Chapter 10

Unit IV: Plant Anatomy (Structural Organisation)

Secondary Growth

Learning Objectives

The students should be able to,

- *Analyze primary and secondary growth.*
- *Discuss the increase in length and width of the plant.*
- *Explain secondary growth in dicot stems.*
- *Explain secondary growth in dicot roots.*

CLVCSK

Chapter Outline

How do the trees increase their girth?

Figure 10.1: *Taxus* wood

We have studied in the previous chapters the primary internal structure of monocots and dicots. If you look at the stem of grass (monocot), it is soft, whereas in the neem (dicot), the stem is very hard and woody, why? It is the secondary growth which confers the hardness to wood of dicot stems and roots. In monocots, usually there is no secondary growth and so they are soft.

The increase in girth is called **secondary growth** or **growth in girth** and we shall discuss the details of secondary growth in this chapter.

The plant organs originating from the apical meristems pass through a period of expansion in length and width. The roots and stems grow in length with the help of apical meristems. This is called **primary growth or longitudinal growth.** The gymnosperms and most angiosperms, including some monocots, show an increase in thickness of stems and roots by means of **secondary growth or latitudinal growth.**

The secondary growth in dicots and gymnosperms is brought about by two lateral meristems.

- Vascular Cambium and
- Cork Cambium

Activity

Generally monocots do not have secondary growth, but palms and bamboos have woody stems. Find the reason.

10.1 Secondary Growth in Dicot Stem

Vascular Cambium

The vascular cambium is the lateral meristem that produces the secondary vascular tissues. i.e., secondary xylem and secondary phloem.

Origin and Formation of Vascular Cambium

A strip of vascular cambium that is believed to originate from the procambium is present between xylem and phloem of the vascular bundle. This cambial strip is known as **intrafascicular or fascicular cambium**. In between the vascular bundles, a few parenchymatous cells of the medullary rays that are in line with the fascicular cambium become meristematic and form strips of vascular cambium. It is called **interfascicular cambium**.

This interfascicular cambium joins with the intrafascicular cambium on both sides to form a continuous ring. It is called a **vascular cambial ring.** The differences between interfascicular and intrafascicular cambia are summarised below:

Intrafascicular cambium	Interfascicular cambium
Present inside the vascular bundles	Present in between the vascular bundles.
Originates from the procambium.	Originates from the medullary rays.
Initially it forms a part of the primary meristem.	From the beginning it forms a part of the secondary meristem.

Organization of Vascular Cambium

The cells of vascular cambium do not fit into the usual description of meristems which have isodiametric cells, with a dense cytoplasm and large nuclei. While the active vascular cambium possesses cells with large central vacuole (or vacuoles) surrounded by a thin, layers of dense cytoplasm.

Further, the most important character of the vascular cambium is the presence of two kinds of initials, namely, **fusiform initials** and **ray initials**.

Fusiform Initials

These are vertically elongated cells. They give rise to the longitudinal or axial system of the secondary xylem (treachery elements, fibres, and axial parenchyma) and phloem (sieve elements, fibers, and axial parenchyma).

Based on the arrangement of the fusiform initials, two types of vascular cambium are recognized.

Storied (Stratified cambium) and Non-Storied (Non-stratified cambium)

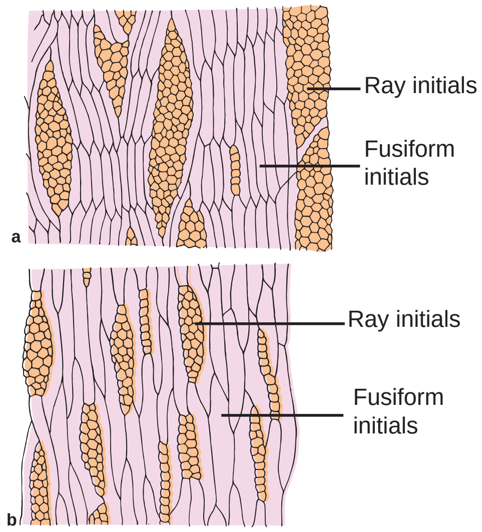

Figure 10.2: Tangential longitudinal section (TLS) of cambium (a) Storied cambium (b) Non-storied cambium

If the fusiform initials are arranged in horizontal tiers, with the end of the cells of one tier appearing at approximately the same level, as seen in tangential longitudinal section (TLS), it is called **storied (stratified) cambium**. It is the characteristic of the plants with short fusiform initials. Whereas in plants with long fusiform initials, they strongly overlap at the ends, and this type of cambium is called **non-storied (non-startified) cambium**.

Ray Initials

These are horizontally elongated cells. They give rise to the ray cells and form the elements of the radial system of secondary xylem and phloem.

Activity of Vascular Cambium

The vascular cambial ring, when active, cuts off new cells both towards the inner and outer side. The cells which are produced outward form secondary phloem and inward secondary xylem.

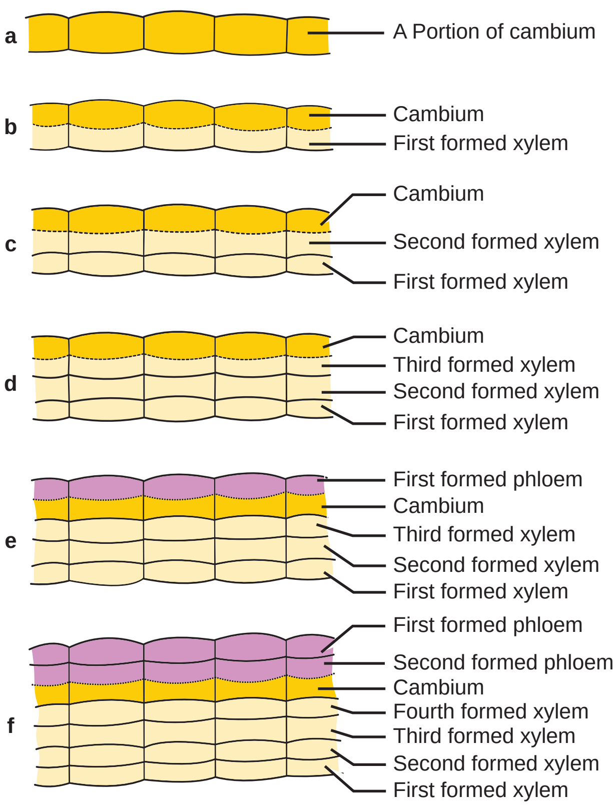

Figure 10.3: Diagrammatic representation of vascular cambial activity (a–f)

At places, cambium forms some narrow horizontal bands of parenchyma which passes through secondary phloem and xylem. These are the rays.

Due to the continued formation of secondary xylem and phloem through vascular cambial activity, both the primary xylem and phloem get gradually crushed.

Secondary Xylem

The secondary xylem, also called **wood**, is formed by a relatively complex meristem, the vascular cambium, consisting of vertically (axial) elongated fusiform initials and horizontally (radially) elongated ray initials.

> DO YOU KNOW?
>
> **Xylotomy**
> The study of wood by preparing sections for microscopic observation.

The axial system consists of vertical files of treachery elements, fibers, and wood parenchyma. Whereas the radial system consists of rows of parenchymatous cells oriented at right angles to the longitudinal axis of xylem elements.

The secondary xylem varies very greatly from species to species with reference to relative distribution of the different cell types, density and other properties. It is of two types.

Porous Wood or Hard Wood

Generally, the dicotyledonous wood, which has vessels is called **porous wood** or **hard wood**. Example: *Morus rubra.*

Non- Porous Wood or Soft Wood

Generally, the gymnosperm wood, which lacks vessels is known as **non- porous wood** or **soft wood**. Example: *Pinus*.

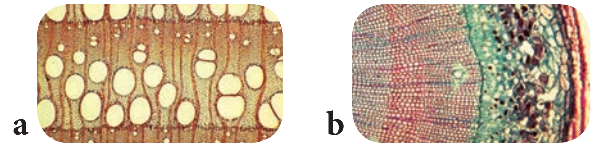

Figure 10.4: Structure of porous (a) and non-porous wood (b)

Differences between Porous Wood and Non-porous Wood

Porous wood or Hard wood, Example: *Morus*	Non porous wood or Soft wood, Example: *Pinus*
Common in angiosperms	Common in gymnosperms
Porous because it contains vessels	Non-porous because it does not contain vessels

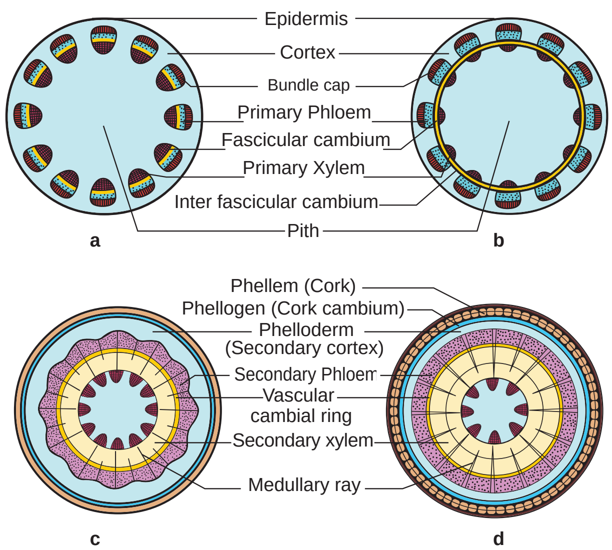

Figure 10.5: Secondary growth in dicot stem (diagrammatic) - stages in transverse section (a–d)

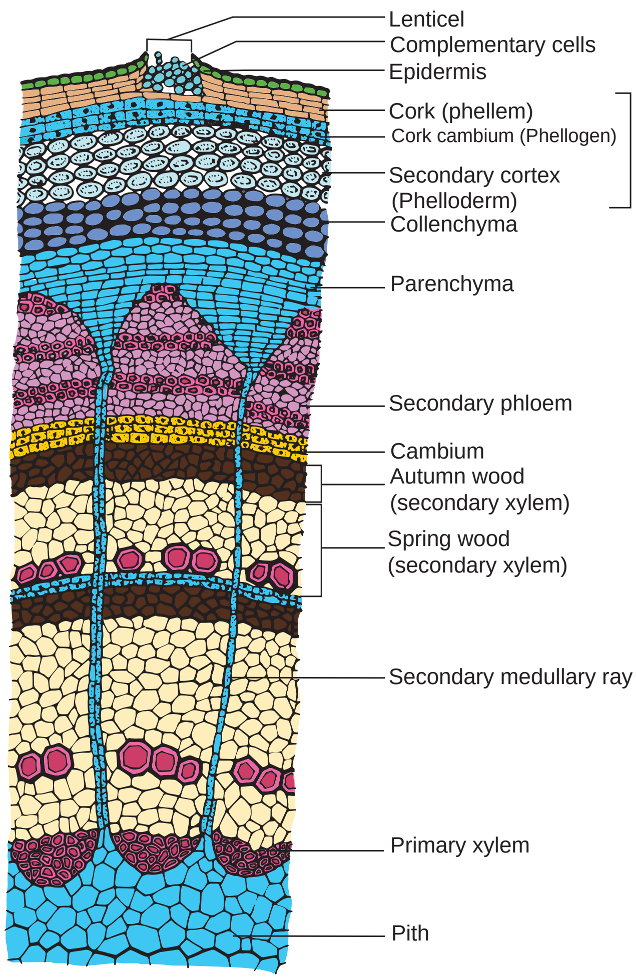

Figure 10.6: Secondary growth in two year old dicot stem – A portion enlarged

Annual Rings

The activity of vascular cambium is under the control of many physiological and environmental factors. In temperate regions, the climatic conditions are not uniform throughout the year. In the spring season, cambium is very active and produces a large number of xylary elements having vessels/tracheids with wide lumen. The wood formed during this season is called **spring wood or early wood**. The tracheary elements are fairly thin walled. In winter, the cambium is less active and forms fewer xylary elements that have narrow vessels/tracheids and this wood is called **autumn wood or late wood.** The treachery elements are with narrow lumen, very thick walled.

> **DO YOU KNOW?**
>
> - Usually more distinct annual rings are formed in the regions where climatic variations are sharp.
> - Usually more distinct annual rings are formed in temperate plants and not in tropical plants.
> - Usually least distinct annual rings are formed in seashore region because the climatic conditions remain same throughout the year.
> - Generally annual rings are also less distinct in desert plants.

The spring wood is lighter in colour and has a lower density whereas the autumn wood is darker and has a higher density.

The annual ring denotes the combination of early wood and late wood and the ring becomes evident to our eye due to the high density of late wood. Sometimes annual rings are called **growth rings** but it should be remembered all the growth rings are not annual. In some trees more than one growth ring is formed with in a year due to climatic changes.

Additional growth rings are developed within a year due to adverse natural calamities like drought, frost, defoliation, flood, mechanical injury and biotic factors during the middle of a growing season, which results in the formation of more than one annual ring. Such rings are called **pseudo-** or **false- annual rings**.

Each annual ring corresponds to one year's growth and on the basis of these rings, the age of a particular plant can easily be calculated. The determination of the age of a tree by counting the annual rings is called **dendrochronology**.

Importance of Studying Growth Rings

- Age of wood can be calculated.
- The quality of timber can be ascertained.
- Radio-Carbon dating can be verified.
- Past climate and archaeological dating can be made.
- Provides evidence in forensic investigation.

Dendroclimatology

It is a branch of dendrochronology concerned with constructing records of past climates and climatic events by analysis of tree growth characteristics, especially growth rings.

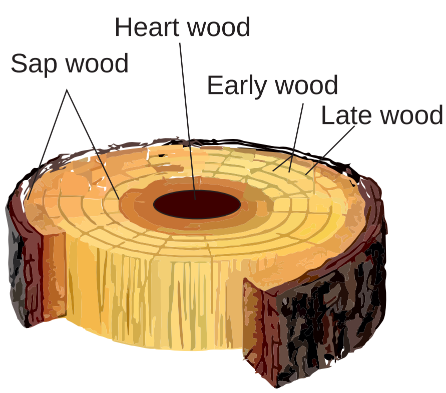

Figure 10.7: Structure of wood – Image shows early wood and late wood

The age of American, *Sequoiadendron* tree is about 3500 years.

Differences Between Spring Wood and Autumn Wood

Spring wood or Early wood	Autumn wood or Late wood
The activity of cambium is faster.	Activity of cambium is slower
Produces large number of xylem elements.	Produces a fewer xylem elements.
Xylem vessels/ trachieds have wider lumen.	Xylem vessels/ trachieds have narrow lumen.
Wood is lighter in colour and has lower density	Wood is darker in colour and has a higher density.

Another feature of wood related to seasonal changes is the diffuse porous and ring porous condition. On the basis of diameter of xylem vessels, two main types of angiosperm woods are recognized.

❖ **Diffuse porous woods**

Diffuse porous woods are woods in which the vessels or pores are rather uniform in size and distribution throughout an annual ring.

Example: *Acer*

❖ **Ring porous woods**

The pores of the early wood are distinctly larger than those of the late wood. Thus rings of wide and narrow vessels occur.

Example: *Quercus*

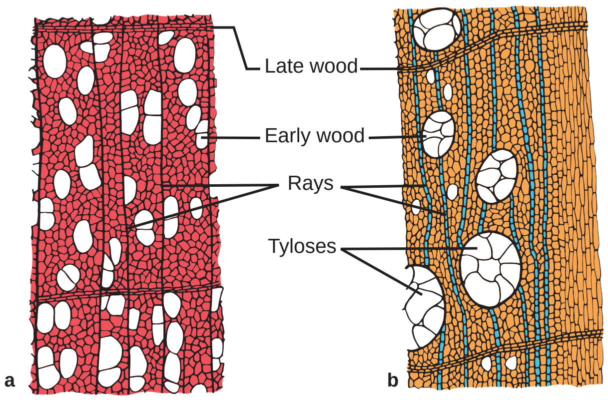

Figure 10.8: Transverse section of wood showing. a. Diffuse porous. b. Ring porous

> **DO YOU KNOW?** The word “Porous” is used by the wood anatomists to refer to the appearance of the vessels as pores in transverse section.

Differences Between Diffuse Porous Wood and Ring Porous Wood

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.

Tyloses

In many dicot plants, the lumen of the xylem vessels is blocked by many balloon-like ingrowths from the neighbouring parenchymatous cells. These balloon-like structures are called **tyloses**.

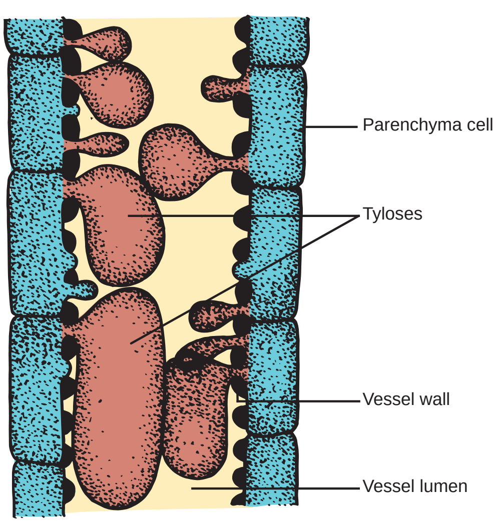

Figure 10.9: Structure of tyloses

Usually, these structures are formed in secondary xylem vessels that have last their function i.e., in heart wood.

In fully developed tyloses, starchy crystals, resins, gums, oils, tannins or coloured substances are found.

> **DO YOU KNOW?** There are tylosoids in gymnosperms and angiosperms
>
> In **gymnosperms**, the resin ducts are blocked by tylose- like ingrowths from the neighbouring resin producing parenchyamatous cells. Example: *Pinus*.
>
> In **angiosperms**, the sieve tubes are blocked by tylose- like ingrowths from the neighbouring parenchyamatous cells. Example: *Bombox*.
>
> These are called **tylosoids**

Wood is also classified into **sap wood** and **heart wood**.

Sap Wood and Heart Wood

Sap wood and heart wood can be distinguished in the secondary xylem. In any tree the outer part of the wood, which is paler in colour, is called **sap wood or alburnum.** The centre part of the wood, which is darker in colour is called **heart wood or duramen.** The sap wood conducts water while the heart wood stops conducting water. As vessels of the heart wood are blocked by tyloses, water is not conducted through them. Due to the presence of tyloses and their contents the heartwood becomes coloured, dead and the hardest part of the wood.

From the economic point of view, generally the heartwood is more useful than the sapwood. The timber from the heartwood is more durable and more resistant to the attack of microorganisms and insects than the timber from sapwood.

> **DO YOU KNOW?** When, the heart wood of a tree is destroyed, no vital function of the plant is affected.
>
> When, the sap wood is destroyed, the plant will die because conduction of water will be blocked.

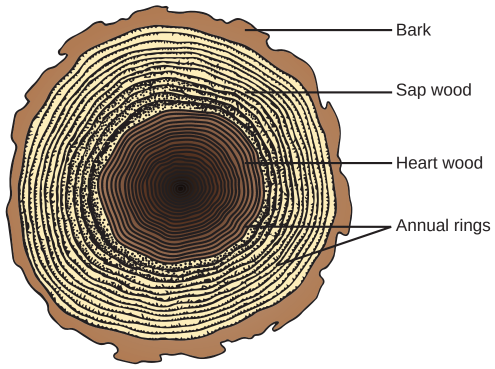

Figure 10.10: Cross - section of wood showing annual ring

Differences Between Sap Wood (alburnum) and Heart Wood (duramen)

Sap Wood (Alburnum)	Heart Wood (Duramen)
Living part of the wood.	Dead part of the wood.
It is situated on the outer side of wood	It is situated in the centre part of wood
It is pale coloured	It is dark coloured
Very soft in nature	Hard in nature
Tyloses are absent	Tyloses are present
It is not durable and not resistant to microorganisms	It is more durable and resists microorganisms

Secondary Phloem

The vascular cambial ring produces secondary phloem or bast on the outer side of the vascular bundle.

Just as the secondary xylem, the secondary phloem also has two tissue systems – the axial (vertical) and the radial (horizontal) systems derived respectively from the vertically elongated fusiform initials and horizontally elongated ray initials of vascular cambium. While sieve elements, phloem fibre, and phloem parenchyma represent the axial system, phloem rays represent the radial system. Life span of secondary phloem is less compared to secondary xylem. Secondary phloem is a living tissue that transports soluble organic compounds made during photosynthesis to various parts of plant.

Some commercially important phloem or bast fibres are obtained from the following plants.

i. Flax-*Linum usitatissimum*
ii. Hemp-*Cannabis sativa*
iii. Sun hemp-*Crotalaria juncea*
iv. Jute-*Corchorus capsularis*

> **Be friendly with your environment (Eco friendly)**
> Why should not we use the natural products which are made by plant fibres like rope, fancy bags, mobile pouch, mat and gunny bags etc., instead of using plastics or nylon?

Periderm

Whenever stems and roots increase in thickness by secondary growth, the periderm, a protective tissue of secondary origin replaces the epidermis and often primary cortex. The periderm consists of phellem, phellogen, and phelloderm.

Phellem (Cork)

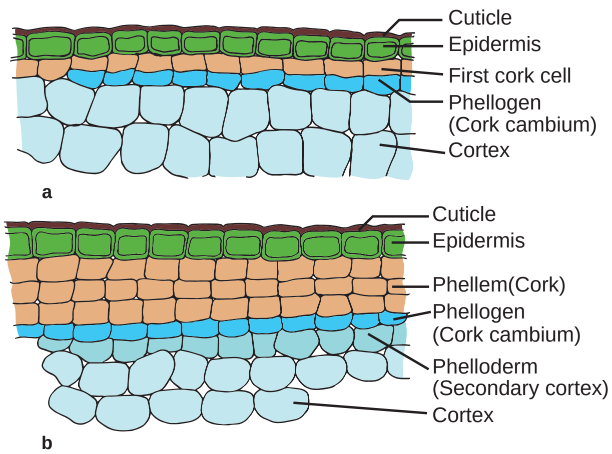

Figure 10.11: The cross section of periderm (a–b)

It is the protective tissue composed of non-living cells with suberized walls and formed centrifugally (outward) by the phellogen (cork cambium) as part of the periderm. It replaces the epidermis in older stems and roots of many seed plants. It is characterized by regularly arranged tiers and rows of cells. It is broken here and there by the presence of lenticels.

Phelloids
Phellem (Cork) like cells which lack suberin in their walls.

Phellogen (Cork Cambium)

It is a secondary lateral meristem. It comprises homogenous meristematic cells unlike vascular cambium. It arises from epidermis, cortex, phloem or pericycle (extrastelar in origin). Its cells divide periclinally and produce radially arranged files of cells. The cells towards the outer side differentiate into phellem (cork) and those towards the inside as phelloderm (secondary cortex).

Phelloderm (Secondary cortex)

It is a tissue resembling cortical living parenchyma produced centripetally (inward) from the phellogen as a part of the periderm of stems and roots in seed plants.

Differences Between Phellem and Phelloderm

Phellem (Cork)	Phelloderm (Secondary cortex)
It is formed on the outer side of phellogen.	It is formed on the inner side of phellogen.
Cells are compactly arranged in regular tires and rows without intercellular spaces.	Cells are loosely arranged with intercellular spaces.
Protective in function.	As it contains chloroplast, it synthesises and stores food.
Consists of non-living cells with suberized walls.	Consists of living cells, parenchymatous in nature and does not have suberin.
Lenticels are present.	Lenticels are absent.

DO YOU KNOW?

Rhytidome is a technical term used for the outer dead bark which consists of periderm and isolated cortical or phloem tissues formed during successive secondary growth. Example: *Quercus*.

Polyderm is found in the roots and underground stems.eg. Rosaceae. It refers to a special type of protective tissues consisting of uniseriate suberized layer alternating with multiseriate nonsuberized cells in periderm.

Bark

The term 'bark' is commonly applied to all the tissues outside the vascular cambium of stem (**i.e., periderm, cortex, primary phloem and secondary phloem**). Bark protects the plant from parasitic fungi and insects, prevents water loss by evaporation and guards against variations of external temperature. It is an insect repellent, decay proof, fireproof and is used in obtaining drugs or spices. The phloem cells of the bark are involved in conduction of food while secondary cortical cells involved in storage.

If the phellogen forms a complete cylinder around the stem, it gives rise to **ring barks**. Example: *Quercus*. When the bark is formed in overlapping scale like layers, it is known as **scale bark**. Example: Guava. While ring barks normally do not peeled off, scale barks peeled off.

Figure 10.12: *Quercus* Tree-showing ring bark

Figure 10.13: Guava tree showing scale bark

Lenticel

Lenticel is raised opening or pore on the epidermis or bark of stems and roots.

It is formed during secondary growth in stems. When phellogen is more active in the region of lenticels, a mass of loosely arranged thin-walled parenchyma cells are formed. It is called **complementary tissue** or **filling tissue**.

Lenticel is helpful in exchange of gases and transpiration called **lenticular transpiration**.

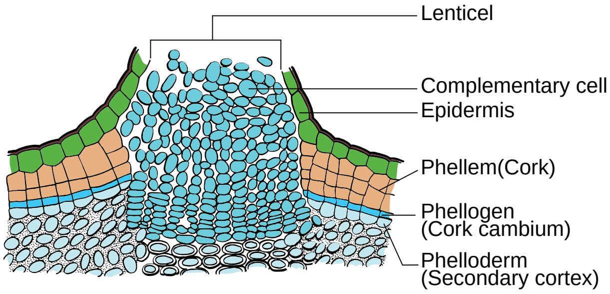

Figure 10.14: Structure of Lenticel

10.2 Secondary Growth in Dicot root

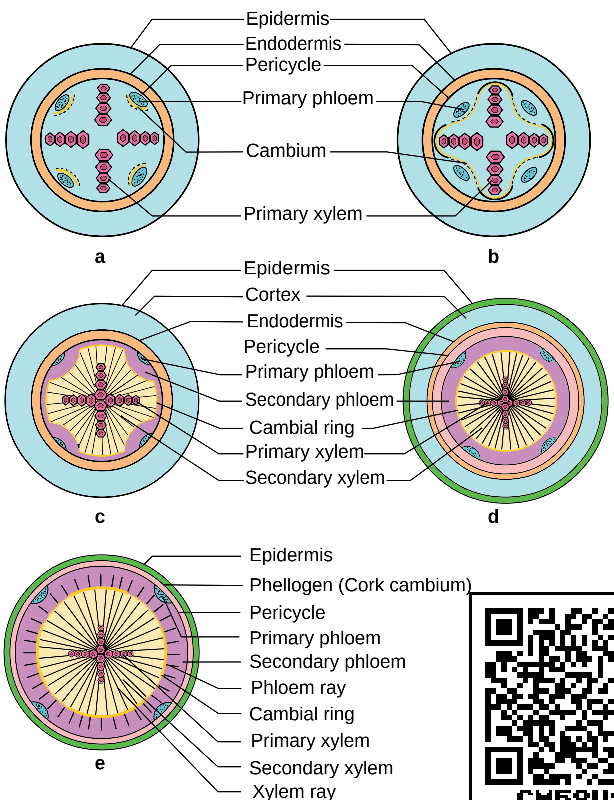

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Figure 10.15: Different stages of the secondary growth (diagrammatic) in a typical dicot root (a–e)

Secondary growth in dicot roots is essential to provide strength to the growing aerial parts of the plants. It is similar to that of the secondary growth in dicot stem. However, there is marked difference in the manner of the formation of vascular cambium.

The vascular cambium is completely secondary in origin. It originates from a combination of conjunctive tissue located just below the phloem bundles, and as a portion of pericycle tissue present above the protoxylem to form a complete and continuous wavy ring. This wavy ring later becomes circular and produces secondary xylem and secondary phloem similar to the secondary growth in stems.

Differences Between Secondary Growth in Dicot Stem and Root

Secondary growth in dicot stem	Secondary growth in dicot root
The cambial ring formed is circular in cross section from the beginning.	The cambial ring formed is wavy in the beginning and later becomes circular.
The cambial ring is partially primary (fascicular cambium)and partially secondary (Interfascicular cambium) in origin.	The cambial ring is completely secondary in origin.
Generally, periderm originates from the cortical cells (extrastelar in origin).	Generally, periderm originates from the pericyle. (intrastealar in origin)
More amount of cork is produced as stem is aboveground	Generally, less amount of cork is produced as root is underground.
Lenticels of periderm are prominent.	Lenticels of periderm are not very prominent.

Summary

Secondary growth deals with the formation of additional vascular tissue by the activities of vascular and cork cambia and secondary thickening meristem (STM). It increases the girth of stem and roots of gymnosperms, most angiosperms, and some monocot plants. Vascular cambium possesses two kinds of initials they are, fusiform and ray initials. Fusiform initials give rise to the axial tissue system whereas ray initials give rise to radial tissue system of stems and roots.

Wood is a very important product of secondary growth. It is classified into various types. Based on respectively on the presence or absence of vessels, - porous and non-porous wood. Based on the wood formed during seasons, - spring wood and autumn wood. The spring and autumn wood, together is called **annual ring**. The lumen of the xylem vessels of heart wood are blocked by many balloon like ingrowths from neighbouring parenchymatous cells called **tyloses**.

The periderm, a secondary protective tissue consists of phellem, phellogen and phelloderm. Secondary growth produces a corky bark around the tree trunk that protects the interior parts from heat, cold, infection etc. Secondary growth of root is different from stem in the method of formation of vascular cambium.

Evaluation

1. Consider the following statements

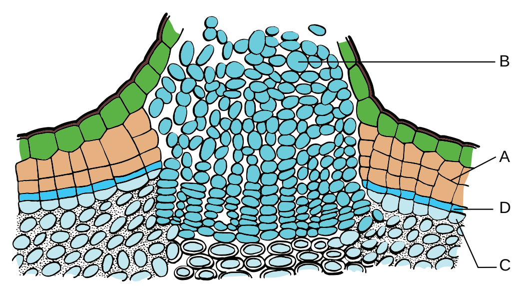
   In spring season vascular cambium

   i. is less active
   ii. produces a large number of xylary elements
   iii. forms vessels with wide cavities of these,

   a. (i) is correct but (ii) and (iii) are not correct
   b. (i) is not correct but (ii) and (iii) are correct
   c. (i) and (ii) are correct but (iii) is not correct
   d. (i) and (ii) are not correct but (iii) is correct.

2. Usually, the monocotyledons do not increase their girth, because
   a. They possess actively dividing cambium
   b. They do not possess actively dividing cambium
   c. Ceases activity of cambium
   d. All are correct

3. In the diagram of lenticel identify the parts marked as A,B,C,D



   a. A. phellem, B. Complementary tissue, C. Phelloderm, D. Phellogen.
   b. A. Complementary tissue, B. Phellem, C. Phellogen, D. Phelloderm.
   c. A. Phellogen, B. Phellem, C. Phelloderm, D. complementary tissue
   d. A. Phelloderm, B. Phellem, C. Complementary tissue, D. Phellogen

4. The common bottle cork is a product of
   a. Phellem b. Phellogen
   c. Xylem d. Vascular cambium

5. What is the fate of primary xylem in a dicot stem showing extensive secondary growth?
   a. It is retained in the centre of the axis
   b. It gets crushed
   c. May or may not get crushed
   d. It gets surrounded by primary phloem

6. In a forest, if the bark of a tree is damaged by the horn of a deer, How will the plant overcome the damage?
7. In which season the vessels of angiosperms are larger in size, why?
8. Continuous state of dividing tissue is called meristem. In connection to this, what is the role of lateral meristem?
9. A timber merchant bought 2 logs of wood from a forest & named them A & B, The log A was 50 year old & B was 20 years old. Which log of wood will last longer for the merchant? Why?
10. A transverse section of the trunk of a tree shows concentric rings which are known as growth rings. How are these rings formed? What are the significance of these rings?

ICT Corner

Characteristics of Dicot and Monocot Stem and Root

Let's explore **inside Stem and Root** →

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Steps

- Scan the QR code or go to Google play store.
- Type online labs and install it.
- Select biology and select Characteristics of dicot and monocot stem and root.
- Click free sign up and provide your basic information with valid mail-Id.
- Login with your registered mail id and password.
- Choose theory tab to know the basic about anatomical structure of plant parts.
- Choose animation to view the sectioning process.
- Choose simulation tab and view the section of plant parts under microscope.

Activity - Do the section through simulation and record your observations.

URL:
https://play.google.com/store/apps/details?id=in.edu.olabs.olabs&hl=en

* Pictures are indicative only