Chapter IV Vegetative Organs of Seed Plants – the Root

IV. Primary Structure of the Root

- Primary growth: The growth of plants is directly from the proliferation and maturation of cells derived from apical meristem. The whole growth process is called primary growth.
- Primary tissues: Refer to the tissues generated in the process of primary growth.
- Primary structure: Primary tissues jointly constitute root structure, consisting of three parts from inside to outside, namely: epidermis, cortex and vascular cylinder.

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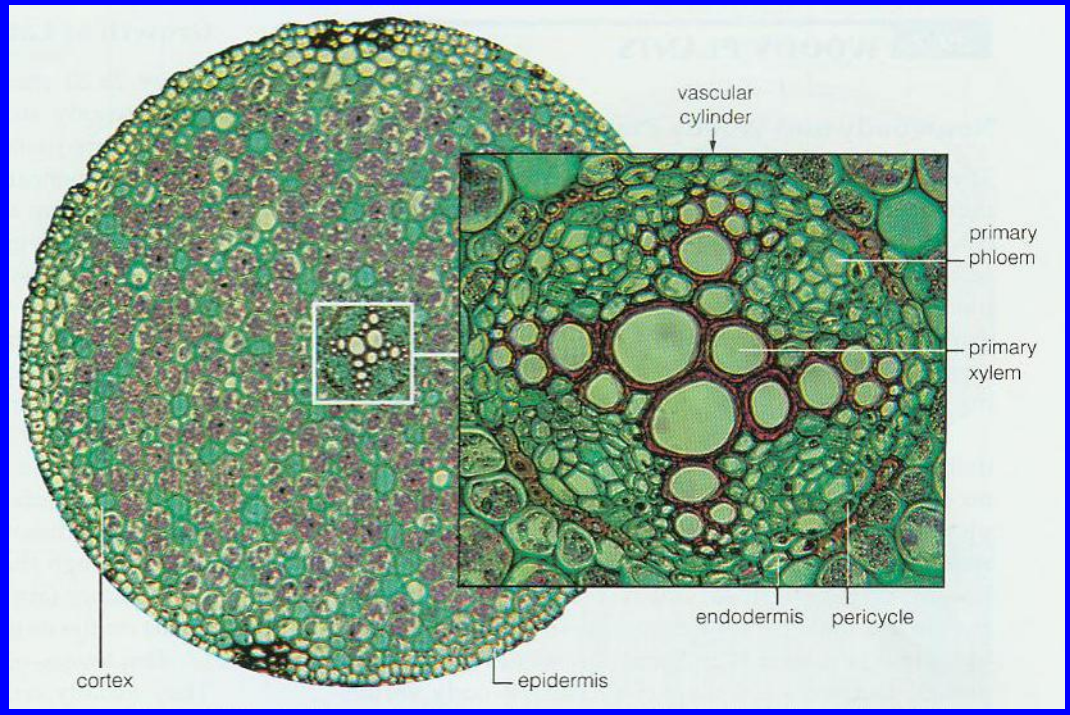
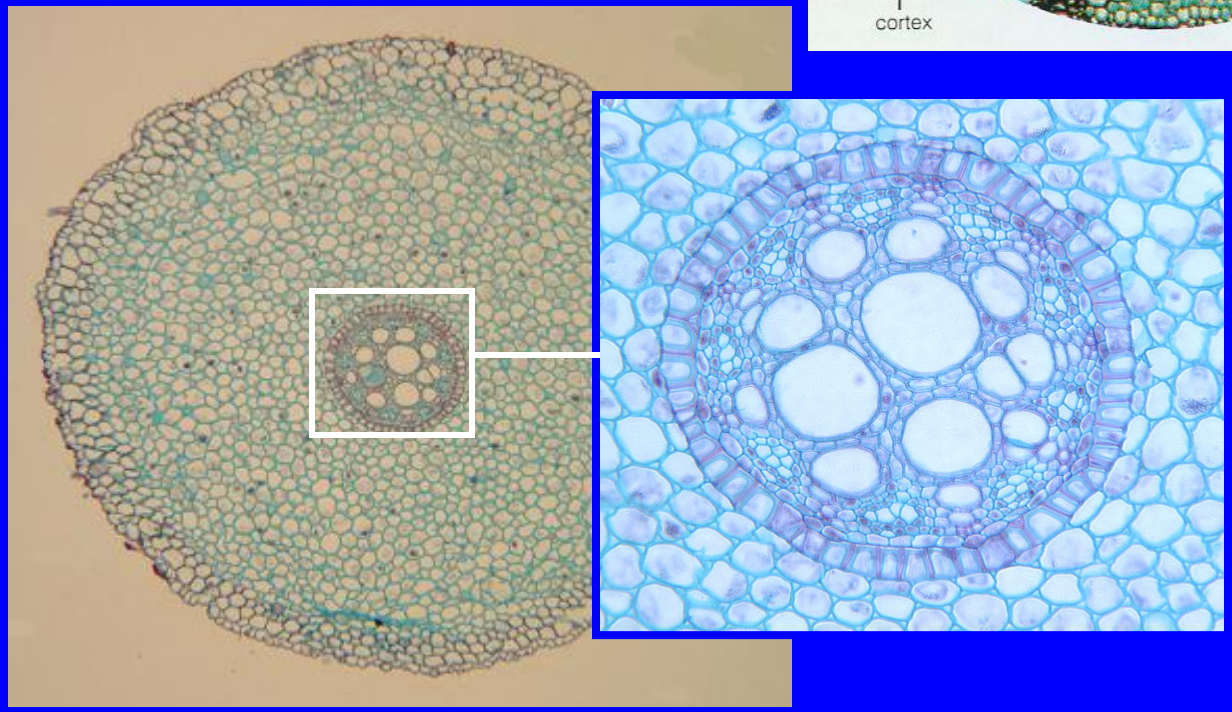
Transverse section showing the primary structure of flowering plant roots.





(I) Epidermis

Epidermis is on the outermost of the maturation zone of a root and developed from procuticle. In general, it is composed of one layer of living epidermis cells, which are approximately in a rectangular cylinder and arranged tidily and tightly and have a thin wall and thin cuticle and **no stomata, and some are extended to form root hair.**

(I) Cortex

Cortex is developed from fundamental meristem, consists of multiple layers of parenchyma cells and has remarkable intercellular spaces.

Exodermis: The outermost layer of cells of cortex, **tightly arranged, without intercellular space**, becoming a continuous layer and able to replace epidermis.

Endodermis: The innermost layer of cells of cortex, **tightly arranged, without intercellular space**.

Casparian strip

On partial primary wall of an endodermal cell, often there is a wall structure, which is thickened into a strip due to embolization and lignification. It encircles the radial wall and transverse wall of the cell and form a complete ring. It is called Casparian strip. It is a structure playing a role in hindering or restricting moisture and solute.

As for monocotyledon, the internal tangential wall is also thickened due to embolization and lignification. On the wall, there are pores to make for the passage of substances. A minority of endodermal cells on the ridge of xylem still maintain the structure of initial deveopment stage and have Casparian strips. The wall is not thickened. These cells are called passage cells and make for material exchange.

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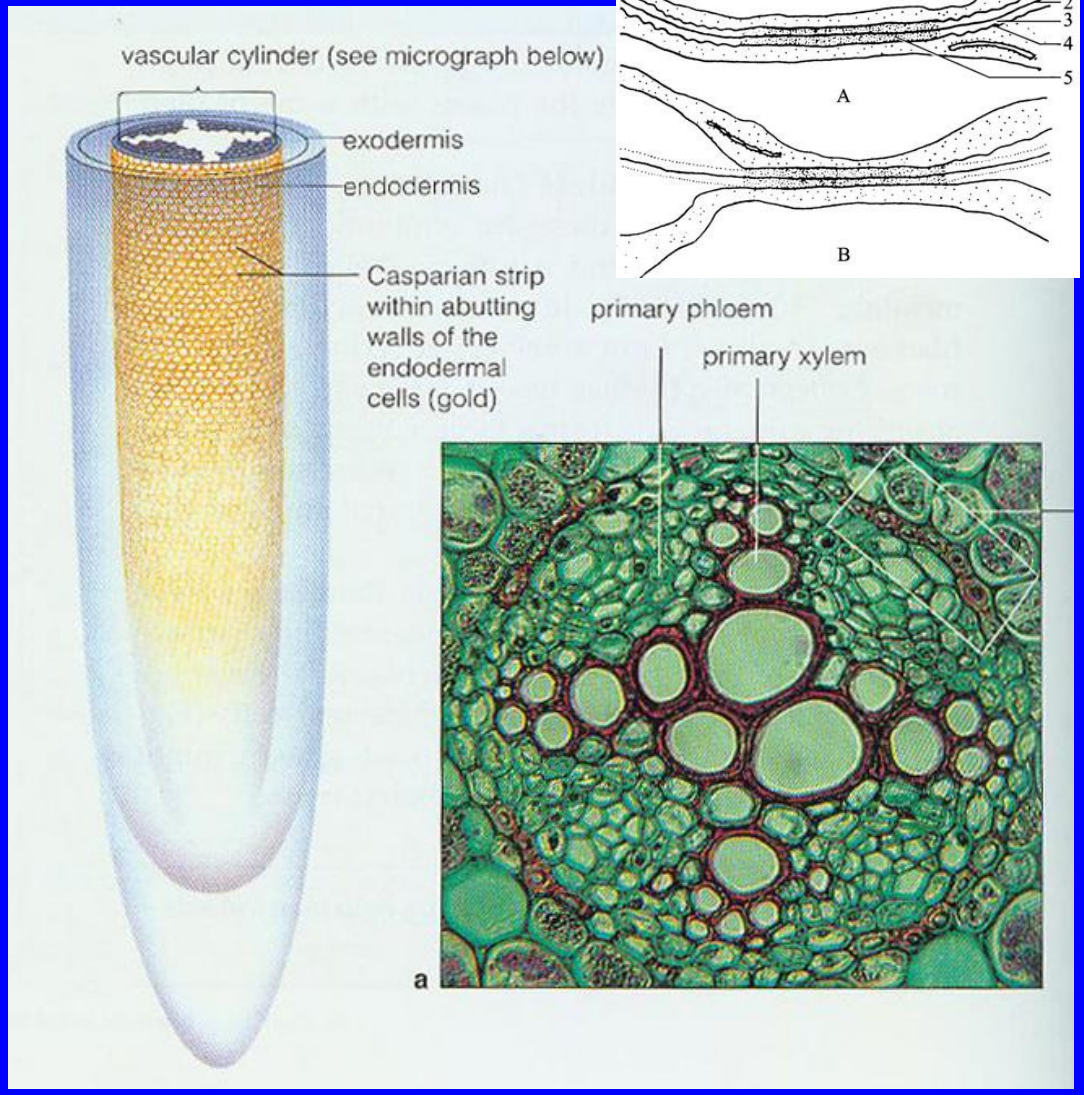
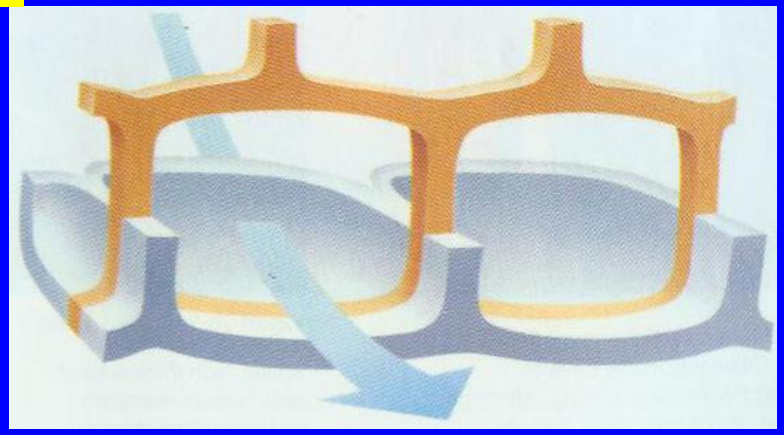
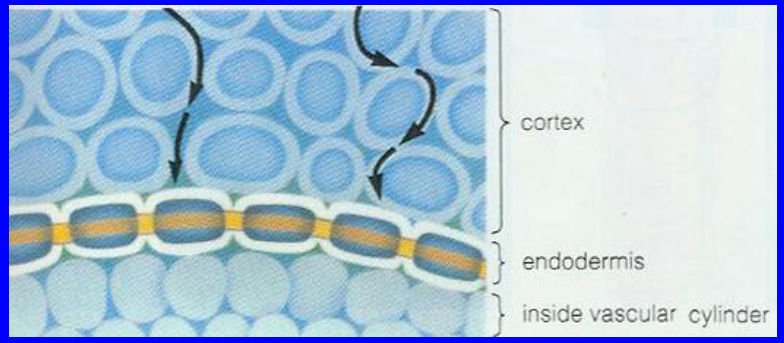
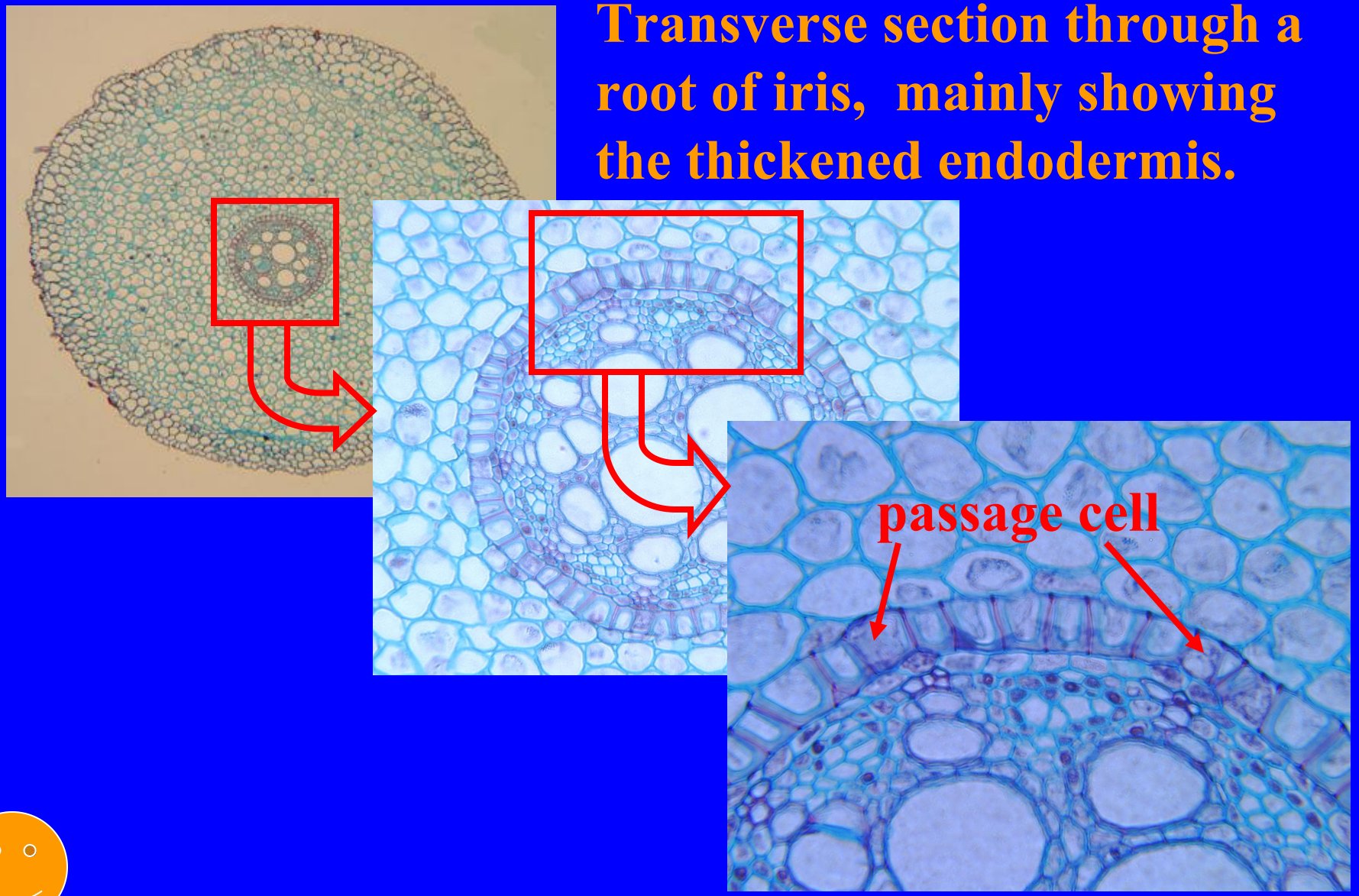


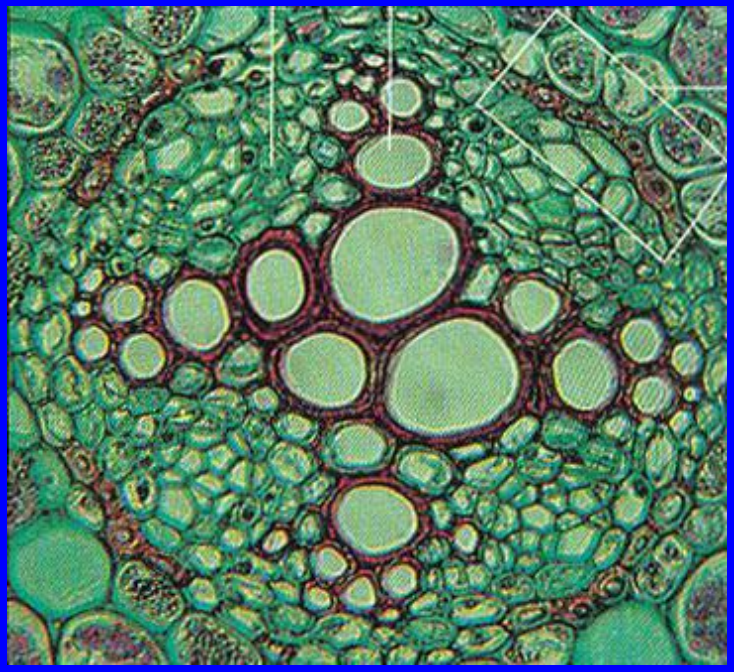




Primary structure of flowering plant root and Casparian strip.



Transverse section through a root of iris, mainly showing the thickened endodermis.

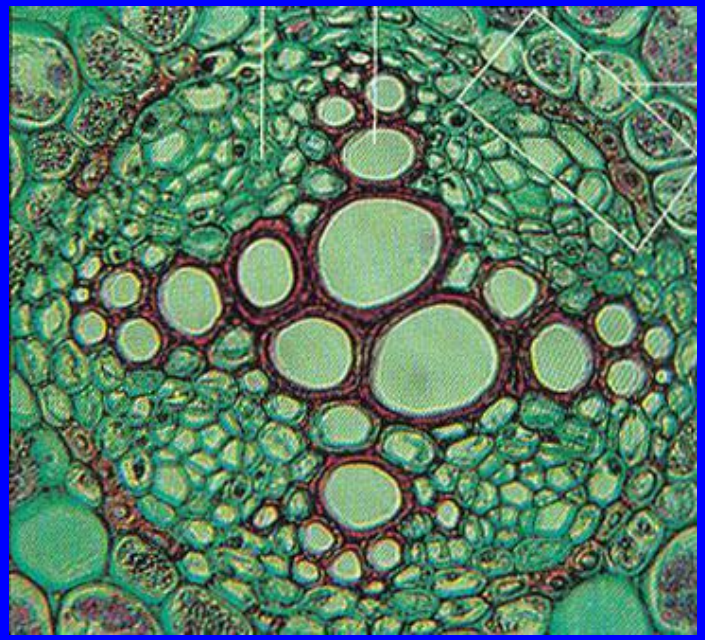


(III) Vascular cylinder

It is a part within endodermis, has a complex structure and comprises pericycle and primary vascular tissue, and some have pith.

1. Pericycle

It is developed from primary cambial cells, maintains potential mitogenetic capacity and consists of one layer of parenchyma cells. Vascular cambium (partial), phellogen, adventitious sprout , lateral root and adventitious root all may be generated from pericycle.



2. Primary vascular tissue

It consists of primary xylem and primary phloem, which are arranged alternately. During differentiation, it is gradually maturated inwardly and is exarch.

(1) Primary xylem: It has a simple structure and consists of vessel, tracheid, xylon and parenchyma cells.

① Protoxylem: Near pericycle, it is a part that becomes mature first and consists of annular or spiral vessels with a small lumen. On the transverse section, there are radial edges, i.e.: xylem ridges. For different plants, the number of xylem ridges is relatively stable, such as diarch, triarch and tetrarch, but as for different varieties or main and lateral roots, the number of ridges may be different.

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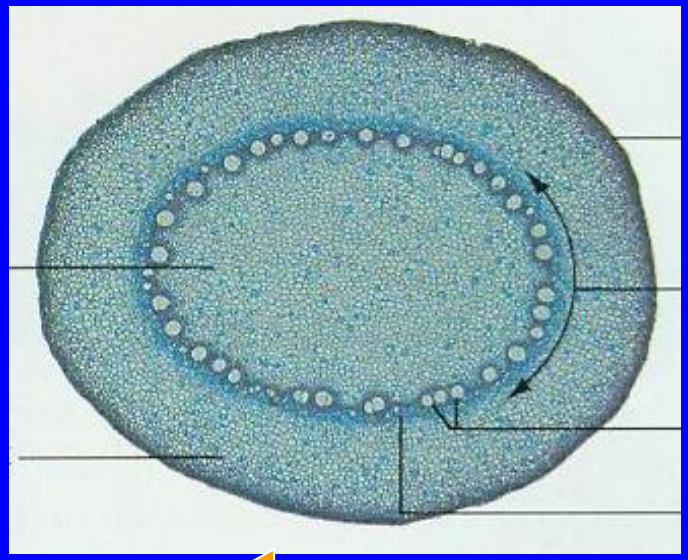
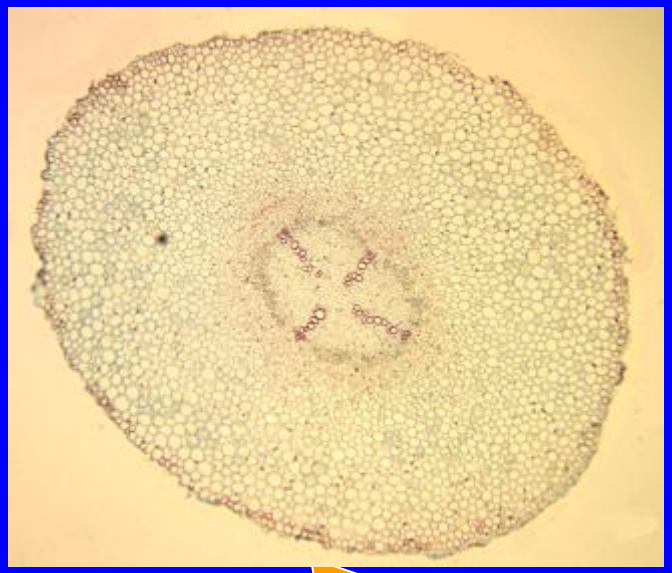


Polyarch

Root of a corn plant, transverse section.

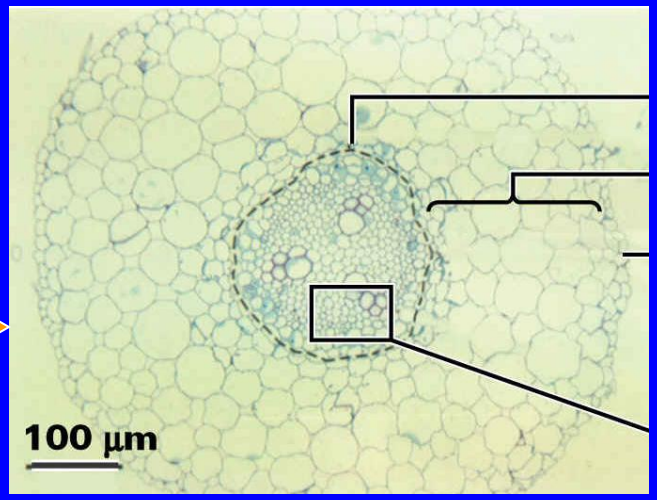
Tetrarch

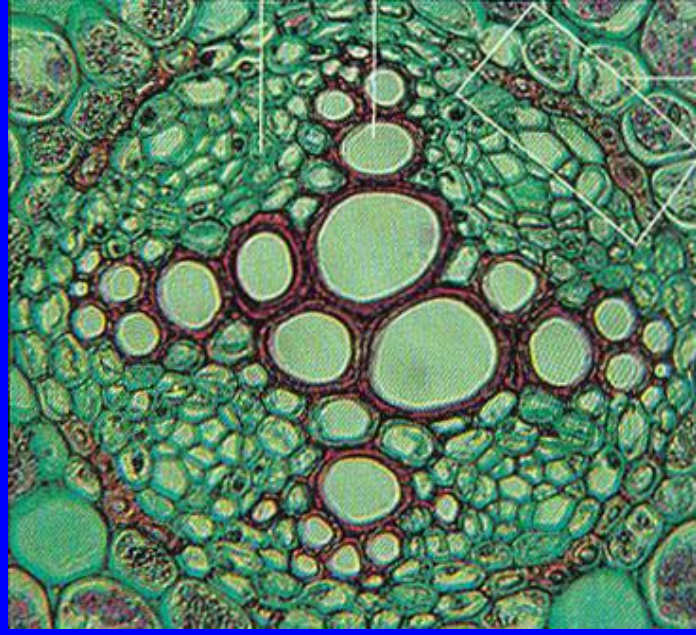


Root of a bean plant.

Triarch

Root of a soybean plant.





② Metaxylem: It is in the middle of the asymptotic root, becomes mature late and consists of scalariform, reticulate or pitted vessels with large lumen.

(2) Primary phloem: Consist of sieve tube , companion cell, phloem parenchyma cell and phloem fiber.

3. Pith

As for most monocotyledons as well as some herbaceous plants and most woody plants of dicotyledons, the central part of the root is not differentiated into xylem and instead, parenchyma tissue or sclerenchyma tissue forms a pith.

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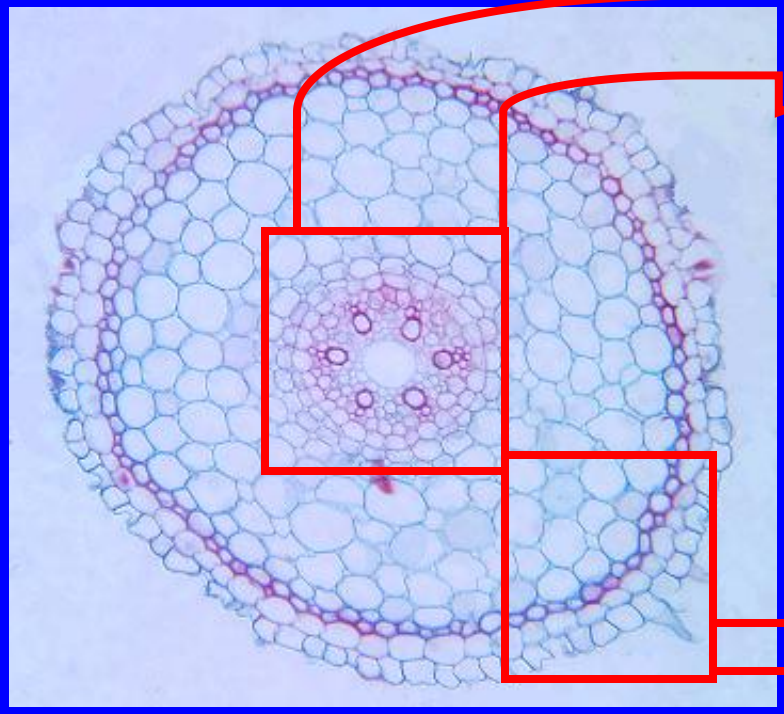
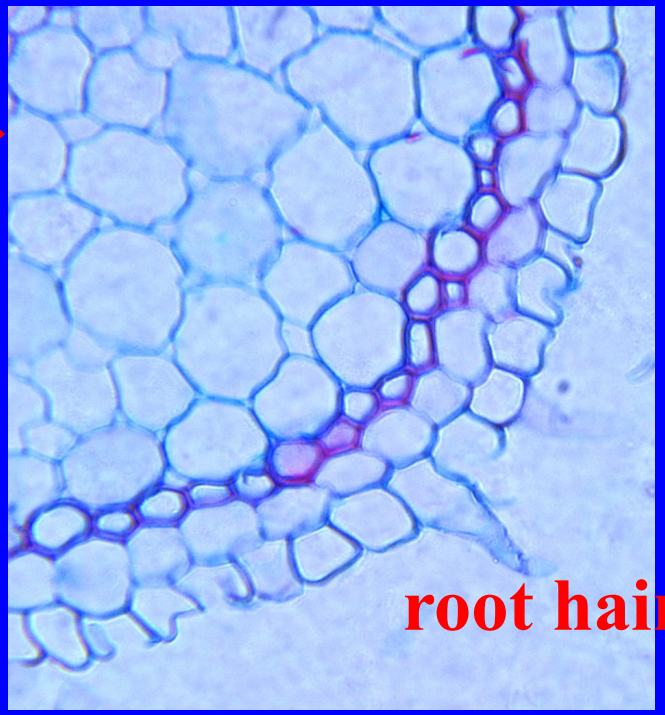
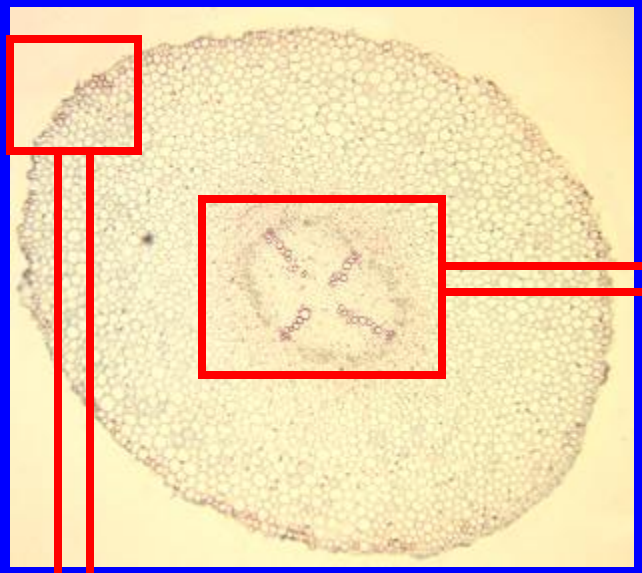
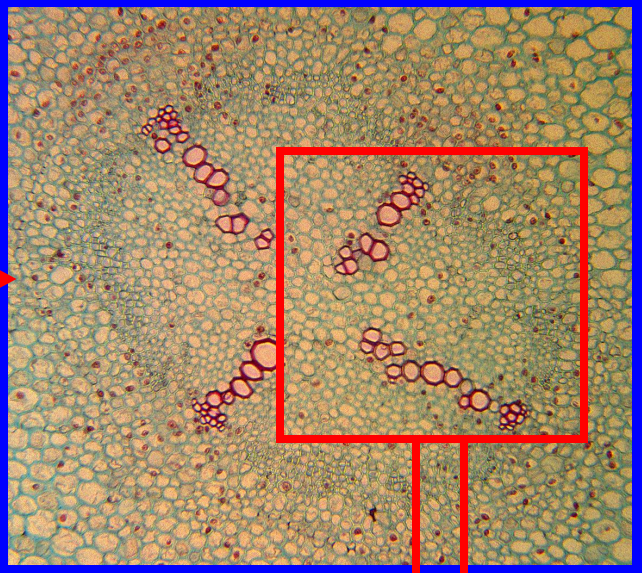


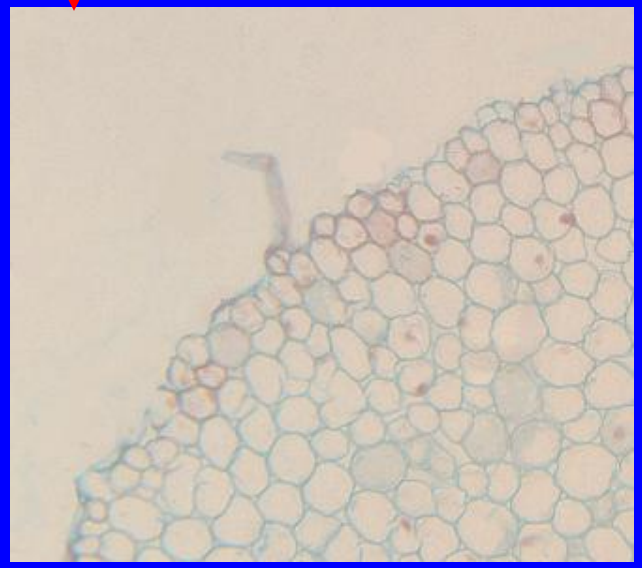


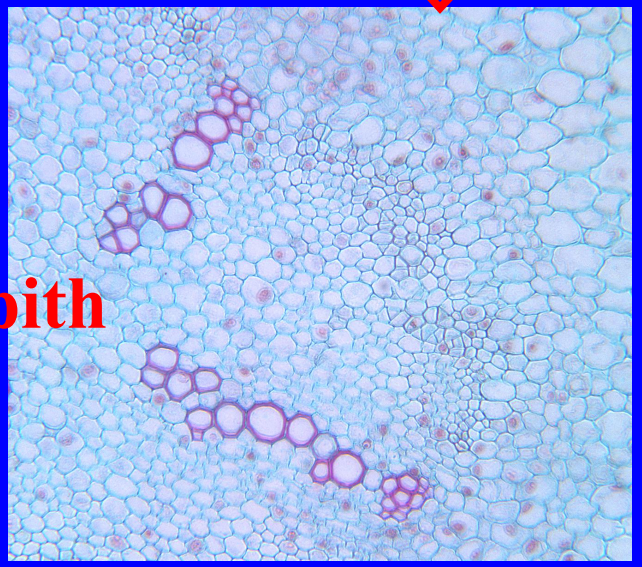
Transverse section showing the primary structure of rice root.

Light micro-graph of a bean root, showing the primary structure.



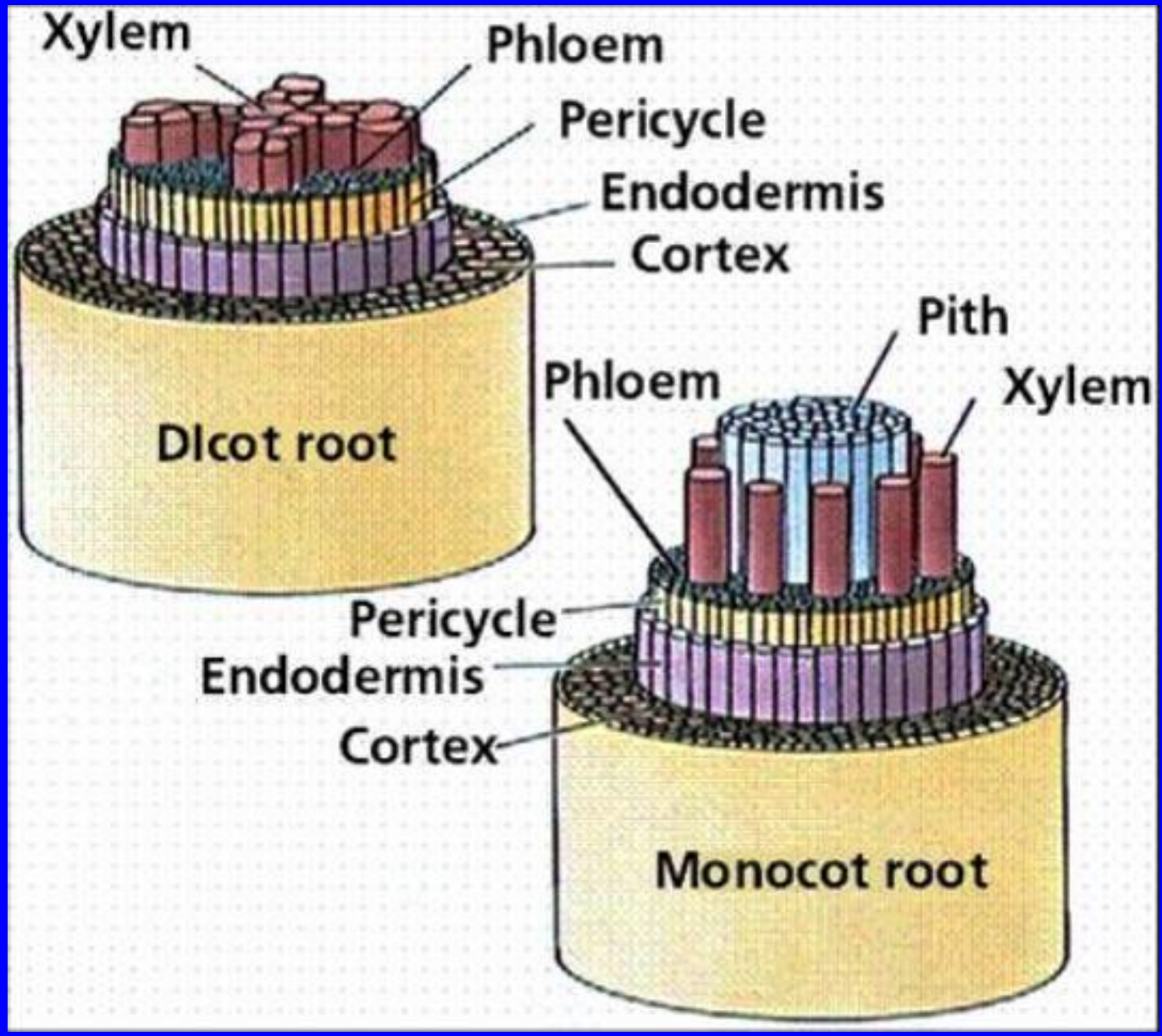






pith

Comparison betwen monocotyledons and dicotyledons in primary structure of root



V. Secondary Growth and Secondary Structure of the Root

- Secondary growth: After the end of primary growth, lateral meristem, i.e.: vascular cambium, is generated between primary xylem and primary phloem and then divided tangentially. After division, growth and differentiation, the quantity of the vascular tissues of the root increases and the root is thickened. This process is called secondary growth.

  Phellogen is generated to form a new protective tissue – periderm. It is also a part of secondary growth.

  Secondary growth is unique to the roots of gymnospermae and most dicotyledons.

- Secondary structure: The secondary vascular tissue and periderm generated during secondary growth jointly constitute the secondary structure of a root.

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(I) Generation and activity of vascular cambium

1. Generation: It starts from the inner side of primary phloem, i.e.: the parenchymal tissue between two primary xylem ridges.

2. Activity process:

   (1) Some cells are periclinally divided into a strip-like cambium;

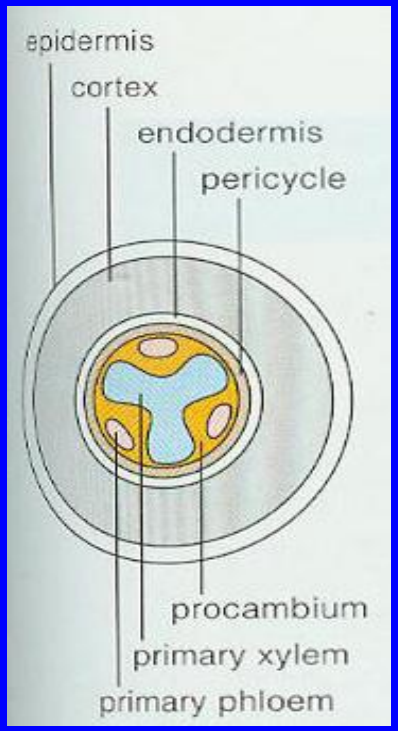
   (2) They are extended on the two sides, evolved outwardly and connected to pericycle cells at the ridge;

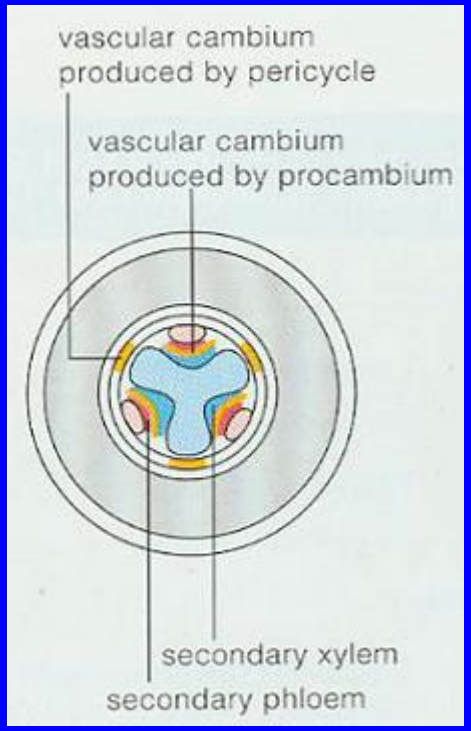
   (3) Pericycle cells resume mitogenetic capacity and take part in the formation of cambium;

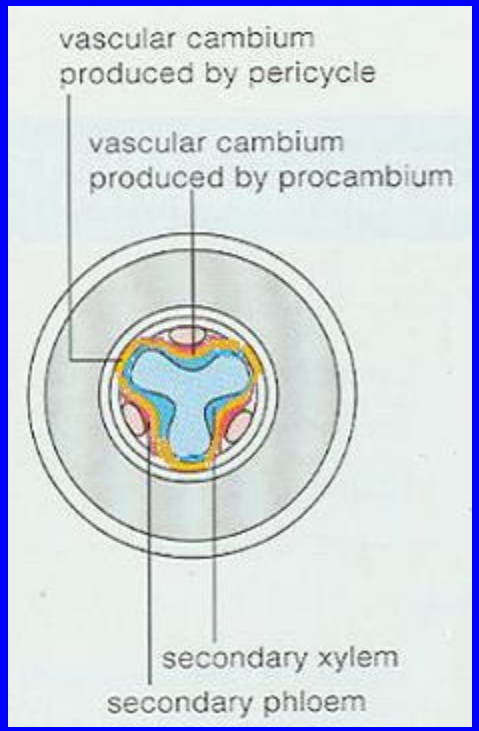
   (4) A complete and continuous cambium ring is formed;

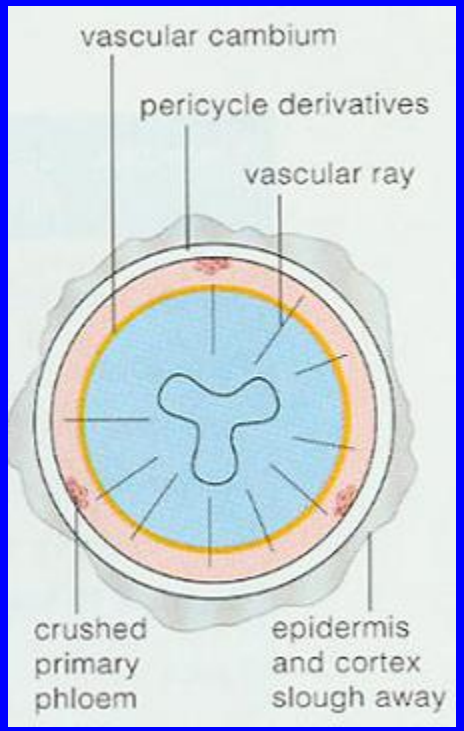
   (5) Different time of generation results in variable-speed division and makes the cambium ring in an uneven wavy shape;

   (6) Tangential division increases the quantity of secondary xylem and makes the cambium ring a relatively tidy circle. Uniform-speed division begins.









A ring of vascular cambium forms and gives rise to secondary xylem and phloem.

3. The activity results in generation of secondary structure

(1) Secondary vascular tissue: The root with secondary growth always contains a cambium.

① Secondary xylem: The cells generated from inward division of a cambium form new xylem, which is **outside** the primary xylem.

② Secondary phloem: The cells generated from outward division of a cambium form new phloem, which is **inside** the primary phloem.

(2) Vascular ray: The tissue newly generated in the secondary structure is a group of radially arranged parenchyma cells. As a structure for transverse transport of water, inorganic salts and organic nutrients, it internally and externally runs through secondary xylem and secondary phloem. These two lines are called xylem ray and phloem ray respectively.

(3) Features of secondary structure formed by a cambium

① In the secondary vascular tissue, secondary xylem and secondary phloem are arranged oppositely. The vascular ray is a new tissue.

② Following the proliferation of secondary vascular tissue, the cambium is enlarged continuously. Therefore, the division of cambium cells includes tangential division mainly as well as radial division and division in other directions.

③ Secondary structure is dominated by secondary xylem, whereas secondary phloem accounts for a small ratio.

(II) Generation and activity of phellogen

1. Generation: The pericycle cells of the root resume mitogenetic capacity and form phellogen, which is lateral meristem.
2. Activity: Phellogen is tangentially divided and outwardly forms a large amount of phellem, covering root surface; inwardly forms a small amount of phelloderm of parenchymal tissue; the three layers are collectively called periderm.
3. Features: The earliest phellogen is generated in pericycle, but its effect is terminated by a specific period. The generation of a new phellogen is gradually moved inwardly, and may be as deep as to the exterior of secondary phloem. New phellem is formed continuously so that the exterior of the root is always covered with phellem.

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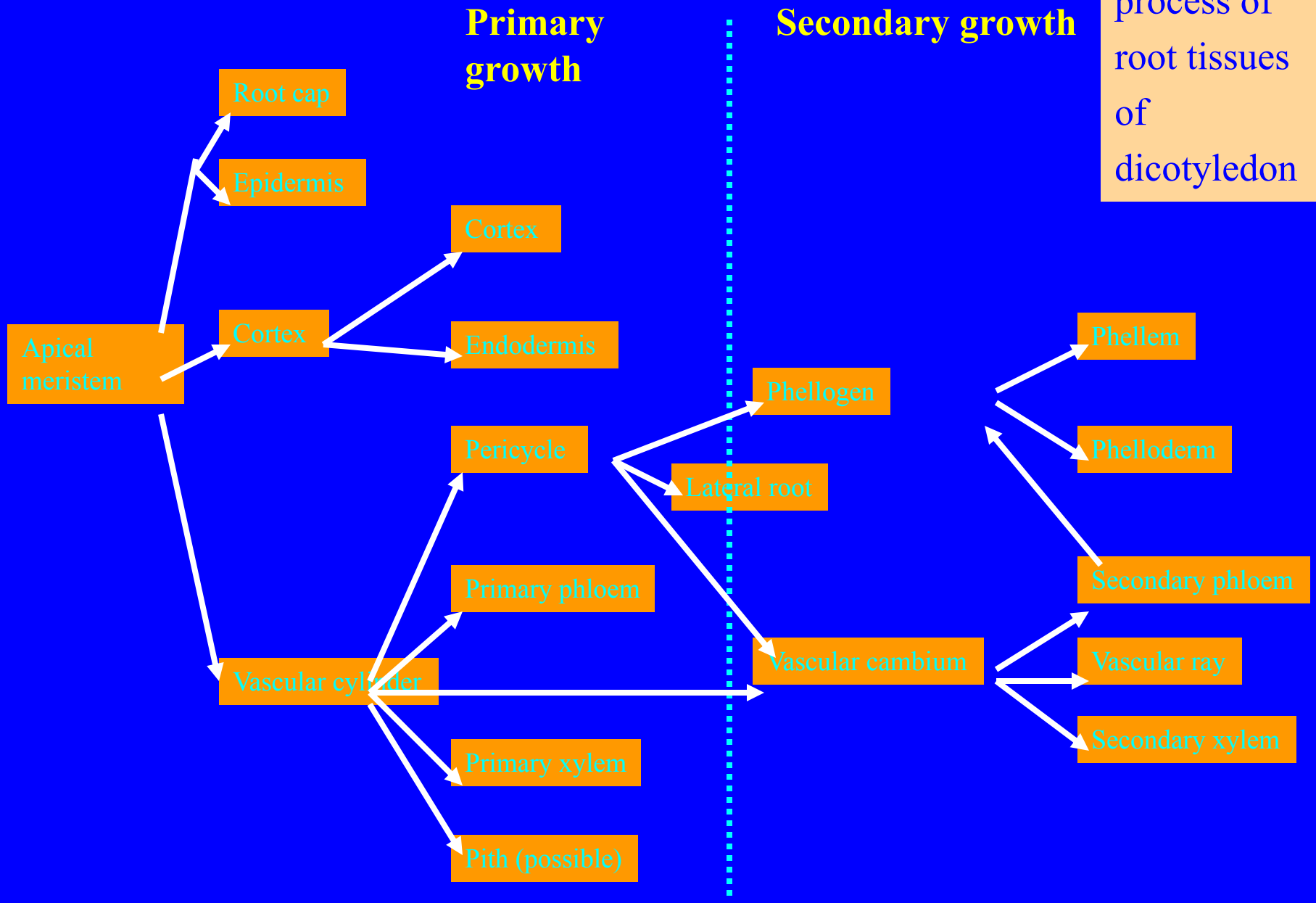
Atomization process of root tissues of dicotyledon



Assignments

- What are the similarities and differences of plant roots in primary and secondary structures?

Answer:

1. Similarities

2. Differences