are fewer in number.	Abundant xylem fibres are produced.
Wood is lighter in colour.	Wood is darker in colour.

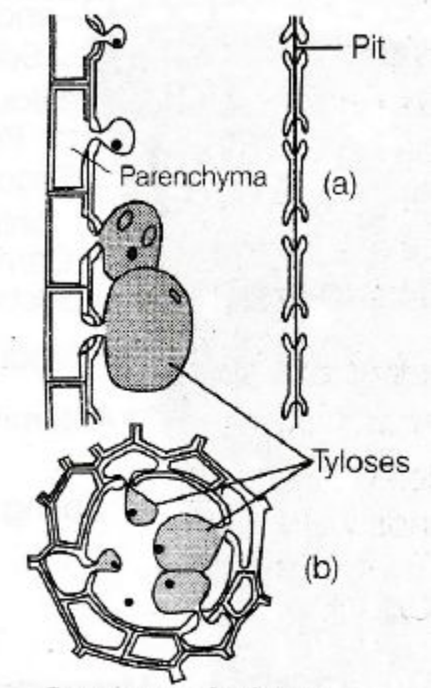
Diffuse porous wood	Ring porous wood
This type of wood is formed where the climatic conditions are uniform.	This type of wood is formed where the climatic conditions are not uniform.
The vessels are more or less equal in diameter in any annual ring.	The vessels are wide and narrow within any annual ring.
The vessels are uniformly distributed throughout the wood.	The vessels are not uniformly distributed throughout the wood.



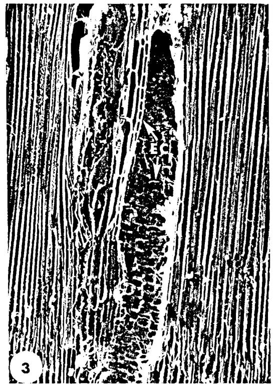
(a) ring porous (b) semi ring porous (c) diffuse porous

Tyloses and tylosoid:

- Tyloses are the balloon like protrusions into the tracheary elements of the secondary xylem
- Developed from adjacent xylem parenchyma and ray parenchyma cells
- Formed by enlargement of pit membrane of half bordered pits from living parenchyma cells into vessels or tracheid
- Tylosis contains a nucleus and a small amount of cytoplasm withstarch, resin and other matters
- A single tylosis may divide to form a multiple structure
- Normally they are formed in the heart wood to give extra mechanical support and prevents vessels from collapsing under pressure of secondary wood
- Tyloses also prevent the flow of sap through the vessels, thereby blocking spread of fungal bacterial and viral diseases
- Tyloses are also observed in the sap wood in association with diseasesTyloses are found in plants like *Tinospora, Morus, Quercus* etc.
- Tylosoid are observed in gymnosperms when epithelial cells of resin ducts enlarge and block the duct
- In angiosperms parenchyma proliferate into the sievetube to form tylosoid
- Tylosoids never protrude through pits



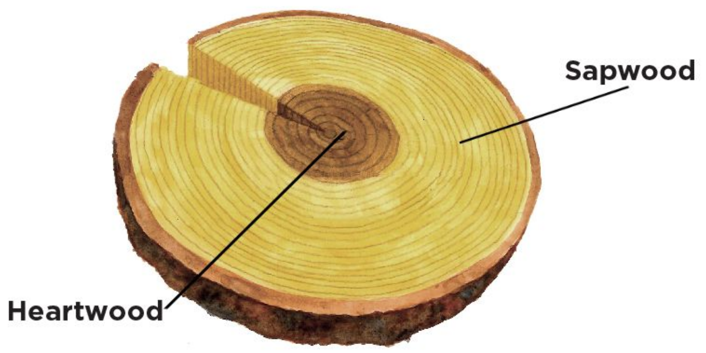
Structure of tyloses in woody tissue



ig. 3. Radial longitudinal surface, sapwood. The longitudinal anal is not occluded. The small epithelial cells (EC) can be

Fig. 4. TLS, heartwood. The radial resin canal is occlude

Sap wood Heart Wood



- The outer and comparatively newer secondary xylem is the sap wood or alburnum
- The centrally placed older hard portion is termed as the heart wood or duramen
- Sap wood is light coloured , having living cels along with tracheary element and fibres
- Functions in water and solute transport, mechanical support and storage of food
- Heart wood consists of dead elements only
- Functions in mechanical support only
- Filled with substances like oil, gum, resin and tannin
- Heart wood becomes more compact and dark coloured by loss of protoplast, reduction of water content, withdrawal of food matter, lignification of walls,
- Heart wood is commercially more valuable than sap wood
- Heart wood yields good quality of timber due to durability and resistance to decay
- Haematoxylin dye is obtained from the heart wood of *Haematoxylum campechianum*

Differences between Sapwood and Heartwood

Sapwood	Heartwood
It is also called alburnum.	It is also called duramen.
Sapwood represents the outward wood of the plant.	Heartwood represents the central wood of the plant.
	It is dark in colour and heavier in weight.
Consists of living cells.	Living cells absent.
Represents functional part of the secondary xylem (wood).	Represents non-functional part of the secondary xylem (wood).
Tracheids and vessels not plugged by tyloses.	Tracheids and vessels plugged by tyloses.
Tannis, resins, gummy substances not deposited in tracheary elements.	Tannins, resins, gummy substances deposited in tracheary elements.
Economically not important because of being easily attacked by pathogens and insects.	Economically very important because of being resistant to pathogens and insects.
It is not durable.	It is durable.

Secondary Phloem:

- Secondary phloem cells are produced on the outer side of cambium by tangential division
- Amount of secondary phloem is less than secondary xylem
- Both vertical (sieve tube, companion cell, phloem parenchyma fibre) and horizontal systems (ray parenchyma) are present in secondary phloem
- Vertical system is generated from fusiform initials
- Both storied and non-storied ray parenchyma are found
- Presence of sclereids in association with fibres (fibre sclereids) increase the mechanical strength
- Secondary phloem play role in vertical conduction of solute and storage of starch, crystals and other ergastic substances
- Phloem rays establish connection with xylem rays through cambium
- Responsible for horizontal transport of photosynthate
- Rays may be uniseriate and parenchymatous; multiseriate and homogeneous made up of either upright or procumbent cells or multiseriate and heterogeneous composed of both upright and procumbent cells
- No growth rings are observed in secondary phloem

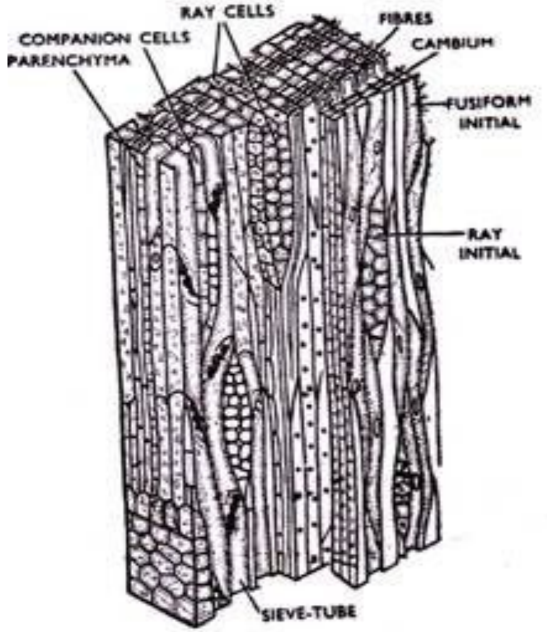
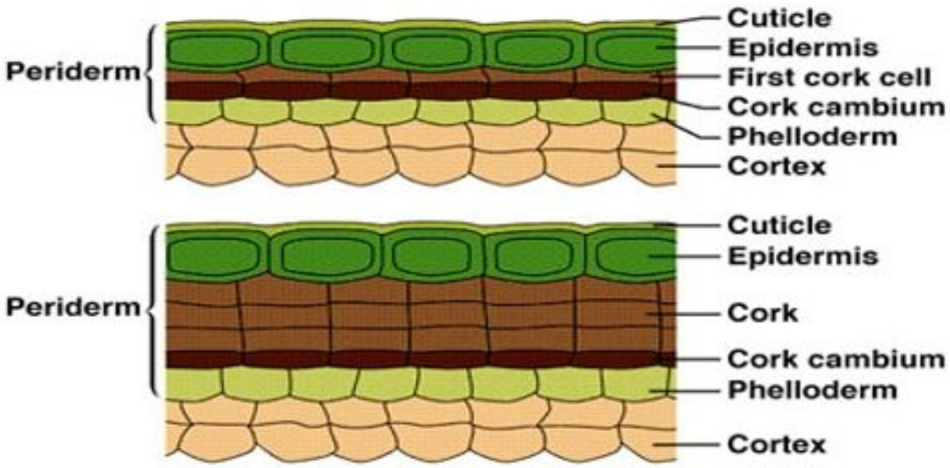
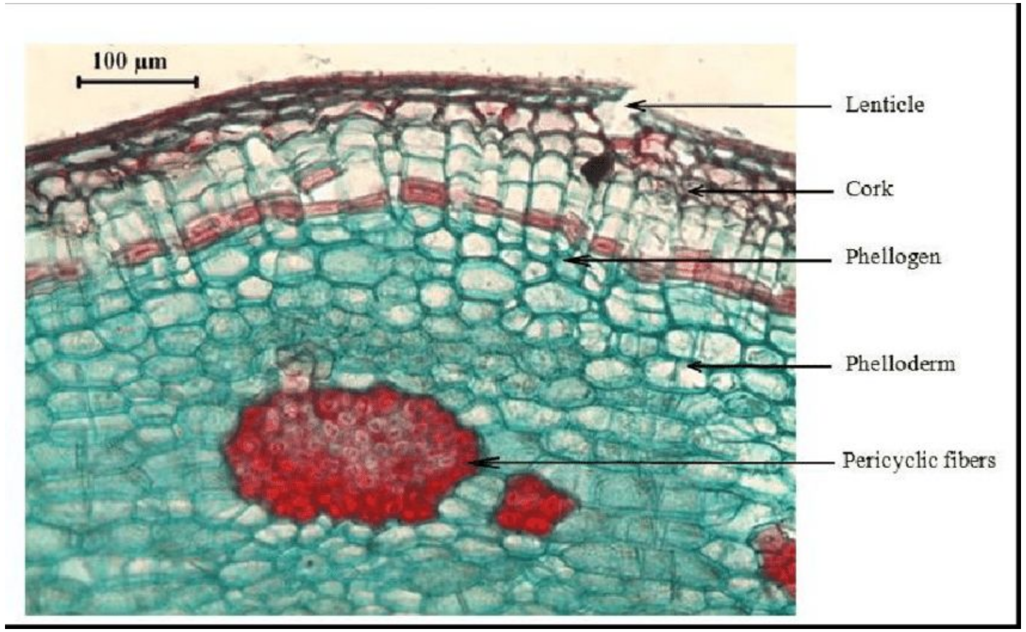


Fig. 635. Block diagram of secondary phloem with the cambium showing the elements.

Extrastelar Secondary Growth

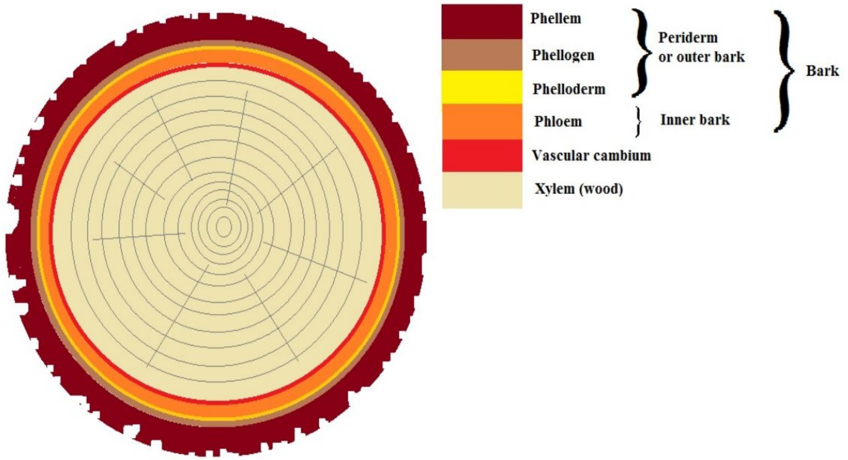
- Due to continuous secondary growth in the stellar region a huge pressure is exerted on the extrasteler region and as a result the epidermis gets ruptured exposing the inner tissue
- Another dermal tissue develops to protect these inner tissues just below the epidermis and called periderm
- Periderm consists of three parts-phellogen, phellem and phelloderm
- Phellogen or cork cambium develop as a secondary meristem from the upper cortical, sub-epidermal or epidermal layer itself
- It consists of compactly arranged, rectangular, radially flattened cells that divide tangentially to produce tissues in both centripetal and centrifugal direction
- It produces more phellem on the outer side than phelloderm on the inner side
- The phellem or cork cells are compactly arranged without any intercellular spaces
- After differentiation they become dead, air-filled and accumulate colouring material
- As the cell walls contain yhick layer of suberin the cells become impervious to air and water
- In *Eucalyptus* the cork cells are thick walled and resin filled
- But normally they are thin walled and peel off as sheets
- Peridem serves as a secondary protective tissue against desiccation and mechanical injuries
- Phelloderm on the inner side are living cells isodiametric in nature,with intercellular spaces and resemble the cortex
- They can photosynthesize and store food

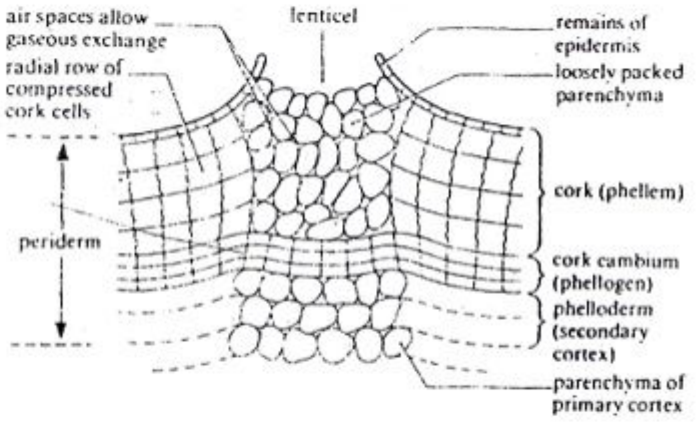




Bark, Lenticel, Rhytidome ,Polyderm

- In large trees, periderm is not adequate to withstand the pressure of continued secondary growth
- Thus additional periderm layers are formed in the cortex pericycle and phloem
- All the dead phellem contributed by the living phellogen constitute the bark
- Due to formation of successive layers of periderm in the deeper regions the bark is formed in concentric rings and known as ring bark
- When periderm is formed as overlapping scale like layers, it is called scale bark
- As suberized cork cells are impervious to gases, small lens-shaped pores develop on the surface of the stem to facilitate gaseous exchange, called lenticels
- It initiate just beneath the stomata either just before periderm formation, simultaneously with periderm formation or after periderm formation
- Parenchyma cells adjacent to substomatal cavity loose chlorophyll, divide in all planes to form a loose mass of colourless cells
- Phellogen also add such cells on the outer side; this whole substomatal loose cell mass is called complementary cells





Structure of Lenticel

- Continued addition of complementary cells protrude the epidermis outward and finally it ruptures
- Often a mass of compact cells (closing cells) alternate with loose cells and form a layer called closing layer
- Closing layer help to keep the complememtary cells inposition
- During active growing season the closing layer ruptures due to pressure created by addition of complementary cells, at the end of growing season it is again formed

- Complementary cells are thin walled non-suberized and with intercellular spaces
- Lenticels can be formed below peridem also
- They may be transverse or longitudinal based on orientation
- Three types of lenticels are observed in dicots

1. Complementary cells suberized and compact (*Magnolia, pinus)*
2. Complementary cells alternately loose, nonsuberised and compact, suberized (*Tilia, Quercus)*
3. Multiple layers of alternate loose non-suberized complementary cells and suberized ,compact cells (*Betula, Fagus)*

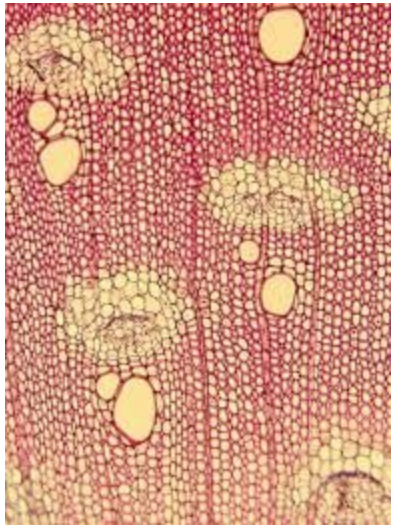
- All the periderm bands , enclosed cortex, secondary phloem and tissues present external to innermost phellogen are collectively called as **Rhytidome** or **outer bark**
- The living part of the bark inside the rhytydome is called **inner bark**
- **Polyderm** is a special protective tissue consisting of 20 or more alternating layers of uniseriate suberized and multiseriate non-suberized cells
- Observed in underground roots of rosaceae, onagraceae etc.

<u>Anomalous Secondary Growth</u>

- When secondary growth deviates from the normal one it is called **<u>anomalous secondary growth</u>**
- It may be formed due to any of the following reasons

1. Cambium normal in position but abnormal in activity
2. Cambium abnormal in position but normal inactivity
3. Due to formation of intraxylary phloem or interxylary phloem
4. Due to formation and activity of accessory cambium
5. **Interxylary phloem** is the secondary **phloem** on the inner side which is embedded within mass of secondary xylem.

- **Intraxylary phloem** is the secondary **phloem** present in the innermost region of primary xylem.
- **Intraxylary phloem** is present in pith region.



Interxylary phloem

Intraxylary phloem

Anomalous secondary growth in *Bignonia*

- Initially normal cambial ring produces normal vascular bundles
- As soon as the vessels with large lumens are formed, four opposite small segments of cambial ring ceases to form secondary xylem
- Instead they form secondary phloem on the outside only
- The rest four alternate cambial rings form normal secondary xylem and phloem
- As a result four wedges of secondary phloem are found in the cylinder of secondary xylem
- As the stem grows in thickness the wedges of phloem goes deeper
- The vascular cambium finally splits into eight strips; four of which occur at the bottom of the wedge and the rest four at the peripheral margin
- Thus anomalous activity is due to normal cambial position but abnormal function

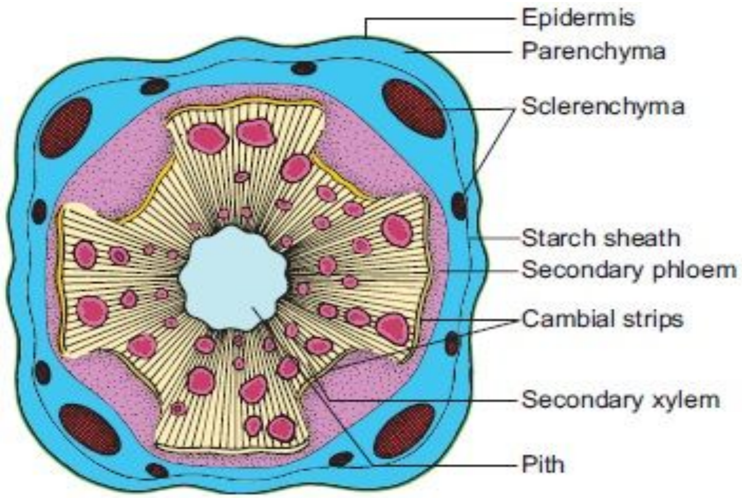
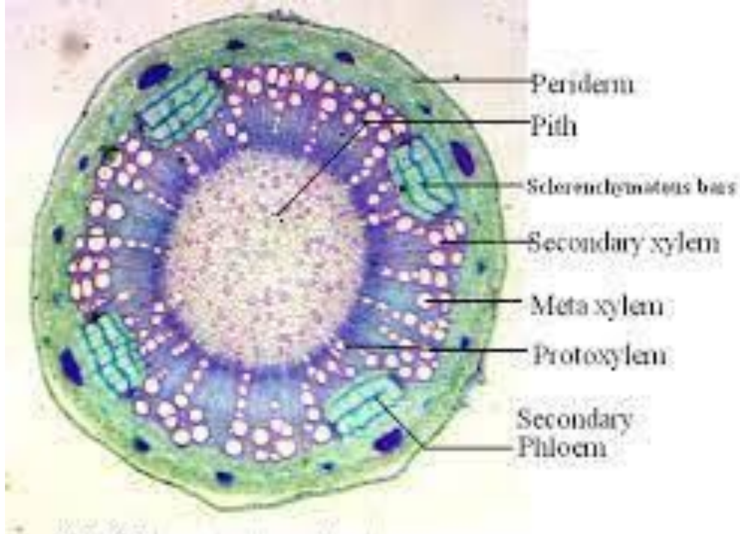


Figure 10.19: Transverse section of *Bignonia* stem (diagrammatic) showing anomalous secondary growth



T.S of Bignonia stem showing anomalous secondary growth

Anomalous Secondary Growth in *Boerhavia*

- *Boehavia* exhibit accessory cambia that form vascular and non vascular tissue
- Primary vascular bundles are of different sizes and exists in rings
- Two largest central bundles form the innermost ring
- Middle ring consists of 6-14 loosely arranged bundles
- Inner and middle ring consists no interfascicular cambium
- Outermost ring consists of 15-20 further smaller bundles
- Outermost bundles form both inter and intrafascicular cambium and thus forms a complete ring
- Intrafascicular cambium form secondary phloem on the outside and secondary xylem on the inside
- Interfascicular cambium divides to form parenchyma cells at the periphery and conjunctive tissue on the inside

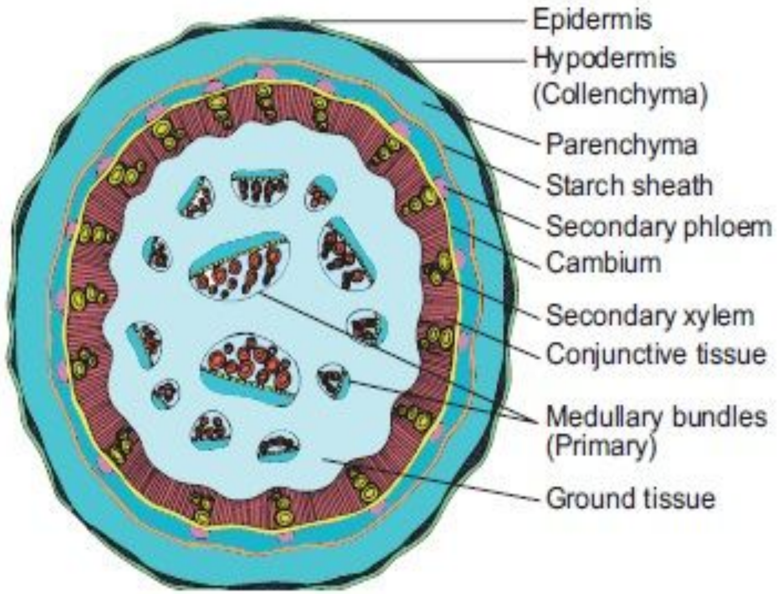
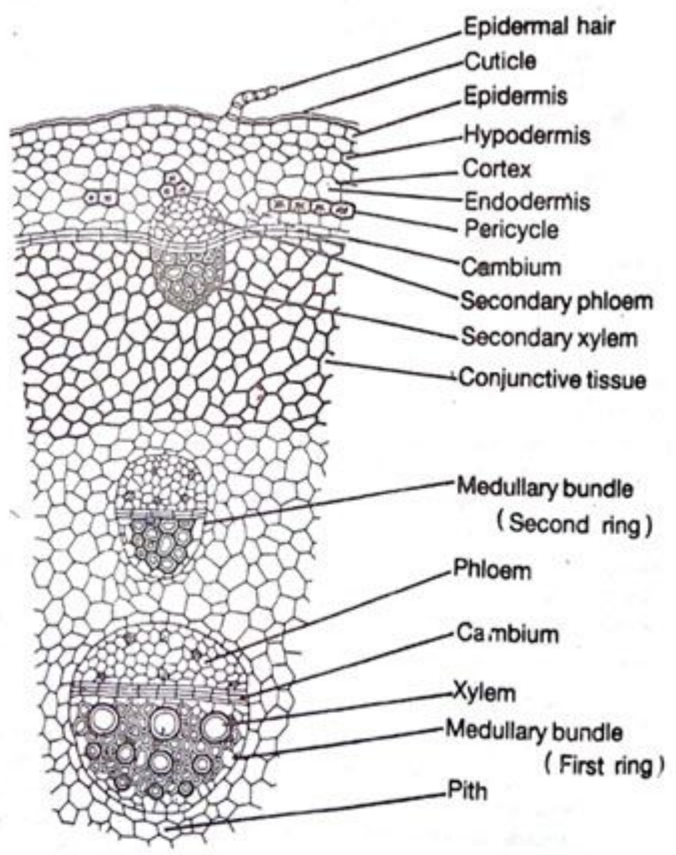


Figure 10.22: Transverse section (T.S) of Boerhaavia stem (diagrammatic) showing anomalous secondary growth

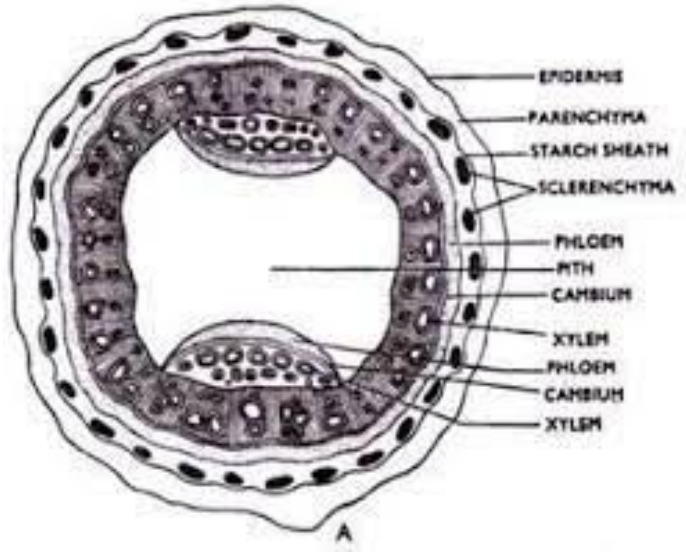
- Conjunctive tissue consists of elongated cells that gets transformed into sclerenchyma layers by lignin deposition
- With further secondary growth the cambium donates a broad zone of anomalous wood inwardly
- The anomalous wood consists of secondary xylem contributed by intrafascicular cambium, lignified conjunctive tissue and adjacent cells of pith

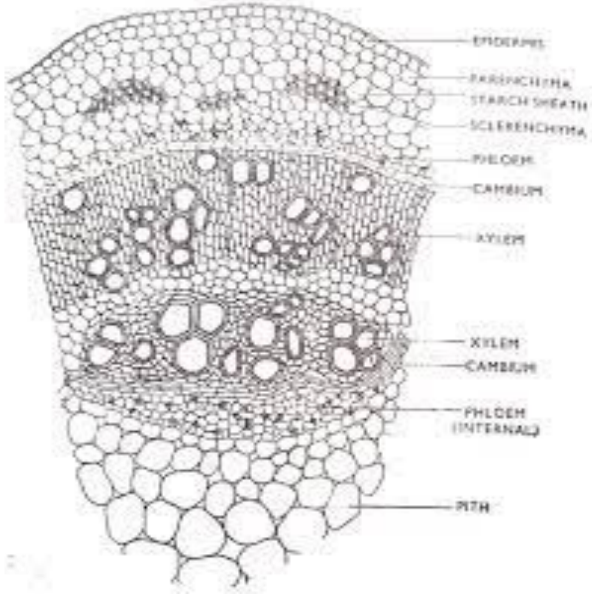


Anomalous Secondary Thickening
In Boerhavia Stem (Cellular Diagram)

<u>Anomalous Secondary Growth In *Tecoma*</u>

- Anomalous secondary growth in *Tecoma* occurs due to formation of intraxylary phloem
- Inter and intrafascicular cambium unites to form a complete cambial ring which functions normally
- After a period of normal activity two additional strips of cambium originate below secondary xylem on two opposite sides of the pith
- Each strip function abnormally donating secondary phoem towards the centre and secondary xylem towards the periphery
- Gradually two arcs of secondary vascular bundles are formed at the margin of the pith showing inverse orientation of wood and bast
- Phloem developed towards the pith side is known as intraxylary phloem or internal phloem





Anomalous Secondary growth in *Dracena*

- *Dracena* is an arborescent monocot and hence lack secondary growth
- Primary bundles are distributed over the ground tissue without definite arrangement
- Mature stem shows secondary vascular bundles in conjunctive tissue
- Conjunctive tissues are parenchymatous in nature that becomes lignified in later stage
- Secondary bundles remain arranged in somewhat radial rows
- Secondary growth is brought about by a special type of vascular cambium called <u>secondary thickening meristem</u>
- It develops in the older region of stem consisting of parenchyma cells, either fron cortex or pericycle
- Cambial cells divide tangentially and initially towards inside only
- Some of the inner derivatives differentiate into conjunctive tissye while others differentiate into vascular strands

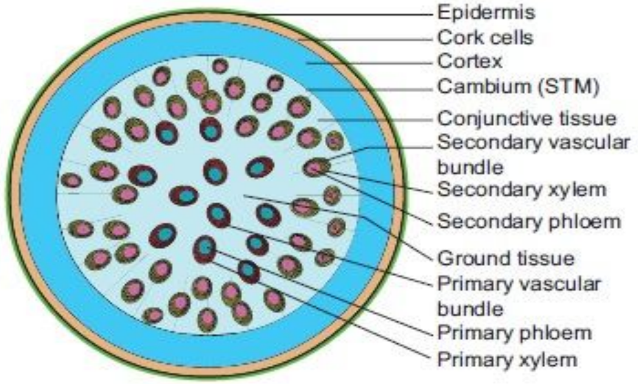
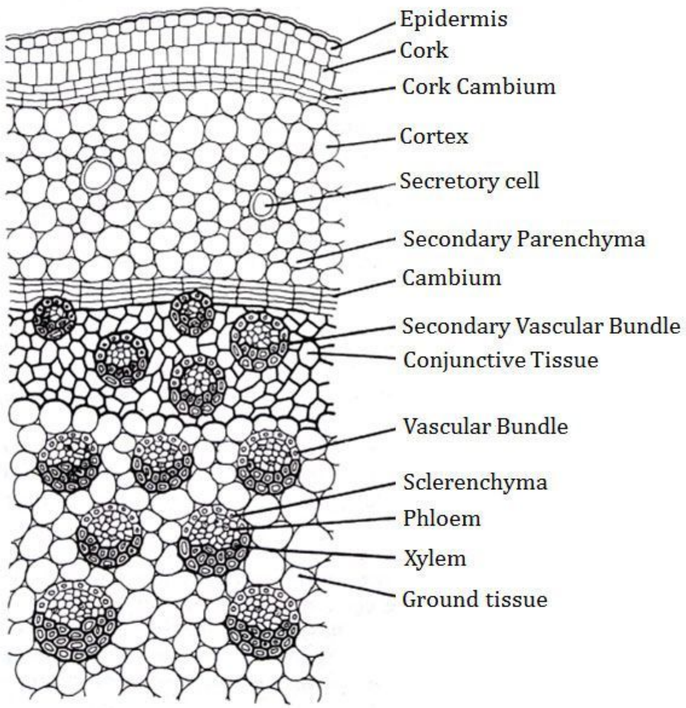


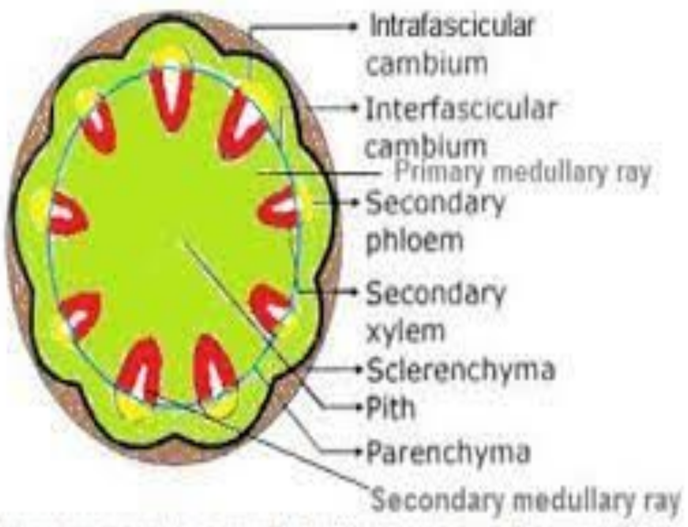
Figure 10.25: Transverse section of *Dracaena* stem (diagrammatic) showing anomalous secondary growth



Anomalous Secondary Thickening in *Dracaena (Diagram)*

Anomalous Secondary Growth in *Tinospora* Root

- Anomalous secondary growth is observed in storage roots (aerial roots of *Tinospora*)
- Both intrastelar and extrasteler cambium is observed
- Few parenchyma cells beneath the phloem and pericycle cells adjacent to the protoxylem become meristemaic and function as cambium
- They join with each other to form a complete cambium ring
- It produces secondary phloem and secondary xylem outside and inside respectively as in atem
- Primary xylem and phloem are thus pushed to the centre and periphery respectively
- Cells of the outer cortex and epidermis rupture forming peridrem



Anomalous secondary growth in *Tinospora* stem (diagrammatic)