ANATOMY OF FLOWERING PLANTS

SECONDARY GROWTH

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Secondary Growth :

- By the activity of lateral meristems (vascular cambium and cork cambium), increase in the circumference/girth/ thickness of the plant organs is called secondary growth.
- Normally secondary growth takes place in roots and stem of dicotyledons & gymnosperms.
- The tissues involved in secondary growth are two lateral meristems : vascular cambium and cork cambium.
- Secondary growth is not found in the leaves and monocots.
- Due to lack of cambium in monocotyledons, secondary growth is absent. But exceptionally secondary growth takes place in some monocotyledons. Such as- Palm, Date Palm, Coconut Palm, Yucca, Dracaena, Kingia, Sansiviera, Smilax, Agave etc. These plants show abnormal secondary growth.

Secondary growth in dicot stem:

Intra Stelar Secondary growth:

- The growth in this region starts earlier than extra stelar region.

Formation of ring of vascular cambium:

- A cambium that lies inside the vascular bundle is called **intrafascicular cambium**.
- This is a type of primary meristem.
- Firstly the parenchymatous cells of medullary rays in the line with intrafascicular cambium becomes meristematic and develop a new cambium called as **interfascicular cambium**, which is secondary lateral meristem.
- **Intrafascicular** and **interfascicular cambium** are joined to form **vascular cambium.**
- The latter is formed in the form of a complete ring composed of single layer of cells.
- In diocot stem some part of vascular cambium is primary and some part is secondary.

Two types of cells are found in the ring of this vascular cambium.

(i) Fusiform initials (form secondary xylem and phloem)

(ii) Ray initials (form secondary medullary rays)

Fusiform initials are long with pointed ends, while ray initials are spherical. Activity of fusiform initials is more in vascular cambium.

Activity of vascular cambium :

(a) Activity of fusiform ipitials :

- Continuous periclinal divisions (parallel to longitudinal axis} takes place in fusiform initials, then few cells are formed towards the periphery and these cells are differentiated into secondary phloem or bast and the cells which are formed towards the centre (towards pith) are differentiated into secondary xylem or wood.
- The cambium is generally more active on the innerside than on the outer.
- Normally more secondary xylem is formed as compared to the secondary phloem due to unequal distribution of hormones.

  (Secondary xylem is formed 8-10 times more as compared to the sec. phloem).

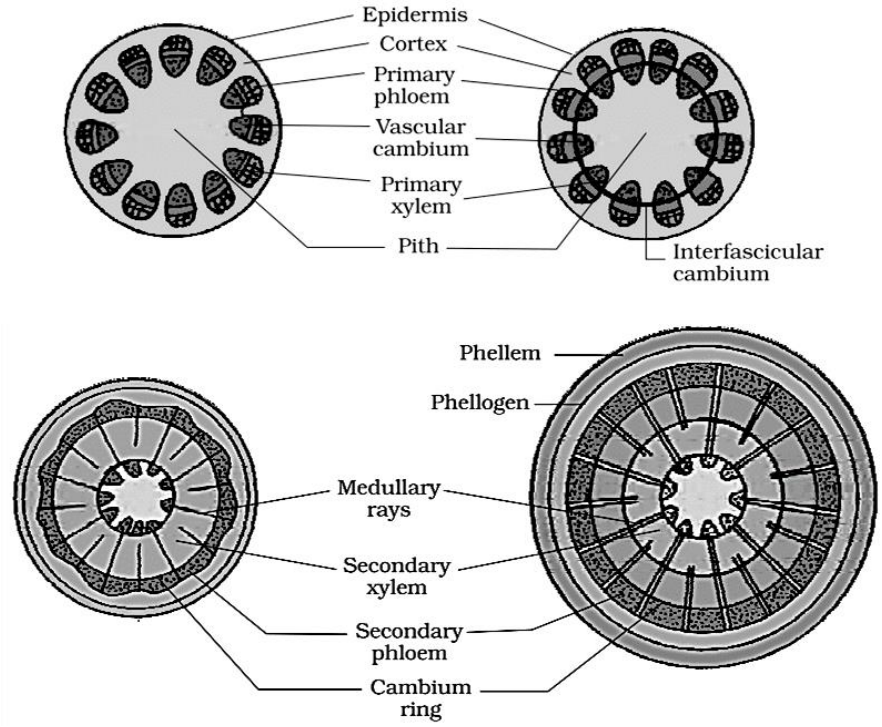


Fig. Secondary growth in a dicot stem (diagrammatic) – stages in transverse views

- By the pressure of secondary xylem, all the primary tissues- such a~ primary xylem, pith are pushed towards the centre.
- The primary xylem however remains more or less intact in or around the centre. The primary phloem and earlier secondary phloem (old secondary phloem) get gradually crushed due to the continued formation and accumulation of secondary xylem.

(b) Activity of Ray initials :- Due to periclinal divisions ray initials cuts off (form) parenchymatous cells; These are called vascular rays (Xylem rays & phloem rays) or secondary medullary rays which passes through the secondary xylem and secondary phloem in the radial direction. They conduct water and food in radial direction. The order of development of vascular rays are both centripetal and centrifugal.

Formation of Annual Rings

Annual rings are formed due to unequal activity of vascular cambium.

- The activity of cambium does not remain same, it is changeable in the whole year.
- Activity of vascular cambium is under the control of many physiological and environmental factors.
- In temperate regions, the climatic conditions are not uniform through the year.
- In the spring season, vascular cambium is very active and produces a large number of secondary xylem elements having vessels with wider cavities/lumens. The wood formed during this season is called spring wood or early wood.
- In winter and autumn season, the vascular cambium is less active and forms fewer secondary xylem elements that have vessels with narrow lumen and this wood is called winter wood or autumn wood or late wood.
- The spring wood is lighter in colour and has a lower density whereas the autumn (or winter) wood is darker and has a higher density.

Note:

(1) The autumn and spring wood are formed in the form of concentric rings, called growth rings.

(2) The two kinds of woods that appear as alternate concentric rings, constitute an annual ring. A ring of autumn wood and a ring of spring wood are collectively known as Annual ring. The

number of annual rings, formed in a tree give the idea of the age of the tree. The study of determination of age of a tree/plant by counting annual rings is called Dendrochronology.

(3) The annual rings are counted from the base of the stem because basal part has maximum annual rings and upper part has less. Therefore, counting from the basal region can give the correct idea.

(4) A piece of wood is taken from the stem up to central region from the base of stem with the help of increment borer instrument. The annual rings are counted from that piece and again inserted (fitted) into the same stem at the same place.

(5) More distinct/dear annual rings are formed in that regions where climatic variations are sharp.

(6) More distinct annual rings are formed in temperate plants. Because in temperate regions, the climatic conditions are not uniform throughout the year.

(7) Distinct annual rings are not formed in tropical plants. Distinct/clear annual rings are not formed in India except Himalayan regions (Shimla, Nainital etc.).

(8) Least distinct annual rings are formed in seashore regions/coastal regions because the climate remains the same throughout the year.

(9) More clear annual rings are ·formed in deciduous plants as compared to evergreen plants.(In temperate region)

(10) In deserts annual rings are less distinct.

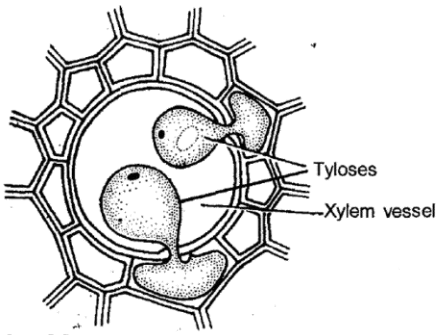
(11) In annual rings bands of secondary xylem and xylem rays (Ray parenchyma) are present.

HEART WOOD & SAP WOOD :

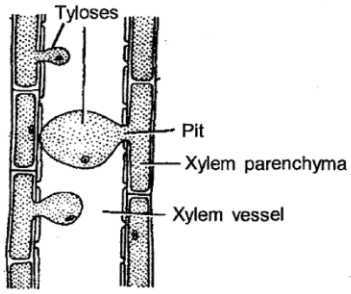
- In old trees, the greater part of secondary wlem is dark brown.
- The organic compounds like tannins, resins, gums, oils and aromatic substances etc. are filled in lumen of tracheids and vessels of secondary xylem. Due to this, central region of secondary xylem becomes dark brown. It is called heart wood or duramen. These substances make it hard. durable and resistant to the attack of micro-organisms and insects. Heart wood comprises dead elements with highly lignified walls. Heart wood provides mechanical strength to stem.
- The peripheral region of secondary wlem which is light in colour, is called sap wood or albumum.
- The function of sap wood is conduction of water and minerals.

- Heart wood does not conduct water because :-

1. Cavities of tracheids and vessels are progressively filled with waste materials.
2. The bladder/balloon like ingrowth of parenchyma cells enter in the lumen of vessels (mainly) & tracheids through the pits. Such bladder like ingrowths are called tyloses or tracheal plugs. Tyloses block the lumen of tracheary elements (vessels & tracheids).



T.S. of Sec. xylem vessel showing tyloses



L.S. of Sec. xylem vessel showing tyloses

- Heart wood provides stiffness to the stem. The waste materials of heart wood are antiseptic in nature. Heart wood is resistant to the attacks of termites and insects and in rainy season it does not imbibe water. Thus it is the best quality of wood.
- Study of wood is known as Xylotomy. The wood is actually a secondary xylem .
- Position of youngest secondary phloem is just outside the vascular cambium .
- Position of oldest secondary phloem is just inside the primary phloem .
- Position of youngest layer of secondary xylem is just inside the vascular cambium .
- Position of oldest layer of secondary xylem is just outside the primary xylem .
- As the time passes amount of heart wood increases more as compared to sap wood .

CLASSIFICATION OF WOOD :

(A) On the basis of amount of parenchyma wood is classified into two groups :-

1. **Manoxylic wood** :- Such type of wood contains more amount of living parenchyma. It is loose wood. Eg. Cycas.
2. **Pycnoxylic wood** :- Such wood contains less amount of living parenchyma.
   Example :- Pinus (Conifers)

(B) Classification based on vessels :-

On the basis of presence or absence of vessels, wood is classified into two categories -

1. **Non-porous wood / Homoxylous wood** :- Vessels are absent in this type of wood.
   Example :- Mostly gymnosperms

2. **Porous wood / Heteroxylous wood** :-Vessels are present in this type of wood. e.g Mostly dicots (Angiosperms) On the basis of arrangement of vessels porous wood is divided into two groups.

(i) Ring porous wood :- Vessels are arranged in the rings in this type of wood.
Example = In temperate region plants. Ex. Dalbergia

(ii) Diffused porous wood :- Asystematical distribution of vessels is found in this type of wood.
Example :- In tropical region plants. Ex. Azadirachta (Neem).

- Most durable wood Tectona grandis (Teak = Sag wan)

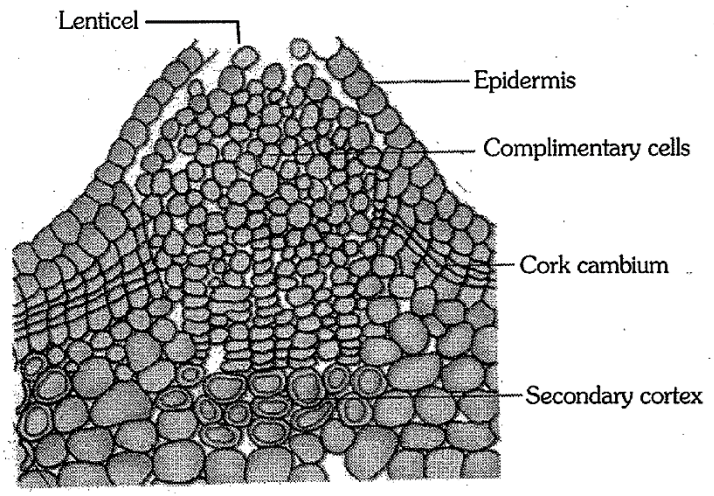
SECONDARY GROWTH IN EXTRA STELAR REGION:

- It occurs **due to the activity of cork cambium.**
- The latter is also known as **Phellogen or Extrastelar cambium.** (The cells of the cork cambium are **rectangular).**
- Cork cambium usually originates from the **outer layer of cortex** because the latter becomes meristematic.
- Cork cambium is formed in the form of a **single layered ring.**
- It forms sec. tissue in cortical region.
- It divides **periclinally** & forms some cells towards the outside (epidermis) and some cells towards the inside (cortex).
- Those cells formed towards outside are dead due to deposition of suberin in their middle lamella.
- These cells are called **Cork or Phellem.**
- Those cell formed towards inside are differentiated into parenchyma and may contain chloroplasts.
- These are called **secondary cortex or Phelloderm.**
- **Phellogen, phellem and phelloderm are collectively called periderm.**
- **Phellogen (cork cambium) + Phellem (cork) + Phelloderm (secondary cortex) = Periderm.**

- The highest activity of cork cambium is in winter (Autumn) season.
- Ring of cork cambium remains living only for one year.
- Each year, a new cork cambium is formed below the previous cork cambium.
- This new cambium is derived from the secondary cortex or phelloderm.

Lenticels : At certain regions. the phellogen (cork cambium) cuts off/forms closely arranged parenchymatous cells on the outer side instead of cork cells. These thin walled. rounded. colourless. parenchymatous cells are called complementary cells. These cells are not suberized. As the complementary cells increase in number. pressure is exerted on the epidermis due to which it ruptures, forming a lens-shaped openings called lenticels.

Complementary cells are formed by the activity of phellogen (cork cambium).



Transverse section of stem passing through a lenticel

- Lenticels are found in most of the woody trees. (Absent in woody climbers)
- Lenticels are mainly found on woody stems and they are never found on leaves. They are also present on some fruits.
- Lenticels are not found in herbaceous dicots and monocot plants.

Functions:

1. **Exchange of gases :** Lenticels permit the exchange of gases between the outer atomosphere and the internal tissue of the stem (main function).
2. **Help in transpiration** i.e., Lenticular transpiration.

Bark:

- **Bark is a non-technical term that refers to all tissues exterior to the vascular cambium, therefore including secondary phloem. Bark that is formed early in the season is called early or soft bark. Towards the end of the season, late or hard bark is formed.**
- The dead tissue present outside the cork cambium is generally called **outer bark** & phloem, pericycle and secondary cortex is called inner bark.
- Sometime outer bark is made of combined dead cell layers of periderm.
- All the dead tissues formed outside the inner most cork cambium (cork & many periderm) is called **Rhytidome**.
- Rhytidome includes cork and tissues which become dead due to the pressure of cork.

KINDS OF BARK

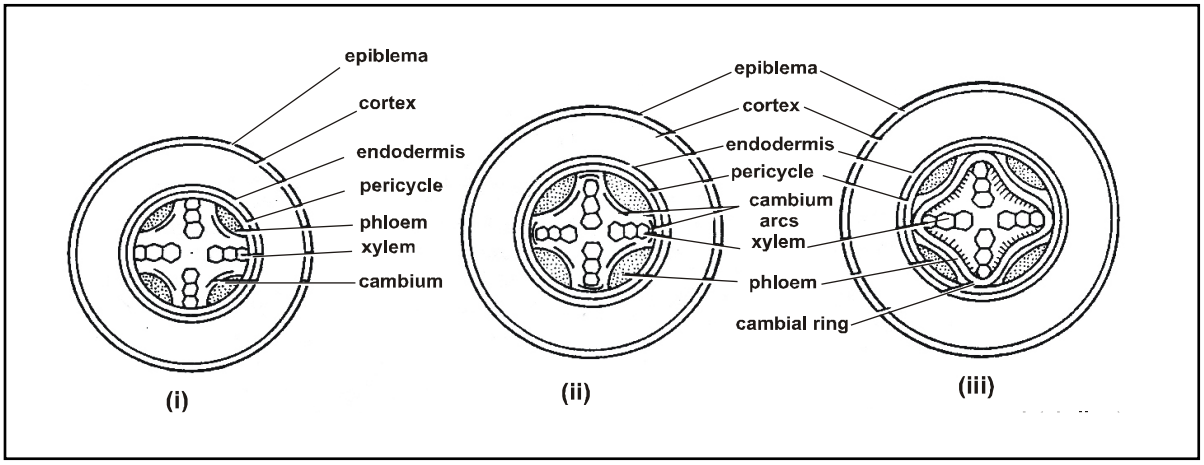
1. **Ring Bark = Sheet bark** :- Continuous bark of equal thickening is called ring bark. It is formed around the stem in the form of a complete ring. When cork cambium is continuous then ring bark is formed.

   Example :- Bhojpatra (Betula utilis) -A complete distinct ring bark is formed in this plant. Its bark was used as a writing material /as a paper in ancient period, only cork layer was used. Ring bark is also formed in Eucalyptus.
2. **Scaly Bark** :- Discontinuous bark of unequal thickening is called scaly bark. This bark is formed around the stem in the form of pieces or fragments or patches. When cork cambium is discontinuous then scaly bark is formed. eg. Guava (Psidium guajava). Neem (Azadirachta indica), Mango {Mangifera indica) and Tamarind = lmli (Tamarindus) etc. plants.

- Highly distinct scaly bark is formed in Psidium guajava (Guava)
- Scaly bark is found in most of the woody plants.
- If bark is removed in the form of a ring (Girdling) from the base of main stem then root dies first due to lack of food.
- Girdling is not possible is monocot stem because vascular bundles are scattered.
- If complete bark is removed then plant dies due to excessive water loss.
- Bark that is formed early in the season is called early or soft bark. Towards the end of the season late or hard bark is formed.
- Secondary phloem and periderm are included in bark.

SECONDARY GROWTH IN DICOT ROOT:

- **Conjunctive tissue** becomes meristematic below phloem bundles and form separate curved strips of vascular cambium during the secondary growth in a dicotyledon root.



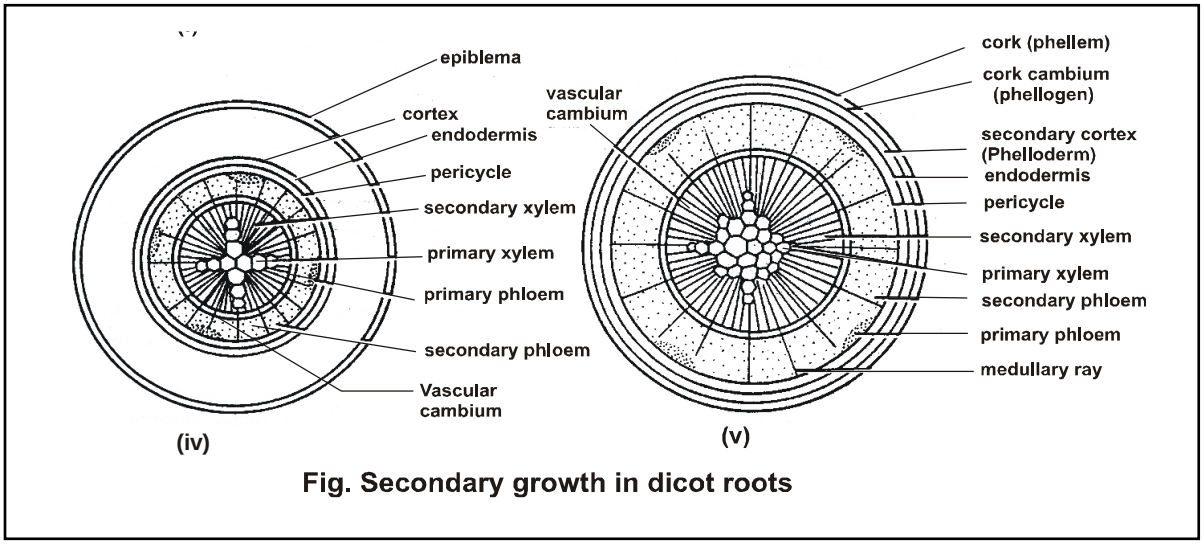
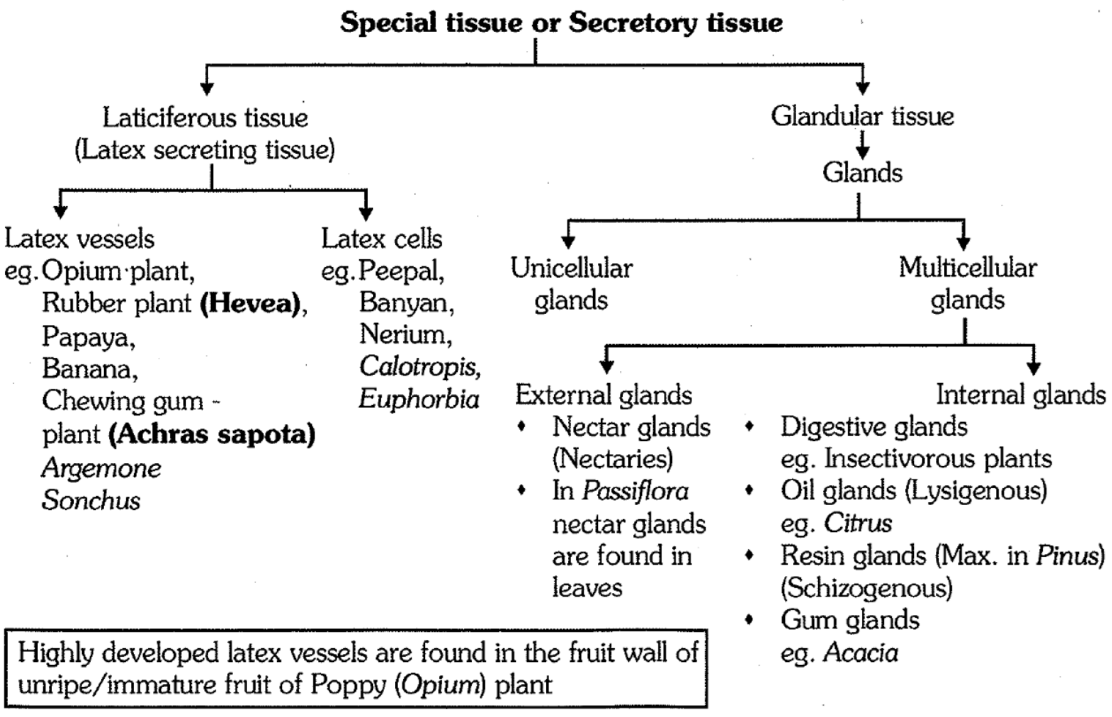


Fig. Secondary growth in dicot roots

- Now the cells of **pericycle** lying **opposite to protoxylem** also becomes meristematic to form additional strips of cambium.
- In this way a complete ring of vascular cambium is formed due to joining of these two.
- The shape of ring of vascular cambium is wavy in the beginning, but later on it becomes circular due to the pressure of secondary xylem.
- The activity of vascular cambium of root is similar as activity of vascular cambium of stem.

- Vascular cambium forms secondary xylem towards the inner side and secondary phloem towards the outer side.
- The portion of vascular cambium which is formed by pericycle is responsible for the formation of pith rays. These are made up of parenchyma. These pith rays are known as primary medullary rays (Multiseriate).
- A few medullary or pith rays are also formed from remaining vascular cambium. These are called secondary medullary rays (uniseriate). Thus two types of medullary rays are found in the secondary structure of roots.

SPECIAL TISSUES



STELE

- All the tissues which are present inside the endodermis constitute the stele.
- The stele is the whole central mass of vascular tissue (vascular cylinder) with or without pith surrounded by endodermis. Stele is surrounded by endodermis but endodermis is originally

the part of cortex. It is not a part of stele. Van Tieghem and Douliot put forward the concept of stele/stelar theory.

- According to him stele is the central part or core of the axis of the plant which includes the vascular system and its related structures.
- The tissues which lies inside the stele are called intrastelar tissues and the tissues which lies out side the stele are known as extra stelar tissues.
- Stelar system started from pteridophytes.

TYPES OF STELE (On the basis of evolution)

1. Protostele or Mono stele or solid stele eg.- Rhynia, Homiophyton, Psilotum, Lycopodium.
2. Siphonostele :-

(i) Ectophloic siphonostele
Example :- Equisetum, Osmunda

(ii) Amphiphloic siphonostele
Example :- Adiantum, Marsilea

3. Dictyostele or Polystele
Example - Pteridium, Pteris, Dryopteris
4. Eustele :- eg. stem of gymnosperms and dicots.
5. Atactostele :-
e.g. :- Monocot stems

ANOMALOUS PRIMARY STRUCTURE

(1) Anomalous structure in dicotyledon stem

- **Scattered Vascular Bundles** :- In some of dicotyledon stem, vascular bundles are not arranged in a rin, they are Scattered in the ground tissue.
Examle : Thallictrum, Nymphaea, Papaver orientale & Peperomia. _,

(2) Anomalous structure in monocot stem :-

- Normally vascular bundles are found in monocotyledon stems in scattered form but in the stem of some monocotyledon plants vascular bundles are arranged in rings. Ex. Members of family Gramineae, such as Triticum (Wheat), Secale, Avena, Oryza (Rice) etc.

Some Extra Points

1. Cricket bat → from Salix [Willow] wood
2. Hockey blade → from Morus [Mulberry] wood
3. Billiards's ball → Phytelophus Uvory Palm)
4. Violin → Picea (Spruce)
5. Monarch Condition → in Trapa root
6. Triarch Condition → in Pisum root
7. Tetrarch Condition → in Helianthus annuus (Sunflower) and Cicer arietinum (Gram) root
8. Chewing gum is made by latex of Achras sapota.
9. Cystolith containing cells are found in the upper epidermis of Ficus leaf, called lithocytes/Uthocysts.
10. Lignin (xylem) is stained by safranin and phloem is stained by fast green.
11. Transition of exarch bundles of root to endarch bundles of stem occurs in hypocotyl
12. A nectar secreting gland cell contains granular cytoplasm and a large conspicuous nucleus.
13. In some plants like datepalm increase in thickeness of stem occurs due to primary thickening meristem.

ANOMALOUS SECONDARY GROWTH IN DICOT STEM

1. Formation of cork cambium from Epidermis
   Example : Malus pumila, Solanum dulcamara, Quercus suber(oak).
- The commercial cork is obtained from the plant Quercus suber,which is commonly found in Portugal and Port of Spain

2. **Formation of cork cambium from pericycle** :- Example- Clematis
3. **Formation of cork cambium from phloem** :- Vilis and Berberis '
4. Phloem is embedded into the secondary xylem in some plants. Such phloem is called included phloem or intraxylary phloem. This is secondary anomalous structure.
   Example : Leptadaenia, Salvadora etc. dicot stem.

ANOMALOUS SECONDARY GROWTH

Gymnosperm stem :- In Cycas and Gnetum ula, successive rings of vascular cambium are found.