6. Briefly explains wood and growth rings formation as a result of secondary growth

7. Names the tissues included in bark and wood

8. Lists out the differences between sap wood and heart wood

9. Mentions the differences between soft wood and hard wood

10. State the importance of secondary growth for the existence of perennial plants

2025 AL REVISION

BIOLOGY

4.2 PLANT GROWTH

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Growth and development process of a plant

Plant growth

Growth involves irreversible increase of dry mass associated with the development of an organism. Often it is associated with increase of cell number as a result of producing more cells from the meristem accompanied by cell elongation.

Plants continue growth throughout the life known as indeterminate growth.

Primary structure of root

Apart of the distribution pattern of xylem and phloem tissue structures of both monocot and dicot roots are more or less similar.

- Outermost cell layer is epidermis. Some epidermal cells produce finger like extensions called root hairs. Epidermis protects inner parts while root hairs involve in the absorption of water and minerals.
- Between epidermis and vascular cylinder there is a ground tissue known as cortex which is made up of mostly parenchyma cells with intercellular spaces.

Learning Outcomes:

1. States basic differences between primary and secondary growth of plants

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2. Briefly describes the histological structures of primary dicotyledonous root and monocotyledonous root

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3. Briefly describes the differences between histological structure of primary dicotyledonous stem and monocotyledonous stem

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4. Briefly describes the process of secondary growth of dicotyledonous stem using appropriate line diagrams

5. States how the secondary growth of a dicotyledonous root differ from the secondary growth of a dicotyledonous stem

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Heart Wood and Sap wood:

- As a woody plant ages, the older layers of secondary xylem no longer transport water and minerals.
- These layers are called heartwood because they are close to the centre of the stem or root.
- The newest outer layers of secondary xylem, still transport xylem sap are known as sapwood.
- The heartwood is generally darker than sapwood because of resins and other compounds that permeate the cell cavities and help protect the core of the tree from fungi and wood-boring insects.
- Only the young secondary phloem functions in phloem translocation and old secondary phloem is sloughed off.

Hard wood and soft wood

- Hard wood is the secondary xylem of dicot angiosperms while wood of gymnosperms are named soft wood
- Xylem vessels are absent in soft wood

Growth rings:

- The thickness of secondary xylem and the lumen of vessels are larger in periods of warm and wet seasons compared to other growth season of the year. These differences are visible in a cross section as lighter and darker rings. These are referred as growth rings.
- In temperate regions, wood that develops early in spring is known as spring wood. This xylem tissue consists of xylem vessels with large lumens and thin walls. This structure maximizes delivery of water to new leaves.
- The wood produced during rest of the growing season is called summer wood. These xylem tissues consist of xylem vessels with thick walls and small lumen, do not transport much water but provide more support.
- These two woods collectively known as an annual ring. A year's growth appears as distinct ring in the cross section of most tree trunks and roots. Therefore age of the tree can be estimated by counting annual rings in trees growing in temperate regions.

- Cortex mainly stores carbohydrates, and also transports water and minerals towards the endodermis.
- Innermost single cell layer of the cortex is the endodermis.
- Endodermis contains a suberin belt called casparian strip and no inter-cellular spaces. Therefore, it blocks cortical apoplast from the vascular apoplast.
- Interior to endodermis there is a pericycle containing two or three parenchyma cell layers. These cells in dicot roots have meristematic function and involve in the formation of lateral roots and secondary growth of the root.
- Inner to pericycle there is vascular tissues as a solid core. Xylem can be found in the middle and it is star shaped in a cross section of a dicot root. Phloem is located in the groove between the arms of xylem.
- In monocot roots, vascular tissue consists of a central core of parenchyma cells surrounded by a ring of alternating xylem and phloem. Pericycle in monocot roots is not meristematic

Primary structure of dicotyledonous plant stem :

- The outermost epidermal cell layer protects inner parts from desiccation and infections. The epidermis is interrupted by pores called stomata.
- Interior to epidermis is cortex mostly containing parenchyma cells.
- Collenchyma cells may also be present just beneath the epidermis to provide strength.
- Sclerenchyma such as fibers are also present in the cortex to provide additional support.
- Vascular bundles arranged as a ring. Vascular bundle contains primary phloem towards cortex primary xylem towards pith and in-between a cambium tissue.
- Outside vascular bundle, there is a cluster of sclerenchyma cell.
- Inner to vascular bundles large pith which is also made up of parenchyma cells can be found.
- Lateral shoots develop from axillary buds

- For gaseous exchange small pores are present in the periderm known as lenticels which are formed by loosely arranged cork cells. They appear as horizontal slits.
- Further growth of stem or root breaks the layer of cork cambium and it lacks its meristematic activity and its cells become cork cells
- A new cork cambium is initiated inside which with produce a new layer of periderm.
- As new cells are added, the outer regions of cork will crack and peel off in many tree trunks.
- Due to the tissue layers produced by vascular cambium and cork cambium, girth of the stem or root increases in secondary growth.
- Bark is all tissues out of the vascular cambium (cork is commonly and incorrectly referred to as bark). Its main components are secondary phloem and periderm.

Primary structure of the monocotyledonous stem:

- Ground tissue of monocot stem is not differentiated into cortex and pith.
- The vascular bundles are scattered throughout the ground tissue in most monocot stems.
- Each vascular bundle is surrounded by sclerenchyma. It consists of a xylem tissue and a phloem tissue but no cambium in between xylem and phloem.

- Secondary vascular tissue is produced by the action of vascular cambium.
- In a typical woody stem, the vascular cambium consists of a continuous cylinder of undifferentiated cells of often only a single cell layer in thickness, located outside the pith and primary xylem and to the inside of the cortex and primary phloem.
- In a typical woody root, the vascular cambium forms laterally exterior to the primary xylem and interior to the primary phloem and pericycle.
- As these meristematic cells divides they increase circumference of the vascular cambium and also add secondary xylem to the inside of the cambium and secondary phloem to the outside.
- Viewed in a cross section, the vascular cambium appears as a ring of initials.
- Some initials are elongated and are oriented with their long axis parallel to the axis of stem or root.
- They produce cells such as tracheids, vessel elements, parenchyma and fibers of the xylem, as well as sieve-tube elements companion cells, phloem fibers and phloem parenehyma.
- The other initials are shorter and oriented perpendicular to the axis of the stem or root.
- They produce vascular rays-mostly parenchyma cells that connect secondary xylem and phloem, store carbohydrates and aid in wound repairing.
- As the secondary growth continues over many years, layers of secondary xylem (wood) accumulate.
- The walls of the secondary xylem cells are heavily lignified and account for the hardness and strength of wood.
- During early stages of secondary growth, the epidermis pushed outwards, causing it to split, dry and falls off the stem or root.
- A cylinder of diving cells that arises in the outer layer of cortex in stems and in the pericycle in the roots becomes meristematic forming a cork cambium.
- Cork cambium produces cork cells to the exterior, and to the interior. Cells added to the exterior become cork.
- Cork cambium and tissues it produces are collectively called periderm
- As the cork cells mature, they deposit a waxy, hydrophobic material called suberin in their walls and they become dead cells.
- The cork tissues function as a barrier that helps protect the stem or root from water loss, physical damages and pathogens.
- Each cork cambium and the tissues it produces comprise a layer of periderm which is impermeable to water and gasses.

Secondary growth :

- Increase in the diameter of stems and roots in plants due to the new cells produced by lateral meristems is called secondary growth.
- This occurs in stems and roots of woody perennial plants including, all gymnosperms species and many dicot species.
- Lateral meristems, namely vascular cambium and cork cambium produce cells and tissues in the secondary growth.
- The vascular cambium adds secondary xylem (wood) towards primary xylem and secondary phloem towards primary phloem, increasing vascular flow and support for the shoots.
- The cork cambium produces tough thick covering consisting mainly of wax impregnated cells that protect the stem from water loss and from invasion of insects, bacteria and fungi.
- In woody plants, primary growth and secondary growth occur simultaneously. As the primary growth adds new cells and lengthens stems and roots in the younger regions of a plant, secondary growth increases the diameter of stems and roots in older regions where. primary growth has ceased.