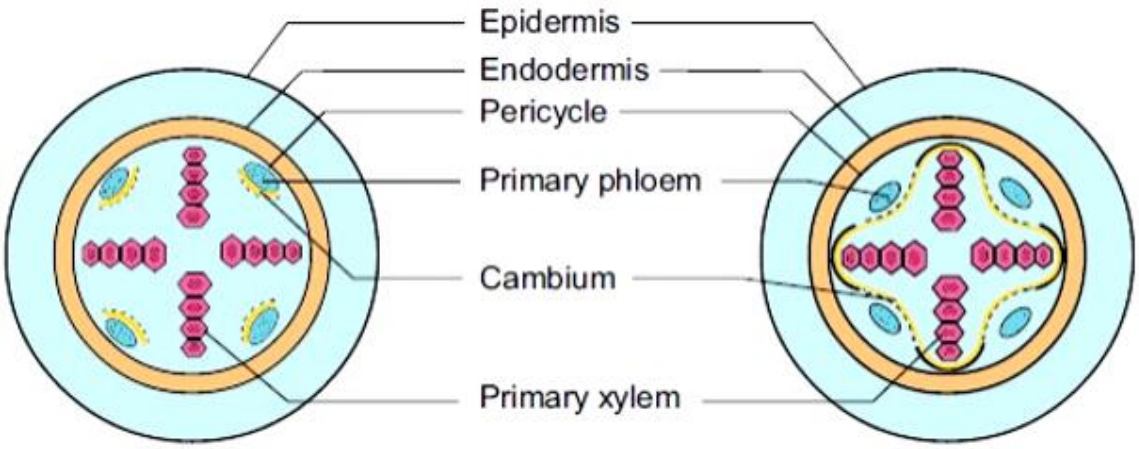
1. Secondary growth in Roots

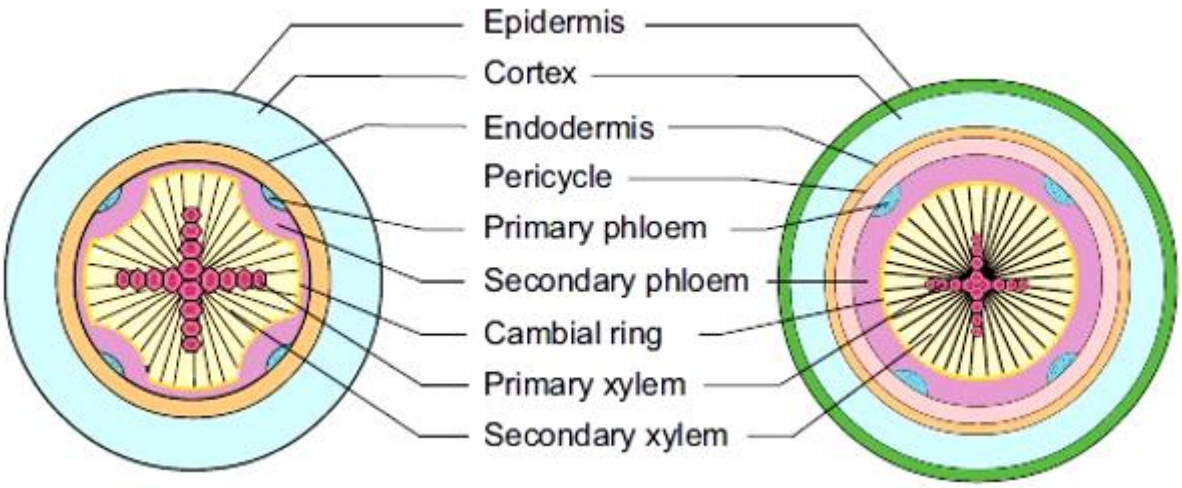
- Secondary growth in thickness of root is due to the addition of new tissues by the activity of vascular cambium and cork cambium.
- Monocot roots do not show secondary growth.
- Dicot roots have radial and exarch vascular bundles.
- Conjunctive tissue is present between xylem and phloem.

Activity of Cambium

- The conjunctive tissue becomes meristematic and forms a small strip of cambium just below the primary phloem.
- At the same time, cells of pericycle present outside protoxylem also become meristematic and forms small cambial strips.
- These two cambial strips join together and form a wavy band of cambium.



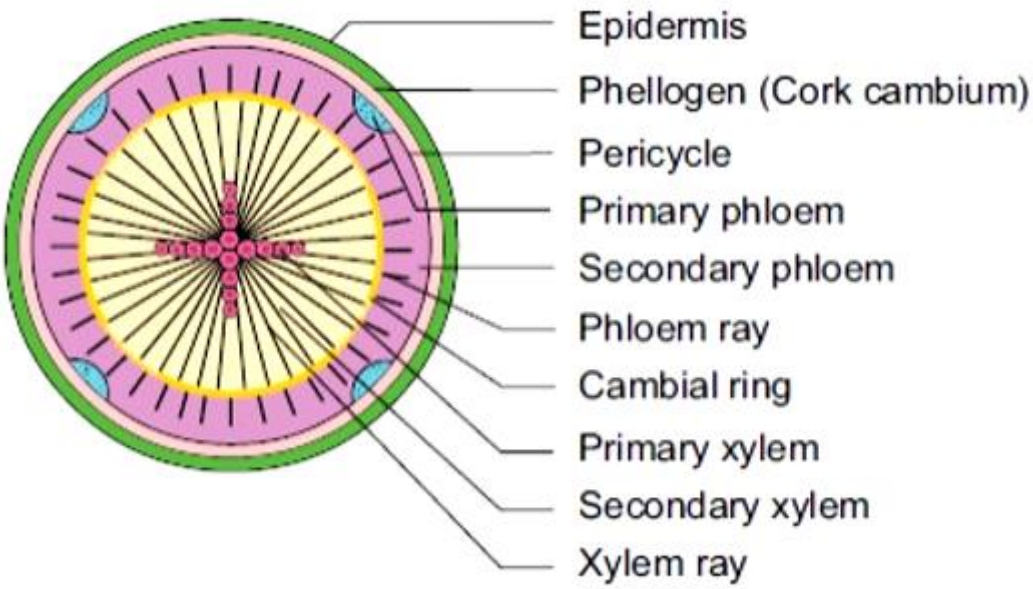
- The cambial cells below the phloem become active first. It cuts off cells to either side, with more cells on the inner side.
- This causes the phloem and cambium is pushed outwards.
- Hence the wavy cambium gradually becomes a circular cambium.
- Then it forms secondary xylem and phloem tissues.
- But, it does not form any annual rings.



Periderm formation

- The cells of pericycle become meristematic and forms secondary meristems called cork cambium or phellogen.

- These cells cut off phellem towards the outer region and phelloderm towards the inner region.
- These three tissues together form the outer protective layer of a root known as the periderm.



2. Secondary Growth in Dicot Stem (With Diagram)

Secondary tissues are formed by two types of lateral meristems, vascular cambium and cork cambium or phellogen. Vascular cambium produces secondary vascular tissues while phellogen forms periderm.

A. Formation of Secondary Vascular Tissues:

They are formed by the vascular cambium. Vascular cambium is produced by two types of meristems, fascicular or intra-fascicular and inter-fascicular cambium. Intra-fascicular cambium is a primary meristem which occurs as strips in vascular bundles. Inter-fascicular cambium arises secondarily from the cells of medullary rays which occur at the level of intra-fascicular strips.

These two types of meristematic tissues get connected to form a ring of vascular cambium. Vascular cambium is truly single layered but appears to be a few layers (2-5) in thickness due to presence of its immediate derivatives. Cells of vascular cambium divide periclinally both on the outer and inner sides (bipolar divisions) to form secondary permanent tissues.

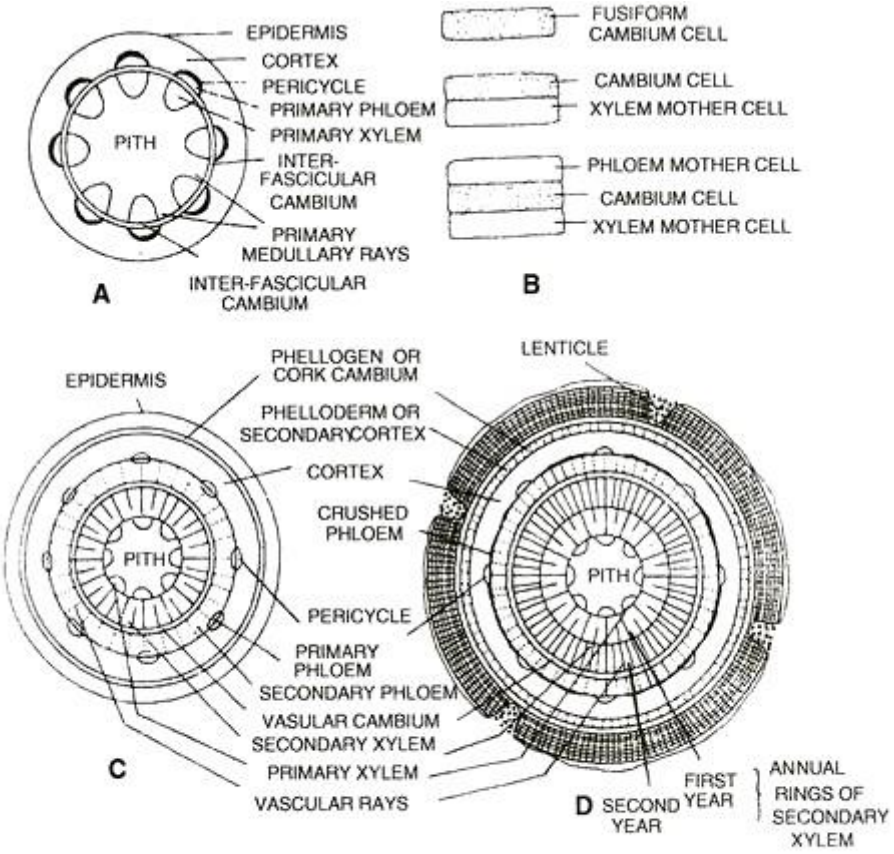


Fig. 6.28. A, complete ring of vascular cambium formed by strips of intrafascicular cambium and inter-fascicular cambium. B, formation of secondary vascular tissue mother cells; C, the beginning of secondary growth (mostly made up of secondary vascular tissues) of dicot stem (diagrammatic); D, two-year stage of secondary growth of a dicot stem.

1. Vascular Rays:

The vascular rays or secondary medullary rays are rows of radially arranged cells which are formed in the secondary vascular tissues. They are a few cells in height.

The part of the vascular ray present in the secondary xylem is called wood or xylem ray while the part present in the secondary phloem is known as phloem ray. The vascular rays conduct water and organic food and permit diffusion of gases in the radial direction. Besides, their cells store food.

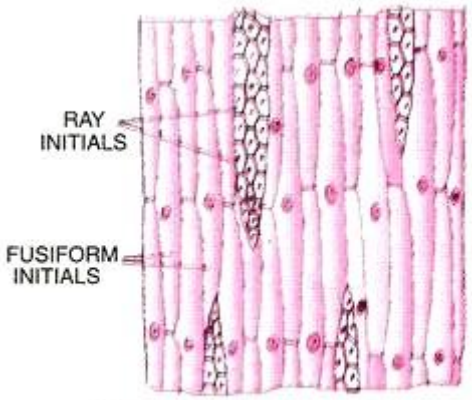


Fig. 6.29. L.S. Vascular cambium showing fusiform and ray initials.

2. Secondary Phloem (Bast):

It forms a narrow circle on the outer side of vascular cambium. Secondary phloem does not grow in thickness because the primary and the older secondary phloem present on the outer

side gets crushed with the development of new functional phloem (Fig. 6.28 D). Therefore, rings (annual rings) are not produced in secondary phloem. The crushed or non-functioning phloem may, however, have fibres and sclereids.
Secondary phloem is made up of the same type of cells as are found in the primary phloem (metaphloem)— sieve tubes, companion cells, phloem fibres and phloem parenchyma.

3. Secondary Xylem:

It forms the bulk of the stem and is commonly called wood. The secondary xylem consists of vessels, tracheids (both tracheary elements), wood fibres and wood parenchyma.
Secondary xylem does not show distinction into protoxylem and meta-xylem elements. Therefore, vessels and tracheids with annular and spiral thickenings are absent. Fibres are abundant.
Width of secondary xylem grows with the age of the plant. The primary xylem persists as conical projection on its inner side. Pith may become narrow and ultimately get crushed.
The yearly growth of secondary xylem is distinct in the areas which experience two seasons, one favourable spring or rainy season) and the other un-favourable (autumn, winter or dry summer).
Hence the annual or yearly growth appears in the form of distinct rings which are called annual rings (Fig. 6.30).
Annual rings are formed due to sequence of rapid growth (favourable season, e.g., spring), slow growth (before the onset of un-favourable period, e.g., autumn) and no growth (un-favourable season, e.g., winter). Annual rings are not distinct in tropical areas which do not have long dry periods.

Fig. 6.30. Part of T.S. old stem showing annual rings.

Annual Rings (Growth Rings), It is the wood formed in a single year. It consists of two types of wood, spring wood and autumn wood (Fig. 6.31).

The spring or early wood is much wider than the autumn or late wood. The autumn or late wood is dark coloured and of higher density. It contains compactly arranged smaller and narrower elements which have comparatively thicker walls. In autumn wood, tracheids and fibres are more abundant than those found in the spring wood.

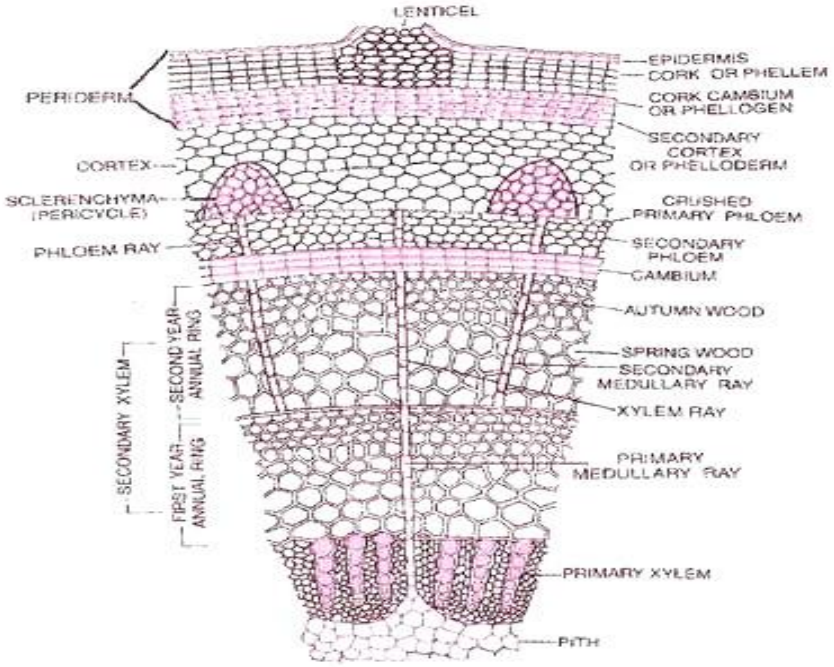


Fig. 6.31. Part of detailed structure of transverse section of two year old dicot stem showing secondary growth.

B. Formation of Periderm:

In order to provide for increase in girth and prevent harm on the rupturing of the outer ground tissues due to the formation of secondary vascular tissues, dicot stems produce a cork cambium or phellogen in the outer cortical cells. Rarely it may arise from the epidermis (e.g., Teak, Oleander), hypodermis (e.g., Pear) or phloem parenchyma.

Phellogen cells divide on both the outer side as well as the inner side (bipolar) to form secondary tissues. The secondary tissue produced on the inner side of the phellogen is parenchymatous or collenchymatous. It is called secondary cortex or phelloderm. Its cells show radial arrangement.

Phellogen produces cork or phellem on the outer side. It consists of dead and compactly arranged rectangular cells that possess suberised cell walls. The cork cells contain tannins. Hence, they appear brown or dark brown in colour. The phelloderm, phellogen and phellem together constitute the periderm (Fig. 6.34).

Lenticels:

Lenticels are aerating pores in the bark of plants. They appear on the surface of the bark as raised scars containing oval, rounded or oblong depressions (Fig. 6.34 A). They occur in woody trees but not in climbers. Normally they are formed in areas with underlying rays for facilitating gas exchange. Lenticels may occur scattered or form longitudinal rows.

They enclose intercellular spaces for gaseous exchange. The complementary cells are formed from loosely arranged phellogen cells and division of sub-stomatal parenchyma cells. The suberised nature of complementary cells checks excessive evaporation of water.

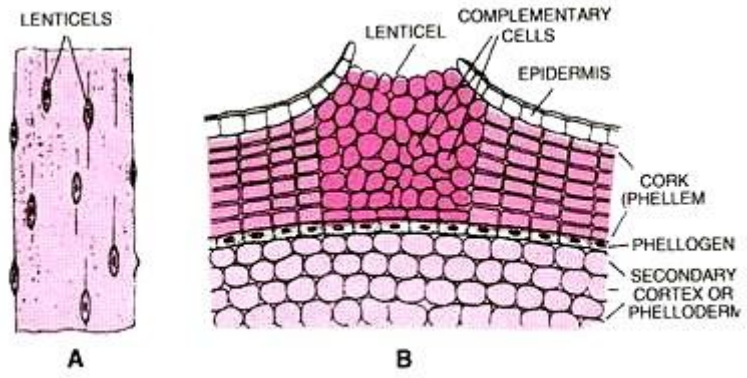
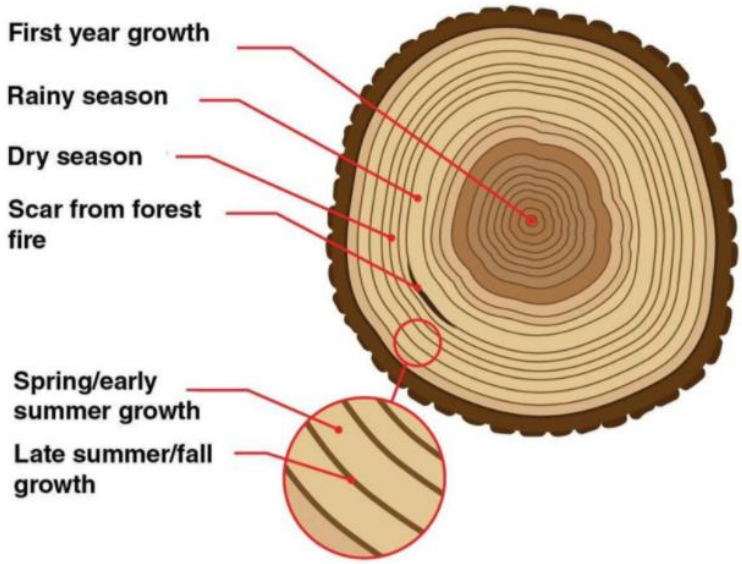


Fig. 6.34. Lenticels. A, external view of lenticels; B, T.S. lenticel.

Bark:

In common language and economic botany, all the dead cells lying outside phellogen are collectively called bark. The outer layers of the bark are being constantly peeled off on account of the formation of new secondary vascular tissues in the interior.

Bark formed in early growing season is early or soft bark. The one formed towards end of growing season is late or hard bark.



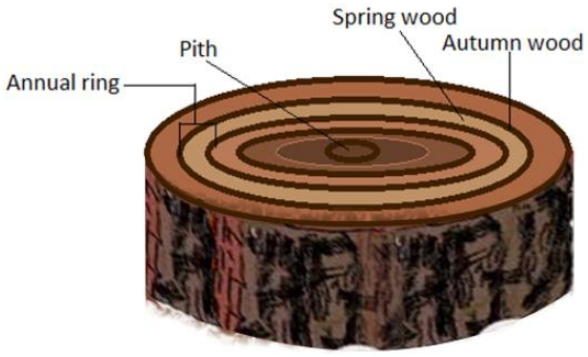
C. Annular rings-

- The two types of wood the spring and autumn wood alternate in a dicot stem appearing like concentric rings which are together known as Annular rings/growth rings.
- These rings alternate according to the season and they are of lighter and darker shades.
- Now one dark (autumn wood) ring and one light (springwood) ring form a single annular ring or they are also known as growth rings.
- This means one spring wood ring and one autumn wood ring together represent a year.
- In tropical regions, the cambium is almost equally active throughout the year, thus there is no distinction like spring & autumn wood.

Difference between springwood and autumn wood

- The wood that is formed in the spring season due to high cambium activity is termed earlywood or springwood.

- In the winter season the activity of cambium reduces to a large extent and the wood produced during that time is called autumn wood or latewood.



LATE WOOD AND EARLY WOOD