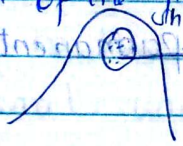
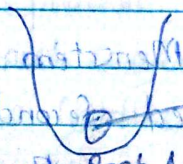
SPB 9406 : MORPHOGENESIS AND ANATOMY

- Plant Morphology - is the study of the physical form and external structure of plants.
- Maphogenesis - process by which plant structures are formed.
- Anatomy - it is concerned with the internal plant structure at cellular and microscopic levels.

- Maphogenesis and Anatomy therefore refers to the formation of plant tissues and organs from primary structures called Meristematic cells that eventually lead to plant growth and development.
- The adult plant body of a vascular plant results from Meristematic Activity.
- Plant Meristems are centers of Mitotic cell division and comprise a group of undifferentiated self-renewing cells from which most of the plant structures arise.





Types of Meristems.

Shoot Apex Meristem.

- These cells divide repeatedly to lead to the formation of specialized shoot organs such as leaves, stems and flowers.
- They are classified based on their origin and development.
- Their positioning.

Classification Based on Origin function and plane of division and Development.

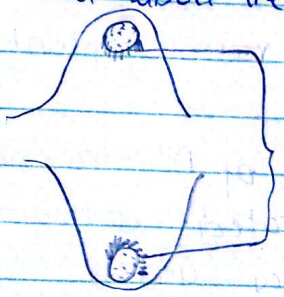
- Meristems based on the origin can be classified into the following types;

1) Promeristem.

- These are a group of young meristematic cells within a

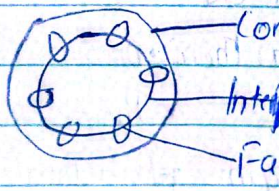
growing organ that are likely to develop into new tissues.
- They are located in the embryonic tissues, and are sometimes called Embryonic Meristems.
- In most plants they occupy a small area at the tip of the stem and the root.
- The Promeristem divides to form a primary meristem.

ii) Primary Meristems
- Are derived from Promeristems and are present below the apex at the shoot and above the Promeristem of the root Apices.



The Primary meristems divide to form permanent tissues.

iii) Secondary Meristems.
- Tissues developing from the Primary Meristem responsible for secondary growth of plant are called Secondary Meristem.
- With laps of time and pace of growth, the plant attains secondary structures and height; this enables it to withstand the effect of environmental pressures such as blowing wind and running water. The plant therefore has to acquire girth (width)



✓ Secondary Meristems includes;
- Cambium - Primary / fascicular cambium.
- Cork cambium.
- Interfascicular cambium.

Classification Based on the Position.

On basis of position of plant body, Meristems are of three types;

i) Apical Meristem
ii) Intercallary Meristem.
iii) Lateral Meristem.

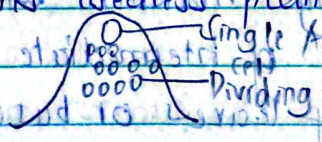
i) Apical Meristem.

- Are found at the Apices or growing points of roots and shoots and they bring about increase in length.
- It includes both the Promeristem and Primary Meristem.
- Several theories have been put forward to explain the activity of Apical Meristems.

I. The Apical Cell Theory.

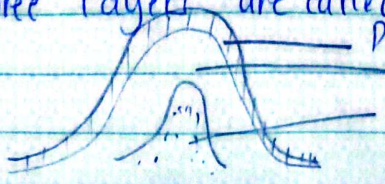
This theory was first proposed by a scientist called Hofmeister (1854) but was advanced by Nageli (1874). According to their theory, a single Apical cell is the structural and functional unit of the Apical Meristem; which governs the entire process of Apical growth.

- However, such organization has only been found in Cryptograms (seedless plants).



II Histogen Cell Theory.

- It was proposed by Hanstein (1868)
- According to this theory, Root and shoot Apices consists of the central or inner mass called Plerome surrounded by a middle region composed of isodiametric cells called Periblem and the outermost uniseriate layer called Dermatogen.
- These three layers are called Histogen.



iii) Tunica - Corpus Theory.

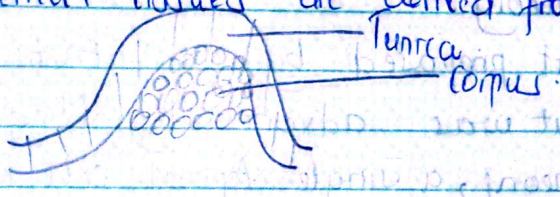
- This was proposed by a German, scientist called Schmidt (1924)
- According to this theory, the mass of dividing meristematic cells are of 2 types,

a) Tunica - which is the outer layer consisting of one position of different meristems or peripheral layers of cells that form other region.

b) Corpus - is the central undifferentiated multi-layered mass of cells.

NB/ The term 'Tunica' means coat while Corpus means body.
Tunica-corpus derived from coat and body.

- The epidermis is derived from the outer layer of Tunica. while the other internal tissues are derived from Corpus



ii) Intercullary Meristems.

They lie between the region of permanent tissues and are considered as part of primary meristems which have become detached due to the formation of intermediate permanent tissues.
- They occur at the bases of leaves or bases of internodes.

iii) Lateral Meristems.

- They are arranged parallel to the sides of organ and normally divide periclinally or radially to give rise to secondary permanent tissues.
- They usually increase the thickness of the plant.

Classification on Basis of their function.

- On the basis of their functions, meristem are divided into 3;

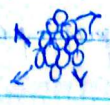
1. Protoderm Meristem - it is the outermost layer of the shoot or root apex (the young growing region), which develops to form epidermal tissue systems. (Epidermis)

2. Procambium meristem
- This is composed of narrow, elongated meristematic cells which give rise to the vascular tissue system. (Vascular tissues)

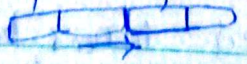
3. Ground meristem
- It is composed of large thick-walled cells which develop into the ground tissue system consisting of the hypodermis, cortex and the pith. (Hypodermis, cortex, pith)

Classification on the Basis of plane of division.
- The pattern of growth and plane of division of meristematic tissues is important in governing the mode of plant growth.
- There are 3 types of Meristems based on this classification;

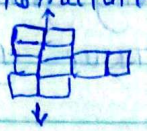
1. Mass Meristems
- In such meristems, cell division occurs in all planes resulting in an increase in volume.
- It is mostly observed in meristems of the cortex and pith.



2. Rib or file Meristems.
- The meristematic cells divide in only one plane leading to the formation of a filament of cells or rib.

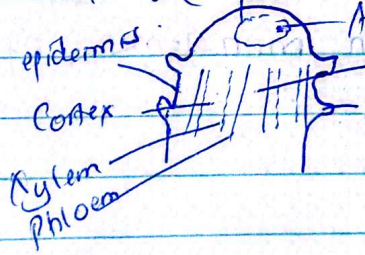


3. Plate Meristem
- These cells divide in two planes resulting in an increase in area of the organ or structure eg leaf



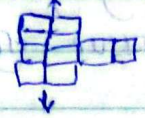
Morphogenesis of the Shoot Apex.
- The Apical Meristem which occurs just above the surface of shoot branches consists of continually dividing cells which are undifferentiated making up the shoot apex.
- This apical meristem is responsible for creation of new cells and causes the growth of the plant shoot making it to be driven upwards, exposing the structures to light for photosynthesis and air for gaseous exchange.

- The Tunica-Corpus theory best explains the morphogenesis and tissue organisation of the shoot apex.
- The Tunica, which is the outermost layer of meristematic cells, differentiate into the epidermis of the primary shoot system while the corpus differentiates into tissues of cortex, the vascular bundles and the pith



The apical meristem also gives rise to the leaf primordium at regular intervals.
- Since the leaves has specialised tissues, both the tunica and corpus participate in its formation.
Development of the leaf primordium is so rapid such that the earlier formed structures soon enclose the apical meristem

3. Plate Meristem
- These cells divide in two planes resulting in increase in surface area of the organ e.g. leaf



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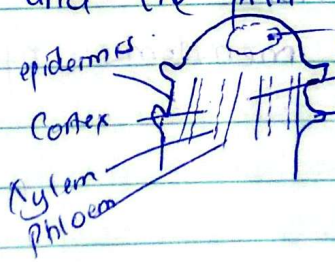

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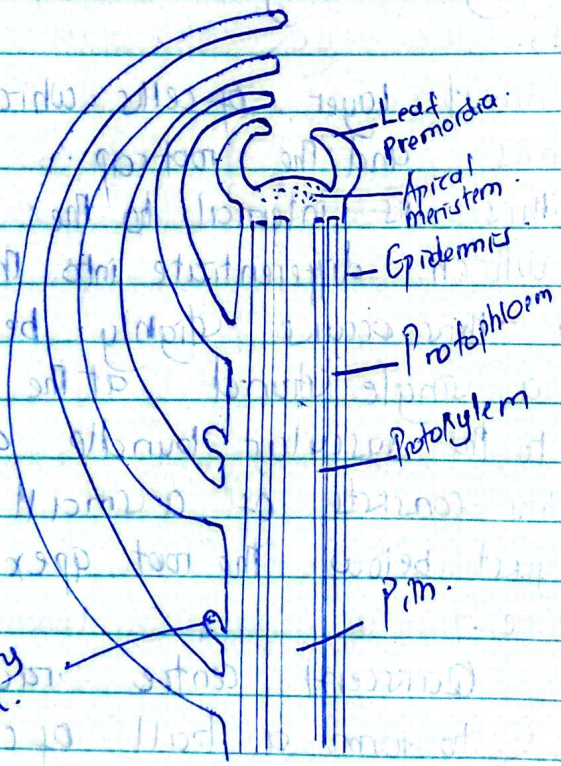
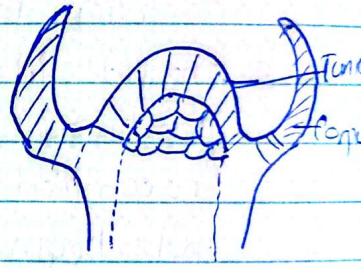
- Mature leaves eventually differentiate from the older leaf primordia as new primordia are continually formed at the shoot tip.
- Spatial arrangement of the primodia determines positioning of mature leaves on the stem. eg If the leaf primodia are paired, they give rise to a pair of leave on the stem.
- Axillary bud primordia are usually observed at the axil of developing leaves near the shoot apex.
- This usually develop into lateral shoots.
- Both the Tunica and Corpus participate in axillary bud formation.



Diagramatic representation of the shoot apex.



The tunica and corpus of the shoot apex.

Morphogenesis of the Root Apex

- The root apex is a region of active cell division and differentiation thinning primary root growth.
- It consists of the root cap, the meristematic zone, and the elongation zone.
- The most obvious difference in appearance between the stem and the root apex is the absence of bulges that lead to the formation of the leaf primordia and activity of
- However, there is considerable similarity in the shoot and root apical meristems.

✓ Meristematic Zone.

- This consists of actively dividing cells which give rise to the following structures;
1. Protoderm - the outermost layer of cells which later differentiate to form the epidermis and the root cap.
2. Ground Meristem - This is internal to the protoderm and it produces cells which differentiate into the root cortex.
3. Procambial Strand - this occurs slightly behind the root apex and begins as a single strand at the centre of the root. It gives rise to the vascular bundle and the pith
4. Quiescent Centre - This consists of a small group of slowly dividing cells just below the root apex but above the procambial structure.

The cells of the Quiescent centre radiate from the meristematic cells to form a ball of cells while the cells at its periphery are hemispherical or cup-shaped

- It has been suggested that the Quiescent has the following roles;

i) It provides a reserved block of cells / storage of diploid cells which make up the root apical meristem.
ii) It is the site of hormonal synthesis. eg IAA which promotes lengthening of the differenciating cells.
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apical meristem.

ii) It participates in georeaction of the root.

✓ Root Cap

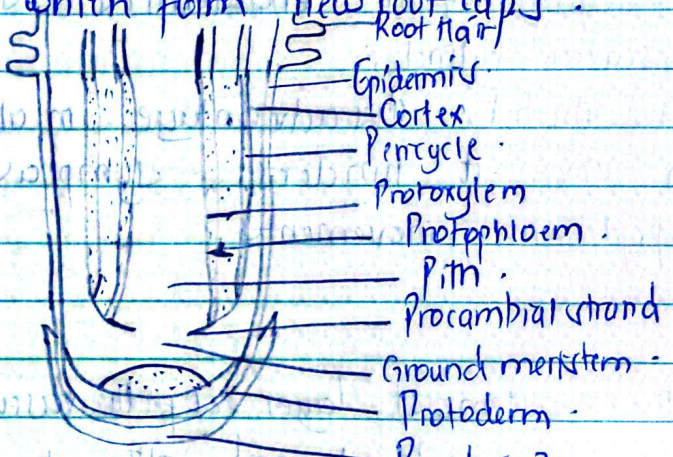
- It is a thin layer of cells produced by the apical meristems which performs the following roles;

i) Protects the delicate root apical meristem.

ii) It senses gravity and causes downward growth of the root.

iii) Secretes mucilage which reduces friction as the root grows down into the soil.

- The outer cells of the root cap are easily sloughed off and are replaced by a new group of cells called calyptrogen which form new root caps.



Longitudinal section of the root apex of a dicot plant.

Primary Structure of The Root.

a) Epidermis

- This is the outermost layer also called Piliferous layer. It is characterised by the presence of Root Hairs and its main role is to protect the internal tissues. Although it lacks a cuticle as observed in the stem.

b) Root Cortex

- This is mostly made of parenchyma cells although

chlorenchyma and collenchyma may develop especially when the root is exposed to the sunlight.
- In aquatic environments, the parenchyma cells convert to air-storing aerenchyma.
Aerial roots like in the orchids, have specialised tissues called velamen in the cortex which aid in moisture and nutrient absorption.

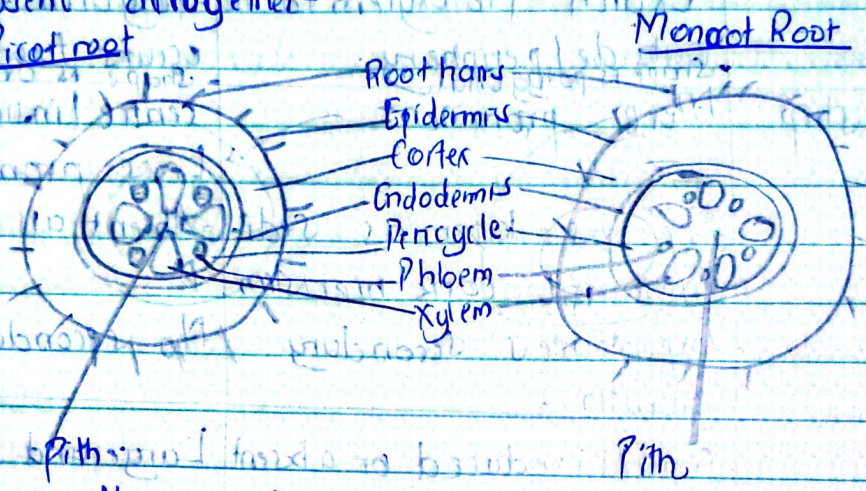
c) Endodermis.
- It is the innermost layer of the cortex which contains a single layer of barrel-shaped cells.
- It is characterised by the presence of a casparian strip which has suber in and lignin deposits which increase the structural integrity of the endodermis supporting/holding up the vascular cylinder.
- It has a slight disadvantage in absorption of the soil solution since it hinders symplastic movement but favours apoplastic movements.

d) Pericycle.
This is the outermost layer of the vascular cylinder.
It is usually single-layered although it can be multi-layered.
It consists of parenchyma cells but sclerenchyma can be found in some plant species.
- The cells of the pericycle can regain meristematic activity to give rise to lateral roots.

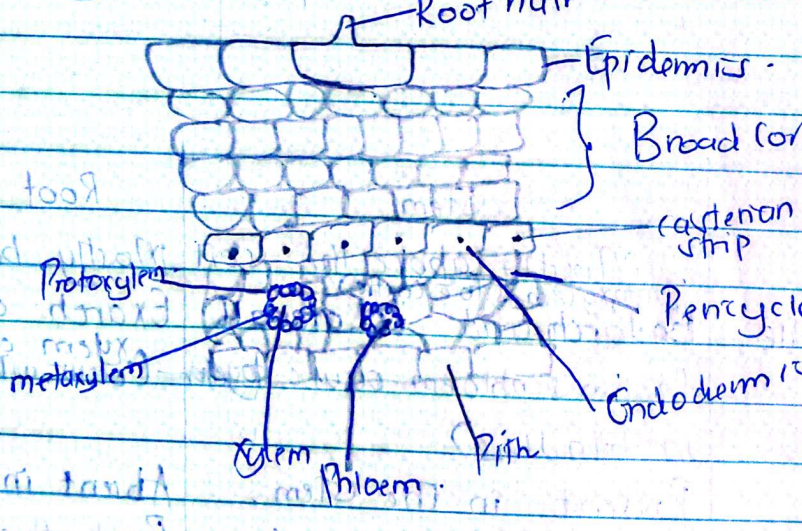
e) Vascular Tissue.
There are separate xylem and phloem tissues in the root.
The xylem alternates with the phloem in a conditions called radial arrangement.
- The protoxylem occurs toward the outside while the

metaxylem is towards the inside, a condition called exarch.

- There is A large prominent pith is usually present in monocote roots but in dicots it may be small or absent altogether



Vertical / Cross section of the Primary root.



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Characteristic	Dicot Root	Monocot Root
1. Cortex	Narrow	Wide
2. Xylem	Number varies from 2-6, rarely more than 6. Exarch - protoxylem to the outside/periphery.	Usually numerous but rarely limited eg onions Polyarch - protoxylem occurs towards the centre/inside.
3. Casparian strip	More prominent (Shape is polygonal)	Less prominent. (Shape is oval)
4. Cambium	Appears later as sedimentary cork meristem. Experiences secondary growth.	Absent all together. No secondary growth
5. Pith	Small/reduced or absent	Large and well developed
6. Conjuctive tissues	Parachymatous	Sclerenchymatous.
7. Type of Root.	Most of them have taproots	Mainly fibrous root.

Characteristic	Stem	Root.
1. Positioning	Mostly above the soil	Mostly below the soil.
2. Vascular bundle	Endarch (protoxylem is to the centre) and collateral: Exylem & phloem occur together in bundles)	Exarch and radial xylem and phloem occur within the same radius
3. Cuticle.	Present in the stem.	Absent in the root.
4. Growing tips	Protected by young leaves (apical bud/primordia)	Protected by the root cap.
5. Root/stem Hairs	Root hairs are absent but some multicellular hairs are present in some species.	Root hairs are present.
6. Nodes and Internodes.	Present	Absent
7. Branch origin.	Exogeneous	Endogeneous.
8. Xylem	Endarch	Exarch.

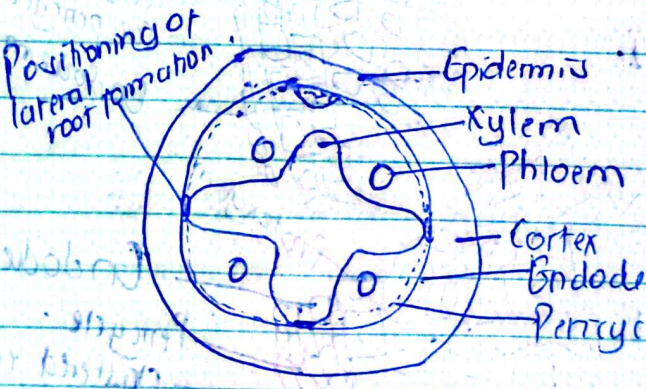
Formation of Lateral Roots

Lateral root formation has two major points of differences with the formation of axillary buds which leads to the formation of axillary roots.

i) Lateral roots arise from some distance from the root apex.

ii) They originate deeply within the root from the pericycle.

- The origin of lateral roots is therefore said to be endogeneous while the origin of lateral shoots are exogeneous.
- Lateral root meristem emerge from the pericycle which is found beneath the endodermis.
- Structurally, lateral root formation is usually restricted to the regions opposite to the xylem and emerge in vertical rows, the number being equal to the number of xylem strands present.



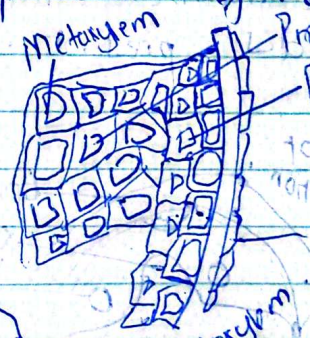
In the formation of lateral roots, the cells of the pericycle lie against protoxylem become meristematic and begin to divide fast in all planes.

- Rapid mitosis results in the production of a bulge of cells which symbolizes the beginning of lateral root formation.
- As the bulge increases in size, apical meristems are developed at their tips and in some cases a root cap is developed.

- As the bulge grows, the endodermis is pushed outwards eventually rapturing to create a pathway for the developing lateral root.
- This root growth is enhanced / activated by enzyme and hormone secretion which enables it to forced its way through the cortex of the main root.
Eventually a lateral root emerges through a raptured epidermis.
By this time of the rapture, a procambial strand which bears a new xylem and phloem has already developed in the differentiating tissues of the lateral apex.
- Further differentiation takes place in the procambial strand takes place to cause the formation vascular tissues of the lateral roots which then become joined to the xylem and phloem of the lateral roots.

Tissue differentiation in lateral root formation

I.



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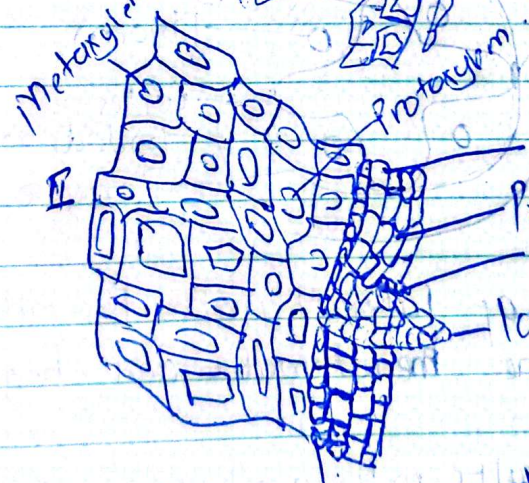
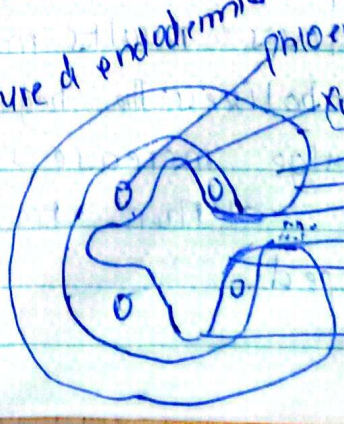
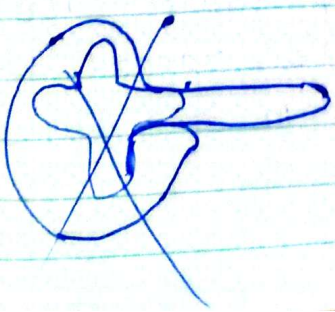


Ruptured endodermis





Root Secondary Growth.

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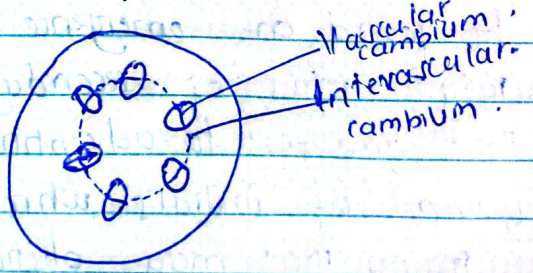
- Roots of most gymnosperms, dicots and a few monocots undergo secondary growth.
- Most Pteridophytes and Monocotes do not showsec growth
- Sec growth in the roots results from the activity of two;
  1- Vascular Cambium.
  2. Cork Cambium (Phellogen)
- In between the phloem & xylem there exists the vascular cambium which initiates the production of new cells.
- The vascular cambium of the roots originates from cells located between the primary phloem and primary xylem called conducting tissues.
- These vascular cambium regain their meristematic activity which quickly spreads to include the cells of the pericycle which are found over the protoxylem poles.
- The cambial activity results in the formation of secondary xylem to the inside and secondary phloem to the outside.
- In due course, cambial activity which begins at specific pockets transforms into a sheath which surround the outline of the xylem.
- At advanced stages of vascular cambium activity, all the primary tissues to the outside of the pericycle, may become sloughed off.



At the same time, after initiation of vascular cambium activity the cells of the pericycle begin to divide and develop into a phellogen (cork cells) to the outside.
- The phellogen is meristematic and it produces secondary cortex (phellodem) to the inside and cork tissues (phellem) to the outside

Phelogen in roots → pericycle.

Both the phellodam and phellem rapidly grow into a tissue-filled bark

~~Peripheral Root System~~

1. Adventitious Roots

- These develop from non-root tissues such as the stem, or leaves of the shoot, or from older leaves.
- They are mostly produced in response to stressful environment such as deprivation of nutrients, or adverse environmental conditions
- The primodia for these roots may be developed early but lie domant for a considerable period of time. Such adventitious roots are said to be preformed. Alternatively, the primordia may be initiated as a result of changes in local environment or some damages to the roots and these are said to be induced. induced.

Examples of adventitious roots are; ✓ Junction roots.
✓ Nodal roots
✓ Prop roots.

~~Nodal roots~~

The roots form at the nodes or the internodes during the early stages of stem development

- They can also be found on emergence of leaves, branch traces, or from medullary rays of secondary tissues.

The primordia that give rise to adventitious roots arise from single or a group of initials which grow to the point of crushing any tissues that may obstruct it.

Induced primordia, on the other hand, mostly develop from the vascular cambium or its derivatives.

2 Mycorrhigal Roots.

- There exists associations between certain groups of fungi and the roots of secondary plants forming mycorrhizae.
- The roots formed may be shortly but have a high biomass turnover rate.

Mycorrhizae association begin at the tip of young lateral roots and the first tissues to be invaded are the rootcap, the rhizodermis and the ectodermis. Eventually the cortex becomes involved. arbuscles.

- Development of mycorrhigal associations are dermined by factors eg soil moisture/ texture, pH, salinity and soil type.
- There are two types of Mycorrhigal Association;
  1. Endomycorrhizae.
  2. Ectomycorrhizae.

1. Endomycorrhizae.

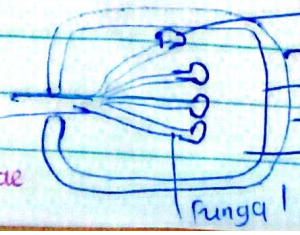
They are wide spread in Gymnosperms and Angiosperms where they associate with several genera of Ascomycota.

The fungi hyphae are aseptate and actually penetrate the host cell walls forming tree-like branches with tiny swellings at the tip called arbuscles.

- The ramification of arbuscles is such that there may be no wall separating the fungi and host cell plasmallema.
- Fungal invasion is usually confined to the rhizodermis, exogoderm is and cortex, the endoderes and vascular tissue are usually not molested.

Vesicles of carbohydrates and lipids are formed between the protoplasm and fungus resulting in vesicular arbuscular mycorrhizae (VAM) which may be inter or intracellular.

- The arbuscles are short-lived and soon degenerate to become digested and absorbed by host cell.



Endomycorrhizae

2. Mycorrhigal Roots

- There exists associations between certain groups of fungi and the roots of secondary plants forming mycorrhizae.
- The roots formed may be shortly but have a high biomass turnover rate.

Mycorrhizae association begin at the tip of young lateral roots and the first tissues to be invaded are the root cap, the rhizodermis and the ectodermis. Eventually the cortex becomes involved. arbuscles.

- Development of mycorrhigal associations are dominated by factors eg soil moisture/ texture, pH, salinity and soil type.
- There are two types of Mycorrhigal Association;
  1. Endomycorrhizae
  2. Ectomycorrhizae.

1. Endomycorrhizae

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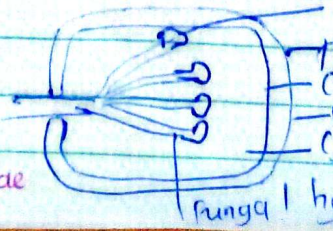

Endomycorrhizae

Root-Stem transition theory.

2. Ectomycorrhizae

These are developed by Ascomycetes, Fungi imperfecti and Basidiomycetes.

The fungi form a hyphal envelope around the growing root tip and in some cases, may enter the cortex but never penetrate the cell walls. Instead, the hyphae anastomose/merge to form a network called Hartig-net.

Over time, the external hyphal envelope form a compact mass called mantle which covers the root tip and thereby the transport between the root and the soil only occurs through hyphae/mantle.

3. Root Nodules.