In most of the shrubs and trees of dicotyledons and gymnospermsic plants, after the completion of the primary growth in length and diameter, further growth in diameter takes place due to the formation and addition of new secondary tissues by the activity of cambium. The addition of new secondary tissues to the primary tissues results in the increase in growth in diameter or thickness of the root and stem. This growth in thickness by the addition of secondary tissue in stelar and extrastelar region is known as secondary growth. The secondary growth may be thus defined as "**the increase in growth in thickness due to the formation and addition of new secondary tissues by the activity of cambium and cork cambium**"

SECONDARY GROWTH

Secondary Growth in Sunflower (Dicot) Stem:

The Sunflower stem shows secondary growth in stelar and extra stelar regions.

Secondary growth in stelar region of the stem:

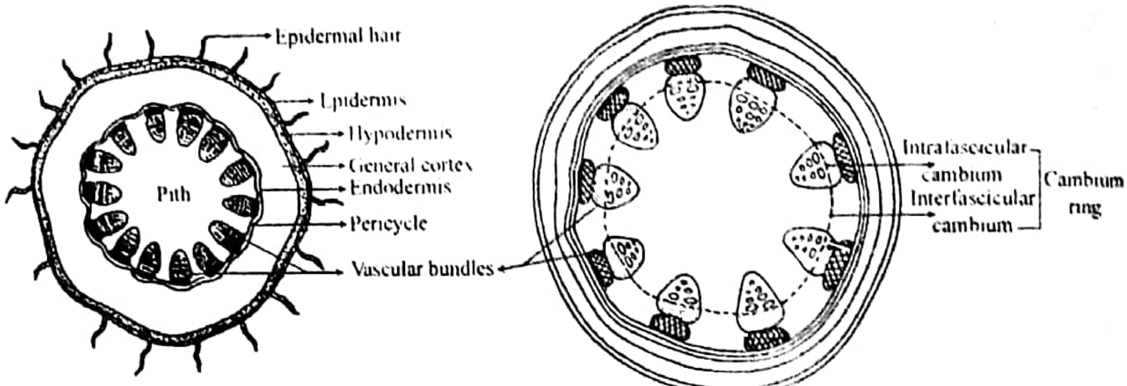
The process of secondary growth in the stelar region of Sunflower stem involves the following events such as

1. There is a single ring of open vascular bundles inside the stele. The cambium of the vascular bundles is called intrafascicular cambium (fascicle = bundle) very soon some cells of the primary medullary rays become meristematic and form a strip between the vascular bundles called the interfascicular cambium.

2. The interfascicular cambium grows on both sides and finally joins to the intrafascicular cambium. It results into the formation of a complete ring called the cambium ring.

3. The cambium ring is meristematic and few layered. The cells of cambium ring divide and redivide tangentially, and result into the

formation and addition of new cells to both external and internal sides of the cambium ring.



Diagramatic T.S. of Sunflower stem showing primary structures

Diagramatic T.S. of Sunflower stem showing cambium ring

Fig.4.1 (A-B). Diagramatic T.S. of Sunflower stem showing primary structures and cambium ring.

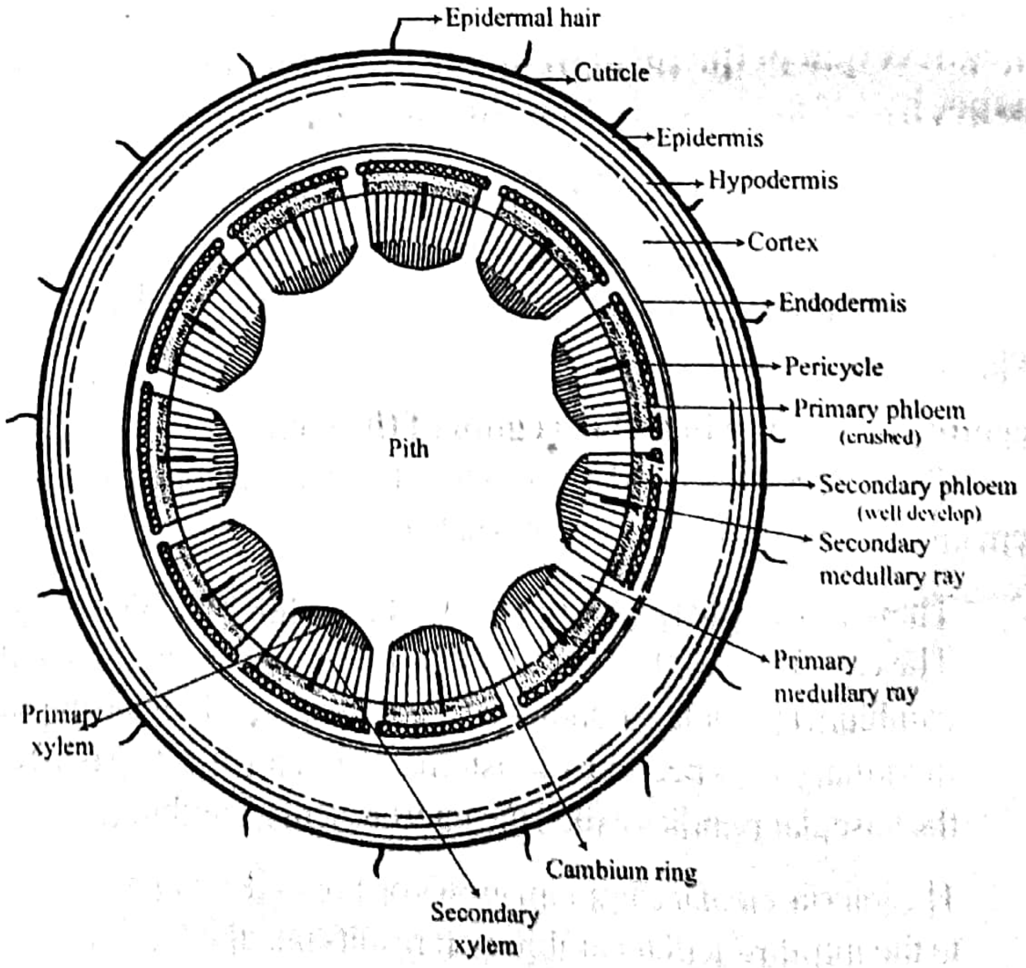


Fig.4.2. Diagramatic T.S. of Sunflower stem showing secondary growth in stelar region.

4. The new cells produce on outer side of he cambium ring are gradually differentiated into a new tissue called the secondary phloem. The secondary phloem is composed of sieve tubes, companion cells, phloem parenchyma and an abundant amount of phloem sclerenchyma.

5. The new cells produced on innerside of the cambium ring are gradually differentiated into a new tissue called the secondary xylem or wood. Cambium ring is more active on inner side than outerside. Therefore secondary xylem is formed in large amount as compared to the secondary phloem. The secondary xylem is composed of vessels, tracheids, xylem parenchyma and large amount of xylem sclerenchyma.

6. Some new cells produced on inner side of the cambium ring here and there in the secondary xylem differentiated into parenchymatous cells which form the secondary medullary rays.

7. Due to the addition of new secondary tissues the primary xylem of the vascular bundle pushed towards the centre of the stem and the primary phloem pushed towards the periphery and finally gets crushed against the pericycle.

Secondary growth in extra stelar region of the stem:

The secondary phloem and xylem produced in the stelar region of the stem exert great pressure on the extrastelar region (which is made up endodermis, cortex, hypodermis and epidermis). Due to this pressure the epidermis ruptures here and there. The hypodermis gets flattened tangentially. Similarly the cortex also gets affected. In order to replace these ruptured and highly affected tissues, some new protective tissues are developed by the activity of cork cambium in the extrastealar region and result into growth in thickness of the stem. This is called extrastelar secondary growth in the Sunflower stem.

The process of secondary growth in extra stelar region includes following events such as

1. Some outer layers of hypodermis become meristematic and form a cambium ring called the cork cambium or phellogen.

2. The cork canmbium divides and redivides and produces new cells on inner side. These cells are thin walled, green and give rise to a new cortex called the secondary cortex or phelloderm.

3. The cork cambium produces new cells to the outer side in radial rows. These cells are narrow and rectangular in shape. Very soon these cells become dead and impermiable to water due to the deposition of suberin. The suberin deposited layers of these cells together called as the cork or phellem.

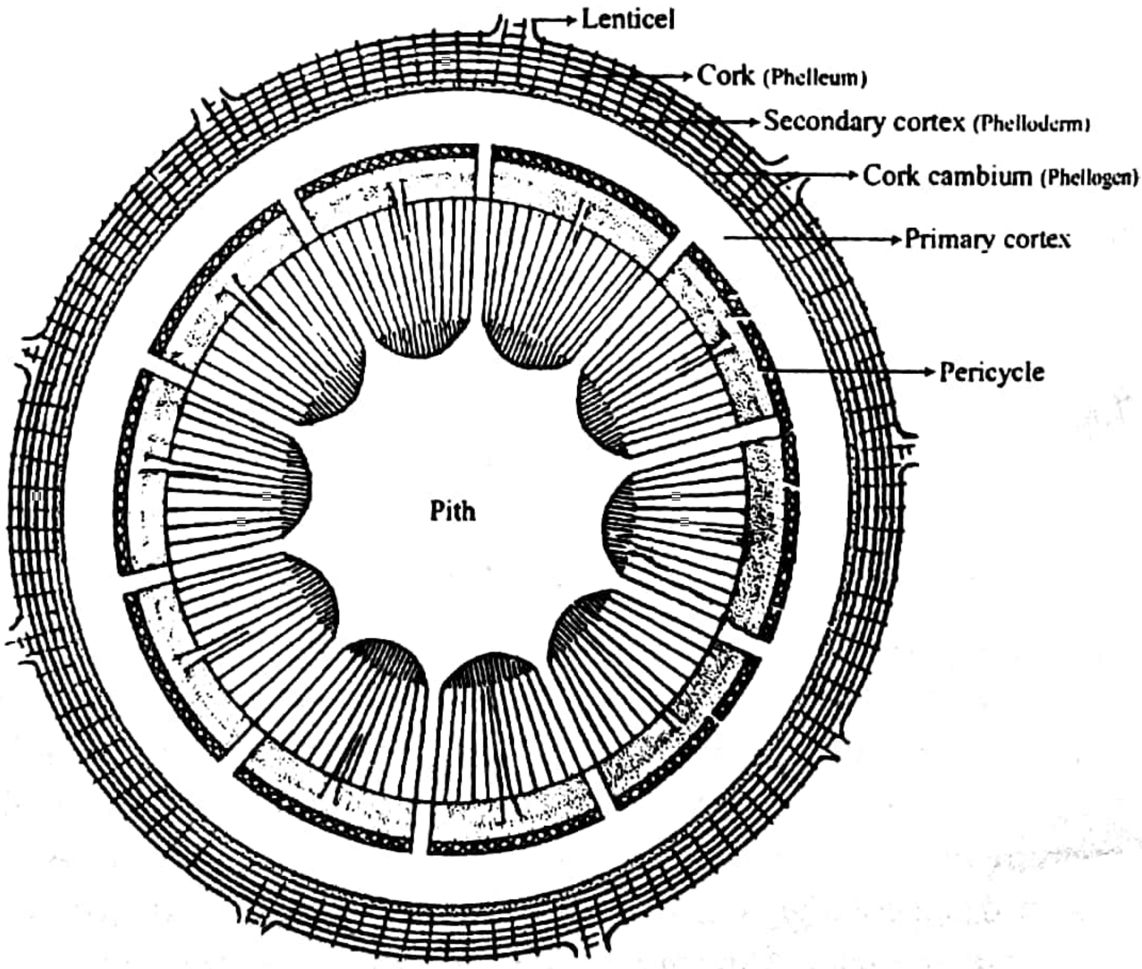


Fig.4.3. Diagramatic T.S. of Sunflower stem showing complete secondary growth.

4. The ruptured epidermis, cork and secondary cortex together is called as bark.

5. The cork cambium at certain places produces very small, thin walled parenchymatous cells on the outer side below the ruptured epidermis. This region is called as Lenticel or air pore which brings about the exchange of gases.

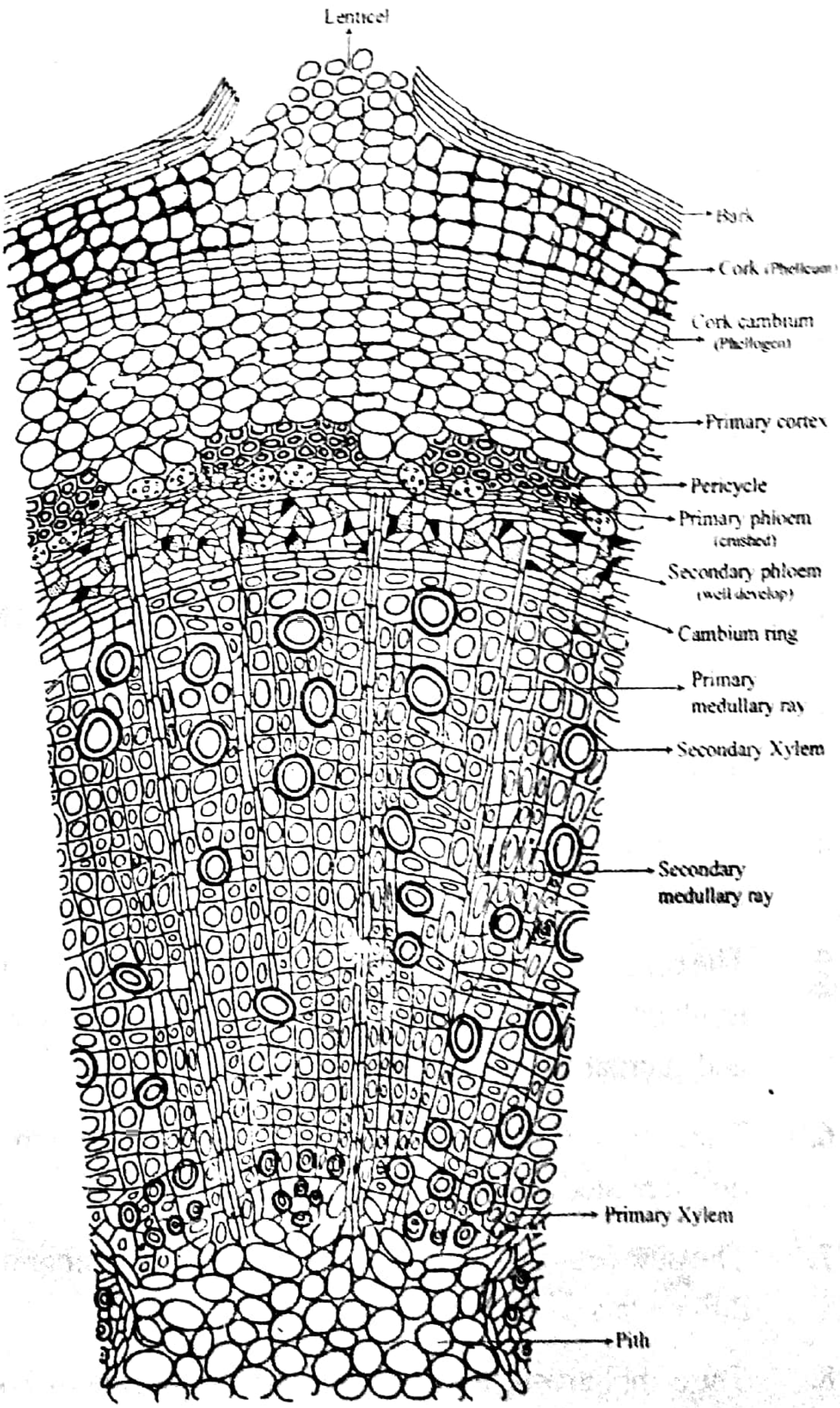


Fig.4.4. Sectors of T.S. of Sunflower stem showing cellular details after complete secondary growth.

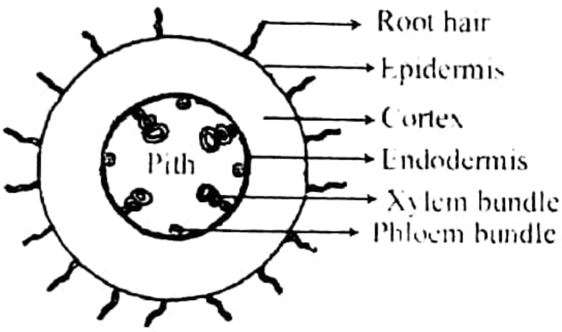
Secondary Growth in Sunflower (Dicot) Root:

The Sunflower stem shows secondary growth in stelar and extra stelar regions.

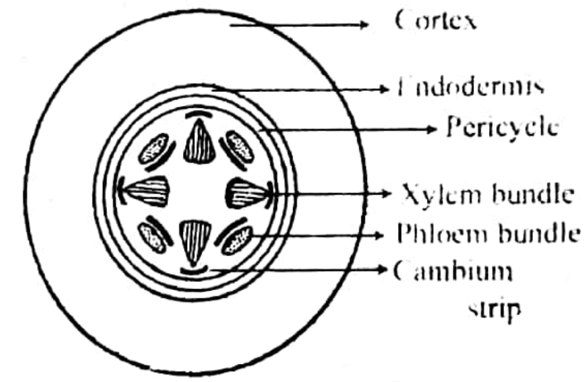
Secondary growth in stelar region of the root:

The process of secondary growth in the stelar region of Sunflower root includes the following events such as

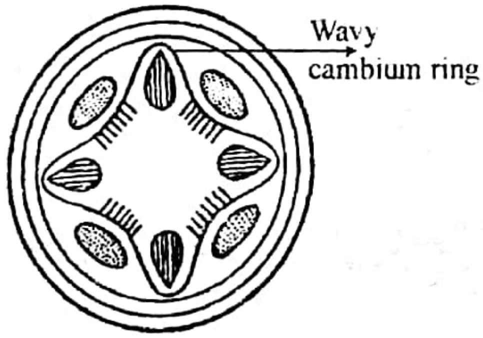
1. There is a single ring of four radial, exarch, closed vascular bundles inside the stele. Very soon some cells of the conjuctive become meristematic and form a strip called the cambium strip. At the same time cells of pericycle outside of each xylem bundles become meristematic and form a strip called the cambium strip.
2. The cambium strips grow on both sides and finally join together and form a wavy cambium ring.
3. All the xylem bundles now remain inside the cambium ring and the phloem bundles outside the cambium ring.
4. By further growth the wavy cambium ring becomes circular in outline.
5. The cells of cambium ring divide and redivide tangentially and result into the formation and addition of new cells to both external and internal sides of the cambium ring.
6. The new cells produced on outerside of the cambium ring are differentiated into secondary phloem.
7. The new cells produced on inner side of the cambium ring are differentiated into secondary xylem.
8. The cambium ring is more active on innerside than the outerside. Therefore secondary xylem is formed in large amount as compared to the secondary phloem. The secondary xylem is composed of large vessels, tracheids, little xylem fibre and well developed xylem parenchyma.



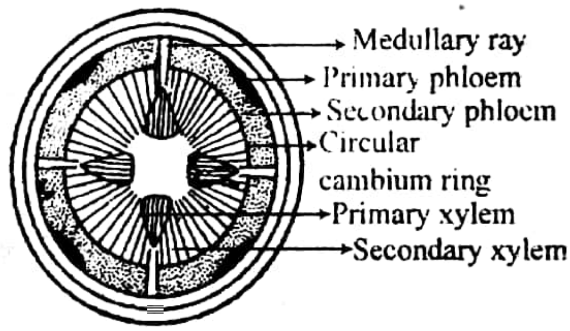
Diagramatic T.S. of
Sunflower root showing
primary structures



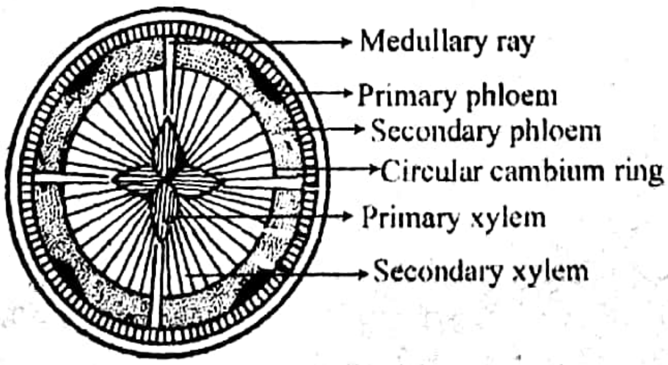
Diagramatic T.S. of
Sunflower root showing
cambium strips



Diagramatic T.S. of
Sunflower root showing
Wavy cambium ring



Diagramatic T.S. of
Sunflower root showing
Circular cambium ring



Diagramatic T.S. of Sunflower root showing
complete secondary growth

Fig.4.5 (A-E). Diagramatic T.S. of Sunflower root showing different stages of secondary growth.

Secondary growth in extra stelar region of the root:

The secondary phloem and xylem produced in the stelar region of the stem exert great pressure on the extrastelar region (which is made up of endodermis, cortex and epidermis). Due to this pressure the epidermis ruptures here and there. Similarly the cortex also ruptures and destroyed. In order to replace these ruptured and highly destroyed tissues, some new protective tissues are developed by the activity of cork cambium in the extrastelar region and result in thickness of the root. This is called extrastelar secondary growth in Sunflower root. The process of secondary growth in extrastelar region includes the following events such as

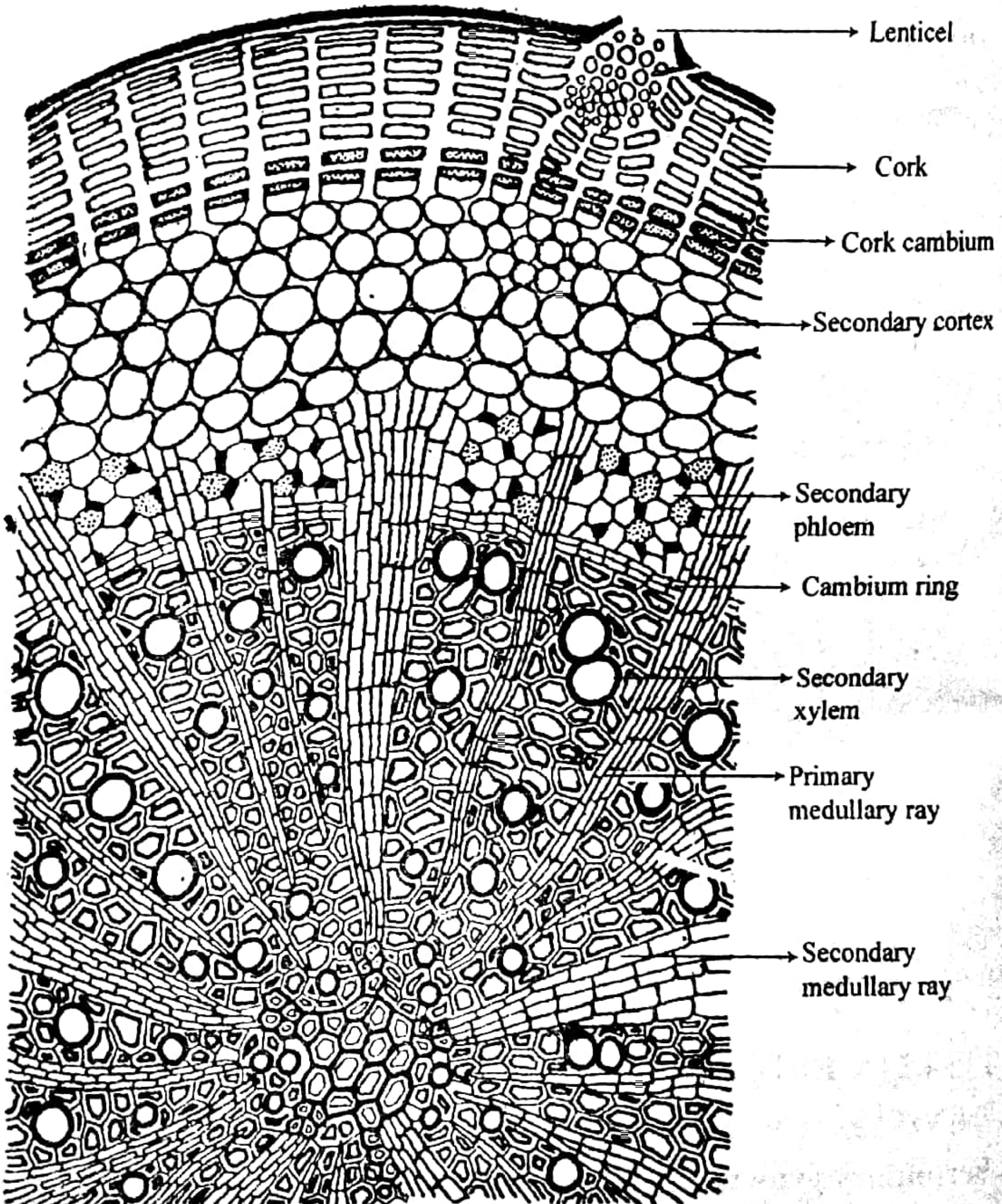


Fig.4.6. A sector of T.S. of Sunflower root showing cellular details after complete secondary growth.

1. The cells of pericycle become meristematic and function as the

cambium ring called the cork cambium or phellogen.

2. The cells of cork cambium divide and redivide and produce new cells on inner side. These cells give rise to secondary cortex or phelloderm. The secondary cortex cells are thin walled, rounded or oval, parenchymatous and with intercellular spaces.

3. The cells of cork cambium divide and redivide and produced new cells on the outer side in radial rows. These radial rows with narrow and rectangular cells together called as the cork or phellem.

4. The ruptured epidermis, cork and secondary cortex together is called as Bark.

5. The cork cambium at certain places produces very small thin walled parechymatous cells on the outerside below the ruptured epidermis. This region is called as lenticel or air pore which brings about the exchange of gases.

ANOMALOUS SECONDARY GROWTH

Angiosperms show a great similarity in the anatomy of stem and root. Howerver, there are few families in which some plants show a slight or greater amount of deviations in normal anatomical structures. These deviations or abnormalities are generally referred as anomalies or anomalous secondary growth. Anomalies are found in both dicot and monocot plants. The anomalies may develop in the primary structures or during the process of secondary growth. Examples of plants showing anomalies are ***Dracaena*** stem, ***Achyranthes*** stem, ***Bignonia*** stem, ***Beet*** **root** etc.

In most of the dicotyledon stems, normal structures with a ring of collateral vascular bundles are present. During the process of secondary growth inter and intrafascicular cambium is developed and forms a complete cambium ring. The cambium ring produces more secondary xylem on the innerside and very less secondary phloem on the outerside. In addition to this certain abnormalities are developed either due to abnormality in the primary structures or due to the abnormal process of secondary growth.

Formation of Anomalous Structures in *Dracaena* (Monocot) Stem:

Dracaena is a monocot plant belonging to the family **Liliaceae**. It is an ornamental plant and shows erect and woody habit. It shows anomalies in primary structures of the stem. The primary structures and anomalous secondary growth are well studied in transverse section of the stem.

Primary Structures:

Dracaena stem is circular in outline in T.S. The T.S. shows following primary structures such as

1. Epidermis
2. Hypodermis
3. Ground tissue
4. Vascular bundles

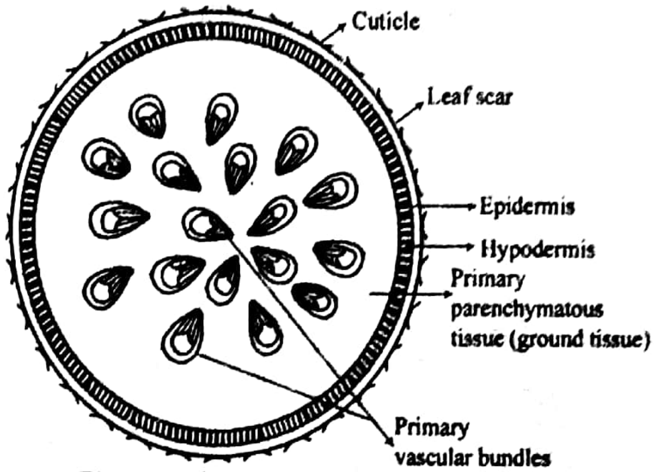


Fig. 4.7. Diagramatic T.S. of Dracaena stem showing primary structures

Epidermis:

It is outermost protective layer of the stem. It is made up of a single layer of barrel shaped cells. It has thick cuticle and scars of fallen leave, on the outer surface.

Hypodermis:

It is present just below the epidermis. It is made up of few layers of sclerenchymatous cells.

Groud tissue:

It is present below the hypodermis. It is multilayered and present in major portion of the stem. It is made up of many layers of thin walled parenchymatous cells with intercellular spaces between them.

Primary vascular bundles:

The vascular bundles are numerous, large, wedge shaped, conjoint, collatral and closed. They are irregularly scattered in the ground tissue generally in the centre of the stem.

Anomalous Structures:

Dracaena stem shows anomalous secondary growth. The process of formation of anomalous structures includes following events such as

1. During the process of formation of anomalous structures, few layers of the ground tissue just at the periphery of the primary vascular bundles become meristematic and act as cambium ring.
2. The cambium ring cells divide and redivide and produce new cells to both outer and inner side of the ring.

3. The new cells are produced on outer side of the cambium ring are gradually differentiated into a new parenchymatous tissue called the secondary parenchyma.

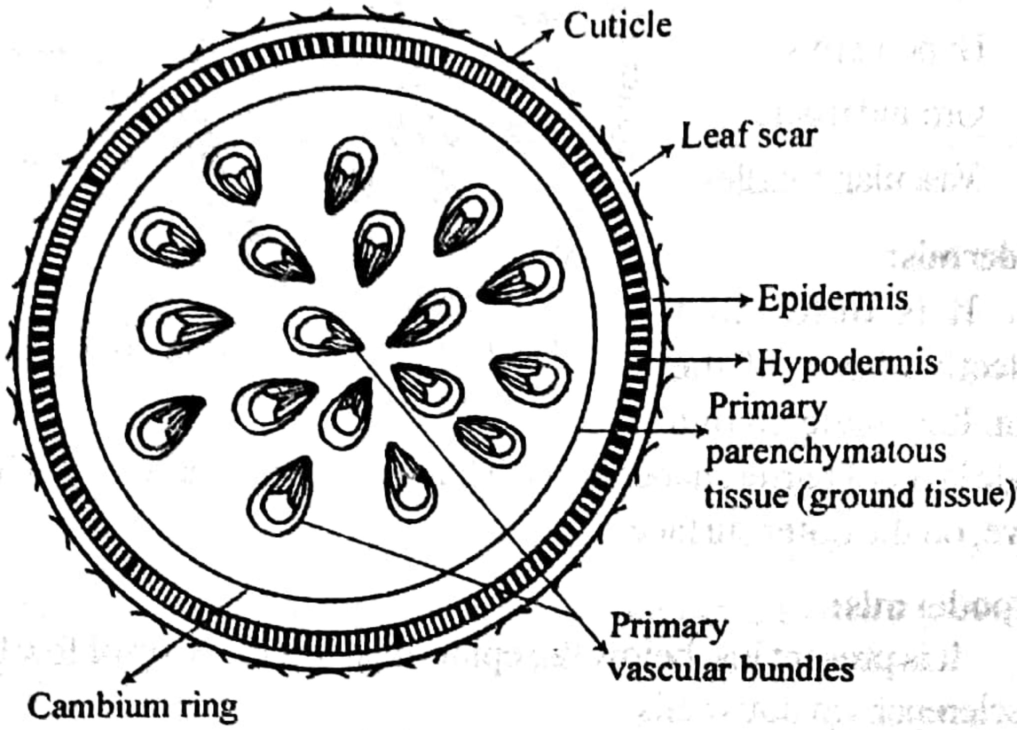


Fig. 4.8 a. Diagramatic T.S. of Dracaena stem showing cambium ring

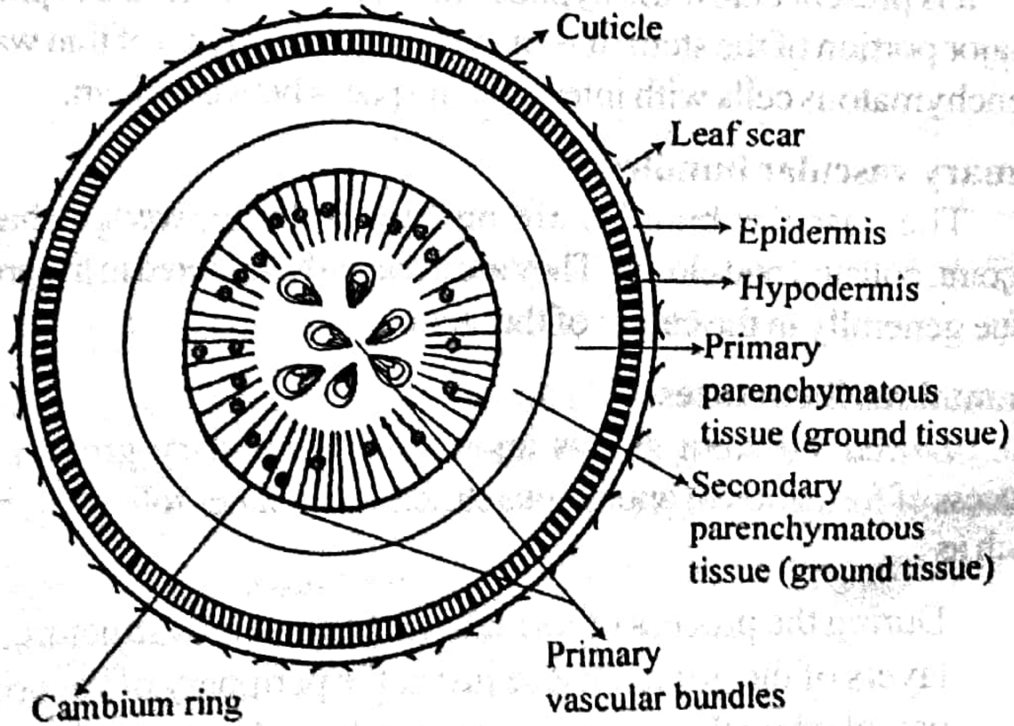


Fig. 4.8 b. Diagramatic T.S. of Dracaena stem showing Secondary structures

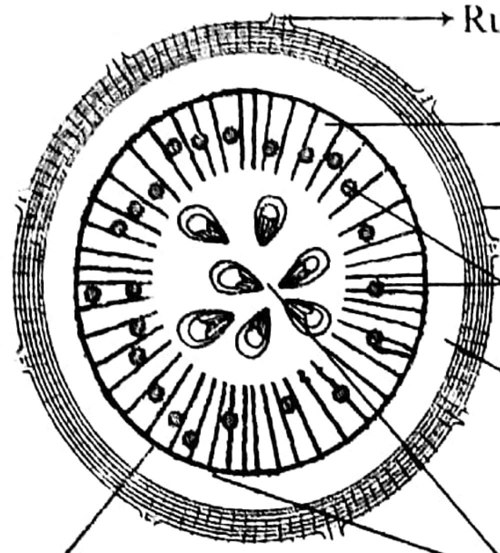


Fig. 4.8 c. Diagramatic T.S. of Dracaena stem showing anomalous secondary growth

4. The new cells are produced on inner side of the cambium ring are gradually differentiated into a thick slender of wood which consists of a group of lignified cells called the conjuctive tissue and distinct secondry vascular bundles.The secondary vascular bundles are more or less radially arranged and are of concentric or amphivasal type. (Xylem surrounded by phloem). The cambium ring is more active on inner side and hence the conjuctive tissue and secondary amphivasal or concentric vascular bundles are formed in large amount as compared to the secondary parenchyma.
5. Due to addition of new tissues like secondary parenchyma, conjuctive tissue and secondary vascular bundles, the primary vascular bundles are pushed more towards the centre. The addition of these new tissue results in growth in diameter of the stem.

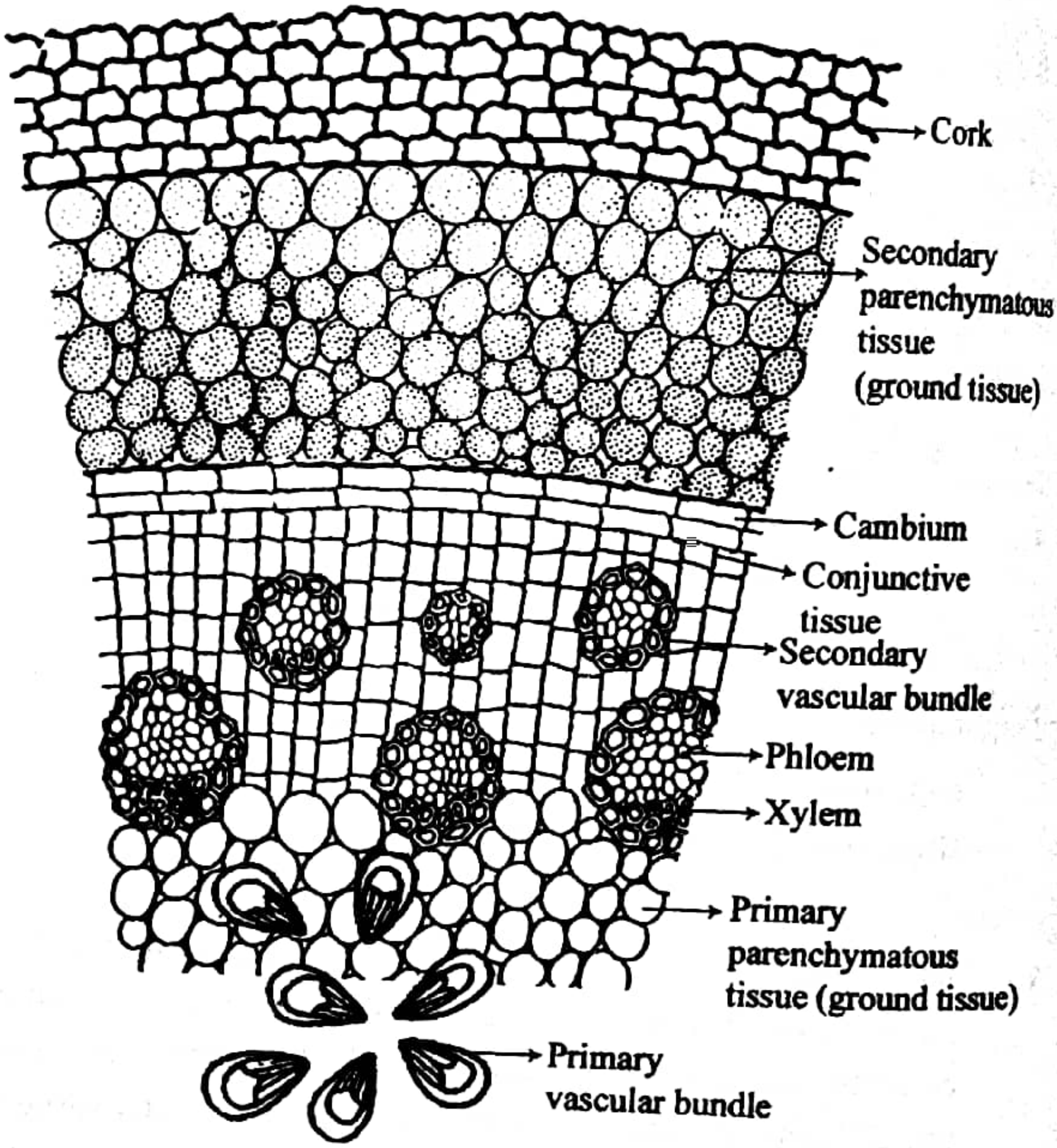


Fig.4.9. Sectors of T.S. of Dracaena stem showing cellular details after complete anomalous secondary growth

6. In peripheral region of the stem, the layers of ground tissue between the secondary parenchyma and the hypodermis become meristematic. These cells divide tangentially and add new cells. The new cells differentiated into few layered bands of tissue called the cork. The process of formation of bands of cork is repeated several times so that in the old stem the cork appears banded or multistorial.

7. Due to the addition of bands of cork, the hypodermis gets crushed.

Anomalous Secondary Growth in *Achyranthes* (Dicot) Stem:

Achyranthes is a dicot plant belonging to the family ***Amarantaceae.*** It is an errect herb with angular stem. The primary structures and the anomalous secondary growth are well studied in T.S. of the stem.

Achyranthes stem is circular wavy in outline in T.S. The T.S. shows following primary structures with some anomalies such as

Epidermis:

It is outermost layer of the stem. It is made up of a single layer of barrel shaped cells.It has a thick cuticle and multicellular hairs on the surface.

Hypodermis:

It is present just below the epidermis. It is made up of a few layers of collenchyma below the ridges and chlorenchyma below the grooves (Furrows).

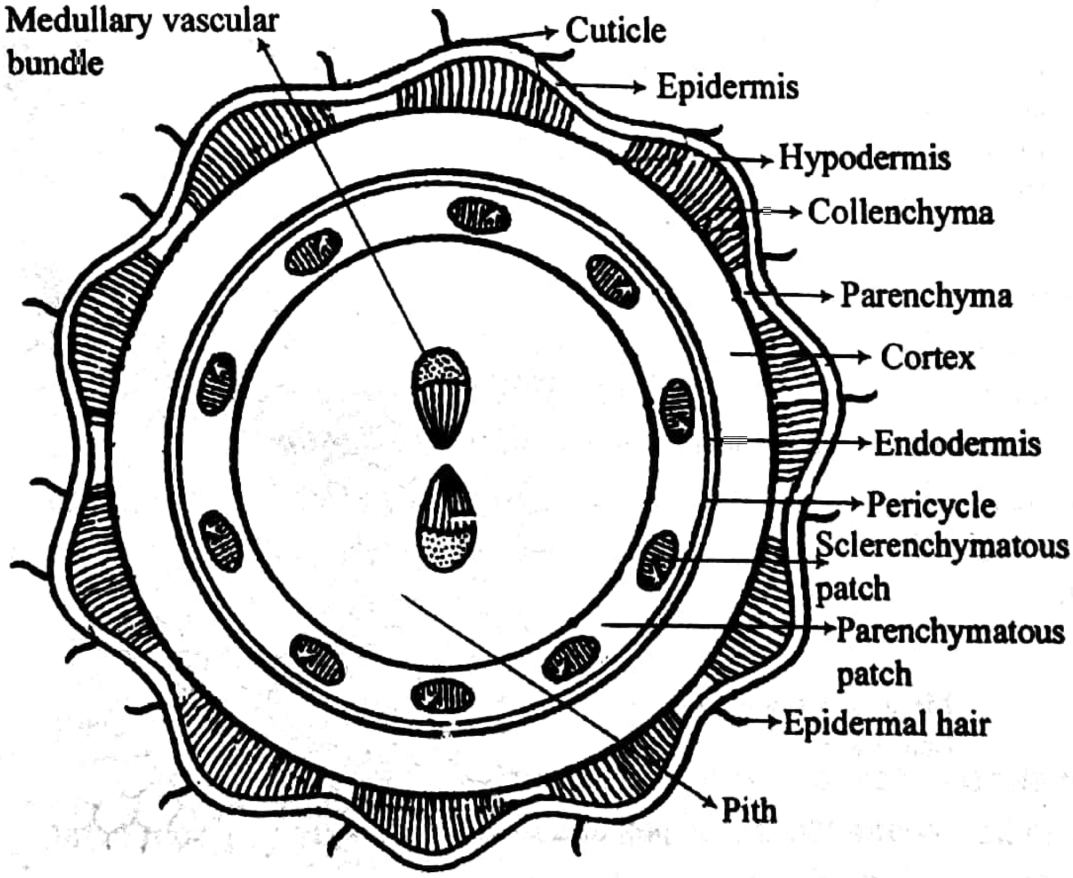


Fig.4.10. Diagramatic T.S. of *Achyranthes* stem showing primary structures

Cortex:

It is present below the hypodermis. It is made up of 3-4 layers of parenchymatous cells with intercellular spaces between them.

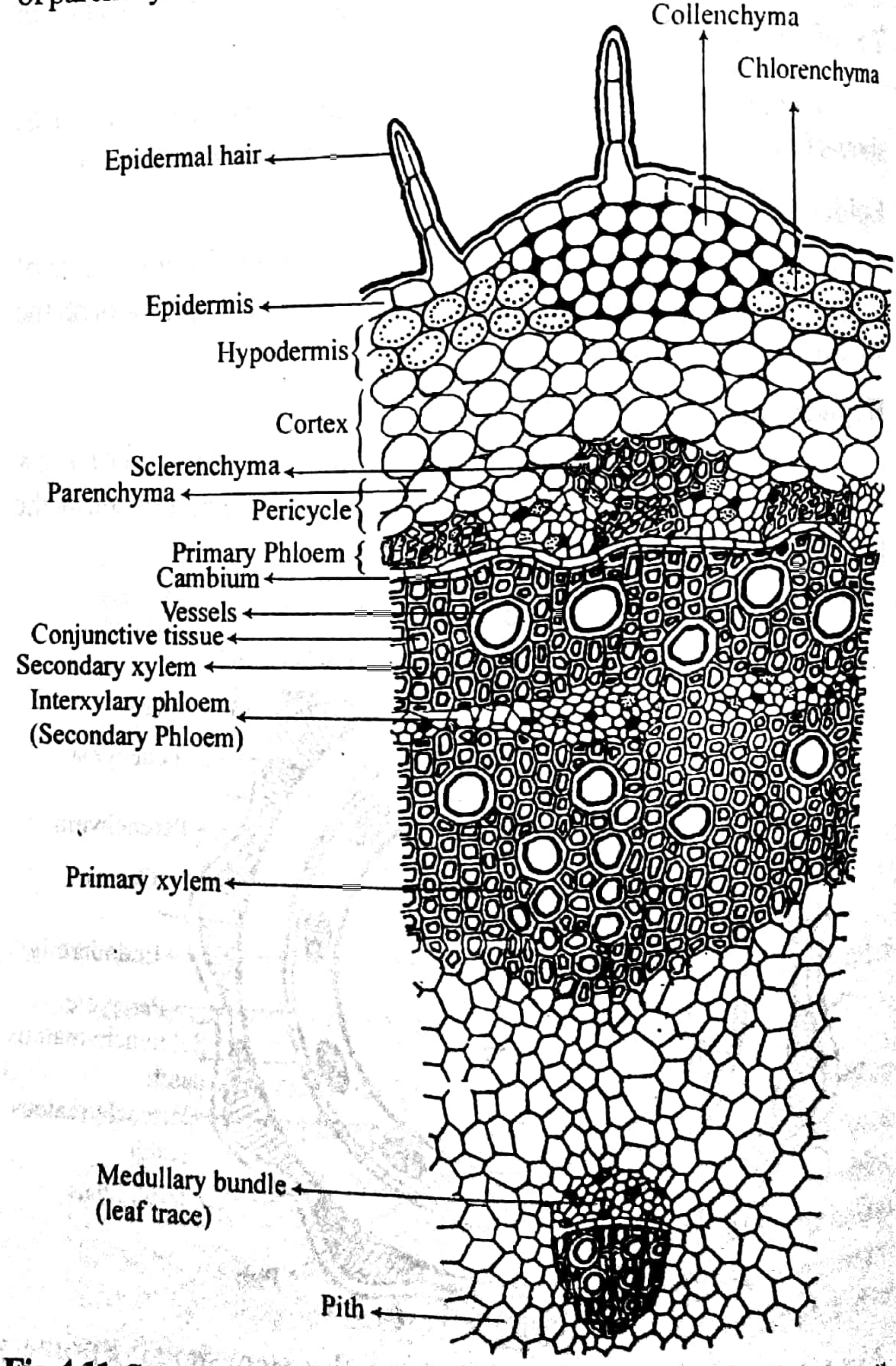


Fig.4.11. Sectors of T.S. of *Achyranthes* stem showing cellular details and anomalous structures

Endodermis:

It is the innermost layer of cortex. It is single layered and not well developed.

Pericycle:

It is present just below the endodermis. It is made up of few layers of sclernchyma below the ridges and parenchyma below the furrows.

Vascular system:

The vascular system is present below the pericycle. It has conjoint, collateral, endarch and open vascular bundles. The phloem and xylem are separated by the cambium. Primary phloem present in the form of crushed and crumpled patches generally below the ridges. Secondary phloem forms a complete zone and made up of sieve tubes, companion cells and phloem parenchyma. Secondary xylem is embeded into thick walled conjuctive tissue. The xylem elements and the conjuctive tissue are not differentiated and only large vessels are seen prominently, certain groups of phloem bundles occur mixed with the conjuctive tissue.These phloem bundles are known as phloem islands or included phloem or interxylary phloem. Primary xylem groups are present in crushed form pushed towards the pith.

During the process of secondary growth an extrastealar cambium is developed in the form of arcs in the pericycle region. This cambium is called as pericyclic cambium.These cambium strips produce secondary vascular bundles and lignified conjuctive tissue.The conjuctive tissue and secondary xylem bundles are not differentiated except the larger vessels. Therefore the thin walled phloem of the secondary vascular bundles apears in the form of patches in the lignified conjunctive tissue. This phloem is called as included phloem or interxylary phloem or secondary phloem.

Pith:

It is the central part of the stem. It is well developed and made up of many layers of parechymatous cells without intercellular spaces between them. Two vascular bundles are present in the centre of the pith with their xylem facing each other. These vascular bundles are called the medullary bundles. The medulary bundles occur throughout the length of the plant and these are said to be leaf traces.

Anomolous Secondary Growth in Mirabilis jalapa

Mirabilis jalapa is a 4 'o clock plant commonly known as "Gulbaksha".
Mirabilis is a dicot belongs to family Nyctaginaceae.
T.S. of stem shows two grooves / furrows having numerous hairs.
Internal structure of Mirabilis stem shows following parts :
1) Epidermis
2) Hypodermis
3) cortex
4) vascular bundles.

1) **Epidermis** :→
Epidermis is single layered, outermost layer of stem which is protective in nature.

2) **Hypodermis** :→
It is present below the epidermis. It is made up of collenchymatous cells. Hypodermis is few layered.

3) **Cortex** :→
Cortex is few layered made up of parenchymatous cells. It is present below the hypodermis. Next to cortex endodermis is present which is single layered. Next to endodermis pericycle is present. Pericycle is made up of sclerenchyma cells.

4) Vascular bundles :-

Vascular bundles are scattered in ground tissue. Each vascular bundle is open.

[1884]
According to De Barry normal cambium ring is not formed in Mirabilis. Entire new cambium develops in outer region of vascular bundles from pericycle. Recently Mikesell and Popham in (1977) have supported this observation and stated that first cambium arises either in the inner cortex or in pericycle. i.e. in stelar or extra-stelar region. ~~[1977]~~

Maheshwari shown that first cambium ring develops normally in outermost region of vascular bundles. This cambium produces xylem towards inner side and phloem towards outer side. Thus there is a ring of vascular bundles formed. This cambium then stop its activity, after completion of it's function.

Second and subsequent cambium develops later on and performs same function as previous cambium. and adds more vascular bundles in stelar region. cells of last cambium form lignified tissue towards inner side. Then, normal cork and cambium is formed.

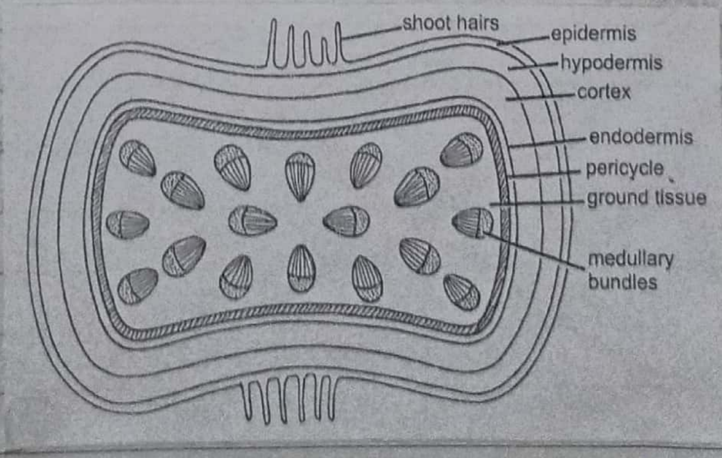


Fig. T.S. of young stem of Mirabilis

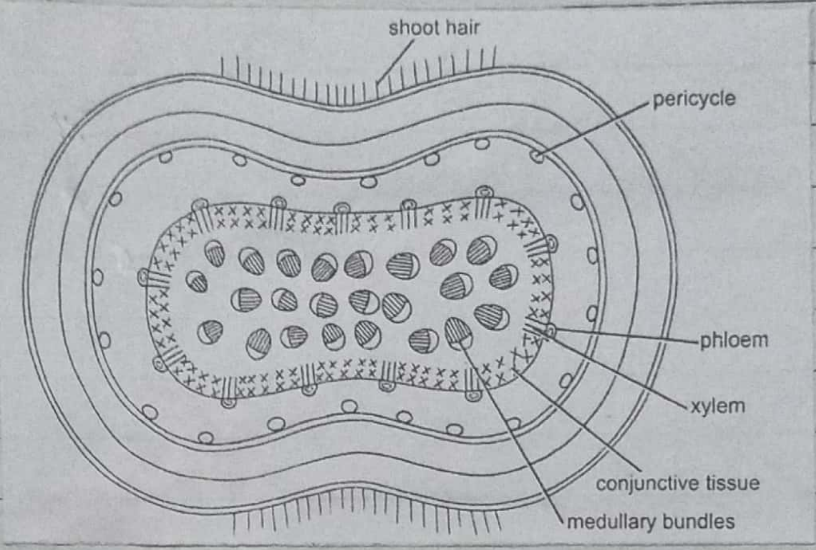


Fig. T.S. of stem of Mirabilis after secondary growth.

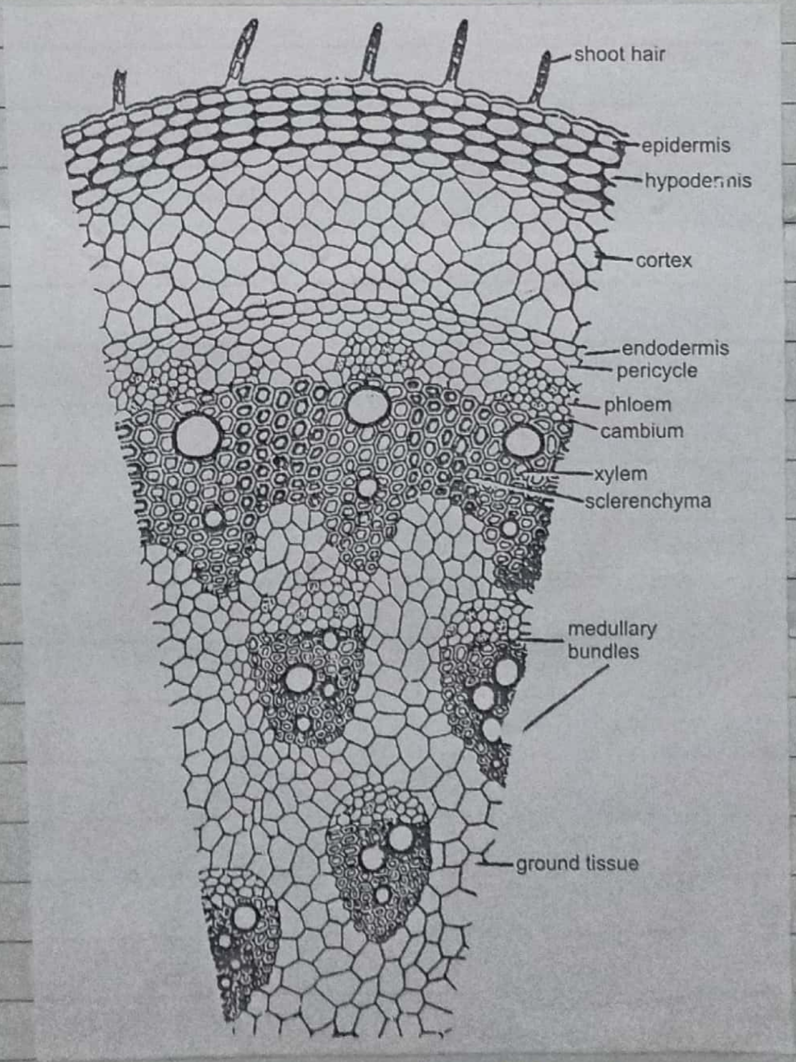


Fig. cellular details of Mirabilis stem after secondary Growth

Anomolous Secondary Growth in Bignonia Stem

Bignonia venusta is a common climber plant which belongs to family Bignoniaceae.
T.S. of young stem of Bignonia shows ridges and furrows. There is maximum deposition of Collenchyma below the ridges and minimum deposition of chlorenchyma below furrows.
T.S. of Bignonia stem shows following structures:
1) Epidermis
2) Hypodermis
3) Cortex
4) Vascular bundles
1) Epidermis is outermost and protective in nature.
2) Hypodermis present below the epidermis. ~~Cortex~~ Hypodermis consists of two different types of cells i.e. Collenchyma & chlorenchyma. Collenchyma present below the ridges and chlorenchyma below the furrows.

3) Cortex :- It is present below the hypodermis and made up of parenchymatous cells. Cortex ends with endodermis.
* In Bignonia stem endodermis is not clear. Next to endodermis pericycle is present. Pericycle is heterogenous in nature i.e. It is made up of two different types of cells i.e. parenchyma & sclerenchyma. Towards ridges sclerenchyma are present.

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Vascular bundles :-

Each vascular bundle is conjoint collateral and all the vascular bundles are arrenged in a ring.

In the centre pith is present.

During secondary growth of Bignonia Inter & intra-fascicular cambium become active to form normal cambium ring. This cambium ring is first cambium ring, which cutts of secondary phloem and secondary xylem. Secondary xylem present towards inner side and secondary phloem towards outer side.

After some time cambium forms less amount of xylem towards inner side and large amount of phloem towards outer side. This activity of cambium takesplace at four diagonal places and results into the formation of four deep wedges of phloem projecting into xylem. The width of these wedges is irregular. Cambium strip which performs normal activity after short period central portion becomes abnormal and starts forming more phloem towards outer side as compared to xylem which are present towards ~~out~~ inner side. It results into the formation of more wedges of phloem. Thus there are four big-sized and small-sized wedges of phloem formed. In phloem band of sclerotic cells is developed.

Cortical cells form cork cambium and pericycle fibres cast off after it's activity & stem becomes circular.

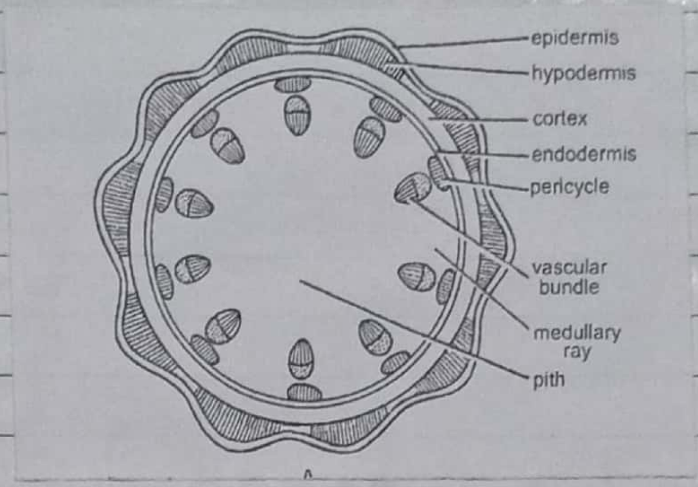


Fig. T.S. of Young Stem of Bignonia

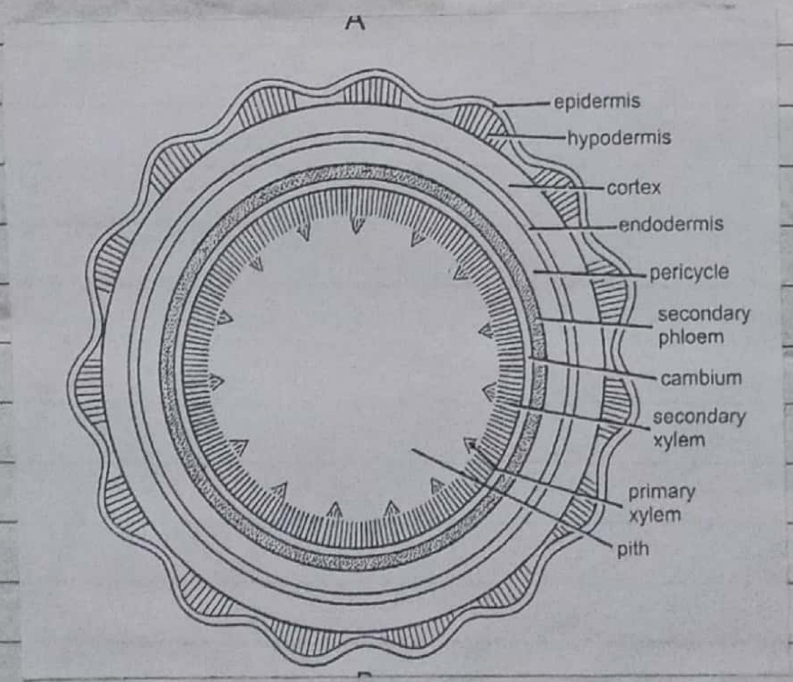


Fig. Early stage of secondary growth in Bignonia Stem

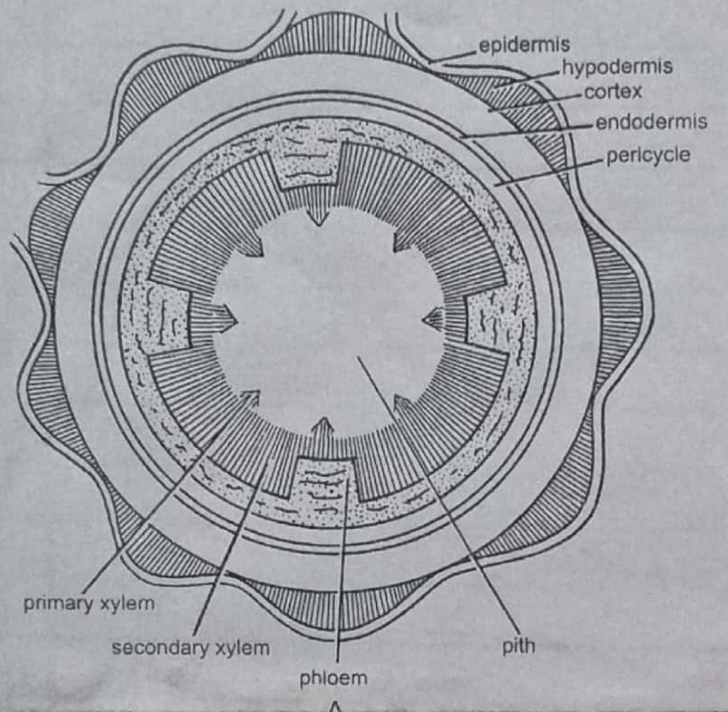


Fig. T.S. of *Bignonia* stem showing scondary growth with 4 wedges.

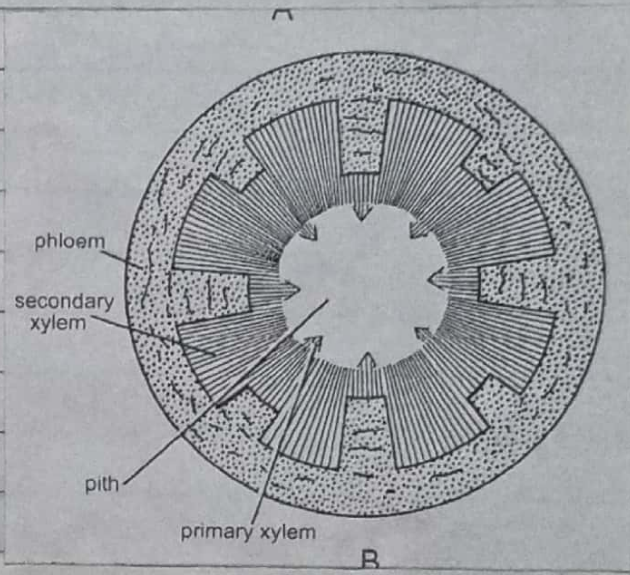


Fig. T.S. of *Bignonia* Stem showing secondary growth with 8 wedges [04 small & 04 large]

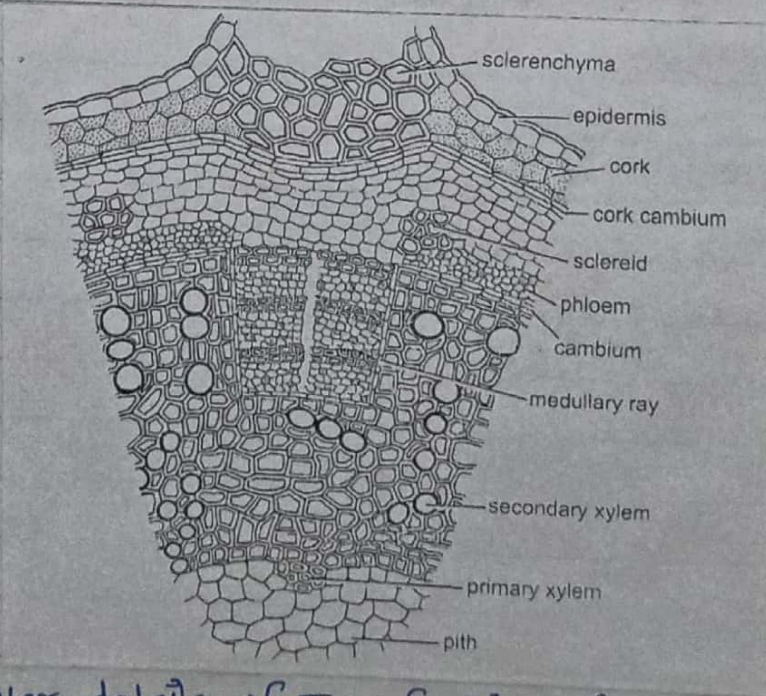


Fig. Cellular details of T.S. of *Bignonia* stem after complete Secondary growth.

In roots and stems having secondary growth, the epidermis is replaced by a protective layer of secondary origin called **periderm**. It generally develops in gymnosperms and dicotyledonous axis and is rarely; formed in leaves or monocotyledons. The periderm is also formed along surfaces exposed after abscission of plant parts, such as leaves or branches. It also develops as protective layer near injured parts (wound periderm).

The term periderm is more distinct than bark. The latter designates all tissues outside the vascular cambium. In secondary state, it includes secondary phloem and all tissues outside it. It can be distinguished into outer non-living and inner living parts. The functional phloem is the innermost part of the living bark.

STRUCTURE OF PERIDERM

The periderm includes the **phellogen** or cork cambium, the meristem that produces the periderm; the **cork** or **phellem**, the protective tissue formed outside by the phellogen, and the inner cortex or **phelloderm**, the living parenchyma, formed inside by the phellogen. Due to the formation of cork, the tissues outside it usually die out.

Rhytidome. It is a dead part of the bark composed of layers of tissues isolated by the periderm and of layers of no longer periderm. It is, thus, well developed in older stem and root and consists of outer bark.

DEVELOPMENT OF PERIDERM

The first periderm commonly appears during the first year of growth of stem and root. In stem most commonly it originates in the sub-epidermal layer. In some species, the first periderm appears rather deep in the stem, usually in the primary phloem *e.g.*, *Berberis*, and *Vitis* etc. In roots, on the other hands, the first periderm originates in the **pericycle**. In some cases, where the root cortex serves for food storage, it may originate near the surface also. The subsequent periderms may appear the same year or later in the successively deeper layers beneath the first, *i.e.*, from the parenchyma of the phloem, including ray cells.

The first phellogen is usually initiated uniformly around the circumference of the axis. Sometimes, *e.g.*, roots in localized areas which become continued afterwards. The subsequent periderms appear as discontinuous but overlapping layers. These may finally appear as continuous, or partly so, layers around the axis.

The phellogen arises from living cells which are potentially meristematic. In these cells, the initiating divisions may start in presence of chloroplast and ergastic substances, *e.g.*, starch, tannins. But gradually these structures disappear. The phellogen is initiated by periclinal divisions and it produces the phellem and phelloderm by the same type of divisions. The exact sequence of divisions in the initiating periderms may be different even in the plants of same species growing under different conditions. Some preparatory divisions take place before the phellogen is defined. The phellogen is usually the outer layer of the two formed by periclinal division.

The activity of the phellogen is more on the outside and thus, the amount of phelloderm formed is usually very small, sometimes restricted only to few layer of cells. A given phellogen cell usually produces a few cork cells every year. There may or may not be some difference in the size of cells formed during earlier part of the season or later part of the year.

On the basis of manner of function, two types of barks are distinguished—**scale bark** and **ring bark**. The former occurs when subsequent periderms occur in restricted overlapping strata, each cutting out a scale of tissue, *e.g.*, *Pinus* and *Pyrus*, etc. Ring bark results from the formation of successive periderms approximately concentrically around axis, in the form of sheets *e.g.*, *Vitis*, and *Lonicera*, etc.

Wound periderm. The wound periderm is similar to normal periderm in origin and cellular structure (**Morris** and **Mann**, 1955). They differ only in time and place of origin, the wound periderm being restricted only to the injured areas. Its formation is preceded by a sealing of the newly exposed surface by scar (Cicatrice) tissue. This tissue includes dead (necrossed) cells on the surface and living cells beneath, which become suberized and lignified to form the **closing layer**. Wound phellogen arises beneath the closing layer and forms the cork cells on the outside and the parenchyma on the inner side.

At the injured parts the periderm is peeled off to the living cells underneath. The cells so exposed die and a new periderm arises below them. This reaction is made use in commercial cork production of oak, where the first periderm is of inferior quality. The latter formed cork is of superior quality.

Protective tissue in monocotyledons. A periderm similar to that of dicotyledons is rarely produced in the monocotyledons. In most of these plants the epidermis is permanent and therefore, the surface layers are not replaced. In some monocotyledons *e.g.*, *Aloe*, coconut, periderm similar to that of dicotyledons is produced. The method of formation, however, is different. The parenchyma cells in successively deeper layers divide several times periclinally and their products get suberized. This tissue is called **storied bark,** due to its storied appearance as in transactions.

LENTICELS

The limited part of the periderm with more active phellogen producing a tissue with intercellular spaces may be called a lenticel. The phellogen in this part itself also has intercellular spaces. Because of this special structure the lenticels are used for entry of air through the periderm. The lenticels are commonly formed in stems and roots. They protrude out of the surface of axis. Their size is also variable, becoming even up to 1 centimeter. Usually they are irregularly distributed but sometimes they occur in vertical rows opposite the rays.

The phellogen in the lenticels is a continuation of the rest but is bent inwards in this area. The loose tissue formed outside is called **filling tissue** or **complementary tissue (Wortz, 1955).** On the inner side the phelloderm is formed in the normal fashion (Fig. 3).

Three types of complementary cells are generally recognized: (i) Those having complementary tissue composed of suberized cells with intercellular spaces, *e.g.*, *Magnolia, Pyrus* and *Malus*. (ii) The second type consists of mainly non-suberized cells in complementary tissue. At the end of season, however, compact suberized cells are formed, *e.g.*, *Tilia, Quercus*. (iii) In the third type the filling tissue is layered. The suberized cell layers alternate with loose, non-suberized cell layers. Each layer may be one to several cells thick and several strata of each kind of tissue are produced yearly. The suberized cells are called the closing layers which are successively broken by the new growth, but one closing layer on the outside is always intact.

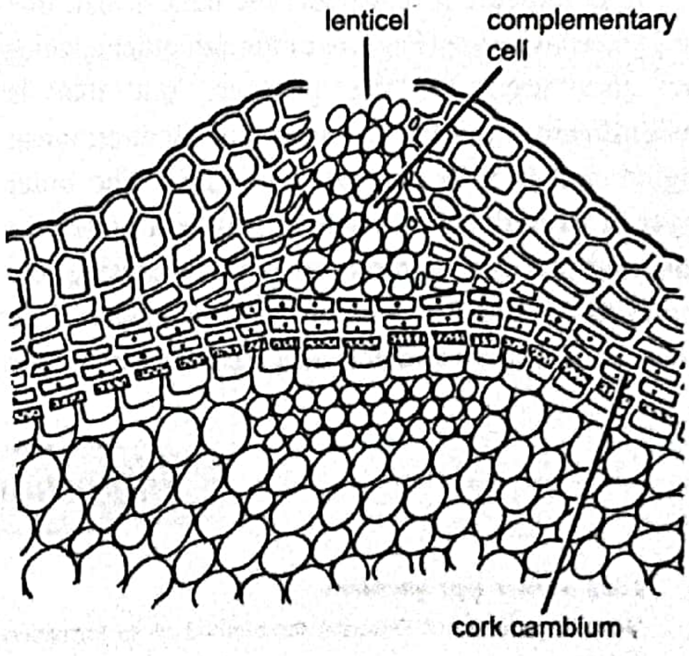


Fig. 3. Lenticel.

Wood Anatomy

Annual rings :-

During secondary growth in stem of perrenial plants xylem consists of concentric ~~rings~~ layers each one of which represents a seasonal increment. In T.S. these layers appears as rings, which are called as "annual rings".

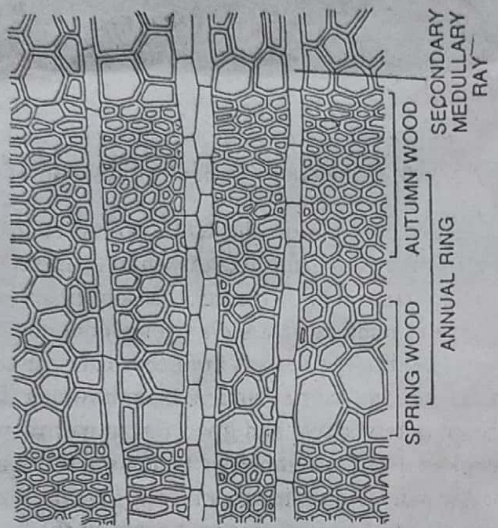
"Annual rings are also called as growth rings".

- Annual rings are characteristic feature of woody plants in temperate region.
- In woody plants, of temperate region there is an alternation of growing and dormant period. Hence, each layer represents a growth of one year.
- Depending upon rate of growth of tree, width of annual rings is different.
- During fevourable season broad rings are produced while during unfevourable season narrow rings are developed.
- This is all because of seasonal activity of cambium ring.
- Depending ~~upon~~ upon seasonal activity of cambium wood is of two types i.e. (1) spring wood and (2) Autumn wood.

Thus, due to formation of spring wood and autumn wood diameter of stem increases.

- Spring wood is also called as early wood or autumn wood is called as late wood.
- During spring or summer season cambium is more active and forms a large amount of vessels with broad cavities, while in autumn or winter

season cambium is less active and gives rise to narrow pitted vessels, i.e. xylem formed during spring are broad while xylem in automn season are narrow.



Annual rings. An annual ring in sectional view (magnified).

Fig. An annual rings

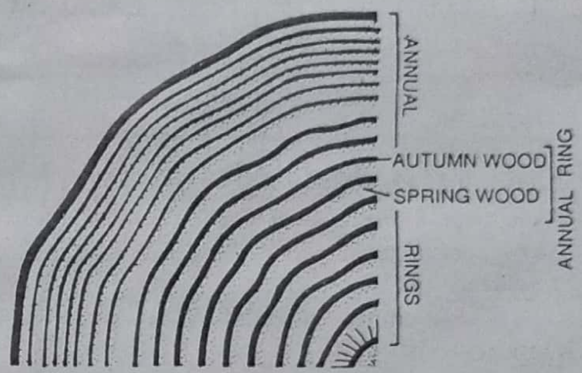


Fig. T.S. of stem showing annual rings.

Sapwood and Heartwood

* **Sapwood :⇒**

The outer region of the old trees is known as "sapwood" or "alburnum".

→ sapwood consists of recently formed xylem elements.

→ sapwood is light in colour and also consists of living cells in association of vessels and fibers.

→ This part of stem performs physiological activities such as conduction of water and nutrients, storage of food, etc.

→ vessels are not plugged with tylose.

→ Sapwood gradually changes into heartwood.

→ During this transformation a changes occur those are as follows :

1) all living cells lose protoplast.
2) water contents of cell walls are reduced.
3) food material is withdrawn from living cells.
4) Tylose block the vessels.
5) wall of parenchymatous cells become lignified.
6) oil, gums, tannins resins and other substances develop in the cells.

* **Heartwood :⇒**

Central region of the old trees is known as "heartwood" or "duramen".

→ It is filled with tannins, resins, gums and other substances, which make heartwood hard and durable.

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→ Heartwood is black to dark brown due to presence of substances in it.
→ vessels are plugged with tylose.
→ Heartwood gives mechanical support to stem.
→ In some plants heartwood remains saturated e.g. Ulmas Malus pumila.
→ In other plants heartwood remains dry or it becomes dry.
e.g. Fraxinus.

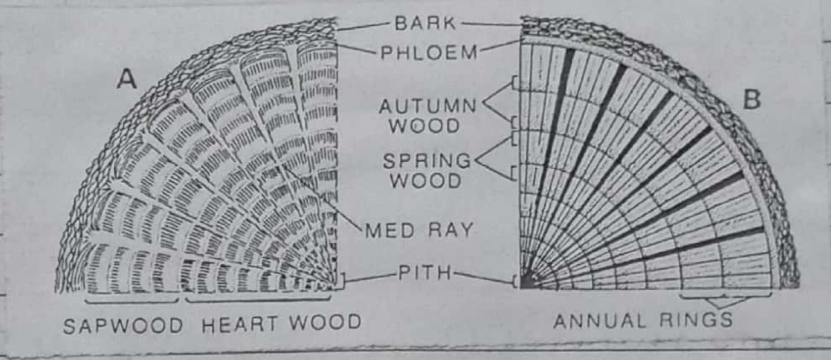

Fig. T.S. of old dicot stem showing sapwood and heartwood.

Fig. T.S. of old dicot stem showing annual rings.

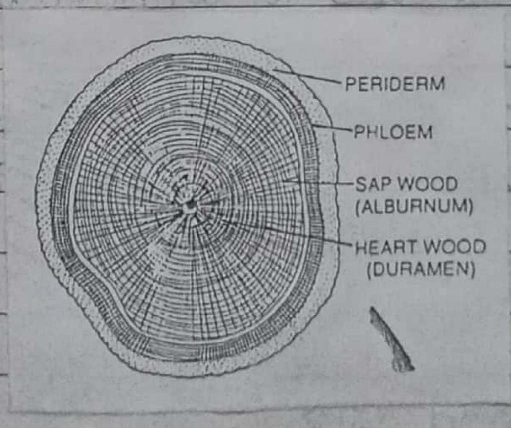

Fig. T.S. of branch of Fraxinus showing heartwood & sapwood.

→*← Tension wood →*←

In angiosperms reaction wood is called as "Tension wood".

- → Tension wood forms on the side of part of plant that is under tension, pulling it towards the affecting force (upwards in case of branch).
- → It has a higher proportion of cellulose than normal wood.
- → Tension wood may have as high as 60% cellulose.
- → It is formed on the upper side of tree branches and leaning trunks.
- → It forms narrower and thinner walled wood and fiber elements.

Reaction Wood :→

Reaction wood in a woody plant is wood that forms in place of normal wood where the cambial cells are originated other than vertically as a response to gravity.

It is typically found on branches and leaning stems. It is an example of mechanical acclimation in trees. ~~Reaction wood is a result of bending and cracking~~. cross-section of reaction wood is asymmetric or elliptical. Reaction wood is helps to maintain the angle of bent or leaning part by resisting further downward bending or failure. Reaction wood is of two types i.e. ① Tension wood & ② compression wood.

In gymnosperms and amborella it is called as compression wood. It has higher proportion of lignin than normal wood. It has, about 30% cellulose as compared to 42% in only normal softwood.

Economic importance of wood → wood elements :

Heartwood is more useful than sapwood. Heartwood is used as a timber because it is more durable than sapwood. The haemotoxylin is obtained from the heartwood of Haemotoxylon campechianum. Due to formation of resins, oils and tannins heartwood is less susceptible to attack by the organisms to decay.

Due to absence of resins, gums and colouring substances sapwood is used ~~as~~ a for pulpwood. overall, wood is used in furniture buildings bridges an a source of energy. Wood from trees and bushes i.e. wood pulp is used in preperation of photographic film, cellophone rayon. Later on wood products can be burnt to obtain thermal energy and can be used as a fertilizer.

Dendrochronology

Each annual ring is corresponds to one year's growth of a specific plant. With the help of these rings age of plant can be calculated.

" The technique which is used to determine the age of tree by counting the annual rings is known as "dendrochronology".

Because of draught condition prevailed in middle of a growing season two annual rings are formed in a single year and in such cases counting of annual rings does not show correct age of tree.